Radioactivity in Food and the Environment, 2022

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Radioactivity in Food and the Environment, 2022

RIFE 28

November 2023

Foreword

The UK’s environmental regulators and food safety agencies are delighted to present the 28th edition of the Radioactivity in Food and the Environment (RIFE) report.

Radiation and radioactive substances have had many beneficial uses including their use in medical diagnostics and therapies, and in power generation. They are unlikely to be harmful if controlled in the right way. Regulation aims to ensure these benefits, whilst keeping people and the environment safe. Our combined independent monitoring of radioactivity in food and the environment is an important part of our regulatory process. This also fulfils a vital role in providing reassurance to members of the public.

In common with previous issues of this report, RIFE 28 sets out the findings of the monitoring programmes of radioactivity in food and the environment carried out in 2022 throughout the UK. These monitoring programmes are undertaken by the Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resources Wales, Northern Ireland Environment Agency, and the Scottish Environment Protection Agency.

The monitoring results and subsequent assessments presented in this report demonstrate that radioactivity in food and the environment is safe. The exposure of members of the public to radiation, resulting from authorised discharges of radioactive waste and direct radiation, near nuclear and non-nuclear sites was far below legal limits in 2022.

The RIFE monitoring programme supports the requirements of the permitting legislation across the UK, together with other national and international agreements, policies, regulations and standards.

General Summary

Radioactivity is all around us. It occurs naturally in the earth's crust, and it can be found in the food we eat, the water we drink, as well as the air we breathe. We are also exposed to artificial sources of radioactivity, such as in medical applications used in hospitals and nuclear power. It is a legal requirement to ensure that the radiation exposure from artificial radioactivity, from all sources, is kept within a safe limit. Globally, strict regulations and recommendations are in place to protect the public and the environment.

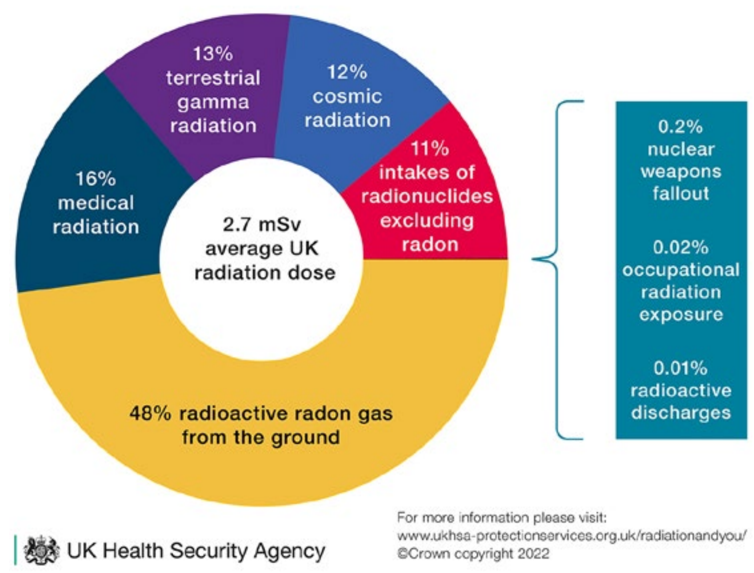
In the UK, the radiation exposure from artificial radioactivity in the environment mainly comes from permitted or authorised releases from UK nuclear sites. In addition to these sites, there are other users of radioactivity, such as hospitals, research or industrial facilities. These other facilities are generally known as the non-nuclear industries. Releases from hospital and research sites are significantly lower than from nuclear sites.

The Radioactivity in Food and the Environment (RIFE) report is published each year by environmental regulators and food standards agencies. This report brings together all the results of monitoring of radioactivity in food and the environment by the RIFE partners (Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resources Wales, Northern Ireland Environment Agency and the Scottish Environment Protection Agency).

The main aim of the RIFE programme is to monitor the environment, and the diet of people living or working near nuclear and selected non-nuclear sites. From this monitoring, we can estimate the amount of radioactivity the public is exposed to, and in particular, those groups of people who are most exposed because of their age, diet, location or lifestyle.

An additional comparison can be made with the exposure from natural radioactivity using a different approach to those estimated for people who live or work near nuclear and other sites. The UK Health Security Agency has published estimates of exposures to the UK population from naturally occurring and artificial sources of radioactivity. The most recent values show that naturally occurring sources, particularly radon gas, accounted for around 84% of the exposure from all sources of radioactivity, with medical radiation contributing around 16%. Artificial radioactivity in the environment, from the nuclear industry and from past testing of nuclear weapons, accounted for less than 0.2% of the exposure to the UK population (See Figure GS).

Figure GS Average UK population exposure from natural and man-made sources of radioactivity



The headlines from the 2022 RIFE programme are:

For all sites

- exposure to the public from all sources of artificial radioactivity in food and the environment was low and well within the legal limit of 1 millisievert (mSv) per year[1], demonstrating that radioactivity in food and the environment is safe
- overall, between 2021 and 2022 there were no significant changes to the radioactivity measured in food and the environment

For nuclear sites

- in 2022, people living around the Cumbrian coast (near Sellafield), Capenhurst and Amersham were the most exposed from releases of radioactivity. The highest exposure was 24% of the legal limit in 2022 due to people eating locally produced seafood (fish and crustacean) around the Cumbrian coast. This is up from 21% of the legal limit in 2021
- in 2022 in Scotland, people eating food collected from areas along the Dumfries and Galloway coastline were the most exposed from releases of radioactivity. The exposure in 2022 was approximately 2% of the legal limit, and as in previous years, this was mostly due to the effects of past discharges from the Sellafield site
- the highest exposure in Wales was for those people living near the former Trawsfynydd nuclear power station, which is being decommissioned. This was due to them consuming locally produced food (milk), containing radioactivity released from past discharges from the station. The exposure was approximately 4% of the legal limit

1. The average individual dose in the UK population (which is not comparable with doses calculated within the RIFE report), mostly due to natural sources, amounts to about 2.3 millisieverts (mSv) per year.

For other areas

- in Northern Ireland, exposure to the public from artificial radioactivity in 2022 was estimated to be less than 1% of the legal limit
- a survey on the Channel Islands confirmed that the radiation exposure due to discharges from the French fuel reprocessing plant at La Hague and other local sources was less than 0.5% of the legal limit
- food and sources of public drinking water that make up a general diet for people were analysed for radioactivity across the UK. Results show that the radiation exposure from artificial radionuclides in people's general diet was very small (less than 0.5% of the legal limit) in 2022

Overall, between 2021 and 2022 there have been no significant changes to the radioactivity measured in food and the environment around UK nuclear sites and other locations remote from these sites. Exposure from all sources of technologically enhanced naturally occuring and artificial radioactivity to members of the public was well below legal limits, demonstrating that radioactivity in food and the environment is safe.

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Technical Summary

This section is divided into the following topics to highlight the scope of this report. These are:

- radiation exposures (doses) to people living near UK nuclear licensed sites
- radioactivity concentrations in samples collected near UK nuclear licensed sites
- external dose rates measured near UK nuclear licensed sites
- UK nuclear licensed site incidents and non-routine surveys
- habits surveys near UK nuclear licensed sites
- monitoring of radioactivity at locations remote from UK nuclear licensed sites (overseas incidents, non-nuclear sites and regional monitoring across the UK)
- the environmental radioactivity monitoring programmes

Radiation exposure (doses) to people living near UK nuclear licensed sites

Radiation doses to people living near nuclear licensed sites are assessed using data from monitoring of radioactivity in food and the environment. Radionuclide concentrations, dose rates, and information on the habits of people living near the sites are used to estimate doses. Where monitoring data are not available, some environmental concentrations are estimated by environmental transfer modelling of reported discharges. People's exposure to radiation (doses) can vary from year to year, due to changes in radionuclide concentrations and external dose rates. Changes in habits data and information, in particular food consumption, can also cause the estimates of dose to vary.

The dose quantity presented in this summary is known as the 'total dose'. This is made up of contributions from all sources of radioactivity from man-made processes. Source specific dose assessments are also carried out in some cases to provide additional information and to compare with the 'total dose' assessment method.

Figure S and Table S show the assessed 'total doses' in 2022, due to the combined effects of authorised/permitted waste discharges and direct exposure from the site ('direct radiation') on those people most exposed to radiation near all major nuclear licensed sites in the UK.

Figure S 'Total doses' in the UK due to radioactive waste discharges and direct radiation, 2022. (Exposures at Sellafield, Whitehaven and LLWR near Drigg receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)

Summary Table S. 'Total doses' due to all sources at major UK sites, 2022[a]

Establishment	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing		
Capenhurst	0.14	Direct radiation
Springfields	0.032	Direct radiation
Sellafield[d]	0.24	Crustaceans, ^{210}Po
Research establishments		
Dounreay	0.010	Direct radiation
Harwell	<0.005	Gamma dose rate over riverbank
Winfrith	0.028	Direct radiation
Nuclear power stations		
Berkeley and Oldbury	0.006	Milk, ^{14}C, ^{35}S
Bradwell	<0.005	Fish, gamma dose rate over sediment, ^{241}Am
Chapelcross	0.009	Milk, ^{35}S, ^{90}Sr
Dungeness	0.011	Direct radiation
Hartlepool	0.011	Gamma dose rate over sediment
Heysham	0.016	Gamma dose rate over sediment
Hinkley Point	0.015	Gamma dose rate over sediment
Hunterston	<0.005	Direct radiation
Sizewell	<0.005	Direct radiation, fish, gamma dose rate over sediment, ^{241}Am
Torness	0.006	Domestic fruit, wild fruit, ^{14}C, ^{90}Sr
Trawsfynydd	0.009	Direct radiation, exposure over sediment
Wylfa	0.014	Direct radiation
Defence establishment		
Aldermaston and Burghfield	<0.005	Direct radiation
Barrow[f]	0.030	Gamma dose rate over sediment
Derby	<0.005	Water, ^{60}Co[e]
Devonport	<0.005	Fish, gamma dose rate over sediment, ^{241}Am[e]
Faslane	0.007	Fish, gamma dose rate over sediment, ^{137}Cs, ^{241}Am[e]
Rosyth	0.006	Crustacean, gamma dose rate over sediment, ^{241}Am[e]
Radiochemical production		
Amersham	0.086	Direct radiation
Industrial and landfill		
LLWR near Drigg[d]	0.24	Crustaceans, ^{210}Po
Whitehaven[d]	0.24	Crustaceans, ^{210}Po

a. Includes the effects of waste discharges and direct radiation from the site. May also include the far-field effects of discharges of liquid waste from Sellafield
b. Committed effective dose calculated using methodology of ICRP 60 to be compared with the annual dose limit of 1 mSv. Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 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 0.014 and 0.22mSv, 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
e. The assessed contribution is based on data at limits of detection
f. Exposures at Barrow are largely due to discharges from the Sellafield site

Doses to individuals are determined for those people most exposed to radiation ('representative person'[2]). The estimated doses are compared with legal limits for the public. The method used to calculate doses to each hypothetical individual is based on guidance from the National Dose Assessment Working Group (NDAWG). NDAWG guidance proposes developing a series of habits profiles of people living and consuming food grown (or sourced) near nuclear licensed sites. These are derived from the habits survey data. Each habits profile provides information on their respective food consumption and occupancy rates. Doses for each habits profile are calculated and the 'representative person' is that profile which receives the highest dose.

In 2022, radiation doses from authorised/permitted releases of radioactivity to people living around nuclear licensed sites, remained well below the UK national limit of 1 millisievert (mSv, a measure of dose) per year (see Appendix 2 for explanation of dose units).

The locations where the public received the highest doses in 2022 were similar to those in 2021. These were the Cumbrian coastal community[3] near Sellafield (0.24mSv), Capenhurst (0.14mSv) and Amersham (0.086mSv). The doses received near Capenhurst and Amersham were dominated by direct radiation from sources on the sites.

The highest dose to the Cumbrian coastal community near Sellafield was mostly due to historical liquid discharges. In 2022, the representative person from the Cumbrian coastal community, was a high-rate crustacean consumer (who also consumed significant quantities of other seafood) and unchanged from that in 2021. The estimated dose was 0.24mSv in 2022. Most of this dose (0.22mSv) was due to the historical discharges of technologically enhanced naturally occurring radioactive material (TENORM) from the former phosphate processing plant near Whitehaven. The remainder of the dose (0.014mSv) was due to the permitted discharges of artificial radionuclides by the nuclear industry. In the previous year (for 2021), the representative person received a dose of 0.21mSv (including a contribution of 0.19mSv and 0.019mSv related to the former phosphate processing plant and the nuclear industry, respectively). The increase in 'total dose' in 2022 was mostly attributed to the increase in polonium-210 concentrations in lobsters at Parton, in comparison to 2021. The largest contribution to dose to seafood consumers in the Cumbrian coastal community was from the radionuclide polonium-210.

2. International Commission on Radiological Protection (ICRP) recommendations [2] use the term 'representative person' for assessing doses to members of the public. It is defined as 'an individual receiving a dose that is representative of the more highly exposed individuals in the population'. RIFE reports published before 2013 referred to an average dose to individuals in a group of people (the 'critical group') rather than to a single person. The 'representative person' concept is considered equivalent to the 'critical group'.

3. The Cumbrian coastal community are exposed to radioactivity resulting from both current and historical discharges from the Sellafield site and naturally occurring radioactivity discharged from the former phosphate processing works near Whitehaven, close to Sellafield.

Polonium-210 is a significant contributor of the dose to the most exposed members of the public because it has a relatively high dose coefficient (a factor used to convert an intake of radioactivity into a radiation dose) as recommended by the ICRP. Polonium-210 is present in the environment from natural sources and from TENORM which used to be discharged from the former phosphate processing plant (near Whitehaven). Nevertheless, polonium-210 concentrations in crustacean samples continued to be within or close to the expected range due to natural sources in 2022. The discharge effects from the Sellafield site and the former phosphate processing plant (near Whitehaven) both impact the same area and therefore the contributions to doses from both sources are considered in Section 3.3.1.

In Scotland, the representative person consuming food (fish, shellfish and wildfowl) collected from areas along the Dumfries and Galloway coastline received the highest source specific dose[4] from authorised releases of radioactivity. The dose to adults was 0.024mSv in 2022, a decrease from 2021 (0.056mSv). As in previous years, most of the dose in 2022 was due to the effects of historical discharges from the Sellafield site.

The highest dose in Wales was near the Trawsfynydd nuclear power station. This site is being decommissioned. The representative person was a consumer of locally produced foodstuffs, and the dose was due to past permitted discharges. The source specific dose[4] to 1-year-old infants was 0.038mSv in 2022; a slight decrease from 2021 (0.040mSv).

Radioactivity concentrations in samples collected near UK nuclear licensed sites

There were no major variations in environmental concentrations of radioactivity in 2022 compared to those in 2021. Near Sellafield, the environmental concentrations of most radionuclides have declined over the past 3 decades, albeit much slower in recent years. In 2022, mean concentrations of technetium-99, caesium-137, plutonium-239+240 and americium-241 in lobsters (Sellafield coastal), and of carbon-14, caesium-137, plutonium-239+240 and americium-241 in Plaice (Sellafield coastal/Whitehaven), were the lowest reported values in recent years.

In 2018, a review of the 2009 UK Radioactive Discharge strategy was published [3]. The review demonstrates clear evidence of progress being made by the UK in meeting the outcomes of the 2009 strategy and contributing towards the objectives of the OSPAR[5] radioactive substances strategy (RSS). Specifically, significant progress has been made towards achieving progressive and substantial reductions in radioactive discharges. Progress is also being made to achieving progressive reductions in concentrations of radionuclides in the marine environment and in achieving progressive reductions in human exposures to ionising radiation (see appendix 2), as a result of planned reductions in discharges [4].

4. See Section 1.2, Appendix 2 and Appendix 5 for more information.
5. The Oslo and Paris Convention for the protection of the marine environment of the North-East Atlantic

The OSPAR Radioactive Substances Committee published its Fifth Periodic Evaluation in 2022, which demonstrated that Contracting Parties, including the UK, have successfully fulfilled the objectives of the OSPAR RSS for 2020 under the North-East Atlantic Environment Strategy (NEAES) 2010 – 2020 and have made significant progress against the ultimate aim of radionuclide concentrations in the environment near background values for naturally occurring radionuclides and close to zero for artificial radionuclides (see Section 1.3.2 for further details) [4]. The UK specific outcomes in the Fifth periodic evaluation (see Annex 2, [4]), reinforces the findings of the 2018 UK strategy for radioactive discharges.

External dose rates measured near UK nuclear licensed sites

Radioactivity in sediments in intertidal areas can potentially make a significant contribution to the total radiation exposure to members of the public. For this reason, in situ measurements of radiation dose rates are taken over exposed areas of sediment. These ‘external doses’ are included in the assessment of doses to the public where they are higher than natural background rates. To determine the dose to the public from any radioactivity that may be present as a result of authorised/permitted discharges, natural background rates are subtracted from the measured dose rates in the assessment.

There were no major changes in external dose rates in intertidal areas in 2022 compared with 2021. At most locations, the external dose rates were close to background rates. Rates were higher in some estuaries near Sellafield (up to twice the background rate) and in the Ribble Estuary.

UK nuclear licensed sites incidents and non-routine surveys

During 2022, as a result of an ongoing programme of monitoring by the operator, radioactive items (particles and objects[6]) from Sellafield were detected on Cumbrian beaches and removed (117 in the 2022 calendar year). The advice from the UK Health Security Agency (UKHSA) and the Food Standards Agency (FSA) is that the risk to the public from the radioactive particles and larger objects found on West Cumbrian beaches is very low. Therefore, measures to protect the public are not needed. A programme of work is in place to meet the primary aim of providing reassurance that overall risks to beach users remain at, or below those estimated in the UKHSA risk assessment. UKHSA published a summary report of assessing the risk to people’s health from radioactive objects on beaches around the Sellafield site in February 2020 [5].

At Dounreay, the comprehensive beach monitoring programme continued for fragments of irradiated nuclear fuel (particles). Last year, the number of particles recovered and the range in radioactivity content were similar to that observed in recent years. Fishing restrictions in a specific area around Dounreay are still in force under the Food and Environment Protection Act (FEPA) 1985 [6].

Special (or ‘ad hoc’) sampling related to nuclear licensed site operation is carried out at sites when needed or to provide one-off data sets. No such need arose in 2022.

6. “Particles and objects” are terms used which encompass discrete radioactive items which can range in radioactivity concentration, size and origin. “Particles” include radioactive scale, fragments of irradiated nuclear fuel and incinerated waste materials (less than 2mm in diameter). “Objects” are larger radioactive artefacts and stones which have radioactive contamination on their surface and are larger than 2mm in size. Particles can be compared according to the hazard posed.

Habits surveys near UK nuclear licensed sites

For 'total dose' assessments, habits data are used to define the exposure pathways (such as, eating locally produced food and time spent on beaches) for members of the public. Habits data are used to define one or more hypothetical individuals[7] (for each pathway). The doses to each hypothetical individual are calculated and the individual with the highest dose is the representative person. The dose calculated in this way is considered representative of the dose to the most highly exposed individuals in the population.

In 2022, the regular programmes of habits surveys, in England and Wales, resumed using a combination of outdoor face-to-face and telephone interviews. Surveys were carried out at Aldermaston and Burghfield, Springfields and Sellafield in England and at Chapelcross and Rosyth in Scotland.

These habits surveys give site-specific information on the diet and occupancy habits of people near nuclear licensed sites. The findings were used to confirm the adequacy of current monitoring programmes, to strengthen and update them with a better representation of relevant exposure pathways, and to improve the assessment of doses to members of the public near nuclear licensed sites.

Monitoring of radioactivity at locations remote from UK nuclear licensed sites

Additional monitoring in the UK and surrounding seas was carried out to assess the impact of non-nuclear sites, the concentrations of radioactivity across the UK (measured as part of the regional monitoring programme) and overseas incidents that may have introduced radioactivity into the environment.

1) Non-nuclear sites

In the past, liquid waste slurry (regarded as TENORM) containing thorium and uranium was discharged from a phosphate processing plant near Whitehaven (Cumbria) into the Irish Sea. These discharges have resulted in an increase in the concentrations of naturally occurring radionuclides in the environment through the production of radioactive decay products (from the radioactive decay of radionuclides previously discharged to sea).

Historically, two decay products, polonium-210 and lead-210, in fish and shellfish (near Whitehaven) have been found to be higher than the maximum expected concentration ranges due to naturally occurring radioactivity. Concentrations have declined significantly since the plant ceased operations in 1992. Since then, polonium-210 and lead-210 have been within or close to the expected natural background concentration ranges. Estimates of the enhanced concentrations in seafood are made by subtracting the median of the expected natural concentration range of these radionuclides from the measured values.

7. A hypothetical individual is used in radiological impact assessments as it is often not possible to identify a specific member of a population whose habits are likely to result in them receiving a dose towards the upper end of the range seen in that population when variability and uncertainty in exposure pathways and source of radiation are considered. Use of the concept of the representative person has been recommended by the ICRP and UKHSA as a practical approach to assess the radiological impact of exposure to a source of radiation.

These radionuclides are important in that small changes in values above background, significantly influence their contribution to the combined dose. The representative person in the area who consumed large amounts of seafood received a dose of 0.22mSv in 2022, and polonium-210 was the most contributing radionuclide. This estimation of dose also includes a much smaller contribution from the effects of discharges from the nearby nuclear site at Sellafield.

Concentrations of tritium were found in leachate from some landfill sites, at quantities 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 or due to disposals of gaseous tritium light devices (such as fire exit signs).

Work to address radioactive contamination is ongoing at Dalgety Bay, Fife. Public protection measures have been established and these were maintained during 2022 and into 2023. This includes continuing a monthly beach monitoring and particle recovery programme. The FEPA Order issued by Food Standards Scotland (FSS) (then FSA in Scotland), prohibiting the collection of seafood from the Dalgety Bay area, remains in force. Together with stakeholders, work continues towards the implementation of the preferred management option for the remediation works. The Scottish Environment Protection Agency (SEPA) is continuing to work with the Ministry of Defence (MOD) and their contractors with regard to the remediation methodology for the site. The remediation contract was awarded by the MOD in February 2020 and an Environmental Authorisations (Scotland) Regulations (EASR18) permit for the required work was granted in May 2021. Remediation work is now underway at Dalgety Bay and is expected to be completed by the end of 2023.

Further details can be found in Section 7.6 of this report and on the radioactive substances pages of SEPA's website: https://www.sepa.org.uk/regulations/radioactive-substances/dalgety-bay/.

2) Regional monitoring of radioactivity across the UK

Regional monitoring in areas remote from nuclear licensed sites continued in 2022 to:

1. establish the extent of long-distance transport of radioactivity from UK and other nuclear licensed sites,
2. identify any general contamination of the food supply and the environment and
3. provide data in compliance with UK obligations under the OSPAR Convention.

From the monitoring of artificial radioactivity in Northern Ireland, consumer doses were estimated to be less than 1% of the annual limit of 1mSv for members of the public in 2022. A survey on the Channel Islands confirmed that doses due to discharges from the French reprocessing plant at La Hague and other local sources were less than 0.5% of the legal limit.

Food and sources of public drinking water that make up a general diet for people were analysed for radioactivity across the UK. In 2022, artificial radionuclides only contributed a small proportion of the total public radiation dose in people's general diet, and this was much less than 0.5% of the legal limit.

The distribution of radionuclides in coastal seas continues to be monitored away from nuclear licensed sites. This supports the UK's marine environmental policies and international treaty commitments. Government research vessels are used in the sampling programme and the results have been used to show trends in the quality of the UK's coastal seas. These surveys, together with the results of monitoring at nuclear licensed sites, contribute to the UK data submitted to the OSPAR Commission. These data also help to measure progress towards the UK government and devolved administrations objectives for improving the state of the marine environment.
Disposal of dredged material from harbours and other areas in England is licensed under the Marine and Coastal Access Act 2009 (MCAA) [7]. In 2022, no requests were received by the Marine Management Organisation (MMO) to apply for additional licences for the disposal of dredged material (containing radioactivity) at sea.

3) Overseas incidents

The accident at the Fukushima Dai-ichi nuclear power station in Japan in March 2011 resulted in significant quantities of radioactivity being released into the air and sea. Controls on imported food and animal feed products from Japan continued in the first half of 2022, under retained European Union (EU) regulations. None of the imports to the UK contained radioactivity that exceeded the maximum permissible levels during this time. In June 2022, the EU retained regulations on Fukushima import controls were revoked for England, Scotland and Wales. In Northern Ireland, European Regulations continue to apply under the terms of the UK's withdrawal agreement from the EU.

Some food imported into the UK may contain radioactive contamination from the 1986 Chernobyl accident and other known or unknown sources. A monitoring system is in place to detect radioactivity in consignments. In 2022, no significant radioactivity (above screening levels) was detected at entry points and there was no need to introduce food safety controls on any consignments.

The environmental radioactivity monitoring programmes

The environmental monitoring programmes in this report are carried out on behalf of the Environment Agency, FSA, FSS, Natural Resources Wales (NRW), Northern Ireland Environment Agency (NIEA) and SEPA and are independent of the industries discharging radioactive wastes. The programmes include monitoring in support of the Scottish Government, Channel Island states, Department of Agriculture Environment and Rural Affairs (DAERA), Department for Energy Security & Net Zero (DESNZ)[8], Department for Environment, Food & Rural Affairs (Defra), NRW and the Welsh Government. The monitoring programmes involve specialist laboratories working together, each with rigorous quality assurance procedures, and a wide range of sample collectors throughout the UK.

8. In February 2023, The Department of Business, Energy & Industrial Strategy (BEIS) was split into 3 new departments, Department for Science, Innovation and Technology, Department for Business and Trade and the Department for Energy Security and Net Zero (DESNZ).

Overall, around 10,000 analyses and dose rate measurements were completed in 2022. The analytical results of the environmental radioactivity monitoring programmes are reported in tables in the relevant sections (Sections 3 to 8). The values provided in the tables are given in three different forms:

4. measurable values (referred to as 'positively detected')
5. less than values (that is, the lowest activity concentration, or dose rate measurement, that can be reliably detected for a given analytical method)
6. not detected (ND) values (meaning that insufficient evidence is available to determine the existence of a radionuclide).

Where the results are an average of more than one measurement, and each value is positively detected, then the result in the table is reported as being positively detected. Alternatively, where there is a mixture of values (both positively detected and less than values), or all are less than values, then the result in the table is reported as a less than value, preceded by a 'less than' symbol (<). The Environment Agency has produced a document that includes radionuclide information, such as the sources, uses, modes of release and nuclear decay data [8].

Only results that are the most relevant for assessing the impact of radionuclide concentrations in food and the environment are provided in each site table. This ensures that reporting of the more meaningful results is manageable. For example, gamma-ray spectrometry can provide a large number of less than values and may not be reported. To identify the most relevant values, to be included in each individual table, one or more of the following conditions is required:

1. all radionuclide results (both positively detected and less than values) are reported in the site table if the radionuclide is specified in the relevant permit/authorisation (as indicated for each site in Appendix 1, Table A1.1 and Table A1.2)
2. all radionuclide results (both positively detected and less than values) are reported that have been analysed using a radiochemistry method (for example, plutonium radionuclides)
3. for any radionuclide that is reported as positively detected in the previous 5 years of annual reporting, all activity concentration data of that radionuclide are reported (they are only excluded from the table after 5 continuous years of reporting 'less than values')
4. for any radionuclide that is reported as positively detected in one of the samples, all activity concentration data of that radionuclide are reported for other samples presented in the table (terrestrial and marine) in that year
5. naturally occurring radionuclides measured by gamma-ray spectrometry (for example potassium-40) are not usually reported unless the intention is to establish whether there is any enhancement above the expected background concentrations (for example from landfill sites)

More information about programmes described in this report is available from the sponsoring agencies. Their contact details can be found on the inside front and back covers of this report. The results of the analysis of food samples collected near nuclear licensed sites in England and Wales are published on the FSA's website (https://www.food.gov.uk).

1 Introduction

Overview

- The Radioactivity in Food and the Environment (RIFE) report represents the collaboration between the Environment Agency, Natural Resources Wales (NRW), Northern Ireland Environment Agency (NIEA) and Scottish Environmental Protection Agency (SEPA) referred to together as the environment agencies in this report, Food Standards Agency (FSA) and Food Standards Scotland (FSS). The monitoring programme is independent of the nuclear industry.
- RIFE provides an open check on food safety and the public's exposure to radiation according to the Ionising Radiation (Basic Safety Standards) (Miscellaneous Provisions) (Amendment) (EU Exit) Regulations 2018 and the Environmental Permitting Regulations 2019 (as amended), retained from the EU Basic Safety Standards Directive 2013 (BSSD 13).
- The monitoring programme results support the UK in meeting its international treaty obligations.
- Annual radiation doses are summarised for major industrial sites; all doses were below the legal limit of 1mSv in 2022.

This section:

1. describes the purpose and scope of the UK monitoring programmes for RIFE
2. provides a summary of the key results in terms of radiation exposures at each major industrial site in 2022
3. gives an overview of the main sources of radiation in a regulatory context

1.1 Scope and purpose of the monitoring programmes

In England and Wales, the FSA and the Environment Agency[9] carry out food and non-food (including seawater, sediments, dose rate) monitoring, respectively. SEPA (working closely with FSS on its programme) and the NIEA both undertake food and non-food monitoring in Scotland and Northern Ireland, respectively. Food monitoring includes the collection and analysis of cow's milk (unless otherwise specified in this report). Surveillance of imports through points of entry continued in 2022. The regular national programme of monitoring of drinking water, air and rain continued on behalf of the DESNZ, NIEA and the Scottish Government. The FSA and SEPA (as part of the joint SEPA/FSS monitoring programme) also carry out UK monitoring of milk and canteen meals that are collected remotely from nuclear licensed sites. Annual surveys of seas around the UK (including locations away from nuclear licensed sites) are monitored on behalf of DESNZ.

9. The Environment Agency has an agreement with Natural Resources Wales to undertake some specific activities on its behalf including radiological environmental monitoring and Radioactive Substances Regulation of nuclear sites in Wales

The FSA has responsibility for food safety in England, Northern Ireland, and Wales, and FSS has responsibility in Scotland. The environment agencies are responsible for regulating environmental protection in England, Northern Ireland, Wales, and Scotland, respectively. This includes the regulation of radioactive discharges and radioactive waste disposal from nuclear and other sites.

The current UK legislation, relating to radioactivity, provides uniform safety standards to protect the health of workers and members of the public. These basic safety standards are retained from European Council (EC) Directives, the most recent one being the Basic Safety Standards Directive 2013 or 'BSSD 13' [9]. This lays down basic safety standards for protecting people against the dangers arising from exposure to ionising radiation. The RIFE report and the associated monitoring programmes were designed to conform to the requirements of Article 36 of the Euratom Treaty (see Section 7 and Appendix 1 in previous RIFE reports, for more details). Specifically, it provides estimates of annual doses to members of the public from authorised practices and enables these results to be made available to stakeholders. Following its withdrawal from the Euratom Treaty, the UK is no longer required to report these data to the EC and has agreed a nuclear cooperation agreement (NCA) with the EU, ensuring both parties continue working together on civil nuclear matters including safeguards, safety, and security. In late December 2020, DESNZ published its transboundary directions to the environment agencies, available from https://www.gov.uk/guidance/transboundary-impacts-of-radioactive-waste-disposal-reporting-and-notification-obligations-euratom-article-37. These directions replace the requirements of Article 37 (related to the transboundary radiological impact of releases during normal operation) of the Euratom treaty following the UK withdrawal from the Euratom Treaty.

The Ionising Radiation (Basic Safety Standards) (Miscellaneous Provisions) (Amendment) (EU Exit) Regulations 2018 [10] came into force to transpose parts of BSSD 13, not already covered within existing statutory regimes. These regulations impose duties on appropriate ministers to ensure that certain functions are carried out in relation to exposures from contaminated land, exposures from buildings or contaminated commodities and to raise awareness and issue guidance about orphan sources (which are not under regulatory control but pose a radiological hazard – see Appendix 2 for definition).

The requirements for regulating public exposure from the disposal of radioactive waste in England and Wales are set out in the Environmental Permitting (England and Wales) Regulations 2016 (EPR 16) [11], in particular Schedule 23 'radioactive substances activities'. These regulations were amended in 2018 by the Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2018 (EPR 18) [12] in order to transpose changes brought about by BSSD 13, and then by the Environmental Permitting (England and Wales) (Amendment) (EU Exit) Regulations 2019 (EPR 19) in 2019 [13]. This was to ensure that the regulations remain fully operable at the end of the transition period following the UK's exit from the EU. Further changes were made in the Waste and Environmental Permitting etc. (Legislative Functions and Amendment etc.) (EU Exit) Regulations 2020, which transfers some functions from the European Commission to the Secretary of State and the devolved administrations [14].

In 2018, the Radioactive Substances (Modification of Enactments) Regulations (Northern Ireland) 2018 (RSR 18) came into force for radioactive substances activities in Northern Ireland [15] by amending the Radioactive Substances Act 1993 (RSA 93) [16]. A guidance document was also published in 2018, providing the scope of and exceptions from the radioactive substances legislation in England, Wales, and Northern Ireland [17].

The requirements for regulating public exposure from the disposal of radioactive waste in Scotland is set out in the Environmental Authorisations (Scotland) Regulations 2018 (EASR18) [18], in particular Schedule 8 'radioactive substances activities'. EASR18 currently applies to both offshore and onshore activities in Scotland. A guidance document has also been published to support the implementation of the regulations. There are four types of authorisation under EASR18: general binding rules, notification, registration and permit (more information can be found at: https://www.sepa.org.uk/regulations/how-we-regulate/environmental-authorisations-scotland-regulations-2018/). The new regulations aim to provide an integrated authorisation framework, which will bring together as far as possible, the authorisation, procedural and enforcement arrangements relating to water, waste management, radioactive substances and pollution prevention and control. This framework is being developed in a phased manner and currently the regulations only apply to radioactive substance activities. In late 2022, SEPA initiated a consultation on the implementation of the EASR18 framework before developing proposals to incorporate the regulation of other environmental activities under EASR18.

In order to transpose the requirements of BSSD 13, the Ionising Radiations Regulations 2017 (IRR 17) [19] came into force in 2018 (replacing the Ionising Radiations Regulations 1999). The Health and Safety Executive (HSE) has also provided practical advice (Code of Practice) to help operators comply with their duties under IRR 17 [20]. IRR 17 controls the radiation exposure of workers and the public apart from that resulting from the permitted disposal of radioactive waste, which is regulated by the environment agencies under the various permitting legislation described previously. The Ionising Radiation (Basic Safety Standards) (Miscellaneous Provisions) Regulations 2018 [21] transposes Directive 2013/59/EU to ensure the UK is committed to maintaining high safety standards for protection against exposure to ionising radiation and includes updated scientific methods.

The Environment Agency and SEPA also have broader responsibilities under the Environment Act 1995 [22] for environmental protection including determining general concentrations of pollution in the environment. The responsibilities for Wales under the Environment Act 1995, have been transferred to NRW.

The monitoring programmes have several purposes:
- environmental and food results are used to estimate and assess dose to the public to confirm that the controls and conditions placed in the authorisations/permits provide the necessary protection and to ensure compliance with legal dose limits
- ongoing monitoring helps to establish the long-term trends in concentrations of radioactivity over time near, and at distance from, nuclear licensed sites
- the results are also used to confirm the safety of the food chain; and
- monitoring the environment provides indicators of radionuclide dispersion around each nuclear site

Most of the monitoring carried out and presented in this report concerns the local effects of discharges from nuclear licensed sites in the UK. Monitoring of food and the environment away from nuclear licensed sites is also carried out, giving information on background concentrations of radionuclides. In previous years, the Environment Agency (with support from NRW), the FSA, FSS and SEPA have all completed reviews of their environmental radioactivity monitoring programmes. Further information is available in earlier RIFE reports (for example, [23]). Reviews are carried out to ensure the monitoring programmes are appropriate and are consistent with advice in the joint agency technical guidance [24,25], resulting in an adjustment and consolidation of the monitoring around some sites. Year on year, the monitoring programmes are also affected by sample availability. The Environment Agency, FSA, FSS, NRW, NIEA, SEPA and DESNZ have also prepared a RIFE summary. This summary report was combined with the UK report on the application of Best Available Techniques (BAT) in civil nuclear facilities (2017 to 2021), which was submitted to the Radioactive Substances Committee of the OSPAR Commission as the UK statement on the implementation of OSPAR Recommendation 2018/1 on Radioactive Substances in early 2023 and will be available at the following webpage - https://www.ospar.org/work-areas/rsc/bat-bep/implementation-reporting/united-kingdom.

The analysis and measurements for the monitoring programmes was carried out by various 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)
- UK Health Security Agency (UKHSA)
- SOCOTEC UK Limited

Details of the methods of sampling and analysis are presented in Section 2 of this report. Section 2 also explains how results are interpreted in terms of public radiation exposures. A summary of the assessment approach and current trends in doses is given in the Section 1.2 [26,27].

1.2 Summary of radiation doses

1.2.1 The assessment process

Most of the monitoring was carried out to determine the effects of discharges from nuclear and non-nuclear operations on the food people consume and their environment. The results are used to estimate and assess annual radiation doses to the public that can then be compared with the relevant dose limits. Dose assessments are retrospective in that they apply to 2022 using monitoring results for that year. The radioactivity concentrations and dose rates reported include the combined radiological impact of all discharges, up to the time of sampling.

In this report, 2 main types of retrospective doses are assessed (see Figure 1.1). The first type of assessment considers the doses from radioactive discharges (gaseous and liquid) to the environment from nuclear licensed sites combined with the dose from site radiation sources (direct radiation). This assessment gives an estimate of the annual 'total dose' to people living near the nuclear licensed sites. The 'total dose' assessment is the main method for estimating radiation exposure to the public.

Figure 1.1 The dose assessment process for major nuclear sites

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

Exposure from direct radiation may be a significant contributor to dose, close to a nuclear site, due to radiation emitting from sources on the site[10]. The Office for Nuclear Regulation (ONR) is responsible for regulating direct radiation. In 2018, Électricité de France (EDF) Energy revised its method of direct dose assessment (for the calendar year) for operating power stations based on measurements of external radiation dose rates at the site boundary, distances to the point of exposure and occupancy data [26]. This is different to the previous method based on generic arguments considering the low dose rates from Advanced Gas-cooled Reactor (AGR) and Pressurised Water Reactor (PWR) power stations. Therefore, values since 2018 will differ from the generic values given previously. The operators of nuclear licensed sites provide estimates of direct radiation doses to the ONR (Table 1.1); annual exposure data are then made available for use in 'total dose' assessments. These dose assessments use recent habits survey data which have been profiled using an agreed method [27].

10 At some locations separate nuclear licensed sites are situated adjacent to one another, for example some EDF Energy operated power stations have a neighbouring decommissioning Magnox station. As these are operated by different employers, workers at one station are considered to be members of the public for the purpose of assessing direct radiation exposure to the other station. Doses to workers are considered differently to those for the public and therefore are not included in 'total dose' assessments.

The second type of assessment estimates annual dose from specific sources and associated exposure pathways (see Appendix 2, and Appendix 5 for more information). These dose assessments provide a check on the adequacy of the annual 'total dose' method (which is the preferred assessment type [28]) and provide information for a range of additional exposure pathways. The sum of the doses from specific sources (terrestrial and aquatic) cannot be directly compared to the assessment of 'total dose' from all sources. This is because the assessment methods use different ways of defining the most exposed people.

Both types of assessment consider those people in the population most exposed to radiation (the 'representative person'). The results from both types of assessments are compared with legal limits. The effective doses (defined in Appendix 2) are calculated and compared with the legal dose limit of 1mSv per year for members of the public. All legal radiation dose limits in the UK are based on recommendations made by the ICRP [2], which are consistent with BSSD 13 [9]. The radiation dose specifically to skin is also assessed in some cases and compared with the legal limit for skin exposure.

The radiation doses resulting from human activities may be compared with the exposure from natural radioactivity. The average individual radiation dose in the UK population (in 2010) from natural radiation was estimated by UKHSA to be approximately 2.3mSv per year [1].

Collective doses are beyond the scope of this report. They are derived using modelling techniques. The EC has published an assessment of individual and collective doses from reported discharges from nuclear power stations and reprocessing sites for gaseous and liquid waste disposals from 2004 to 2008 [29].

Radiation exposures to some specific groups of workers are included in the assessment of doses from nuclear licensed sites. These are people who may be inadvertently exposed as a result of their work. These, for example, include fishermen, farmers, and sewage workers. It is appropriate to compare their doses to the dose limit for members of the public [30]. Those people who specifically work with ionising radiation have their radiation doses assessed and recorded as part of their employer's programme to assess occupational exposure [19].

1.2.2 'Total dose' results for 2022

The results of the assessment for each site are summarised in Table 1.2 (see also Figure S and Table S in the Technical Summary). These data are presented in three parts. The representative person receiving the highest annual doses from the pathways mainly relating to gaseous discharges and direct radiation are shown in part A and those for liquid discharges in part B. Occasionally, the people receiving the highest doses from all pathways and sources are different from those in parts A and B. Therefore, this case is presented in part C. The major contributions to dose are provided. The use of radionuclide concentrations reported at the limits of detection provide an upper estimate of doses calculated for pathways based on these measurements. The full output from the assessment for each site can be provided by contacting one of the agencies listed on the inside front or back covers of this report.

In all cases, doses estimated for 2022 were much less than the annual limit of 1mSv for members of the public. The people most affected from gaseous discharges and direct radiation varied from site to site but the dominant pathway was often direct radiation (from the relevant site), where it was applicable. The people most affected from liquid discharges were generally adults eating seafood or people who spend long periods of time over contaminated sediments, which are coastal (or other) areas that are impacted by liquid discharges.

The representative person who received the highest annual 'total dose' (0.24mSv), is from the Cumbrian coastal community (near Sellafield), who consumed crustaceans at high rates, together with other seafood. The 'total dose' (from all sources) at this site is combined with the effects of all local sources, including specifically the effects of historical discharges of natural radionuclides from the former phosphate processing plant near Whitehaven. The next highest annual 'total doses' were received by people living near the Capenhurst (0.14mSv), and Amersham (0.086mSv) sites; these doses were almost entirely due to direct radiation from the sites and were a small fraction of the dose limit.

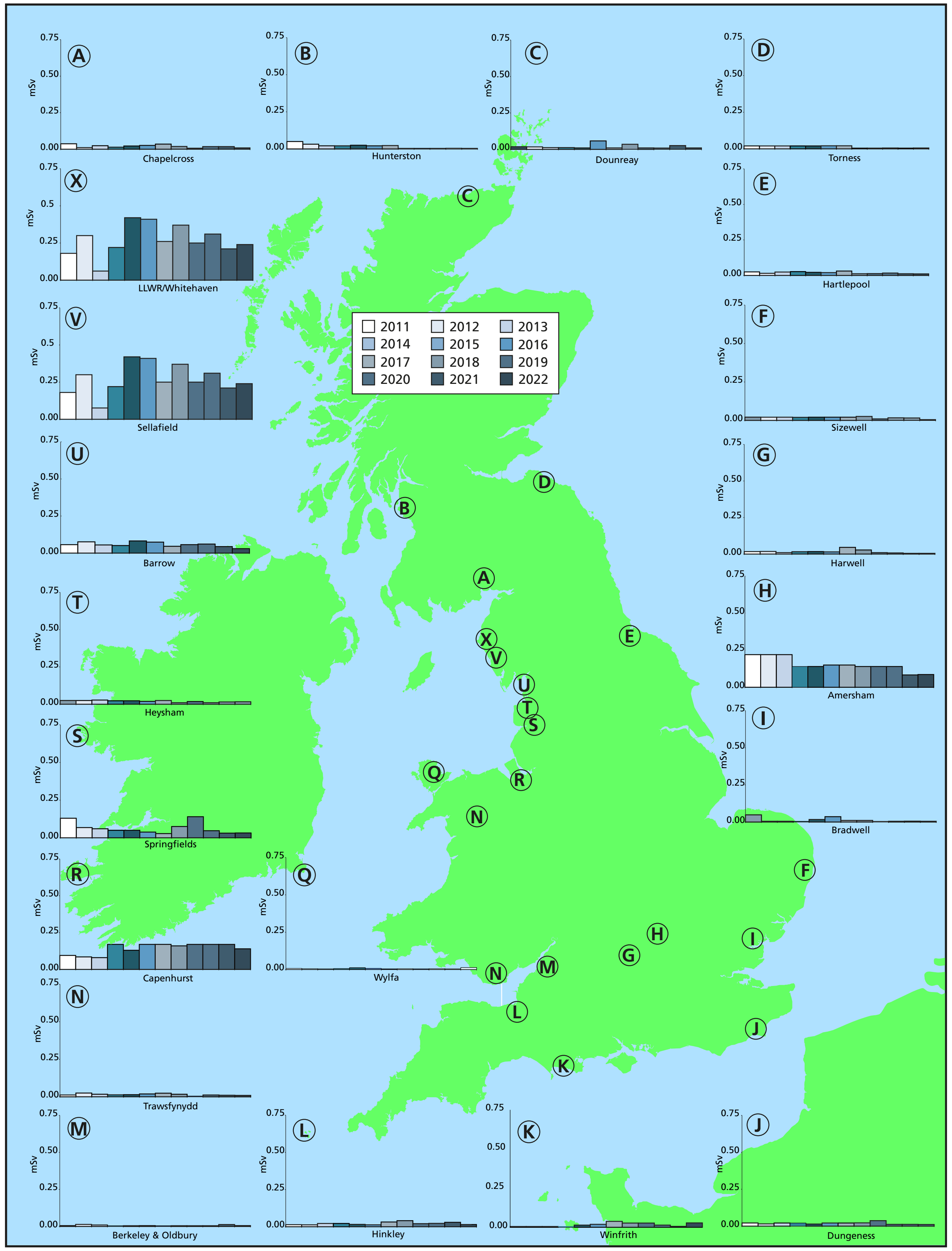
1.2.3 'Total dose' trends

A time-series of annual 'total dose' from 2011 to 2022 is shown in Figure 1.2 (Table 1.3 gives numerical values). Many sites showed a downward trend in 'total dose' over this period. Changes in direct radiation dominated the variation (from year to year) at most of the power station sites, and small variations in external dose rates had relatively large effects at some sites where intertidal occupancy (time spent on beaches and mud/salt marsh areas) were recorded at high rates. After Magnox reactors (and to a lesser extent AGRs) stopped power generation (for example, at Dungeness), direct radiation has reduced at these sites.

The most significant trend in annual 'total dose' due to discharges of waste was for high-rate consumers of seafood in the Cumbrian coastal community (near Sellafield, the former phosphate processing plant near Whitehaven and the Low-Level Waste Repository (LLWR) near Drigg). In this case, the overall downward trend in 'total dose' broadly followed the general downward trend in concentrations of naturally occurring and artificial radionuclides from non-nuclear and nuclear sources, respectively. Year to year changes in radiation doses were also influenced by changes in consumption and occupancy characteristics of local people and the natural variability in radionuclide concentrations in food and the environment. In recent years, doses to these people have varied due to small differences in the concentrations of polonium-210 in local seafood.

The estimate of the annual 'total dose' at Dounreay has decreased in recent years from the peak value in 2008. The increase in 'total dose' at Dounreay in 2016, 2018 and 2021 was mostly due to the concentration of caesium-137 found in venison (game) being included, which had not been sampled in previous years. The changes in 'total dose' at Heysham (2011 and 2016), Hinkley Point (2010 and 2017), Springfields (2012) and Trawsfynydd (2018) were largely due to findings from new habits surveys. At Springfields, the increase in 'total dose' in recent years was due to higher estimate of direct radiation. At Capenhurst, any changes in annual 'total doses' over time are attributable to changes in the estimates of direct radiation from the site. The small increases in 'total dose' at Bradwell and Winfrith in recent years were mostly due to higher estimates of direct radiation from the individual sites. In all cases doses were well below the legal limit of 1mSv.

Figure 1.2 'Total doses' around the UK's nuclear sites due to radioactive waste discharges and direct radiation (2011 to 2022). (Exposures at Sellafield/Whitehaven/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)



1.2.4 Source specific dose results for 2022

The results of the source specific assessments for the main industrial sites in the UK are summarised in Figure 1.3 and Table 1.4. These assessments focus on the effect of gaseous or liquid waste discharges, unlike the assessment of 'total dose' which includes all sources including the effect of direct radiation.

The most significant exposures from seafood (fish and crustacean shellfish) consumption were to the Cumbrian coastal community (at the LLWR near Drigg, and near Sellafield and near the former phosphate processing plant near Whitehaven). The majority of the dose was from non-nuclear industrial operations, resulting in TENORM and, to a much lesser extent, the legacy of historical discharges from Sellafield. The most important pathways and radionuclides at each site were similar to those found for 'total dose'.

Although some source specific doses were estimated to be higher than 'total doses', the reasons for this are understood and relate to the different assumptions of the 2 assessment approaches. The assumptions used for source specific assessments are conservative with respect to adding together the effects of consumption of different foods. The assumptions used for 'total dose' assessments are more realistic, and the estimates from the source specific assessments provide reassurance that the 'total dose' approach is reasonable. Radiation doses to all age groups (see Section 2.6 for the age groups used), calculated using the source-specific method, were all found to be well below the legal limit of 1mSv per year.

1.2.5 Protecting the environment

This report focusses on the risk to the public (in other words, to ensure that radiation doses remain below limits). However, the environment agencies also consider the protection of wildlife and the environment from radiation exposure caused by human activity. The 2007 recommendations of the ICRP concluded that a systematic approach to the radiological assessment of non-human species was required to support the management of radiation effects in the environment [2]. The ICRP, therefore, introduced the concept of Reference Animals and Plants (RAPs) for a system of radiological environmental protection [31]. The ICRP has published its aims covering:

1. prevention or reduction of the frequency of deleterious (harmful) radiation effects on biota (animals and plants) to a level where they would have a negligible impact on the maintenance of biological diversity
2. the conservation of species and the health and status of natural habitats, communities, and ecosystems [32]

In the UK, the current legislative measures for protection of wildlife from radiation are retained from the European Commission directives, on the conservation of wild birds [33] and the conservation of natural habitats and wild flora and fauna [34]. These are implemented through The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019, known as the 'Habitats Regulations' [35].

Figure 1.3 Source specific doses in the UK, 2022. (Exposures at Whitehaven and Sellafield receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations.)

Under the 'Habitats Regulations', the Environment Agency, NRW and SEPA are required to review existing authorisations/permits to ensure that no authorised activity or permission has an adverse effect, either directly or indirectly, on the integrity of Natura 2000[11] habitat sites. Similarly, for any new or varied authorisation/permit, whereby the applicant must assess the potential impact of the discharges on reference organisms that represent species which may be adversely affected.

The Environment Agency has assessed the dose rates to reference organisms and feature species for regulated radioactive waste discharges. It has concluded that the radiation dose to the worst affected organism was less than the agreed dose guideline (40µGy h^{-1}) and therefore, there was likely to be no significant impact on the integrity of habitat sites or their conservation objectives [36,37]. The assessment of impacts on wildlife and plants (non-human) species is also an essential part of the Environment Agency's determination of applications for new and varied environment permits. Further information concerning assessment of dose rates to reference organisms is available in earlier RIFE reports (for example, [38]).

SEPA has carried out a pressures and impacts assessment from radioactive substances on Scotland's water environment. The study concluded that there was no adverse impact on the aquatic environment as a result of authorised discharges of radioactive substances, although it recognised that there may be a need for further data to support this conclusion. SEPA has included a specific habitats assessment in any new authorisation granted by the agency.

SEPA's nuclear power generation and decommissioning sector plan is available on SEPA's website: https://sectors.sepa.org.uk/nuclear-power-generation-and-decommissioning-sector-plan/.

1.3 Sources of radiation exposure

1.3.1 Radioactive waste disposal from nuclear licensed sites

The permits[12] and authorisations issued by the environment agencies to nuclear sites require operators to minimise the amount of all forms of radioactive waste generated. They also limit any liquid or gaseous discharges and ensure that solid low-level waste (LLW) is sent to a suitable disposal site.

Solid LLW from nuclear licensed sites may be transferred to the LLWR near Drigg for a range of treatments or disposal. Solid wastes containing low quantities of radioactivity can also be disposed of at permitted landfill sites (see Section 7). Solid LLW from Dounreay, intended for disposal, can be transferred to the Dounreay LLW facility.

Figure 1.4 shows the nuclear licensed sites that produce waste containing artificial radionuclides. Nuclear licensed sites are permitted/authorised to dispose of radioactive waste and are also subject to the Nuclear Installations Act 1965 [39]. The monitoring programmes reported here cover all these sites.

11.Natura 2000 is made up of sites designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). SACs and SPAs in the UK no longer form part of the EU's Natura 2000 ecological network. The 2019 Regulations have created a national site network on land and at sea, including both the inshore and offshore marine areas in the UK

12.In England and Wales, the term 'permit' replaced 'authorisation' under the Environmental Permitting Regulations (EPR). 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 EPR coming into force in 2010. In Scotland, the term 'permit' replaced 'authorisation' under the Environmental Authorisations (Scotland) Regulations 2018 (EASR18), irrespective of whether the period includes activities prior to EASR18 coming into force in 2018. 'Authorisation' remains the relevant term for Northern Ireland

Figure 1.4 'Principal nuclear site sources of radioactive waste disposal in the UK, 2022. (Showing main initial operation. Some operations are undergoing decommissioning)

Discharges of radioactive waste from other non-nuclear sites such as hospitals, industrial sites and research establishments were also regulated under RSA 93 or EPR 16 (and thereafter, under EPR 19, RSR 18 or EASR 18) in 2022, but not subject to the Nuclear Installations Act. Occasionally, radioactivity is detected in the environment during monitoring programmes because of discharges from these other sites. For example, iodine-131 discharged from hospitals is occasionally detected in river and marine samples. Small amounts of very low level solid radioactive waste are disposed of from some non-nuclear sites to approved landfill sites (for controlled burial, incineration, or other treatment/disposal methods). There is also a significant radiological impact due to historical 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 near Whitehaven, and so monitoring is carried out near this site.

Discharges from other non-nuclear sites are generally considered insignificant in England and Wales, so the environment agencies do not usually carry out monitoring to protect public health. However, some routine monitoring programmes are undertaken in Lancashire and Northamptonshire (Section 7). In Scotland, SEPA carries out routine sampling in the Firth of Clyde and at landfill sites to assess the impact of the non-nuclear industry on the environment. Additionally, to ensure the doses from combined discharges to a sewer network are assessed properly, SEPA periodically undertakes intensive sampling at major sewage treatment plants to monitor the combined discharges from the non-nuclear industry.

Principal permitted/authorised discharges, disposals of radioactive wastes and solid waste transfers from nuclear establishments in 2022, are given in Appendix 1 (Table A1.1 to Table A1.4, inclusive). The tables also list the main discharge and disposal limits that are specified or, in the case of the MOD, administratively agreed. In 2022, discharges and disposals were all below the limits. Solid waste transfers from nuclear establishments in Scotland are also given in Appendix 1 (Table A1.4). Section 7 gives information on discharges from non-nuclear sites.

The discharge limits are set through an assessment process, initiated either by the operator or the relevant environment agency. In support of the process, prospective assessments of doses to the public are made assuming discharges at the specified limits. Using this conservative assumption, discharge limits are set so that doses to the public will be below the source and site dose constraints of 0.3 and 0.5mSv per year, respectively [28]. The determination of discharge limits considers a comprehensive range of pathways including the consumption of food. When determining the limits, the effect of the planned discharges on the environment and wildlife is also taken into account. In addition, the regulations require BAT, under the Environmental Permitting (England and Wales) Regulations, to be used to ensure that discharges and their impact are minimised. The principles of best practicable means (BPM) continue to be applied in Scotland [40]. The UK environment agencies consider that the terms BPM and best practicable environmental option are equivalent to the use of BAT [40,41].

The discharges and disposals made by sites do not normally fluctuate significantly. 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 agencies. In cases where there has been a breach of limits, or if appropriate actions have not been carried out to ensure discharges are minimised, 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 1 (Table A1.5) summarises the types of events that occurred in 2022.

1.3.2 UK radioactive discharges (international agreements and new build)

This section gives information on the context of UK radioactive discharges as they relate to international agreements and the future building of new nuclear power stations.

International agreements

The UK is a contracting party to 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 [42]. In 1998, UK government ministers agreed a long-term RSS and signed the Sintra statement which included the following commitment [43]:

“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 historical levels, resulting from such discharges, emissions, losses, are close to zero.”

A UK Strategy for Radioactive Discharges was published in 2002 [44], to describe how the UK would implement the ministerial agreements reached at the 1998 and subsequent meetings of OSPAR. This strategy was revised in 2009 to include gaseous discharges, from decommissioning as well as operational activities, and from the non-nuclear as well as the nuclear industry sectors [45]. A number of objectives (including the UK’s obligations, with respect to the OSPAR RSS intermediate objective for 2020) and outcomes were identified in the revised strategy. These are summarised in earlier RIFE reports (for example, [46]).

To support implementation of UK government policy concerning the regulation of radioactive discharges into the environment, the Environment Agency, DESNZ and the Scottish and Welsh Governments (collectively and individually) have issued guidance and developed environmental principles. These are also summarised in earlier RIFE reports (for example, [47]).

In 2018, the UK government published its review of the 2009 UK strategy for radioactive discharges [3]. This 2018 review takes account of developments in UK government policy, commercial decisions within the nuclear industry, technological advances, and improvements in our knowledge of the impacts of radionuclides in the marine environment. This review demonstrates the clear evidence of progress being made by the UK in meeting the outcomes of the 2009 strategy and contributing towards the objectives of the OSPAR RSS. Further information and a copy of the report is available on the UK government website:
https://www.gov.uk/government/publications/uk-strategy-for-radioactive-discharges-2018-review-of-the-2009-strategy.

Information on the approach and work in progress within the OSPAR Convention can be found on OSPAR’s website https://www.ospar.org. 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 [48]. The agreement on monitoring (Coordinated Environmental Monitoring Programme), relevant to OSPAR, was revised [49]. The programme includes sampling in 15 sub-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 [50,51]. The UK submission concerning the implementation of the principle of using BAT has been submitted to OSPAR for publication. The Fifth Periodic Evaluation [4], represents the final assessment against the objectives of the RSS and will form the basis of the next OSPAR Quality Status Report, which was published in September 2023 (https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/).

It demonstrated that Contracting Parties have successfully fulfilled the objectives of the OSPAR RSS for 2020 under the North-East Atlantic Environment Strategy (NEAES) 2010 – 2020 and have made significant progress towards fulfilling the ultimate aim of radionuclide concentrations in the environment near background values for naturally occurring radionuclides and close to zero for artificial radionuclides [4].

In October 2021, the Contracting Parties to OSPAR, which includes the UK, agreed the NEAES 2030 [52] and signed the Cascais Declaration [53], setting OSPAR's strategic direction up to 2030. The NEAES includes the new strategic objective (S3):

"OSPAR will prevent pollution by radioactive substances in order to safeguard human health and to protect the marine environment, with the ultimate aim of achieving and maintaining concentrations in the marine environment at near background values for naturally occurring radioactive substances and close to zero for human made radioactive substances."

The work for NEAES 2030 will be taken forward through the delivery of 4 operational objectives:

- S3.O1: On an ongoing basis, OSPAR will further prevent, progressively reduce or, where that is not practicable, minimise discharges of radioactive substances through the application of BAT, taking into account technical feasibility, radiological impact, and legitimate uses of the sea.
- S3.O2: By 2025, OSPAR will identify and consider any obstacles in achieving further reductions in environmental concentrations of radioactive substances in the marine environment and examine possible solutions where appropriate.
- S3.O3: By 2025, OSPAR will identify the different types of loss of radioactive substances that may contribute to pollution of the marine environment. By 2027, OSPAR will determine if any additional measures are required to prevent such pollution, to the extent that such pollution is not already the subject of effective measures agreed by other international organisations or prescribed by other international conventions.
- S3.O4: By 2028, OSPAR will, following the outcome of the Quality Status report 2023, address, where appropriate, any uncertainties by reviewing and updating methodologies to better determine the possible impact of releases, emissions, and losses of radioactive substances on marine ecosystems.

The importance of an integrated approach to stewardship of the marine environment has long been established in the UK. The reports 'Safeguarding Our Seas' [54] and 'Charting Progress 2' [55], provided an initial strategy and assessment on the state of the UK seas. Further information concerning other individual and fully integrated assessments is available in earlier RIFE reports (for example, [47]).

In 2010, the Marine Strategy Regulations 2010 came into force. These Regulations require us to take action to achieve or maintain good environmental status (GES) in our seas (subject to certain exceptions) through the production of a "Marine Strategy" for all UK waters and that this is coordinated across the 4 UK Administrations. The UK Marine Strategy provides the framework for assessing and taking measures to achieve and maintain GES in our seas. It covers a wide range of biodiversity and marine environment descriptors including contaminants and contaminants in seafood.

The UK published an initial assessment of UK seas in 2012 (Part One of the UK Marine Strategy) [56], followed by publication of Part Two, setting out the UK marine monitoring programmes, and Part Three, our Programme of Measures, in 2014 and 2015, respectively [57,58]. In October 2019, following a public consultation, the UK published an update to the UK Marine Strategy Part One. It includes an assessment of progress towards the achievement of GES for UK seas and sets out revised targets and indicators for the next 6 years [59]. The updated UK Marine Strategy Part Two, which sets out the monitoring programmes that we will use to assess the status of UK seas in respect to these targets and indicators was published in March 2021 [60]. The UK Marine Strategy Part Three, which sets out our Programmes of Measures designed to help us achieve or maintain GES, is currently being updated. Further details on the UK Marine Strategy can be found on: https://moat.cefas.co.uk/.

Nuclear new build

In the 2008 white paper 'Meeting the Energy Challenge' [61], the UK government set out its view that new nuclear power stations should have a role to play in this country's future energy mix. More information about the basis of the white paper, subsequent national policy statements, consultations, and decisions, together with details of the approach for assessing potential new nuclear power station designs and approvals for their proposed developments, is available in earlier RIFE reports (for example, [62]). The UK government has further set out its current position on energy policy in the December 2020 white paper, "Powering our Net Zero Future" [63]. In this white paper, the UK government highlights the need to address climate change urgently and it sets out the strategy for wider energy systems to achieve the UK's target of net zero greenhouse gas emissions by 2050. The strategy includes a continuing and future role for nuclear generation to provide reliable clean electricity and it sees a potential additional role for advanced modular reactors (AMR) to provide high temperature process heat in the future. In early 2023, DESNZ published a policy paper, describing the various advance nuclear technologies currently under consideration, and available from https://www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies. The eight nuclear sites, assessed as being potentially suitable for the development of new nuclear power stations in the 2011 national policy statement on nuclear power generation [64] , are shown in Figure 1.5. However, only Hinkley Point C and Sizewell C are being actively pursued. The UK government re-affirmed its position on nuclear power generation as part of the 2022 British Energy Security Strategy, with an aim of generating up to 25% of the projected 2050 UK demand through deployment of civil nuclear [65]. In March 2023 government published its "Powering Up Britain" documents that include its Energy Security Plan. This sets out the steps it is taking to ensure that the UK is more energy independent, secure and resilient. It confirms the aim to make final investment decisions on two new nuclear power stations in the next parliament (in other words by 2029). It also confirmed that government will develop a new Nuclear National Policy Statement. The documents are available from: https://www.gov.uk/government/publications/powering-up-britain

Figure 1.5 Potential sites for new nuclear power stations

As regulators of the nuclear industry, the ONR, the Environment Agency and NRW, are working together to ensure that any new nuclear power stations built in the UK meet high standards of safety, security, environmental protection, and waste management through the generic design assessment process (GDA). The steps undertaken by the regulators are described in previous RIFE reports [66]. More information on the GDA process can be found here: https://www.gov.uk/guidance/new-nuclear-power-stations-assessing-reactor-designs.

Following a request from DESNZ ministers, the ONR, the Environment Agency and NRW began the GDA process on a 470MWe Small Modular Reactor in April 2022. The requesting party for this GDA is Rolls-Royce SMR Ltd. An outline 53-month programme for the three-step assessment process has been proposed for this GDA. The proposed design completed the first step of the GDA in April 2023, with the second step anticipated to take 16 months to complete. Further information will be reported in subsequent RIFE reports.

The construction of Nuclear New Build Generation Company's (NNB GenCo's) new twin UK European Pressurised Reactor™ (EPR™) nuclear power station continues at Hinkley Point C in Somerset. The ONR continues to be engaged in carrying out safety and security assessment and regulating its construction. The Environment Agency also continues to regulate environmental matters at the site under the environmental permits it has granted, including for construction-related discharges. The development of NNB GenCo is of interest to both regulators to ensure that the company has the competences and resources required to secure safety, security, and environment protection throughout construction and as it prepares itself to be an operator.

The ONR and the Environment Agency are continuing to work with NNB GenCo (SZC) Limited that is seeking to construct a new nuclear power station at Sizewell C, Suffolk based upon UK EPR™ reactor and replication of the Hinkley Point C station.

In 2020, the ONR and Environment Agency received applications from NNB GenCo (SZC) Limited for the Sizewell C nuclear site licence and radioactive substances activities permit. In March 2023, the Environment Agency granted the radioactive substances permit to NNB GenCo (SZC) Limited following public consultation. The nuclear site licence application is currently under consideration by the ONR.

1.3.3 Managing radioactive liabilities in the UK

The UK government has been managing radioactive waste for many decades in accordance with the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [67]. This convention aims to ensure that individuals, society, and the environment are protected from the harmful effects of ionising radiation from the management of spent nuclear fuel and radioactive waste. Further information relevant to the UK demonstrating compliance under the Joint Convention is available in earlier RIFE reports (for example, [68]).

The Nuclear Decommissioning Authority (NDA), a non-departmental public body, manages the decommissioning and clean-up of the civil public sector nuclear sites. The NDA reports to DESNZ and is responsible to Scottish ministers. The role of the NDA is strategic, developing and implementing an overall strategy for cleaning up the civil public sector nuclear legacy. The NDA's strategic objective is to manage radioactive waste and dispose of it where possible, or place it in safe, secure, and suitable storage, in line with the UK and devolved administrations' policies.

The Energy Act 2004 [69] requires the NDA to review and publish its strategy every 5 years. Its most recent strategy was published in 2021 [70] and the business plan for 2023 to 2026 is available [71]. In 2019, the NDA published an inventory and forecast of radioactive wastes in the UK (as of 1 April 2019) jointly with DESNZ [72] and a Mission Progress Report in 2021 [73].

In 2007, the UK government and devolved administrations issued a UK-wide policy document, setting out principles for the long-term management of solid LLW [74]. Following the introduction of the LLW policy, the UK LLW Strategy was published in 2010 [75]. A new UK LLW Strategy was published in 2016 [76]. Some LLW, mostly from non-nuclear sites, and some very low-level radioactive waste is currently disposed of in landfill by controlled burial (Section 7). There is still a large amount of solid LLW that will require disposal. Some will be sent to the LLWR near Drigg. The LLW from Dounreay can be disposed of at the new Dounreay LLW Facility close to the site. In 2022, Nuclear Waste Services (NWS) was launched, which brings together the operator of the LLWR, geological disposal facility (GDF) developer Radioactive Waste Management Limited (RWM) and the NDA group's integrated waste management programmes into a single organisation. NWS have assumed responsibility for the development of a GDF. In 2023, DESNZ ran a consultation on proposals to update and consolidate the policies of the UK government and devolved administrations on the management of radioactive substances and nuclear decommissioning into a single UK-wide policy framework [77,78]. This would replace the existing national policy on radioactive waste management [79]. The responses to the consultation are currently under consideration and it is anticipated that the final version of policy framework will be published once the outcomes of the consultation process is known.

The NDA are responsible for implementing UK and Welsh Government policies on the long-term management of higher activity radioactive waste (HAW) through geological disposal. Scottish Government policy is that the long-term management of HAW should be in near-surface facilities. Facilities should be located as near to the site where the waste is produced as possible. Guidance to site operators and regulatory position statements on the management of HAW on licensed site has been issued by the Environment Agency, NRW, SEPA and the ONR [80,81].

The UK government's initial framework was set out in the 2008 'Implementing Geological Disposal' white paper for managing HAW in the long-term through geological disposal and includes the possibility of hosting a GDF at some point in the future [82]. An updated framework was outlined in the 2014 white paper (as a replacement in England and Northern Ireland) and sets out the policy for managing HAW in the long-term through geological disposal [83]. Following completion of the initial actions in the 2014 white paper and subsequent consultation, DESNZ published a policy update in 2018 [84]. This replaces the 2014 white paper in England and also describes the positions of the Devolved Administrations: radioactive waste management is a devolved policy issue. Therefore, the Scottish Government, Welsh Government and Northern Ireland Executive each have responsibility for determining disposal policy in their respective areas. Further information on devolved administrations' policies is available on the GOV.UK website: https://www.gov.uk/government/collections/geological-disposal-facility-gdf-for-high-activity-radioactive-waste.

No specific GDF sites have been selected or are currently under consideration [83]. However, following a national geological screening exercise, RWM/NWS have re-started the process to engage with communities across England to host a GDF. Further information on the aspects of GDF is also available on the website: https://www.gov.uk/government/collections/geological-disposal-facility-gdf-for-high-activity-radioactive-waste.

The Committee on Radioactive Waste Management (CoRWM) continues to provide independent scrutiny of the government's long-term management, storage, and disposal of radioactive waste. CoRWM has published its annual report for 2021 to 2022 [85], proposed work programme for 2022 [86] and a report on the implications of inshore siting of a geological disposal facility [87].

Guidance on requirements for authorisation for geological and near-surface disposal facilities has been published [88–90]. SEPA has issued a policy statement on how it will regulate the disposal of LLW from nuclear licensed sites [91] and published joint guidance with the Environment Agency and NRW on the surrender of nuclear site permits that include how potential onsite disposals of radioactive waste should be considered by site operators [92]. In May 2019, SEPA issued guidance on the decommissioning of non-nuclear facilities (for example, a single laboratory) from radioactive use [93].

Decommissioning of many nuclear sites in Great Britain is currently underway. Following the environment agencies' consultation on the draft guidance, 'Guidance on Requirements for Release of Nuclear Sites from Radioactive Substances Regulation', referred to as 'GRR', the operational feedback from the trial use of the guidance was used to refine the structure and clarity of the guidance. This was published in 2018 [92]. This guidance describes what operators must do to release sites from radioactive substances regulation and is also available via: https://www.gov.uk/government/publications/decommissioning-of-nuclear-sites-and-release-from-regulation/decommissioning-of-nuclear-sites-and-release-from-regulation.

Naturally occurring radioisotopes are enhanced in some wastes (TENORM) and those wastes are subject to existing regulatory systems that are designed to protect human health and the environment. Further information relevant to the UK NORM Waste Strategy, published in 2014, is available in earlier RIFE reports (for example, [47]).

1.3.4 Solid radioactive waste disposal at sea

In the past, packaged solid waste of low radioactivity concentrations 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 [43]. The environmental impact of the deep ocean disposals was assessed by detailed mathematical modelling and has been shown to be negligible [94]. Disposals of small amounts of waste also took place from 1950 to 1963 in a part of the English Channel known as the Hurd Deep. The results of environmental monitoring of this area are presented in Section 8 and confirms that the radiological impact of these disposals was insignificant.

In England, the MMO administers a range of statutory controls that apply to marine works on behalf of the Secretary of State for Environment, Food and Rural Affairs. This includes issuing licences under the Marine and Coastal Access Act 2009 (MCAA) [7] for the disposal of dredged material at sea. In Northern Ireland, Scotland and Wales, licences for disposal of dredged material at sea are the responsibility of DAERA, the Scottish Government (Marine Scotland) and NRW, respectively.

The protection of the marine environment is considered before a licence is issued. Since dredged 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 [95]. The International Atomic Energy Agency (IAEA) has published a system of assessment that can be applied to dredged spoil disposal [96,97] and which has been adapted to reflect operational practices in England and Wales [98]. In 2022, no new requests were received to apply for additional licences for the disposal of dredged material (containing radioactivity) at sea.

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. UKHSA has assessed incidents involving the transport of radioactive materials in the UK [99]. UKHSA have also considered the effects of discharges into the marine environment from the oil and gas industry, with the estimated highest individual dose (per head of population) being less than 0.001mSv per year [100]. Submarine berths in the UK are monitored by the MOD (for example, [101]). General monitoring of the British Isles is carried out as part of the programmes described in this report, to detect any significant effects from the sources above. No such effects were found in 2022. Low concentrations of radionuclides were detected in the marine environment around the Channel Islands (Section 8), and these may be partly due to discharges from the nuclear fuel reprocessing plant at La Hague in France.

The exploration for, and extraction of, gas from shale rock has been investigated in the UK with support from DESNZ. Further details on fracking: developing shale gas in the UK (updated March 2019) are provided on the GOV.UK website: https://www.gov.uk/government/publications/about-shale-gas-and-hydraulic-fracturing-fracking/developing-shale-oil-and-gas-in-the-uk.

This process, along with others for unconventional sources of gas such as coal bed methane, represents a potential source of exposure to naturally occurring radioactivity for the public and workers. The form of the radioactivity could be gaseous, liquid, or solid. Examples of routes of exposure are inhalation of radon gas emissions, and ingestion of water and food where the process has enhanced concentrations of naturally occurring radioactive material (NORM). The environment agencies, FSA or FSS do not currently monitor radioactivity in the environment and food from the exploration and extraction of shale gas.

In November 2019, the UK government announced "an indefinite suspension" of fracking, after a report by the Oil and Gas Authority, an independent subsidiary of DESNZ, found it was not possible to predict the probability or size of tremors caused by the practice. In late 2019, the Scottish Government finalised its policy position of no support for unconventional oil and gas development in Scotland.

As part of the British Energy Security Strategy [65], DESNZ launched a scientific review of shale gas extraction in April 2022 to advise on the latest scientific evidence and developments in relation to shale gas extraction. In September 2022, the UK government lifted its moratorium on UK shale gas production. This will enable developers to seek planning permission where there is local support.

Further information on the previous involvement by each of the environment agencies to support engagement with industry, and other related issues to shale gas extraction, is available in earlier RIFE reports (for example, [68]).

The Environmental Protection Act 1990 provides the basis for a regulatory regime for identifying and remediating contaminated land. In the UK, there is a duty to inspect land under Part II A of the Environmental Protection Act 1990, but there must be reasonable grounds for inspecting land for radioactivity. Reasonable grounds are defined in the statutory guidance. Once it is decided that an area is a special site, it is regulated by the environment agencies in their respective areas.

In England and Wales, regulations were extended in 2007 to cover land contaminated with radioactivity originating from nuclear licensed sites. DESNZ issued revised guidance for radioactive contaminated land to local authorities and the Environment Agency in 2012 [102]. The Environment Agency has issued a series of briefing notes that provide information on land contaminated with radioactivity in England and Wales [103]. In 2018, DESNZ carried out a targeted consultation process on proposed updates to the statutory guidance for radioactive contaminated land on behalf of the UK and Welsh Governments. Updates have subsequently been made to the statutory guidance for England, which was published in 2018 [104]. To date, no site has been legally designated as 'radioactive 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 [105,106].

In 2007, the Radioactive Contaminated Land (Scotland) Regulations came into force by amending Part II 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. In Scotland, clear dose criteria are set for homogeneous and heterogeneous contamination. Also, the risk (probability or frequency of occurrence) of receiving the dose should be considered for the designation of radioactive contaminated land. To date, no site has been designated as 'contaminated land' due to radioactivity in Scotland.

The contribution of aerial radioactive discharges from UK installations to concentrations of radionuclides in the marine environment has been studied [107]. The main conclusion was that aerial discharges do not make a significant contribution to activity concentrations in the marine environment. On occasion, the effects of aerial discharges may be detected in the aquatic environment, and conversely the effects of aquatic discharges may be 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 by UKHSA, the most recent report was published in 2016 [1]. The most significant source of exposure was from natural radiation (radon and thoron gases). Figure 1.6 provides a breakdown of the exposure to the UK population by source. The average individual dose from exposure to all significant sources of ionising radiation was estimated to be about 2.7mSv per year, the same as that reported in the previous review [108]. The dose from radiation in the environment was about 2.3mSv per year, or about 84% of the dose from all sources of radiation. This was dominated by exposure to naturally occurring sources of radiation although there is significant variation across the UK due to local geology and other factors. Only about 0.2% of the annual dose was from artificial sources; and of this, the majority was from radionuclides released during historical testing of nuclear weapons in the atmosphere (global fallout) from the 1950s and 1960s (hereafter referred to as 'nuclear weapons testing'), with exposure to radionuclides routinely discharged by industry contributing less than 0.01% to the total dose. The average individual dose from medical sources was about 0.4mSv per year, or about 16% of the dose from all sources of radiation. Occupational exposure contributed significantly less than 1% of the dose. Further information, including the most recent breakdown of the average individual dose to the UK population by source of exposure, is available on the UKHSA website: https://www.ukhsaprotectionservices.org.uk/radiationandyou/.

The RIFE report is directed at establishing the exposure of people who might receive the highest possible doses due to regulated radioactive waste discharges, because of their age, diet, location or habits. It is the exposure of these people which forms the basis for comparisons with dose limits in UK law.

Figure 1.6 Average UK population exposure from natural and man-made sources of radioactivity

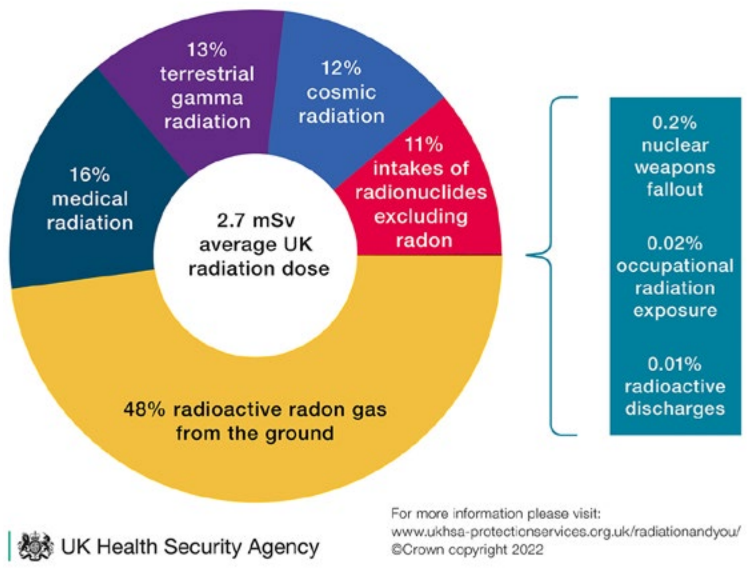


Table 1.1 Individual doses - direct radiation pathway, 2022*

Site	Exposure[a] mSv
Nuclear fuel production and reprocessing	
Capenhurst	0.14
Sellafield	0.003
Springfields	0.032
Research establishments	
Dounreay	0.010
Harwell	0.001
Winfrith (Magnox)	0.028
Nuclear power stations	
Berkeley	0.004
Bradwell	Bgd[b]
Chapelcross	0.003
Dungeness	0.010[c]
Hartlepool	<0.001
Heysham	0.003[d]
Hinkley Point	<0.001[e]
Hunterston	0.004[f]
Oldbury	0.001
Sizewell	0.001[g]
Torness	0.004
Trawsfynydd	0.003
Wylfa	0.013
Defence establishments	
Aldermaston	0.003
Barrow	Bgd[b]
Burghfield	Bgd[b]
Derby	Bgd[b]
Devonport	Bgd[b]
Faslane	<0.001
Rosyth	<0.001
Dounreay (Vulcan)	Bgd[b]

Table 1.1 continued

Site	Exposure[a] mSv
Radiochemical production	
Amersham	0.080
Industrial and landfill sites	
LLWR near Drigg	0.029
Lillyhall (Cycliffe UK limited)	<0.001
Tradebe-Inutec (Winfrith)	0.008[h]

* At some locations separate nuclear licensed sites are situated adjacent to one another, for example some EDF operated power stations have a neighbouring decommissioning Magnox station. As these are operated by different employers, workers at one station are considered to be members of the public to the other station. Doses to workers are considered differently to those for the general public and therefore are not included in 'total dose' assessments

a. Values presented in main table to 2 significant figures or 3 decimal places. Values below 0.001 are reported as <0.001
For EDF sites, the highest dose, irrespective of age group and activity is reported

b. Doses not significantly different from natural background radiation

c. Value for Dungeness A. Dungeness B (0.0020) not used. The dose to workers at Dungeness A from Dungeness B was 0.0041.
The dose to workers at Dungeness B from Dungeness A was 0.025

d. Value for Heysham 2. Heysham 1 (0.0023) not used

e. Value for Hinkley B. Hinkley A (Bgd[b]) not used. The dose to workers at Hinkley A from Hinkley B was 0.0076
The dose to workers at Hinkley B from Hinkley A was Bgd[b]. The dose to workers at Hinkley C from Hinkley A was Bgd[b]
The dose to workers at Hinkley C from Hinkley B was 0.0001

f. Value for Hunterston B. Hunterston A (0.0030) not used. The dose to workers at Hunterson A from Hunterson B was 0.0011
The dose to workers at Hunterston B from Hunterston A was 0.0040

g. Value for Sizewell A. Sizewell B (0.0095) not used. The dose to workers at Sizewell A from Sizewell B was 0.0073

h. The dose to workers at Winfrith (Magnox) from Tradebe-Inutec (Winfrith) was 0.0076

Table 1.2 'Total doses' integrated across pathways, 2022

Site	Representative person[a]	Exposure[b], mSv Total	Dominant contributions[c]
A Gaseous releases and direct radiation from the site			
Aldermaston and Burghfield	Adult game meat consumers	<0.005[d]	Direct radiation
Amersham	Local adult inhabitants (0 - 0.25km)	0.086[d]	Direct radiation
Barrow	Adult potato consumers	<0.005	Gamma dose rate over sediment, potatoes, ^{3}H[e], ^{137}Cs[e]
Berkeley and Oldbury	Infant milk consumers	0.006	Milk, ^{14}C, ^{35}S
Bradwell	Prenatal children of other vegetable consumers	<0.005	Green vegetables, ^{14}C
Capenhurst	Infant poultry meat consumers	0.14[d]	Direct radiation
Chapelcross	Infant milk consumers	0.009	Milk, ^{35}S, ^{90}Sr
Derby	Children potato consumers	<0.005[d]	Potatoes, ^{234}U[e], ^{238}U
Devonport	Adult potato consumers	<0.005	Fish, ^{241}Am[e]
Dounreay	Local adult inhabitants (0.25 - 0.5km)	0.010	Direct radiation
Dungeness	Local adult inhabitants (0.25 - 0.5km)	0.011	Direct radiation
Faslane	Adult occupants for direct radiation	<0.005	Direct radiation
Hartlepool	Local adult inhabitants (0 - 0.25km)	0.008	Direct radiation, gamma dose rate over sediment
Harwell	Local adult inhabitants (0 - 0.25km)	<0.005[d]	Direct radiation, external and inhalation, ^{222}Rn
Heysham	Local adult inhabitants (0-0.25km)	0.006	Direct radiation, gamma dose rate over sediment, external and inhalation, ^{14}C
Hinkley Point	Infant milk consumers	0.009	Milk, ^{14}C
Hunterston	Prenatal children of local inhabitants (0.5 - 1km)	<0.005	Direct radiation
LLWR near Drigg	Infant local inhabitants (0.5 - 1km)	0.031	Direct radiation
Rosyth	Local adult inhabitants (0.5 -1km)	<0.005	Direct radiation
Sellafield	Adult root vegetable consumers	0.010 [d]	Direct radiation, gamma dose rate over sediment, root vegetables, ^{241}Am
Sizewell	Local adult inhabitants (0 - 0.25km)	<0.005	Direct radiation, fish, gamma dose rate over sediment, external and inhalation, ^{14}C ^{241}Am
Springfields	Local adult inhabitants (0.5 - 1km)	0.032[d]	Direct radiation
Torness	Prenatal children of wild fruit and nut consumers	0.006	Domestic fruit, wild fruit, ^{14}C, ^{90}Sr
Trawsfynydd	Prenatal children of local inhabitants (0.5 - 1km)	<0.005	Direct radiation
Winfrith	Local adult inhabitants (0.5-1km)	0.028	Direct radiation
Wylfa	Infant local inhabitants (0.25 - 0.5km)	0.014	Direct radiation
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
Barrow[h]	Adult occupants on houseboats	0.030	Gamma dose rate over sediment
Berkeley and Oldbury	Adult occupants over sediment	<0.005	Fish, gamma dose rate over sediment, ^{241}Am
Bradwell	Adult occupants on houseboats	<0.005	Fish, gamma dose rate over sediment, ^{241}Am
Capenhurst	Occupants on water aged 10y	0.074	Direct radiation
Chapelcross	Adult wildfowl consumers	<0.005	Fish, molluscs, $^{239+240}Pu$, ^{241}Am
Derby	Infant consumers of locally sourced water	<0.005	Water, ^{60}Co[e]
Devonport	Adult consumers of marine plants and algae	<0.005	Fish, gamma dose rate over sediment, ^{241}Am[e]
Dounreay	Adult occupants over sediment	0.009	Gamma dose rate over sediment
Dungeness	Prenatal children of occupants over sediment	<0.005	Direct radiation, gamma dose rate over sediment
Faslane	Adult fish consumers	0.007	Fish, gamma dose rate over sediment, ^{137}Cs, ^{241}Am[e]
Hartlepool	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Harwell	Prenatal chilldren of occupants over riverbank	<0.005	Gamma dose rate over riverbank
Heysham	Adult occupants over sediment	0.016	Gamma dose rate over sediment
Hinkley Point	Prenatal children of occupants over sediment	0.015	Gamma dose rate over sediment
Hunterston	Adult fish consumers	<0.005	Fish, ^{137}Cs, ^{241}Am
LLWR near Drigg[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Rosyth	Adult crustacean consumers	0.006	Crustacean, gamma dose rate over sediment, ^{241}Am[e]
Sellafield[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Sizewell	Adult occupants over sediment	<0.005	Direct radiation, fish, gamma dose rate over sediment, ^{241}Am
Springfields	Adult occupants over sediment	0.008	Gamma dose rate over sediment
Torness	Adult mollusc consumers	<0.005	Fish, molluscs, ^{241}Am
Trawsfynydd	Adult occupants over sediment	0.009	Direct radiation, exposure over sediment
Whitehaven[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Winfrith	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
Wylfa	Adult occupants over sediment	<0.005	Gamma dose rate over sediment
C All sources			
Aldermaston and Burghfield	Adult game meat consumers	<0.005[d]	Direct radiation
Amersham	Local adult inhabitants (0 - 0.25km)	0.086[d]	Direct radiation
Barrow[h]	Adult occupants on houseboats	0.030	Gamma dose rate over sediment
Berkeley and Oldbury	Infant milk consumers	0.006	Milk, ^{14}C, ^{35}S
Bradwell	Adult occupants on houseboats	<0.005	Fish, gamma dose rate over sediment, ^{241}Am
Capenhurst	Local inhabitants aged 10y	0.14[d]	Direct radiation
Chapelcross	Infant milk consumers	0.009	Milk, ^{35}S, ^{90}Sr
Derby	Infant consumers of locally sourced water	<0.005	Water, ^{60}Co[e]
Devonport	Adult consumers of marine plants and algae	<0.005	Fish, gamma dose rate over sediment, ^{241}Am[e]
Dounreay	Adult occupants for direct radiation	0.010	Direct radiation
Dungeness	Local adult inhabitants (0.25 - 0.5km)	0.011	Direct radiation
Faslane	Adult fish consumers	0.007	Fish, gamma dose rate over sediment, ^{137}Cs, ^{241}Am[e]
Hartlepool	Adult occupants over sediment	0.011	Gamma dose rate over sediment
Harwell	Prenatal chilldren of occupants over riverbank	<0.005	Gamma dose rate over riverbank
Heysham	Adult occupants over sediment	0.016	Gamma dose rate over sediment
Hinkley Point	Prenatal children of occupants over sediment	0.015	Gamma dose rate over sediment
Hunterston	Prenatal children of local inhabitants (0.5 - 1km)	<0.005	Direct radiation
LLWR near Drigg[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Rosyth	Adult crustacean consumers	0.006	Crustacean, gamma dose rate over sediment, ^{241}Am[e]
Sellafield[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Sizewell	Adult occupants over sediment	<0.005	Direct radiation, fish, gamma dose rate over sediment, ^{241}Am
Springfields	Local adult inhabitants (0.5 - 1km)	0.032[d]	Direct radiation

Table 1.2 continued

Site	Representative person[a]	Exposure[b], mSv Total	Dominant contributions[c]
Torness	Prenatal children of wild fruit and nut consumers	0.006	Domestic fruit, wild fruit, ^{14}C, ^{90}Sr
Trawsfynydd	Adult occupants over sediment	0.009	Direct radiation, exposure over sediment
Whitehaven[f]	Adult crustacean consumer	0.24[g]	Crustaceans, ^{210}Po
Winfrith	Local adult inhabitants (0.5 -1km)	0.028	Direct radiation
Wylfa	Infant local inhabitants (0.25 - 0.5km)	0.014	Direct radiation

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. Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 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 and based on these measurements, an upper estimate of dose is calculated
d. Includes a component due to natural sources of radionuclides
e. The assessed contribution is based on data at limits of detection
f. The effects of liquid discharges from Sellafield, Whitehaven and LLWR near Drigg are considered together when assessing exposures at these sites beacuse their effects are manifested in a common area of the Cumbrian coast
g. The doses from man-made and naturally occurring radionuclides were 0.014 and 0.22mSv respectively. The source of naturally occurring radionuclides was a phosphate processing works near Sellafield at Whitehaven. Minor discharges of radionuclides were also made from the LLWR near Drigg into the same area
h. Exposures at Barrow are largely due to discharges from the Sellafield site

Table 1.3 Trends in 'total doses' (mSv) from all sources[a], 2005 to 2022

Site	2005	2006	2007	2008	2009	2010	2011	2012	2013
Aldermaston and Burghfield	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Amersham	0.24	0.22	0.23	0.22	0.22	0.22	0.22	0.22	0.22
Barrow[d]								0.057	0.076
Berkeley and Oldbury	**0.090**	**0.042**	0.061	0.041	0.058	0.011	0.006	0.014	0.010
Bradwell	**0.067**	**0.075**	0.070	0.070	0.098	0.13	0.048	<0.005	<0.005
Capenhurst	**0.080**	**0.085**	**0.12**	0.17	0.19	0.26	0.095	0.085	0.080
Chapelcross	0.023	0.024	0.019	0.021	0.017	0.029	0.037	0.011	0.024
Derby					<0.005	<0.005	<0.005	<0.005	<0.005
Devonport	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dounreay	0.043	0.029	0.059	0.078	0.063	0.047	0.018	0.017	0.012
Dungeness	0.55	0.63	0.28	0.40	0.32	0.022	0.021	0.015	0.021
Faslane	**<0.005**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hartlepool	0.021	0.021	0.021	0.026	0.027	0.025	0.025	0.015	0.024
Harwell	**0.022**	**0.026**	0.022	0.020	0.023	0.018	0.017	0.018	0.010
Heysham	**0.028**	0.037	0.038	0.046	0.049	0.057	0.025	0.025	0.028
Hinkley Point	**0.027**	0.048	0.035	0.045	0.055	0.014	0.014	0.013	0.022
Hunterston	0.090	0.074	0.090	0.077	0.067	0.067	0.050	0.032	0.021
LLWR near Drigg[b]	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.061
Rosyth	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sellafield[b]	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.076[c]
Sizewell	0.086	0.090	<0.005	0.031	0.026	0.020	0.021	0.021	0.021
Springfields	**0.15**	0.13	0.11	0.16	0.15	0.17	0.13	0.068	0.060
Torness	**0.025**	0.024	0.022	0.022	0.022	0.025	0.020	0.020	0.020
Trawsfynydd	0.021	0.028	0.018	0.031	0.018	0.028	0.012	0.025	0.017
Whitehaven[b]	0.40	0.43	0.37	0.47	0.28	0.18	0.18	0.30	0.061
Winfrith	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Wylfa	0.010	0.011	0.011	0.011	0.011	0.007	0.008	0.006	<0.005

Table 1.3 continued

Site	2014	2015	2016	2017	2018	2019	2020	2021	2022
Aldermaston and Burghfield	<0.005	<0.005	<0.005	0.010	0.010	<0.005	<0.005	0.008	<0.005
Amersham	0.14	0.14	0.15	0.15	0.14	0.14	0.14	0.083	0.086
Barrow[d]	0.055	0.051	0.082	0.074	0.046	0.057	0.061	0.044	0.030
Berkeley and Oldbury	<0.005	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	0.013	0.006
Bradwell	<0.005	0.017	0.036	0.011	0.011	<0.005	<0.005	0.006	<0.005
Capenhurst	0.17	0.13	0.17	0.17	0.16	0.17	0.17	0.17	0.14
Chapelcross	0.014	0.022	0.026	0.035	0.019	0.007	0.018	0.018	0.009
Derby	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Devonport	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dounreay	0.012	0.010	0.058	0.010	0.035	0.01	0.009	0.026	0.010
Dungeness	0.021	0.014	0.021	0.021	0.022	0.037	0.012	0.012	0.011
Faslane	<0.005	<0.005	0.009	<0.005	0.010	0.007	0.008	0.007	0.007
Hartlepool	0.027	0.022	0.020	0.031	0.012	0.013	0.017	0.012	0.011
Harwell	0.016	0.017	0.015	0.046	0.028	0.010	0.008	<0.005	<0.005
Heysham	0.023	0.023	0.019	0.025	0.010	0.018	0.010	0.015	0.016
Hinkley Point	0.022	0.016	0.013	0.032	0.041	0.021	0.023	0.030	0.015
Hunterston	0.021	0.025	0.021	0.023	<0.005	<0.005	0.005	0.006	<0.005
LLWR near Drigg[b]	0.22	0.42	0.41	0.25	0.37	0.24	0.31	0.21	0.24
Rosyth	<0.005	0.006	0.017	0.026	0.010	<0.005	<0.005	0.011	0.006
Sellafield[b]	0.22	0.42	0.41	0.25	0.37	0.24	0.31	0.21	0.24
Sizewell	0.020	0.021	0.021	0.021	0.026	0.010	0.017	0.016	<0.005
Springfields	0.050	0.050	0.038	0.028	0.075	0.14	0.047	0.031	0.032
Torness	0.020	0.020	0.021	0.021	<0.005	<0.005	0.006	0.005	0.006
Trawsfynydd	0.013	0.014	0.019	0.024	0.017	0.005	0.012	0.010	0.009
Whitehaven[b]	0.22	0.42	0.41	0.25	0.37	0.24	0.31	0.21	0.24
Winfrith	<0.005	0.014	0.019	0.038	0.038	0.027	0.014	0.006	0.028
Wylfa	0.007	0.013	0.008	<0.005	0.006	<0.005	0.006	0.005	0.014

a. Where no data is given, no assessment was undertaken due to a lack of suitable habits data at the time. Data in bold signify assessments performed to show trends in total dose over the five-year period from 2004 - 2008, using subsequently obtained habits data
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv
b. The effects of liquid discharges from Sellafield, Whitehaven and LLWR near Drigg are considered together when assessing exposures at these sites
c. The highest exposure due to operations at Sellafield was to people living in houseboats near Barrow
d. Exposures at Barrow are largely due to discharges from the Sellafield site

Table 1.4 Source specific doses due to discharges of radioactive waste in the United Kingdom, 2022

Establishment	Radiation exposure pathways	Gaseous or liquid source[a]	Exposure, mSv[b] per year	Contributors[c]
Nuclear fuel production and processing				
Capenhurst	Inadvertent ingestion of water and sediment and external[d]	L	0.005	Ext
	Terrestrial foods, external and inhalation near site[e]	G	<0.005[g]	^{3}H[h], ^{99}Tc, ^{234}U
Springfields	Fish, shrimp and wildfowl consumption and external in intertidal areas	L	0.007	Ext, ^{137}Cs
	Terrestrial foods, external and inhalation near site[e]	G	<0.005[g]	^{14}C, ^{90}Sr[h], ^{234}U, ^{238}U
	External in intertidal areas (children playing)[d,i]	L	<0.005	Ext
	External in intertidal areas (farmers)	L	<0.005	Ext
Sellafield[l]	Fish and shellfish consumption and external in intertidal areas (2018-2022 surveys) (excluding naturally occurring radionuclides)[m]	L	0.045	Ext, ^{129}I[h], ^{241}Am
	Fish and shellfish consumption and external in intertidal areas (2018-2022 surveys) (including naturally occurring radionuclides)[n]	L	0.37	^{210}Po
	Fish and shellfish consumption and external in intertidal areas (2022 surveys) (excluding naturally occurring radionuclides)[m]	L	0.027	Ext, ^{129}I[h], ^{241}Am
	Mollusc consumption (2022 surveys) (excluding naturally occurring radionuclides)[m]	L	0.005	$^{239+240}$Pu, ^{241}Am
	Terrestrial foods, external and inhalation near Sellafield[e]	G	0.012	^{14}C, ^{90}S
	Terrestrial foods at Ravenglass[e]	G/L	0.012	^{14}C, ^{90}Sr, ^{106}Ru[h], ^{241}Am
	External in intertidal areas (Ravenglass)[i]	L	0.014	Ext, ^{241}Am
	Occupancy of houseboats (Barrow)[s]	L	0.029	Ext
	External (skin) to bait diggers	L	0.082[j]	Beta
Research establishments				
Culham	Water consumption[k]	L	<0.005	^{137}Cs[h]
Dounreay	Fish and shellfish consumption and external in intertidal areas	L	0.011	Ext
	Terrestrial foods, external and inhalation near site	G	0.010	^{90}Sr[h], ^{129}I[h], ^{238}Pu[h], $^{239+240}$Pu, ^{241}Am[h]
Harwell	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{222}Rn
Winfrith	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{14}C
Nuclear power production				
Berkeley and Oldbury	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Occupancy of houseboats	L	0.009	Ext
	Terrestrial foods, external and inhalation near site[e]	G	0.007	^{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[e]	G	<0.005	^{14}C
Chapelcross	Wildfowl, fish and mollusc consumption and external in intertidal areas	L	<0.005	$^{239+240}$Pu ^{241}Am
	Crustacean consumption	L	<0.005	^{90}Sr[h], $^{239+240}$Pu, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	0.007	^{35}S, ^{90}Sr

Table 1.4 continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[a]	Exposure, mSv[b] per year	Contributors[c]
Dungeness	Fish and shellfish consumption and external in intertidal areas	L	0.006	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{14}C, ^{35}S, ^{60}Co[h]
Hartlepool	Fish and shellfish consumption and external in intertidal areas	L	0.013	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{14}C, ^{35}S[h], ^{60}Co[h]
Heysham	Fish and shellfish consumption and external in intertidal areas	L	0.022	Ext, ^{241}Am
	External in intertidal areas (turf cutters)	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[e]	G	0.005	^{14}C
Hinkley Point	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext
	Terrestrial foods, external and inhalation near site[e]	G	0.007	^{14}C
Hunterston	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{137}Cs, $^{239+240}$Pu, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	0.007	^{14}C, ^{35}S, ^{90}Sr
Sizewell	Fish and shellfish consumption and external in intertidal areas	L	<0.005	Ext, ^{241}Am
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{14}C, ^{35}S[h]
Torness	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	0.006	^{14}C, ^{35}S, ^{90}Sr
Trawsfynydd	Fish consumption and external to anglers	L	0.008	Ext
	Terrestrial foods, external and inhalation near site[e]	G	0.038	^{241}Am
Wylfa	Fish and shellfish consumption and external in intertidal areas	L	0.008	Ext, ^{241}Am
	Terrestrial foods, external and inhalation near site[e]	G	<0.005	^{14}C, ^{35}S
Defence establishments				
Aldermaston & Burghfield	Fish consumption and external to anglers	L	<0.005[i]	Ext
	Terrestrial foods, external and inhalation near site[e]	G	<0.005[i]	^{3}H[h], ^{137}Cs[h], ^{234}U, ^{238}U
Barrow	Occupancy of houseboats[q]	L	0.029	Ext
	Terrestrial food consumption	G	<0.005	^{3}H[h], ^{137}Cs[h]
Derby	Water consumption, fish and shellfish consumption and external to anglers[k]	L	<0.005	^{60}Co[h]
	Terrestrial foods, external and inhalation near site[d]	G	<0.005	^{234}U, ^{238}U
Devonport	Fish and shellfish consumption and external in intertidal areas	L	<0.005	^{241}Am[h]
	Occupancy of houseboats	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site	G	<0.005	^{3}H[h]
Faslane	Fish and shellfish consumption and external in intertidal areas	L	0.010	Ext, ^{137}Cs, ^{241}Am[h]
	Terrestrial food consumption	G	<0.005	^{137}Cs

Table 1.4 continued

Establishment	Radiation exposure pathways	Gaseous or liquid source[a]	Exposure, mSv[b] per year	Contributors[c]
Holy Loch	External in intertidal areas	L	0.006	Ext
Rosyth	Fish and shellfish consumption and external in intertidal areas[q]	L	<0.005	Ext, $^{241}Am^{h}$
Radiochemical production				
Amersham	Fish consumption and external to anglers	L	<0.005	Ext
	Terrestrial foods, external and inhalation near site[e]	G	0.010	^{222}Rn
Industrial and landfill				
LLWR near Drigg	Terrestrial foods[e]	G	0.006	^{14}C, ^{90}Sr, $^{106}Ru^{h}$, $^{129}I^{h}$, ^{137}Cs, ^{241}Pu
	Fish and shellfish consumption and external in intertidal areas (2018-2022 surveys) (including naturally occurring radionuclides)[l, n]	L	0.37	^{210}Po
	Water consumption[k]	L	<0.005	$^{137}Cs^{h}$, $^{241}Pu^{h}$
Whitehaven	Fish and shellfish consumption and external in intertidal areas (2018-2022 surveys) (excluding artificial radionuclides)[i,o]	L	0.33	^{210}Po
	Fish and shellfish consumption and external in intertidal areas (2018-2022 surveys) (including artificial radionuclides)[i,p]	L	0.37	^{210}Po

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

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

b. Unless otherwise stated represents committed effective dose calculated using methodology of ICRP-60 to be compared with the annual dose limit of 1 mSv (see Section 2). Exposures due to marine pathways include the far-field effects of discharges of liquid waste from Sellafield. Unless stated otherwise, the representatie person is represented by adults
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv

c. The contributors that give rise to more than 10% to the dose; either 'ext' to represent the whole body external exposure from beta or gamma radiation, 'beta' for beta radiation of skin or a radionuclide name to represent a contribution from internal exposure. The source of the radiation listed as contributing to the dose may not be discharged from the site specified, but may be from those of an adjacent site or other sources in the environment such as weapons fallout

d. 10-year-old

e. 1-year-old

f. Prenatal children

g. Includes a component due to natural sources of radionuclides

h. The assessed contribution is based on data at limits of detection

i. Includes a component due to inadvertent ingestion of water or sediment or inhalation of resuspended sediment where appropriate

j. Exposure to skin including a component due to natural sources of beta radiation, to be compared with the dose limit of 50 mSv (see Section 2)

k. Water is from rivers and streams and not tap water

l. The estimates for marine pathways include the effects of liquid discharges from LLWR. The contribution due to LLWR is negligible

m. Excluding the effects of enhanced concentrations due to the legacy of discharges of naturally occurring radionuclides from a phosphate-processing works, Whitehaven

n. Including the effects of enhanced concentrations due to the legacy of discharges of naturally occurring radionuclides from a phosphate-processing works, Whitehaven

o. Excluding the effects of artificial radionuclides from Sellafield

p. Including the effects of artificial radionuclides from Sellafield

q. Exposures at Barrow are largely due to discharges from the Sellafield site

2 Methods of sampling, measurement and presentation used in this report

This section explains the scope of the monitoring programmes presented in this report (hereafter referred to as 'programmes') and summarises the methods and data used to measure and assess radioactivity in food and the environment. The bulk of the programmes, assessment methods and data have continued in 2022 unchanged, however the main changes are:

Sampling and measurement

- special sampling at nuclear sites – if judged necessary, this was continued where there were unusual short-term increases in discharges and inadvertent releases

Assessment and presentation

- site maps - maps of sites and sampling locations have been revised and updated
- new habits data - consumption and occupancy rates have been updated with the benefit of recent habits survey results at Aldermaston and Burghfield, Springfields and Sellafield in England, Chapelcross and Rosyth in Scotland

Accompanying this report is a further set of files giving full details of each assessment of 'total dose' summed over all sources at each site.

The appendices of this report contain further details on:
- modelling to extend or improve the results of monitoring (Appendix 3)
- consumption, occupancy and other habits data (Appendix 4)
- dosimetric data (Appendix 5)
- estimates of concentrations of natural radionuclides (Appendix 6)

Guidance on planning and implementing routine environmental radiological monitoring programmes has been published [24,25]. In recent years, the Environment Agency, Food Standards Agency (FSA), Food Standards Scotland (FSS) and Scottish Environment Protection Agency (SEPA) have all completed reviews of their environmental radioactivity monitoring programmes. Further information is available in earlier RIFE reports and in Section 1.1.

2.1 Sampling programmes

The primary purpose of the programmes is to check on the quantities of radioactivity in food and the environment. Results are used to demonstrate that the safety of the public is not compromised and that doses, resulting from discharges of radioactivity, are below the statutory dose limits (see Section 1 for more details). The scope in 2022 extends throughout the UK (and the Channel Islands) and is undertaken independently of the industries which discharge wastes to the environment. Samples of food, water and other materials are collected from the environment and analysed in specialist laboratories. In situ measurements of radiation dose rates and contamination are also made and the results of the programmes are assessed in terms of limits and trends in this report. Subsidiary objectives for the programmes are:
- to provide information to assess the impact on non-human species
- to enable indirect confirmation of compliance with authorised/permitted waste disposals
- to determine whether undisclosed releases of radioactivity have occurred from sites
- to establish a baseline to judge the importance of accidental releases of radioactivity should they occur
- to demonstrate compliance with international obligations, such as The Oslo and Paris Convention for the Protection of the marine environment of the North-East Atlantic (OSPAR)

Routine sampling is focused on nuclear sites licensed under the Nuclear Installations Act, 1965 [39] since these generally discharge more radioactivity (than from non-nuclear sites) and have a greater influence on the environment. The programmes also serve to provide information to assist the environment agencies to fulfil statutory duties, which are further described in Section 1.1. Additional sampling is conducted in areas remote from nuclear sites to establish the general safety of the food chain, drinking water and the environment. Results from this sampling generate data that are used as 'background' activity concentrations to compare with results from around nuclear sites and to show the variation in the quantities of radioactivity across the UK. Quantities of radioactivity in the environment can also be affected by disposals of radioactive waste from nuclear sites abroad and show the legacy of atmospheric fallout from both past nuclear weapons testing and the nuclear reactor accidents (such as at Chernobyl in Ukraine in 1986).

Various methods for undertaking sampling and analysis are available. The programmes are primarily directed at relatively widespread radiological contamination where the likelihood of encounter or consumption is certain. Where a source of potential exposure to particles of radioactivity is concerned, the likelihood of encounter is an important factor. This is considered separately in the main report in site specific programmes targeted at contamination from radioactive particles.

The programmes can be divided into three main sectors, generally based on the source of radioactivity in the environment:
1. nuclear licensed sites discharging gaseous and liquid radioactive wastes
2. industrial and landfill sites
3. UK regional monitoring and overseas accidents

2.1.1 Nuclear licensed sites

Nuclear licensed sites are the prime focus of the programmes as they have been responsible for the largest individual discharges of radioactive waste. Sampling and direct monitoring is conducted close to most of the sites shown in Figure 1.4 (except those which have a very low effect). At Sellafield, radionuclides from liquid discharges can be detected in the marine environment in many parts of north-European waters. Therefore, programmes for this site extend beyond national boundaries.

The frequency and type of measurement and the materials sampled vary from site to site and are chosen to be representative of existing exposure pathways. Knowledge of such pathways is gained from surveys of local peoples' diets and way of life (from habits surveys). Consequently, the programme may vary from site to site and from year to year. Detailed information on the scope of the programme at individual sites is given in the tables of results. The routine programme is supplemented by additional monitoring if applicable, for example, in response to incidents or reports of unusual or high discharges of radioactivity with the potential to enter the food chain or the environment. Results of both routine and additional monitoring are included in this report.

The main aim of the programme is to monitor the environment and diet of people who live or work near nuclear sites, to estimate exposures for those small groups of people who are most at risk from disposals of radioactive waste. It is assumed that if the most exposed people have a dose below the national and international legal limit then all others should receive an even lower exposure. For liquid wastes, the pathways that are the most relevant to discharges are the ingestion of seafood and freshwater fish, drinking water and external exposure from contaminated materials. For gaseous wastes, the effects are due to the ingestion of terrestrial foods, inhalation of airborne activity and external exposure from material in the air and deposited on the ground. Inhalation of airborne activity and external exposure from airborne material and surface deposition are difficult to assess by direct measurement but can be assessed using environmental models. The main part of the monitoring is therefore directed at a variety of foodstuffs and measurements of external dose rates on the shores of seas, rivers and lakes. The programme also includes some important environmental indicators, so that quantities of radioactivity can be put in a historical context.

2.1.2 Industrial and landfill sites

Although the emphasis of the monitoring programme is the nuclear industry, a small proportion of the monitoring programmes are focussed on other activities that may have a radiological impact on people and the food chain. This part of the programme considers the effect of disposals of naturally occurring and artificial radionuclides from non-nuclear industries and of disposal into landfill sites, other than at Dounreay (considered separately in Section 5).

The impact of the non-nuclear industry was studied at several locations in 2022 including East Northants Resource Management Facility (near Kings Cliffe), the River Clyde (Glasgow) and Whitehaven (see Section 7). As in recent years, a small-scale programme was undertaken near Hartlepool (see Section 4.1.1), in addition to that directed at the effects of the power station itself. Sampling and analysis reflected the nature of the sources (of radioactivity) under study and, where appropriate, included consideration of the enhanced concentrations of naturally occurring radionuclides from non-nuclear industrial activity. There are also occasional specific programmes that consider, for example, the effects of land contaminated with historical sources of radioactivity and discharges from non-nuclear sites such as hospitals.

The distribution of landfill sites considered in 2022 is shown in Figure 7.1. Sites were studied to assess the extent of radiological contamination, if any, leaching from the site and re-entering the terrestrial environment (as leachates collected in surface waters close to the sites). The most significant waste disposal site is the Low-Level Waste Repository (LLWR) engineered facility (near Drigg) in Cumbria.

2.1.3 UK regional monitoring and fallout in the UK from overseas accidents

The programme of regional monitoring considers the quantities of radioactivity in the environment in areas away from specific sources as an indication of general radiological contamination of the food supply and the environment. The component parts of this programme are:

- monitoring of the Channel Islands and Northern Ireland
- dietary surveys
- sampling of milk
- drinking water sources, groundwater, rain and airborne particulates
- seawater surveys
- fallout in the UK from overseas accidents

Channel Islands and Northern Ireland

The programmes for the Channel Islands and Northern Ireland are designed to complement that for the rest of the UK and to take into account the possibility of long-range transport of radionuclides.

Channel Islands monitoring is conducted on behalf of the Channel Island States. It consists of sampling and analysis of seafood and indicator materials as a measure of the potential effects of UK and French disposals into the English Channel and historical disposal of solid waste in the Hurd Deep.

Monitoring on the Isle of Man for foodstuffs and indicator materials ceased in 2014 and 2015, respectively. Monitoring of the marine environment is primarily directed at the effects of current and historical disposals from Sellafield.

The Northern Ireland programme is directed at the far-field effects of disposals of liquid radioactive wastes into the Irish Sea. Dose rates are monitored on beaches and seafood and indicator materials are collected from a range of coastal locations including marine loughs.

General diet

The purpose of the general diet surveys is to provide information on radionuclides in the food supply to the wider population (regional diets), rather than to those living near particular sources of radiological contamination such as the nuclear industry. This programme, based on sampling and analysis of canteen meals, provides background information that is useful in interpreting site-related measurements and helps ensure that all significant sources of radiological contamination form part of the site-related programme. Prior to the UK's exit from the EU these data were also supplied as part of the UK submission to the EC under Article 36 of the Euratom Treaty[13] to allow comparison with those from other EU member states (for example, [109]). While these data are no longer supplied to the EC for England, Wales and Northern Ireland, they will continue to be published in the RIFE reports.

Specific foods, freshwater, rain and airborne particulates

Further background information on the relative concentrations of radionuclides is gained from the sampling and analysis of milk. Freshwater, rain and airborne particulates are also analysed to add to the understanding of radionuclide intakes by the population via ingestion and inhalation and as general indicators of the state of the environment.

Milk sampling took place at dairies throughout the UK in 2022. Samples were taken regularly. Prior to the UK's exit from the EU, milk data were also supplied as part of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with those from other EU Member States. While these data are no longer supplied to the EC for England, Wales and Northern Ireland, they will continue to be published in the RIFE reports.

Meat and crop monitoring of naturally occurring and artificial radionuclides, as a check on general food contamination (remote from nuclear sites), ceased in 2014. However, in 2022, surveillance of imported food at ports of entry using radiation screening equipment continued as a means of detecting the effects of overseas incidents. If screening (and subsequent sample analysis) shows quantities of radioactivity that fail to comply with UK food standards (retained from EU directives/regulations), then the consignments are removed from the UK market.

Freshwater used for the supply of drinking water was sampled throughout England, Northern Ireland, Scotland and Wales. Regular measurements of radioactivity in air and rainwater were also made. Prior to the UK's exit from the EU, these data were also supplied as part of the UK submission to the EC under Article 36 of the Euratom Treaty to allow comparison with those from other EU Member States. These data will continue to be published in the RIFE reports.

Seawater surveys

Seawater surveys are conducted in the seas around the UK on behalf of the DESNZ to provide information on radionuclide concentrations and information on water transport mechanisms in the coastal seas of northern Europe. Such information is used to support international studies of the health of the seas under the auspices of the OSPAR Conventions [110], to which the UK is a signatory and in support of research on the fate of radionuclides discharged to sea. These surveys are conducted using government research vessels and are supplemented by a programme of spot sampling of seawater at coastal locations.

Fallout in the UK from overseas accidents

Monitoring of the long-range effects of the Fukushima Dai-ichi accident started across the UK in March 2011. Samples from all sectors of the environment were taken and analysed by gamma spectrometry. The most significant radionuclides to monitor were iodine-131 and caesium-137, which were prevalent in the release from the accident. Very low activity concentrations were detected, and the extended programme ceased later in 2011. Further details of the programme and the results are given in the RIFE report for 2011 [111].

[13] The treaty establishing the European Atomic Energy Community (Euratom) was signed in Rome on 25 March 1957.

Monitoring of the effects of the 1986 Chernobyl accident was undertaken in relation to the upland contamination of lakes. Earlier RIFE reports have provided detailed results of monitoring by the environment agencies and FSA [112]. Sheep monitoring ceased in 2012 due to the removal of restrictions on the movement, sale and slaughter of sheep in parts of Cumbria and North Wales. Sampling for freshwater fish in locations affected by Chernobyl ceased in 2014.

2.2 Methods of measurement

There are two basic types of measurement made:

1. dose rates are measured directly in the environment
2. samples collected from the environment are analysed for their radionuclide content in a laboratory

2.2.1 Sample analysis

Analysis of samples varies depending on the nature of the radionuclide under investigation. The types of analysis can be broadly categorised into two groups:

1. gamma-ray spectrometry
2. radiochemical methods

The former is a cost-effective method of detecting a wide range of (gamma-emitting) radionuclides, commonly found in radioactive wastes, and is used for most samples. Radiochemical methods consist of a range of analyses involving the application of chemical separation and purification techniques to quantify the concentrations of alpha- and beta-emitting radionuclides. These are sensitive determinations, but generally more labour intensive. These methods are only used if alpha and beta concentration data are required for specific radionuclides and are not detectable using gamma-ray spectrometry (see Section 2.4 for discussion on limits of detection).

Several laboratories analysed samples in the monitoring programmes described in this report. Their main responsibilities were as follows:

Cefas	Centre for Environment, Fisheries and Aquaculture Science, gamma-ray spectrometry and radiochemical analysis of food samples in England, Wales, Northern Ireland and the Channel Islands
SOCOTEC	SOCOTEC UK Limited, gamma-ray spectrometry and radiochemical analysis of environmental samples (including analysis of drinking water) in England and Wales
UKHSA	UK Health Security Agency, gamma-ray spectrometry and radiochemical analysis of food and environmental samples from Scotland, air and rain samples in England, Wales and Northern Ireland, and freshwater for Northern Ireland

Each laboratory operates quality control procedures to the standards required by the UK environment and food standards agencies and have their analytical procedures independently assessed by the UK Accreditation Service (UKAS), that ensures the requirements from the international standard ISO 17025 [113] are maintained. Regular calibration of detectors is undertaken and intercomparison exercises are held with participating laboratories. The quality assurance procedures and data are made available to the UK environment agencies, FSA and FSS for auditing. The methods of measurement include alpha and gamma-ray spectrometry; beta and Cerenkov scintillation counting; and alpha and beta counting using proportional detectors. Corrections are made for the radioactive decay of short-lived radionuclides between the time of sample collection and measurement in the laboratory. This is particularly important for sulphur-35 and iodine-131. If a sample is bulked from a sequence of samples over time, the date of collection of the bulked sample is assumed to be in the middle of the bulking period. Otherwise, the actual collection date for the sample is used. In a few cases where short-lived radionuclides are part of a radioactive decay chain, the additional activity ('in-growth' and equilibrium status) produced from radioactive decay of parent and daughter radionuclides after sample collection is also considered. Where necessary, corrections to the activity present at the time of measurement are made to take account for the two radionuclides, protactinium-233 and thorium-234.

The analysis of foodstuffs is conducted on that part of the sampled material that is normally eaten (for example, shells of shellfish and the pods of some legumes are discarded before analysis). The preparation of some foodstuff samples is undertaken in such a way, so losses of activity are minimised. For example, most shellfish samples are boiled soon after collection to minimise losses from the digestive gland. Although some activity may be lost, these generally reflect the effects of the normal cooking process for shellfish. Most other foodstuffs are analysed raw, as it is conceivable that all the activity could be consumed in the raw foodstuff.

2.2.2 Measurement of dose rates and contamination

Measurements of gamma dose in air over intertidal and other areas are normally made at 1m above the ground using RadEye SX Survey Meters or Mini Instruments[14] environmental radiation meters type 6-80, with both type of meters connected to compensated Geiger-Muller tubes, type MC-71. For certain important activities, for example, for people living on houseboats or for wildfowlers lying on the ground, measurements at other distances from the ground may be made. External beta doses are measured on contact with the source, for example fishing nets, using Mini Instruments[14], Smart ION and Electra PB19RD monitors. These portable instruments are calibrated against recognised reference standards and the inherent instrument background is subtracted. There are two quantities that can be presented as measures of external gamma dose rate, total gamma dose rate or terrestrial gamma dose rate. Total gamma dose rate includes all sources external to the measuring instrument. Terrestrial gamma dose rate excludes cosmic sources of radiation but includes all others. In this report, the total gamma dose rate is presented. UKHSA reports terrestrial gamma dose rates to SEPA. Terrestrial gamma dose rate is converted to total gamma dose rate by the addition of 0.037μGy h^{-1} which approximates the contribution made by cosmic radiation [114].

Beta/gamma monitoring of radiological contamination on beaches or riverbanks is undertaken using similar instrumentation to that for measurements of dose rates. The aim is to cover a large area including strandlines where radioactive debris may become deposited. Any item found with activity rates in excess of the action levels is removed for analysis. An action level of 100 counts per second (equivalent to 0.01mSv h^{-1}) is used in England and Wales. At Dalgety Bay and Dounreay, in Scotland, and at Sellafield, in Cumbria, special monitoring procedures are in place due to the potential presence of radioactive particles on beaches. Further information regarding Dalgety Bay and Dounreay, and Sellafield is provided elsewhere in this report.

14.The reference to proprietary products in this report should not be construed as an official endorsement of those products, nor is any criticism implied of similar products which have not been mentioned

2.3 Presentation of results

The tables of monitoring results contain summarised values of observations obtained during the year under review. The data are generally rounded to two significant figures. Values near to the limits of detection will not have the precision implied by using two significant figures. Observations at a given location, for activity concentrations and dose rates, may vary throughout the year. This variability may be due to changes in rates of discharge, different environmental conditions and uncertainties arising from the methods of sampling and analysis.

The method of presentation of the summarised results allows the data to be interpreted in terms of public radiation exposures for comparison with agreed safety standards.

For milk samples, the most appropriate quantity for use in assessments is the arithmetic mean in the year sampled from the farm with the highest mean activity concentration. This is labelled 'max' in the tables of results to distinguish it from the values that are averaged over a range of farms. For other terrestrial foods, an alternative approach is adopted since it is recognised that the possible storage of foods (harvested during a particular time of the year) has to be taken into account. Greater public exposures would be observed coincidental with foods being harvested at times of elevated radiological contamination. For such foods, as well as the mean value, the maximum activity concentration (labelled 'max' in the tables) observed for each radionuclide is presented at any time in the relevant year and forms the basis for the assessment of dose.

Results are presented, where a sample is taken or a measurement is made, for each location or source of supply. Sample collectors are instructed to obtain samples from the same location during the year. Spatial averaging is therefore not generally undertaken, though it is inherent in the nature of some collected samples. A fish may move some tens of kilometres in an environment of changing concentrations in seawater, sediments and lower trophic levels. The resulting quantity of radiological contamination therefore represents an average over a large area. Similarly, cows providing milk at a farm may feed on grass and other fodder collected over a distance of a few kilometres of the farm. In the case of dose rate measurements, the position where the measurement is conducted is within a few metres of other measurements made within a year. Each observation consists of the mean of many instrument readings at a given location.

The numbers of farms that were sampled to provide information on activities in milk at nuclear sites are indicated in the tables of results. Milk samples collected weekly or monthly are generally bulked to provide 4 quarterly samples for analysis each year. Otherwise, the number of sampling observations in the tables of concentrations refers to the number of samples that were prepared for analysis during the year. In the case of small animals such as molluscs, one sample may include several hundred individual animals.

The number of sampling observations does not necessarily indicate the number of individual analyses conducted for a specific radionuclide. In particular, determinations by radiochemical methods are sometimes conducted less frequently than those by gamma-ray spectrometry. However, results are often based on bulking of samples such that the resulting determination remains representative.

2.4 Detection limits

There are two main types of results presented in the tables:

1. positively detected values
2. values preceded by a 'less than' symbol (<)

Where the results are an average of more than one value, and each value is positive, the result is positive.

Alternatively, where there is a mixture of data, or all data is at the limit of detection (LoD) or minimum reporting level (MRL), the result is preceded by a 'less than' symbol. Gamma-ray spectrometry can provide many 'less than' results.

Limits of detection are governed by various factors relating to the measurement method used and these are described in earlier reports [115]. There are also a few results quoted as "not detected" (ND) by the methods used. This refers to the analysts' judgement that there is insufficient evidence to determine whether the radionuclide is present or absent.

2.5 Additional information

The main aim of this report is to present all the results of routine monitoring from the programmes described previously. However, it is necessary to carry out some averaging for clarity and to exclude some basic data that may be of use only to those with specific research interests. Full details of the additional data are available from the environment agencies and FSA. Provisional results of concentrations of radionuclides in food samples collected in the vicinity of nuclear sites in England, Northern Ireland (milk and canteen meals) and Wales are published on the FSA's website (https://www.food.gov.uk).

The main categories of additional data are:

- data for individual samples prior to averaging
- uncertainties in measurements
- data for very short-lived radionuclides supported by longer-lived parents
- data which are not relevant to a site's discharges for naturally occurring radionuclides and for artificial radionuclides below detection limits
- measurements conducted as part of the research programme described in Appendix 7

Very short-lived radionuclides such as yttrium-90, rhodium-103m, rhodium-106m, barium-137m and protactinium-234m (formed by decay of, strontium-90, ruthenium-103, ruthenium-106, caesium-137 and thorium-234, respectively) are taken into account for calculating exposures to members of the public. They are not listed in the tables of results. As a first approximation, their concentrations can be taken to be the same as those of their respective parents.

2.6 Radiation protection standards

The monitoring results in this report are interpreted in terms of radiation exposures of the public, commonly termed 'doses'. This section describes the dose standards that apply in ensuring protection of the public.

UK practice relevant to the public was based on the recommendations of the ICRP as set out in ICRP Publication 60 [116]. The dose standards were embodied in national policy on radioactive waste [79] and in guidance from the IAEA in their Basic Safety Standards (BSS) for Radiation Protection [117]. Legislative dose standards were contained in the BSS Directive 96/29/Euratom [118] and were subsequently incorporated into UK law in the Ionising Radiations Regulations 1999 [119]. To implement the BSS Directive, ministers provided the Environment Agency and SEPA with directions concerning radiation doses to members of the public and their methods of estimation and regulation for all pathways [120,121]. In Northern Ireland, regulations were made to implement the requirements of the BSS Directive in the Radioactive Substances (Basic Safety Standards) Regulations (Northern Ireland) 2003 [122]. The methods and data used in this report are consistent with these (and subsequent) Directions.

The ICRP issued revised recommendations for a system of radiological protection in 2007 as set out in ICRP Publication 103 [2]. UKHSA have provided advice on the application of the ICRP 2007 recommendations to the UK [123]. Overall, they consider that the new recommendations do not imply any major changes to the system of protection applied in the UK. In particular, for authorised/permitted releases, limits for effective and skin doses remain unchanged.
Dose coefficients are also unchanged until such a time as new values are available and receive legislative endorsement.

ICRP (2007) [2] use the term 'representative person' for assessing doses to members of the public. It is defined as 'an individual receiving a dose that is representative of the more highly exposed individuals in the population'. The new term is equivalent to 'critical group' which has been used in some previous RIFE reports. Where appropriate, the term 'representative person' has been adopted in this report. The EU has updated the BSS Directive to account for the changes in ICRP recommendations [9]. The revised directive, 2013/59/Euratom, was published in 2013 and arrangements for transposition of the Directive into UK law are complete. In 2017, the HSE consulted on the changes to the Ionising Radiations Regulations 1999, aiming to transpose the requirements of the revised Euratom Basic Safety Standards Directive 2013 (BSSD 13) (Directive 2013/59/Euratom). The new Ionising Radiations Regulations 2017 (IRR 17) came into force on 1 January 2018 [19], replacing the Ionising Radiations Regulations 1999.

Revised standards in England and Wales concerning radiation doses to members of the public, and their methods of estimation and regulation for all pathways, came into force in 2018 in the Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2018 (EPR 18) [12]. Also, in 2018, the Radioactive Substances (Modification of Enactments) Regulations (Northern Ireland) 2018 and the Environmental Authorisations (Scotland) Regulations 2018

(EASR18) came into force for radioactive substances activities in Northern Ireland [15] and in Scotland [18]. Further changes in UK radiological protection law and standards will be taken into account for future issues of this RIFE report.

The relevant dose limits, for authorised/permitted releases, to members of the public are 1mSv (millisievert) per year for whole-body (more formally 'committed effective') dose and 50mSv per year specifically for skin. The latter limit exists to ensure that specific effects on skin due to external exposure are prevented and is applicable, for example, in the case of handling of fishing gear. The dose limits are for use in assessing the impact of direct radiations and controlled releases (authorised/permitted discharges) from radioactive sources. In situations that present a novel exposure pathway for members of the public, "potential" exposure routes and standards are determined, and these are discussed further in relation to particles of radioactivity [124]. For contamination, known to be due to radioactive particles in the UK, a site-specific assessment is considered in the relevant section of this report.

The mean annual dose received by the 'representative person' is compared with the dose limit. The term 'representative person' refers to those people most exposed to radiation. In this report, they are usually people of the public consuming large quantities of locally harvested food (high-rate consumers) or spending long periods of time in locations being assessed for external exposure. The limits apply to all age groups. Children may receive higher doses than adults because of their physiology, anatomy and dietary habits. The embryo/foetus can also receive higher doses than its mother. Consequently, doses have been assessed for different age groups; for example, adults, children (10-year-old), infants (1-year-old) and prenatal children, and from this information it is possible to determine which of these age groups receives the highest doses.

For drinking water, the Water Supply (Water Quality) Regulations 2016 [125], prescribe the requirements on the quality of water intended for human consumption in respect of radioactive substances and is retained from the 2013 EU Directive [126]. These regulations specify values for radon, tritium and "Indicative Dose" (ID) above which UK regulatory bodies shall assess whether the presence of radioactive substances in drinking water poses a risk to human health that requires action and, where necessary, shall take remedial action to improve the quality of water to a level which complies with the requirement for the protection of human health from a radiation protection point of view. The values are concentrations of 100Bq l^{-1} for radon or tritium and a dose of 0.1mSv from an intake over one year. ID is the sum of the doses from individual radionuclides in drinking water excluding tritium, potassium-40 and radon, and its short-lived decay products. Drinking water is taken to include bottled waters (spring and drinking).

The Water Supply (Water Quality) Regulations [125] also specifies screening values for gross alpha and beta activity of 0.1 and 1.0Bq l^{-1}, respectively. If concentrations are below these values, further investigations are not needed unless it is known that specific radionuclides are present in the drinking water that are liable to cause an ID in excess of 0.1mSv from an intake over one year. Transposition of the Drinking Water Directive into law has now taken place for the whole of the UK. The Water Supply (Water Quality) Regulations 2016 came into force in 2016 in England and Wales (Statutory Instruments, 2016). Similar regulations have been implemented in, Scotland [127], Wales [128] and Northern Ireland [129].

Accidental releases may be judged against UK and ICRP standards in emergency situations [2,130].

In addition, it is government policy that food intervention levels retained from EU standards will be taken into account for setting discharge limits. Guidelines for radionuclides in foods following accidental radiological contamination for use in international trade has been published by the Codex Alimentarius Commission [131].

The focus of this report, and radiological regulation and monitoring more generally, is towards protection of humans. However, ICRP in its 2007 recommendations has concluded that there was a need for a systematic approach for the radiological assessment of non-human species to support the management of radiation effects in the environment [2]. More recently ICRP considered the use of a set of reference animals and plants (RAPs) for dose assessments [31] and have now published their aims in terms of environmental protection, that is:

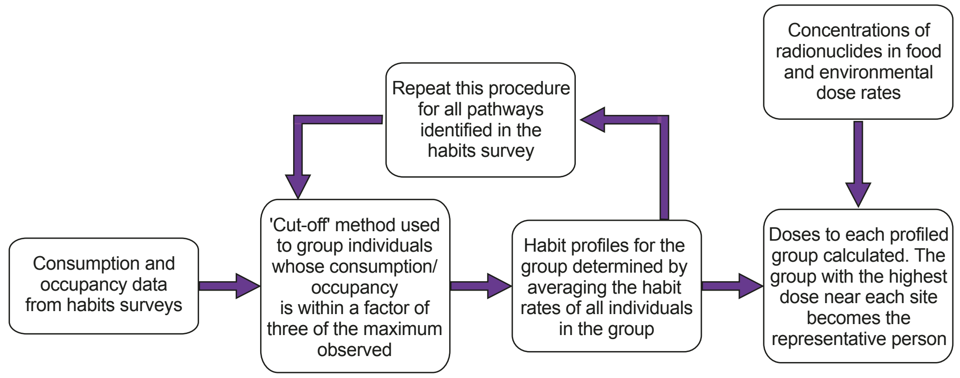
1. prevention or reduction of the frequency of deleterious radiation effects on biota to a level where they would have a negligible impact on the maintenance of biological diversity
2. the conservation of species and the health and status of natural habitats, communities and ecosystems [32]. No dose limits are proposed to apply but a set of derived consideration reference levels of dose for representative species are recommended for use in assessing the impact of different sources of exposure.

The Habitats Directive [34] requires a three-stage approach to the assessment of the impact of radioactive discharges on sensitive habitats. Details are provided in Section 1 of this report.

2.7 Assessment methods

Calculations of exposures to members of the public in this report are primarily based on the environmental monitoring data for the year shown under study. The methods used have been assessed for conformity with the principles endorsed by the UK National Dose Assessment Working Group [30], and were found to be compatible [132]. There are two types of dose assessment made. The first type gives an estimate of the 'total dose' to people around the nuclear sites. It considers the effects of all sources, that is the discharges of gaseous and liquid wastes and direct radiation from sources on the site premises [27]. A flow diagram of the method is given as Figure 2.1.

Figure 2.1 Steps in the 'total dose' methodology



The second type of assessment is focused on specific sources and their associated pathways (see Section 1.2 and Appendix 2 in the main report for additional information). It serves as a check on the adequacy of the 'total dose' assessment and is also compatible with the approach used prior to the introduction of 'total dose' in 2004.

'Total dose' assessments include direct radiation. The estimates of direct radiation dose are provided by The Office for Nuclear Regulation (ONR) based on information supplied by industry [133]. Both types of assessment provide information on two other main pathways:
- ingestion of foodstuffs
- external exposure from contaminated materials in the aquatic environment

Monitoring data is also used to assess doses from pathways, which are generally of lesser importance:
- drinking water
- inadvertent ingestion of water and sediments
- inhalation of re-suspended soil and sediment

In addition, models are used to supplement the monitoring data in 4 situations:
- atmospheric dispersion models are used for non-food pathways where monitoring is not an effective method of establishing concentrations or dose rates in the environment
- food chain models provide additional data to fill gaps and to adjust for high limits of detection
- modelling of exposures of sewage workers is undertaken for discharges from Aldermaston and Amersham

Full details are given in Appendix 3.

For pathways involving intakes of radionuclides, the data required for assessment are:
- concentrations in foodstuffs, drinking water sources, sediments or air
- the amounts eaten, drunk or inhaled
- the dose coefficients that relate an intake or activity to a dose

For external radiation pathways, the data required are:
- the dose rate from the source, for example a beach or fishermen's nets
- the time spent near the source

In both cases, the assessment estimates exposures from these pathways for people who are likely to be most exposed.

2.8 Concentrations of radionuclides in foodstuffs, drinking water sources, sediments and air

In nearly all cases, the concentrations of radionuclides are determined by monitoring and are given in the main text of this report. The concentrations chosen for the assessment are intended to be representative of the intakes of the most exposed consumers in the population. All of the positively determined concentrations tabulated are included irrespective of the origin of the radionuclide. In some cases, this means that the calculated exposures could include contributions due to disposals from other sites as well as from fallout from nuclear weapon testing and activity deposited following a nuclear reactor accident (such as at Chernobyl in 1986). Where possible, corrections for 'background' concentrations of naturally occurring radionuclides are made in the calculations of dose (see Section 2.12).

For aquatic foodstuffs, drinking water sources, sediments and air, the assessment is based on the mean concentration near the site in question. For milk, the mean concentration at a nearby farm with the highest individual result is used in the dose assessment. This procedure accounts for the possibility that any farm close to a site can act as the sole source of supply of milk to high-rate consumers.

For other foodstuffs, the maximum activity concentrations are selected for the assessment. This allows for the possibility of storage of food harvested at a particular time when the peak quantities in a year may have been present in the environment.

The tables of activity concentrations include 'less than' values as well as positive determinations. This is particularly evident for gamma-ray spectrometry of terrestrial foodstuffs. Where a result is presented as a 'less than' value, the dose assessment methodology treats it as if it were a positive determination as follows:
1. when that radionuclide is specified in the relevant permit/authorisation (gaseous or liquid)
2. when that radionuclide was determined using radiochemical methods
3. when a positive result is reported for that radionuclide in another sample from the same sector of the environment at the site (aquatic or terrestrial)

Although this approach may produce an overestimation of dose, particularly at sites where activity concentrations are low, it ensures that estimated exposures are unlikely to be understated.

2.9 Consumption, drinking and inhalation rates

2.9.1 Source specific assessments

In the assessment of the effects of disposals of liquid effluents, the amounts of fish and shellfish consumed are determined by site-specific dietary habits surveys. Data are collected primarily by direct interviews with potential high-rate consumers who are often found in fishing communities. Children are rarely found to eat large quantities of seafood and their resulting doses are invariably less than those of adults. The calculations presented in this report are therefore representative of adult seafood consumers or their unborn children if the prenatal children age group is more restrictive.

In assessments of terrestrial foodstuffs, the amounts of food consumed are derived from national surveys of diet and are defined for 3 age groups: adults, children (10-year-old) and infants (1-year-old) (based on [134]). Adult consumption rates are used in the assessment of doses to prenatal children. For each food type, consumption rates at the 97.5th percentile of consumers have been taken to represent the people consuming a particular foodstuff at a high rate (the consumption rate of the 'representative person').

Drinking and inhalation rates are general values for the population, adjusted according to the times spent in the locations being studied.

The consumption, drinking and inhalation rates are given in Appendix 4. Estimates of dose are based on the most up to date information available at the time of writing the report. Where appropriate, the data from site-specific surveys are averaged over a period of 5 years following the recommendation of the report of the consultative exercise on dose assessments (CEDA) [135].

The assessment of terrestrial foodstuffs is based on two assumptions:

1. that the foodstuffs eaten by the most exposed individuals are those that are sampled for the purposes of monitoring
2. that the consumption of such foodstuffs is sustained wholly by local sources

The two food groups resulting in the highest dose are taken to be consumed at high consumption rates, while the remainder are consumed at mean rates. The choice of two food groups at the higher consumption rates is based on statistical analysis of national diet surveys. This shows that only a very small percentage of the population were critical rate consumers in more than two food groups [136]. Locally grown cereals are not considered in the assessment of exposures as it is considered highly unlikely that a significant proportion of cereals will be made into locally consumed (as opposed to nationally consumed) foodstuffs, notably bread.

2.9.2 'Total dose' assessments

The 'total dose' assessments are based on consumption and occupancy data collected from site specific surveys which are targeted at those most likely to be exposed around the site. The habits profiles that give rise to the highest doses in the assessment of RIFE data are given in files that accompany this report. Care should be taken in using these data in other circumstances because the profile leading to the highest doses may change if the measured or forecast concentrations and dose rates change.

2.10 Dose coefficients

Dose calculations for intakes of radionuclides by ingestion and inhalation are based on the compendium of dose coefficients taken from ICRP Publication 119 [137] and from ICRP 88 [138] and National Radiological Protection Board (NRPB) [139]. In the first half of 2023, ICRP held the first consultation on the publication of revised dose coefficients to members of the public. It is expected that revised dose coefficients to members of the public will be made available over the next few years.

These coefficients (often referred to as "dose per unit intake") relate the committed dose received to the amount of radioactivity ingested or inhaled. The dose coefficients used in this report are provided in Appendix 5 for ease of reference.

Calculations are performed for 4 age groups: adults, children (10-year-old), infants (1-year-old) and prenatal children as appropriate to the pathways being considered. The prenatal age group was introduced following the publication of recommendations by NRPB in 2005 [139]. In RIFE, the dose assessment of the embryo and foetus is from a pregnant 'representative person'. This assumption is considered reasonable in the context of making comparisons with dose limits because it is difficult to demonstrate otherwise. When applied in practice, the doses estimated for the prenatal group are rarely larger than the values for other age groups.

The dose assessments include the use of appropriate gut uptake factors (proportion of radioactivity being absorbed from the digestive tract). Where there is a choice of gut uptake factors for a radionuclide, we have generally chosen the one that gives the highest predicted exposure. In particular, where results for total tritium are available, we have assumed that the tritium content is wholly in an organic form. However, we have also taken into account specific research work of relevance to the foods considered in this report. This affects the assessments for tritium, polonium, plutonium, and americium radionuclides as discussed in Appendix 5.

2.11 External exposure

In the assessment of external exposure, there are two factors to consider:

1. the dose rate from the source
2. the time spent near the source

In the case of external exposure to penetrating gamma radiation, uniform whole-body exposure has been assumed. The radiation as measured is in terms of the primary quantity known as 'air kerma rate', a measure of the energy released when the radiation passes through air. This has been converted into exposure using the factor 1 milligray = 0.85mSv [140]. This factor applies to a rotational geometry with photon energies ranging from 50keV to 2MeV. This is appropriate for the instrument used whose sensitivity is much reduced below 50keV, and to the geometry of deposits of artificial radionuclides. Applying an isotropic geometry gives a value of 0.70Sv Gy^{-1}, which would be more appropriate for natural background radiation. The choice of 0.85 will therefore tend to overestimate dose rates for the situations considered in this report which include both artificial and natural radiation.

For external exposure of skin, the measured quantity is radiological contamination in Bq cm^{-2}. In this case, dose rate factors in Sv y^{-1} per Bq cm^{-2} are used, which are calculated for a depth in tissue of 7mg cm^{-2} [141]. The time spent near sources of external exposure are determined by site-specific habits surveys in a similar manner to consumption rates of seafood. The occupancy and time spent handling fishing gear are given in Appendix 4.

2.12 Subtraction of 'background' activity concentrations

For assessing internal exposures in seafood due to the ingestion of carbon-14 and radionuclides in the uranium and thorium decay series, 'background' activity concentrations are subtracted. Background carbon-14 concentrations in terrestrial foods are also subtracted. The estimates of background activity concentrations are given in Appendix 6. For assessing the artificial effect on external exposures to gamma radiation, dose rates due to background are subtracted. Since measurements made previously as part of the monitoring programmes reported here, the gamma dose rate backgrounds in the aquatic environment are taken to be 0.05μGy h^{-1} for sandy substrates, 0.07μGy h^{-1} for mud and salt marsh and 0.06μGy h^{-1} for other substrates. These data are compatible with those presented in [142]. However, where it is difficult to distinguish the result of a dose rate measurement from natural background, the method of calculating exposures based on the concentrations of artificial radionuclides in sediments is used [143]. Estimates of external exposures to beta radiation include a component due to naturally occurring (and un-enhanced) sources because of the difficulty in distinguishing between naturally occurring and artificial contributions. Such estimates are therefore conservative, compared with the relevant dose limit that excludes natural sources of radiation.

2.13 Uncertainties in dose assessment

Various methods are used to reduce the uncertainties in the process of the dose estimation of the representative person. These address the following main areas of concern:

- programme design
- sampling and in situ measurement
- laboratory analysis
- description of pathways to humans
- radiation dosimetry
- calculational and presentational error

Quantitative estimation of uncertainties in doses is beyond the scope of this report.

3 Nuclear fuel production and reprocessing

Highlights
- 'total doses' for the representative person were 24% (or less) of the annual dose limit for all assessed sites. 'Total doses' increased to the Cumbrian coastal community near Sellafield, compared to the values in 2021, but remained well below the legal limit

Capenhurst, Cheshire
- 'total dose' for the representative person was 0.14mSv and decreased in 2022

Springfields, Lancashire
- 'total dose' for the representative person was 0.032mSv and increased in 2022

Sellafield, Cumbria
- 'total doses' for the representative person were 0.24mSv (or less) and increased in 2022
- the highest 'total doses' were from seafood, dominated by the effects of naturally occurring radionuclides. Historical discharges from the Sellafield site made a lesser contribution
- radiation dose from historical discharges of naturally occurring radionuclides (non-nuclear industry) was lower in 2022. The contribution to 'total dose' from Sellafield discharges decreased in 2022
- gaseous discharges of carbon-14, ruthenium-106, plutonium-alpha and americium-241/curium-242 were slightly higher, in 2022 when compared to those in 2021
- liquid discharges were slightly lower, in 2022 when compared to those in 2021

This section considers the results of monitoring, by the Environment Agency, FSA, NIEA and SEPA, of 3 sites in the UK associated with civil nuclear fuel production and reprocessing. These sites are at:

Capenhurst, a site where uranium enrichment is carried out, and management of uranic materials and decommissioning activities are undertaken; Springfields, a site where fuel for nuclear power stations is fabricated; and Sellafield, a site where irradiated fuel was reprocessed from nuclear power stations (this activity ceased during 2022) and a range of decommissioning and legacy waste management activities are being carried out.

The Capenhurst site is owned partly by Urenco UK Limited (UUK) and partly by the NDA. UUK holds the nuclear site licence, and their main commercial business is production of enriched uranium for nuclear power stations. The NDA's legacy storage and decommissioning activities are managed by Urenco Nuclear Stewardship Limited (UNS), a company of the Urenco Group. Another Urenco Group company, Urenco ChemPlants Limited (UCP), are the operators of the Tails Management Facility. This new plant, on a separate part of the site, opened in 2019 and is currently undergoing commissioning.

Both the Springfields and Sellafield sites are owned by the NDA. The Springfields site is leased long-term to Springfields Fuels Limited (SFL) and used to carry out nuclear fuel manufacture and other commercial activities. SFL have a contract with the NDA to decommission legacy facilities on the site. The main operations on the Sellafield site are fuel reprocessing, decommissioning and clean-up of redundant nuclear facilities, and waste treatment and storage. In 2016, the NDA became the owner of Sellafield Limited, the site licensed company responsible for managing and operating Sellafield on behalf of the NDA, replacing the previous management model of ownership (parent body organisation (PBO) concept) by the private sector.

Windscale was historically a separate licensed site located on the Sellafield site, with 3 nuclear reactors. In 2017, Windscale was amalgamated into the Sellafield nuclear licensed site and Sellafield environmental permits. Decommissioning activities are continuing at Windscale. Most of the radioactive wastes derive from decontamination and decommissioning operations. Gaseous wastes are regulated from specific stacks from Windscale, and liquid radioactive wastes are discharged to the Irish Sea via the Sellafield site pipelines. Both gaseous and liquid discharges are included as part of the regulated Sellafield discharges. Discharges of both gaseous and liquid radioactive wastes are minor compared to those from other Sellafield discharges. Regular monitoring of the environment by the Environment Agency and FSA in relation to any releases from Windscale is conducted as part of the overall programme for the Sellafield site.

Gaseous and liquid discharges from each of these sites (Capenhurst, Springfields and Sellafield) are regulated by the Environment Agency. In 2022, gaseous and liquid discharges were below permit limits for each of the sites (see Appendix 1, Table A1.1and Table A1.2).

3.1 Capenhurst, Cheshire

The Capenhurst site is located near Ellesmere Port and is home to uranium enrichment plants and associated facilities. The major operators at the site are UUK, UNS and UCP. UUK operates 3 plants producing enriched uranium for nuclear power stations. UNS manages assets owned by the NDA, comprising uranic material storage facilities and activities associated with decommissioning. UCP are currently commissioning a new facility, to allow safer long-term storage of depleted uranium, on a separate part of the site. This facility, the Tails Management Facility, will de-convert uranium hexafluoride (UF_6 or "Hex") to uranium oxide (U_3O_8). This will allow the uranium to be stored in a more chemically stable oxide form for potential future reuse in the nuclear fuel cycle. This process will recover hydrofluoric acid for reuse in the chemical industry. The plant is permitted for radioactive substances activities and, when commissioned, will discharge gaseous waste to the environment, aqueous waste to UUK's effluent disposal system and will dispose of solid waste by off-site transfer.

The operators on the Capenhurst site each have their own environmental permits. The UCP permit was varied in 2018 and the UNS permit was varied in 2020. These variations introduced the discharge limits for the new tails facility and revised the discharge limits for UNS.

The most recent habits survey to determine the consumption and occupancy rates by members of the public was undertaken in 2021 [144].

Doses to the public

The ‘total dose’ from all pathways and sources of radiation was 0.14mSv in 2022 (Table 3.1), or 14% of the dose limit, and down from 0.17mSv in 2021. This dose was almost entirely due to direct radiation from the Capenhurst site. The representative person was children exposed to direct radiation close to the site and unchanged from 2021. The trend in annual ‘total dose’ over the period 2011 to 2022 is given in Figure 1.2 and Figure 3.1. Any changes in annual ‘total doses’ over time were due to changes in the estimates of direct radiation from the site.

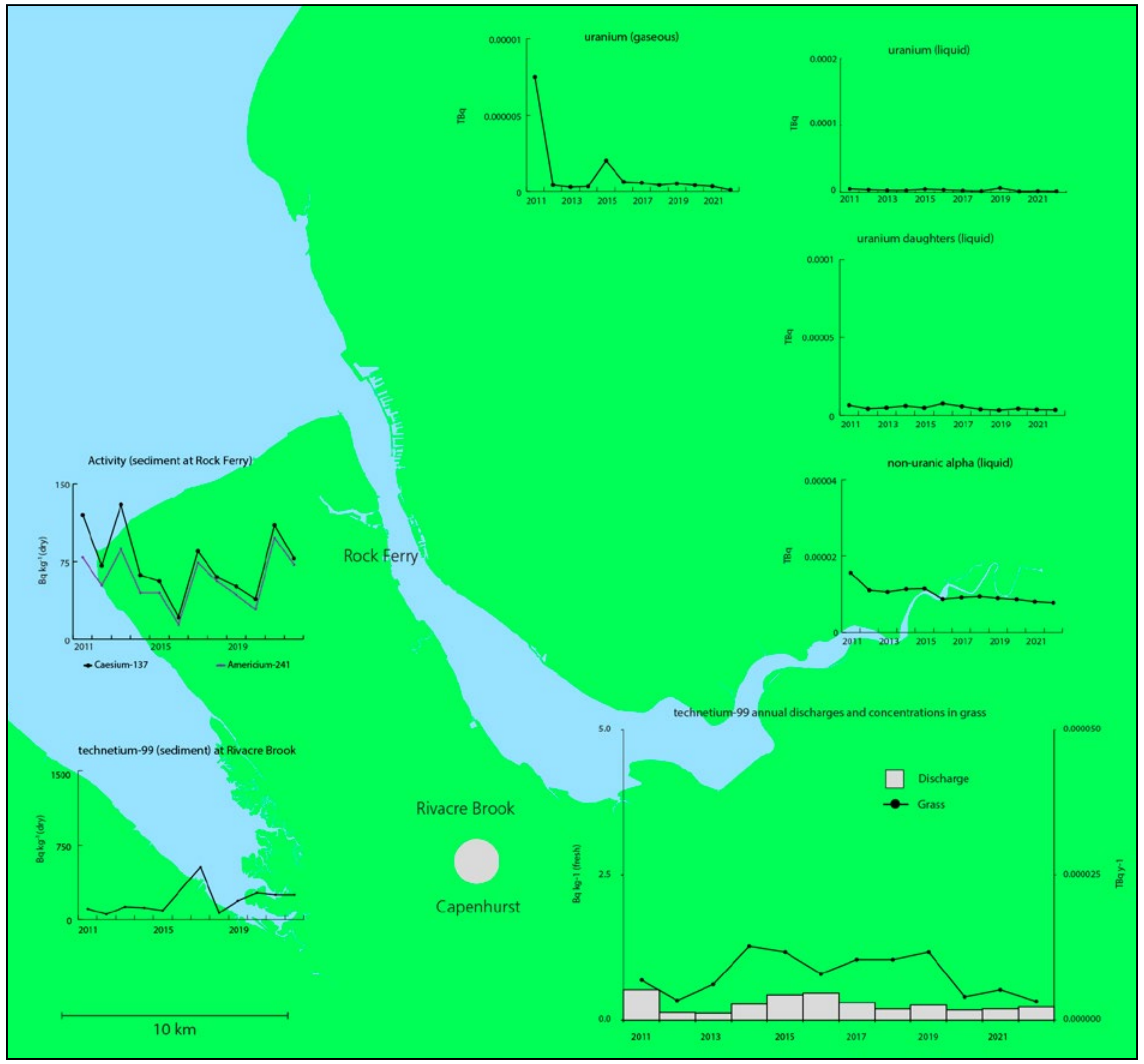
Figure 3.1 Total doses at nuclear fuel production and reprocessing sites between 2011 to 2022 (Exposures at Sellafield/Whitehaven/LLWR receive a significant contribution to the dose from technologically enhanced naturally occurring radionuclides from previous non-nuclear industrial operations)

Source specific assessments for high-rate consumers of locally grown foods, and for children playing in and around Rivacre Brook, give exposures that were less than the ‘total dose’ in 2022 (Table 3.1). The dose for children (10-year-old), who play in and around the brook and may inadvertently ingest water and sediment, was 0.005mSv in 2022 (down from 0.007mSv in 2021). The decrease in dose was due to lower gamma dose rates measured over the riverbank at Rivacre Brook in 2022. The dose is estimated using cautious assumptions for occupancy of the bank of the brook, inadvertent ingestion rates of water and sediment, and gamma dose rates.

Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges from Capenhurst, with small amounts of other radionuclides present in discharges by UNS. The focus for terrestrial sampling was the analyses of technetium-99 and uranium in food (including milk), grass and soil. Results for 2022 are given in Table 3.2(a). Concentrations of radionuclides in milk and food samples around the site were very low and generally similar to those in previous years. As in 2021, isotopes of uranium in silage were enhanced by small amounts (most likely due to natural variation) in 2022. Figure 3.2 shows the trends over time (2012 to 2022) of technetium-99 concentrations in grass. The overall trend reflects the reductions in discharges of technetium-99 from the enrichment of reprocessed uranium in the past. The most recently observed variability (from year to year) in the technetium-99 concentrations is based on data reported as less than values.

Figure 3.2 Discharges of gaseous and liquid radioactive wastes and monitoring of the environment, Capenhurst (2011 to 2022)



Liquid waste discharges and aquatic monitoring

The permit for the UUK Capenhurst site allows liquid waste discharges to the Rivacre Brook for uranium and uranium daughters, technetium-99 and non-uranium alpha (mainly neptunium-237). Monitoring included the collection of samples of fish and shellfish from the local aquatic and downstream marine environment (for analysis of a range of radionuclides) and of freshwater and sediments for the analysis of tritium, technetium-99, gamma-emitting radionuclides, uranium, neptunium-237, and gross alpha and beta. Dose rate measurements were taken on the banks of the Rivacre Brook and surrounding area. Results for 2022 are given in Table 3.2(a) and Table 3.2(b). Concentrations of radionuclides in foods from the marine environment were very low and generally similar to those in previous years. The concentrations in fish and shellfish reflect the distant effects of discharges from Sellafield.

As in previous years, sediment samples collected downstream from the Rivacre Brook contained very low but measurable concentrations of uranium (enhanced above natural concentrations) and technetium-99. As expected, enhanced concentrations of these radionuclides (and others) were measured close to the discharge point (Rivacre Brook). Technetium-99 and uranium radionuclide concentrations from this location were higher in 2022, in comparison to those in 2021, but similar to those in other recent years. Variations in concentrations in sediment from the brook are also to be expected due to differences in the size distribution of the sedimentary particles. Concentrations of radionuclides in freshwaters at the discharge point (and at other freshwater locations) were very low in 2022. Measured gamma dose rates near to the discharge point were lower in 2022, in comparison to those in 2021. Downstream of the Rivacre Brook, at the location where children play, dose rates over grass were also lower in 2022.

Figure 3.2 also shows the trends over time of the releases of several other permitted radionuclides and activity concentrations in environmental samples. During the period 2011 to 2022, the overall trend was a reduction of liquid discharges over time, with most of the reductions attributed to progress in decommissioning of some older plant and equipment.

Concentrations of technetium-99 in sediment (Rivacre Brook) from liquid discharges were detectable close to the discharge point in 2022. Concentrations of caesium-137 and americium-241 in sediments at Rock Ferry on the Irish Sea coast were from past discharges from Sellafield carried into the area by tides and currents. The concentrations were generally similar over most of the time period and any fluctuations were most likely due to the effects of normal dispersion in the environment. The lowest activity concentrations at Rock Ferry were reported in 2016.

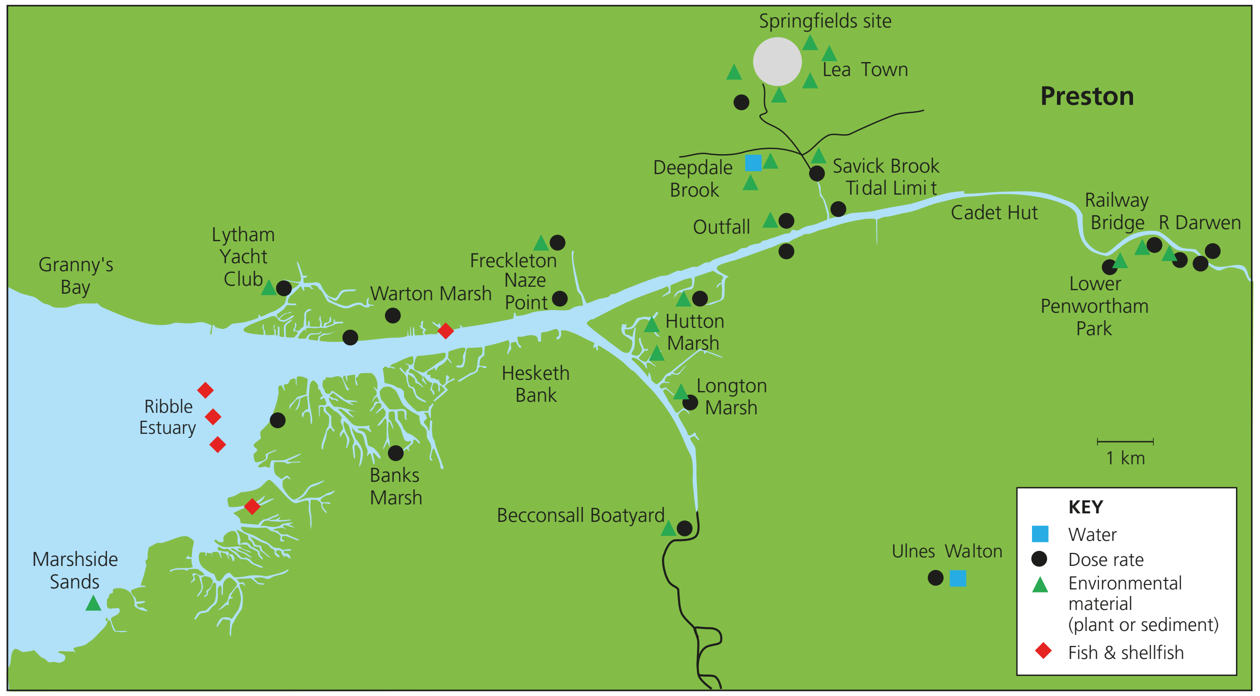
3.2 Springfields, Lancashire

The Springfields site at Salwick, near Preston, is operated by SFL under the management of Westinghouse Electric Company UK Limited, on behalf of the NDA. The main commercial activity is the manufacture of fuel elements for nuclear reactors and the production of uranium hexafluoride. Other important activities include recovery of uranium from residues and decommissioning redundant plants and buildings, under contract to the NDA, who retain responsibility for the historical nuclear liabilities on the site.

Research and development, carried out by the National Nuclear Laboratory, produces small amounts of other gaseous radionuclides that are also discharged under permit (see Appendix 1, Table A1.1).

Monitoring around the site is carried out to check not only for uranium concentrations, but also for other radionuclides discharged in the past (such as actinide decay products from past discharges when uranium ore concentrate (UOC) was the main feed material) and for radionuclides discharged from Sellafield. The monitoring locations (excluding farms) used to determine the effects of gaseous and liquid discharges are shown in Figure 3.3.

Figure 3.3 Monitoring locations at Springfields, 2022 (not including farms)



The most recent habits survey was undertaken in 2022 [145]. In the 2022 survey, no houseboat dwellers were recorded, therefore this assessment was discontinued. Figures for consumption rates, together with occupancy and handling rates, are provided in Appendix 4 (Table A4.2).

Doses to the public

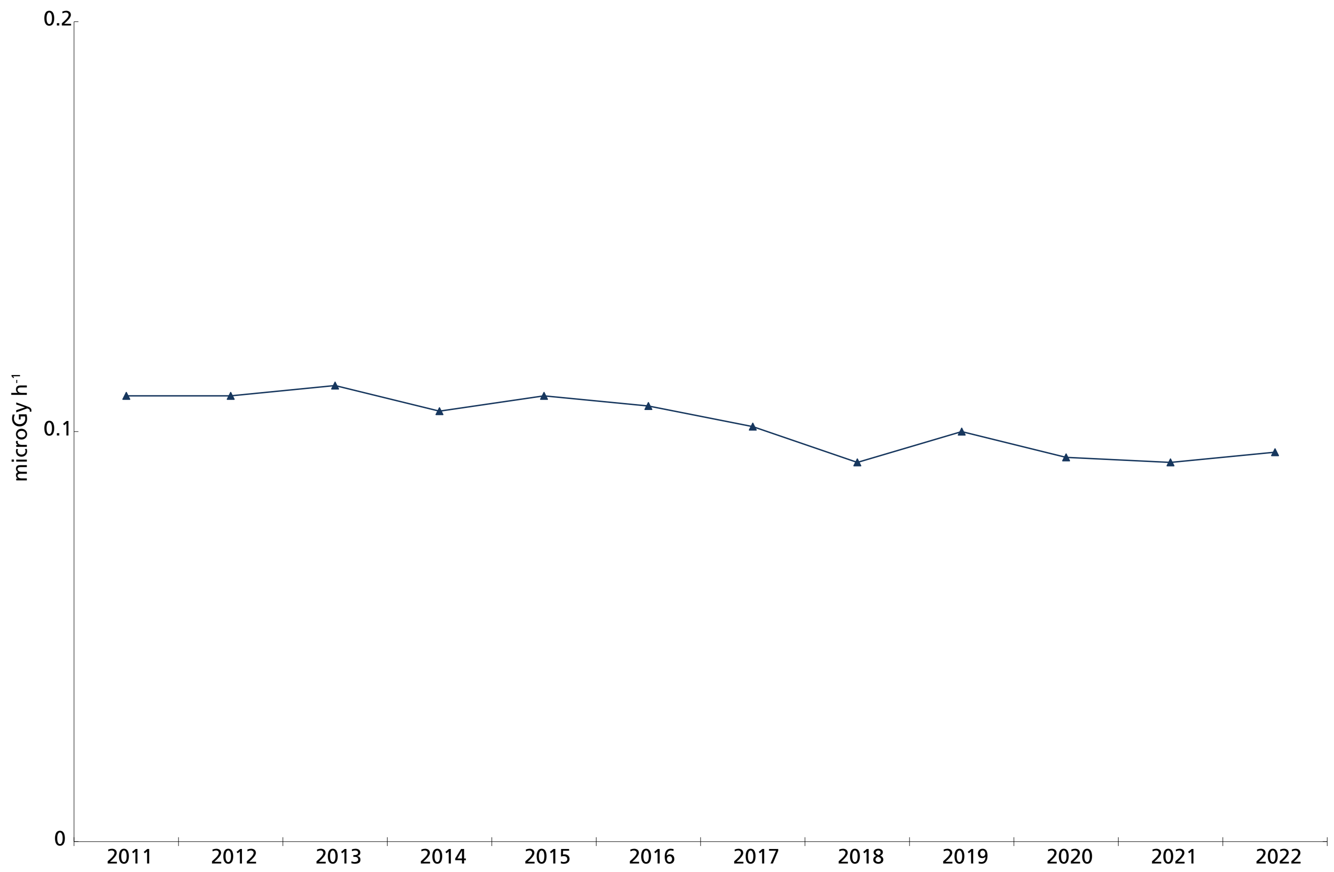
The ‘total dose’ from all pathways and sources of radiation was 0.032mSv in 2022 (Table 3.1), or approximately 3% of the dose limit, up from 0.031mSv in 2021. In 2022, the representative person was adults living near to the site and a change from 2021 (adults spending time over saltmarsh). Most of the dose to the representative person was from direct radiation. This change is due to a higher estimate of direct radiation (given in Table 1.1) and to a lesser extent, the revision of habits data. The annual direct radiation exposure was higher in 2022 (0.032mSv) in comparison to that in 2021 (0.017mSv).

Source specific assessments give exposures that were all less than the ‘total dose’ in 2022 (Table 3.1) for:

- consumers of locally grown food and of seafood (including wildfowl)
- farmers spending time on the banks of the estuary
- children playing on the banks of the estuary

No houseboat occupancy was observed during the 2022 habits survey. Trends in source-specific doses for a high-rate houseboat dweller are presented in earlier RIFE reports. Gamma dose rates at Becconsall over the period 2011 to 2022 are given in Figure 3.4.

Figure 3.4 Gamma dose rates at Springfields (2011 to 2022)



The dose for high-rate consumers of seafood and wildfowl was 0.007mSv in 2022, with approximately 0.005mSv from external exposure (the remainder being from consumption of fish, crustaceans and wildfowl) and lower than that in 2021 (0.015mSv). The most important radionuclides were caesium-137 and americium-241 from past discharges from the Sellafield site.

A source specific assessment for external exposure to farmers was Less than 0.005mSv in 2022 (Table 3.1) and lower than that reported in 2021 (0.031mSv). The estimated doses to high-rate consumers of locally grown food, and to children playing on the banks of the estuary were all less than 0.005mSv in 2022.

It has been previously shown that assessed annual doses to the public from inhaling sediment from the Ribble Estuary, re-suspended into the air, were much less than 0.001mSv, and negligible in comparison with other exposure routes [146].

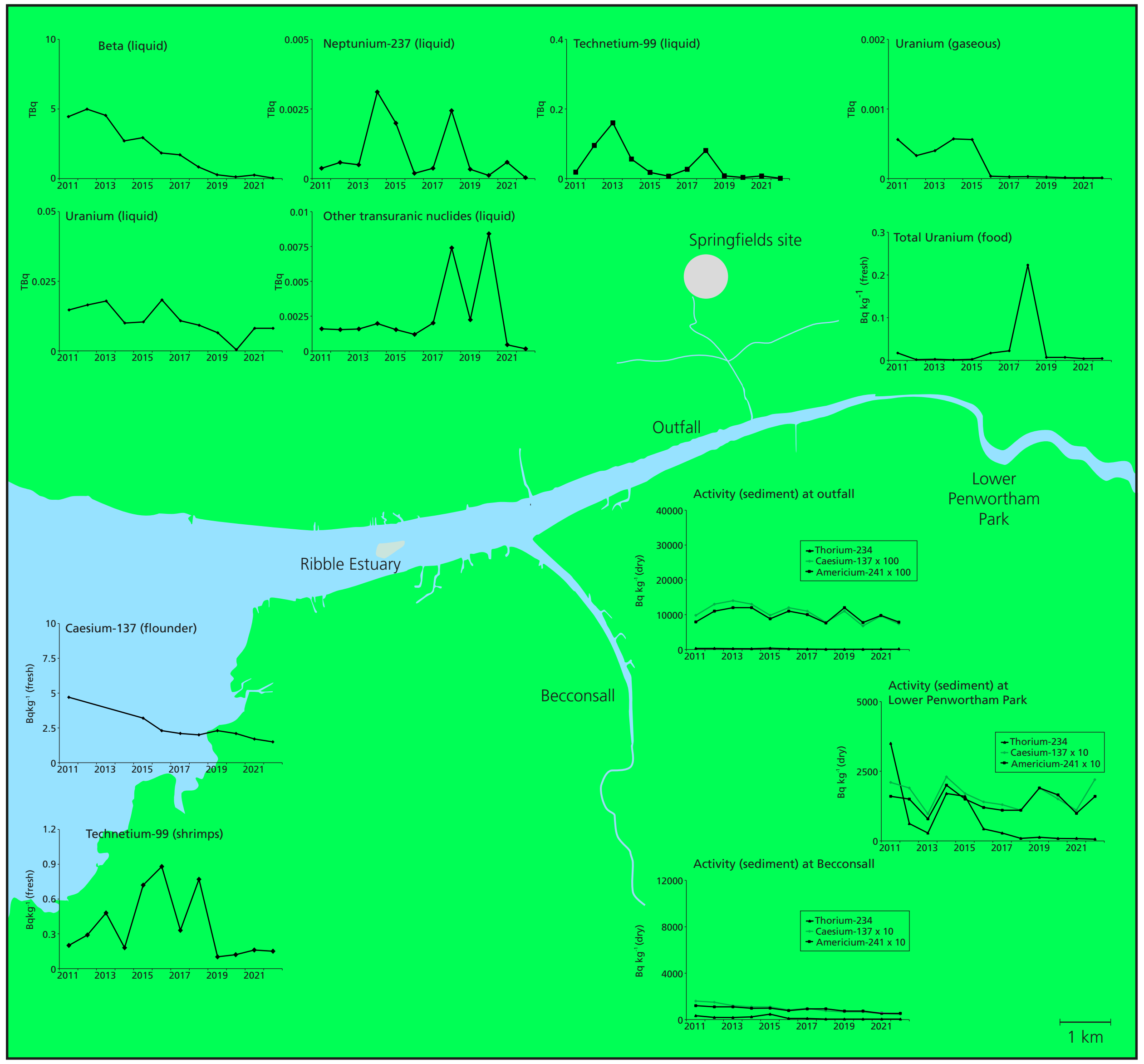
Gaseous discharges and terrestrial monitoring

Uranium is the main radioactive constituent of gaseous discharges, with small amounts of other radionuclides present in discharges from the National Nuclear Laboratory’s (NNL) research and development facilities.

The focus of the terrestrial sampling was for the analyses of tritium, carbon-14, strontium-90, iodine-129, and isotopes of uranium, thorium, plutonium and americium in milk and vegetables. Grass, soil and freshwater samples were collected and analysed for isotopes of uranium. Data for 2022 are given in Table 3.3(a). Uranium isotope concentrations in beetroot were similar to those in 2021. Concentrations of thorium were also low in vegetable and silage samples. As in previous years, elevated concentrations of uranium isotopes were measured in soils around the site, but the isotopic ratio showed that they were most likely to be naturally occurring. Overall, results were broadly similar to those of previous years.

Figure 3.5 shows the trends over time (2011 to 2022) of gaseous uranium discharges and total uranium radionuclide concentrations in food (cabbage; 2011 to 2013: beetroot; 2014 to 2022). Over the period, uranium discharges have declined, with the lowest value reported from this site in 2020. Total uranium was detected in cabbage and beetroot samples during the period, but the concentrations were very low. The apparent peak of uranium in beetroot in 2017 was also low and significantly less than that found in soil samples.

Figure 3.5 Discharges of gaseous and liquid radioactive wastes and monitoring of the environment, Springfields 2011 to 2022.



Liquid waste discharges and aquatic monitoring

Permitted discharges of liquid waste (including gross alpha and beta, technetium-99, thorium-230, thorium-232, neptunium-237, uranium and "other transuranic radionuclides") are made from the Springfields site to the Ribble Estuary via 2 pipelines. All discharges, except technetium-99, were slightly lower in 2022, in comparison to those in 2021. Compared to previous years, discharges are now generally lower for beta-emitting radionuclides. This includes the short half-life beta-emitting radionuclides (mostly thorium-234) that have decreased following the end of the UOC purification process in 2006. Process improvements in the uranium hexafluoride production plants on the Springfields site have reduced the amounts of other uranium compounds needing recycling. These improvements, alongside a reduction in legacy uranic residue processing, have led to a corresponding reduction in discharges of uranium in recent years. Discharges of technetium-99 depend almost entirely on which legacy uranic residues are being processed. Since completion of one particular residue processing campaign (in 2012), technetium-99 discharges have generally declined, with the lowest value (reported as <1% of the annual limit) from this site in 2021.

The Ribble Estuary monitoring programme consisted of 'in situ' dose rate measurements, the collection and analysis of sediments for uranium and thorium isotopes and gamma-emitting radionuclides.

Results for 2022 are shown in Table 3.3(a). As in previous years, radionuclides due to discharges from both Springfields and Sellafield were detected in sediment and biota in the Ribble Estuary. Radionuclides found in the Ribble Estuary originating from Sellafield were technetium-99, caesium-137 and americium-241. Isotopes of uranium and the short half-life radionuclide thorium-234 were also found from Springfields. Concentrations of the latter were closely linked to recent discharges from the Springfields site. In 2022, thorium-234 concentrations in sediments (over the range of sampling sites) were generally similar compared to those in 2021. Over a much longer timescale these concentrations have declined due to reductions in discharges as shown by the trend of sediment concentrations at the outfall, Lower Penwortham and Becconsall (Figure 2.5, [47]). The most significant change in the discharge trends was the step reduction of short half-life beta-emitting radionuclides in liquid discharges, mostly thorium-234. The reduction was because the UOC purification process ended in 2006. In more recent years, thorium-234 concentrations have generally declined by small amounts in sediments at Lower Penwortham and Becconsall (Figure 3.5), with the lowest values reported at Lower Penwortham in 2022.

Caesium-137, americium-241 and plutonium radionuclides were found in biota and sediments from the Ribble Estuary in 2022. The presence of these radionuclides was due to past liquid discharges from Sellafield, carried from west Cumbria into the Ribble Estuary by sea currents and adsorbed on fine-grained muds. The concentrations observed were generally similar to those in recent years.

Figure 3.5 also provides trend information over time (2011 to 2022) for a number of other permitted radionuclides and activity concentrations in food. Liquid discharges of uranium radionuclides steadily decreased (and other discharges to a lesser extent) over the whole period, whilst technetium-99 discharges generally decreased overall (but peaked in 2012). Caesium-137 concentrations in flounder showed variations between years and this was most likely due to natural changes in the environment, although there is evidence of decreasing concentrations overall.

Gamma dose rates (Table 3.3(b)) in the estuary were generally higher than expected natural background rates (see Section 2.12), and this is due to Sellafield-derived gamma-emitting radionuclides (caesium-137 and americium-241). In 2022, gamma dose rates in the estuary, were generally lower (by small amounts) to those in 2021, but with some small variations at some sites. Beta dose rates over salt marsh (where comparisons can be made) were similar to those in recent years.

3.3 Sellafield, Cumbria

Sellafield Limited is responsible for the operation of the Sellafield site and is a wholly owned subsidiary of the NDA. In 2022, the main operations on the Sellafield site were:

- reprocessing (until July 2022) and post-operational clean out at the Magnox reprocessing facility
- the decommissioning and clean-up of redundant nuclear facilities
- waste treatment and storage.

The site also contains the Calder Hall nuclear power station and the Thermal Oxide Reprocessing Plant (THORP), which are both undergoing decommissioning.

Nuclear fuel reprocessing at THORP ceased in 2018, resulting in reduced gaseous and liquid discharges in the intervening period. THORP will continue to serve the UK until the 2070's as a storage facility for spent AGR fuel. In July 2022, the Magnox reprocessing facility took its final feed of spent nuclear fuel marking the end of 58 years of Magnox reprocessing. The facility will now enter the post-operational clean-out phase. The Sellafield site also contains the Calder Hall Magnox nuclear power station, which ceased generating in 2003 and is undergoing decommissioning.

The environmental permit for receipt and disposal of radioactive waste was revised and re-issued to the site operator in 2020 [147], and again in 2021 [148]. Further details of the revised permit can be found in previous RIFE reports (for example, [66]). The 2021 revision focussed on strengthened conditions in relation to the Magnox swarf storage silo (MSSS) [148]. In October 2023, the Environment Agency decided to grant a permit variation requested by Sellafield Limited. The changes to the environmental permit include:

- the registration of the Magnox Swarf Storage Silo Retrievals Ventilation System stub stack which is being constructed to minimise and reduce facility gaseous discharges during operational activities by improving gaseous abatement with the use of additional High Efficiency Particulate Air (HEPA) filters
- to register an Outfall X to discharge construction related aqueous waste arisings (non-sewage trade waste) to the River Calder via surface water drainage.
- The removal of the Gaseous Annual Site Limits for Krypton-85 & Antimony-125 following the completion of Magnox reprocessing in July 2022
- a change to the site map and a reduction to the Radium-226 limit in response to Sellafield Ltd.'s application to extend the Calder Landfill Extension Segregated Area (CLESA) environmental safety case into the 'valley area'
- further information on this variation can be found on the (https://consult.environment-agency.gov.uk/cumbria-and-lancashire/ca20-1pg-sellafield-ltd-sellafield-site-epr-kp3690/)

With the completion of Magnox reprocessing in July 2022 (and a period of post-operational clean out), the gaseous and liquid discharge limits relating to this waste stream will revert to the lower discharge limits as described in the permit documentation[15] [147,148]. The remaining gaseous limits (except those for krypton-85 and antimony-125, which are currently being reviewed in the current consultation) are upper limits, which are in force until the active commissioning of HEPA filtration in the MSSS stack as detailed in the footnotes of Table A1.1.

The gaseous discharge limits presented in Table A1.1 for the revised permit (except ruthenium-106) are the upper limits, which are in force until the completion of Magnox reprocessing and the active commissioning of HEPA filtration in the MSSS stack as detailed in the footnotes of Table A1.1. Similarly, the upper liquid discharge limits for tritium, carbon-14 and technetium-99 are in force until the completion of Magnox reprocessing (Table A1.2), the lower limits are in force for the other radionuclides.

Sellafield Limited continued retrievals of sludge from legacy pond facilities in 2022 and continues to prepare for retrievals of intermediate level waste from legacy facilities to reduce environmental risk. Some of these projects have the potential to impact on discharges to the environment.

A full habits survey is conducted every 5 years in the vicinity of the Sellafield site, which investigates the exposure pathways relating to liquid and gaseous discharges, and to direct radiation. Annual review surveys are also undertaken between these full habits surveys. These annual surveys investigate the pathways relating to liquid discharges, review high-rate fish and shellfish consumption by local people (part of the Cumbrian Coastal Community group) and review their intertidal occupancy rates. The most recent full habits survey was conducted in 2018 [149]. In 2022, some changes were found in the amounts (and mixes) of seafood species consumed and intertidal occupancy rates [150]. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 4 (Table A4.2). Further afield, the most recent habits surveys were conducted to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast in 2017 [151] and around Barrow and the south-west Cumbrian coast in 2012 [152]. The results of these surveys are used to determine the potential exposure pathways, related to liquid discharges from Sellafield in Cumbria.

Habits surveys to obtain data on activities undertaken on beaches relating to potential public exposure to radioactive particles in the vicinity of the Sellafield nuclear licensed site were undertaken in 2007 and 2009 [153,154].

An important source of naturally occurring radionuclides in the marine environment has been the phosphate processing plant near Whitehaven in Cumbria. Although the plant closed in 1992, the effects of these past operations continue due to the decay products of the long-lived parent radionuclides discharges to sea. Naturally occurring radionuclides from this (non-nuclear) industrial activity are also monitored and assessed (see Section 7.4). The discharge effects from the Sellafield site and the former phosphate works both influence the same area and therefore the contributions to doses from both sources are considered in Section 3.3.1.

Monitoring of the environment and food around Sellafield reflects the historical and present-day Sellafield site activities. In view of the importance of this monitoring and the assessment of public radiation exposures, the components of the programme are considered here in depth. The discussion is provided in 4 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.

15. The radionuclides affected are tritium, carbon-14 and iodine-129 for discharges to air (Table A1.1) and tritium, carbon-14 and technetium-99 for discharges to water (Table A1.2). The use of the lower limits has been administratively agreed (with effect from October 2022) through the compilation of Environment Agency requirements, approvals and specifications (CEAR) documentation and will be formally incorporated into the next permit variation, which will be reported in future RIFE reports.

3.3.1 Doses to the public

'Total dose' from all pathways and sources

The annual 'total dose' from all pathways and sources of radiation is assessed using consumption and occupancy data from the full habits survey of 2018 [149] and the yearly review of shellfish and fish consumption, and intertidal occupancy in 2022 [155]. Calculations are performed for 4 age groups (adults, 10-year-old children, 1-year-old infants and prenatal children). The effects on high-rate consumers of fish and shellfish from historical discharges of naturally occurring radionuclides from non-nuclear industrial activity from the former phosphate works near Whitehaven (see Section 7.4) are included to determine their contribution to the annual 'total dose'. These works were demolished in 2004 and the authorisation to discharge radioactive wastes was revoked. The increase in concentrations of naturally occurring radionuclides (due to TENORM) from historical discharges is difficult to determine above a variable background (see Appendix 6).

In 2022, the highest 'total dose' to the Cumbrian coastal community[16], near Sellafield, was assessed to have been 0.24mSv (Table 3.16), or 24% of the dose limit to members of the public, and up from 0.21mSv in 2021. As in previous years, most of this dose was due to radioactivity from sources other than those resulting from Sellafield discharges, in other words, from historical discharges of naturally occurring radionuclides from past non-nuclear industrial activity. The representative person was adults consuming crustacean shellfish at high rates who also consumed significant quantities of other seafood (fish) and unchanged from 2021. The increase in 'total dose' in 2022 was mostly attributed to the increased polonium-210 concentrations in lobsters at Parton. Polonium-210 (and lead-210) are important radionuclides as small changes in concentrations above the natural background of these radionuclides, significantly influence the dose contribution from these radionuclides (due to a relatively high dose coefficient used to convert an intake of radioactivity into a radiation dose) and therefore the value of the estimated dose.

Direct radiation from the Sellafield site (0.003mSv, Table 1.1) in 2022 was considered in the 'total dose' assessments, but this made an insignificant contribution to the highest 'total dose'.

The most significant contributors to the 'total dose' in 2022 were from crustacean (95%), fish (4%), external exposure over sediments (1%) and other pathways (1%). The listed food groups are consumption pathways, the other pathways include direct radiation and external exposure over saltmarsh. The most important radionuclide was polonium-210 (93%) with transuranic radionuclides (including plutonium-239+240 and americium-241) contributing approximately 2% of the dose.

16.The Cumbrian coastal community are exposed to radioactivity resulting from both current and historical discharges from the Sellafield site and naturally occurring radioactivity discharged from the former phosphate processing works near Whitehaven, close to Sellafield.

The dose in 2022 from artificial radionuclides discharged by Sellafield (including external radiation) and from historical discharges of naturally occurring radionuclides (from past non-nuclear industrial activity) contributed 0.014mSv and 0.22mSv, respectively[17]. In 2021, the contributions were 0.019mSv and 0.19mSv, respectively. In 2022, the contribution from external radiation was 0.002mSv (unchanged from 2021). Data for naturally occurring radionuclides in fish and shellfish, and their variation in recent years, are discussed in Section 7.4.

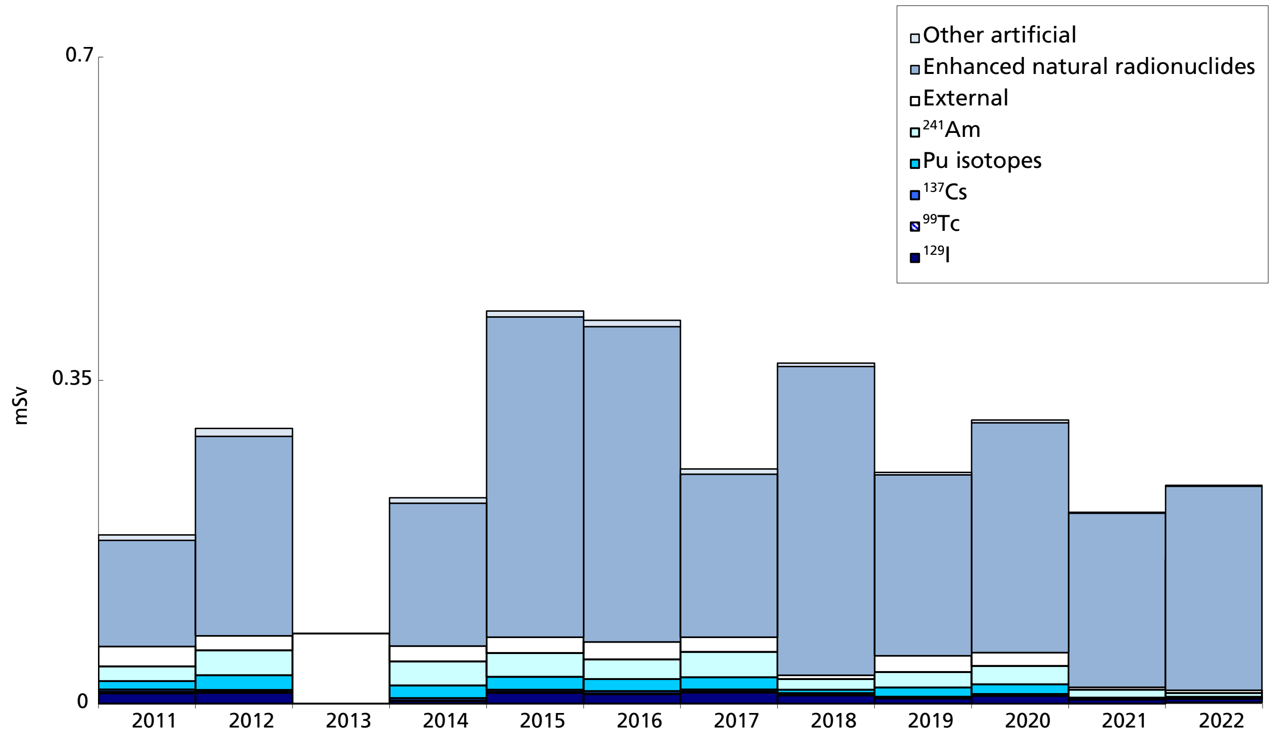
The contribution to the 'total dose' of 0.014mSv in 2022 from artificial radionuclides (including external radiation) was lower, in comparison to that in 2021. The decrease in the contribution to the 'total dose' from 2022 was mostly attributed to lower americium-241 concentrations in lobsters from the Sellafield coastal area and to a lesser extent the revision of habits information (reduction in the consumption rates and breadth of species consumed). The contributing radionuclides in 2022 were mostly americium-241 (33%), iodine-129 (30%) and plutonium radionuclides (6%). External exposure contributed 20% of the 'total dose' from artificial radionuclides (9% in 2021).

The contribution to the 'total dose' of 0.22mSv in 2022 from naturally occurring radionuclides (from past non-nuclear industrial activity) was higher in comparison to that in 2021 (0.29mSv). In 2022, the most contributing radionuclide was polonium-210 (~99%). The increase in 'total dose' in 2022 was mostly attributed to higher polonium-210 concentrations in lobsters from Parton, in comparison to 2021. In 2021, polonium-210 concentrations (above expected background) in locally caught lobsters contributed 0.19mSv to the 'total dose'. Polonium-210 concentrations (above expected natural background) in fish samples contributed 0.001mSv to the 'total dose' in 2021.

Contributions to the highest annual 'total dose' each year (2011 to 2022), from all pathways and sources by specific radionuclides, are given in Figure 3.6. Inter-annual variations were more complex and governed by both natural variability in seafood concentrations and real changes in the consumption and occupancy characteristics of the local population. Over a longer period, the trend is of generally declining dose (Figure 2.6, [47]).

17.Values are rounded to 2 significant figures, or 3 decimal places, depending on their magnitude.

Figure 3.6 Contributions to 'total dose' from all sources at Sellafield, 2011 to 2022 (The highest 'total dose' in 2013 due to Sellafield discharges was to people living on houseboats near Barrow in Cumbria)



Since 2011, the larger step changes (from 2012 to 2013) were due to variations in naturally occurring radionuclides, mainly polonium-210 and lead-210, from past non-nuclear industrial activity at the former phosphate processing plant near Whitehaven. The largest proportion of the 'total dose', from 2011 to 2012 and 2014 to 2020, was due to enhanced naturally occurring radionuclides (from past non-nuclear industrial activity) and a smaller contribution from the historical discharges from Sellafield. In 2013, the highest 'total dose' (relating to the effects of Sellafield) was entirely due to external radiation from sediments. The change was due to both decreases in polonium-210 (a naturally occurring radionuclide from past non-nuclear industrial activity at the former phosphate processing plant near Whitehaven) and a revision of habits information, resulting in a change in the representative person. In the following year (2014), the increase in 'total dose' was due to a change in the habits information from the most recent survey. Thereafter, the relative changes in dose were largely due to variations in polonium-210 concentrations in locally caught lobsters and crabs.

The contributions, from all pathways and sources, to the highest annual 'total dose' from the non-nuclear and nuclear industries, and, for adults only, from each pathway of exposure, are also given in Figure 3.7 (2011 to 2022) and Figure 3.8 (2018 to 2022), respectively. The overall trend from the nuclear industry is a generally declining dose (Figure 3.7), broadly reflecting a general reduction in concentrations in seafood of artificial radionuclides from the nuclear industry, over the period 2011 to 2022. The pathways of exposure contributing the highest dose were mollusc, crustacean and sea fish consumers.

Figure 3.7 Contributions from nuclear and non-nuclear industries to 'total dose' from all sources at Sellafield, 2011 to 2022 (The highest 'total dose' in 2013 due to Sellafield discharges was to people living on houseboats near Barrow in Cumbria)

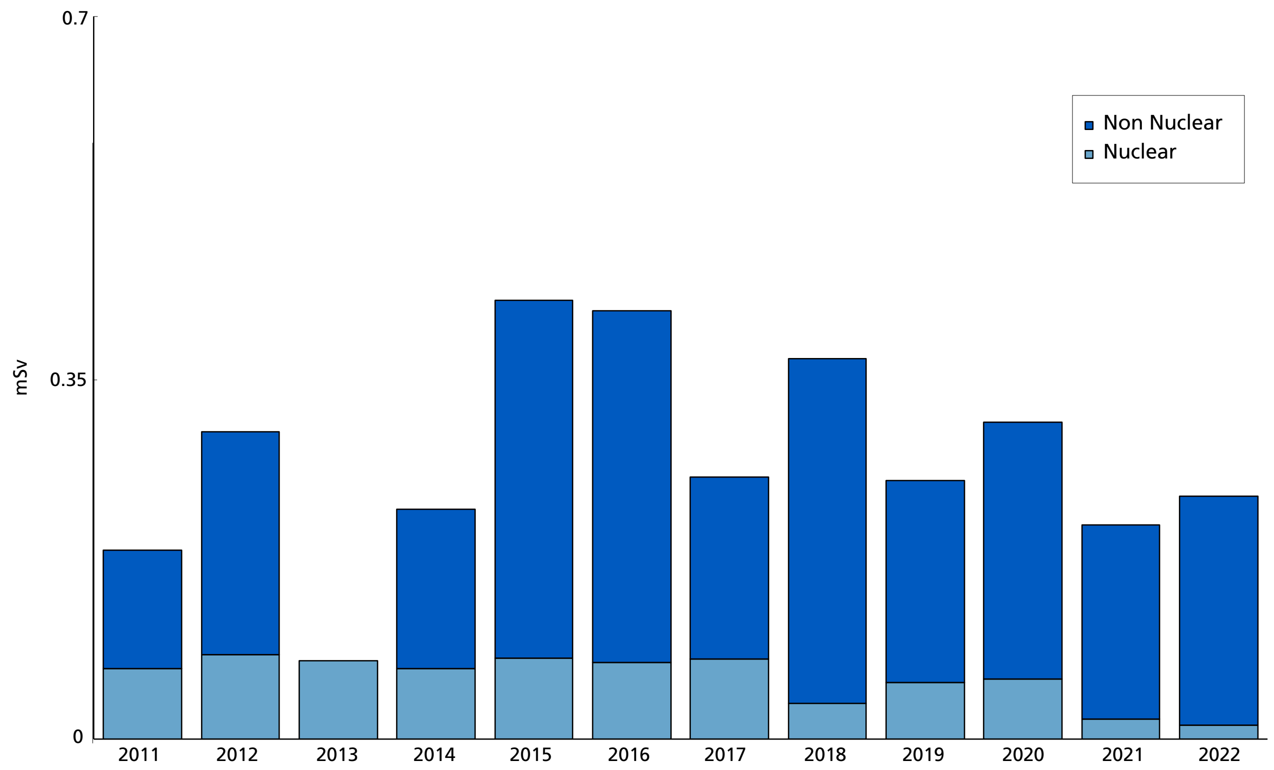
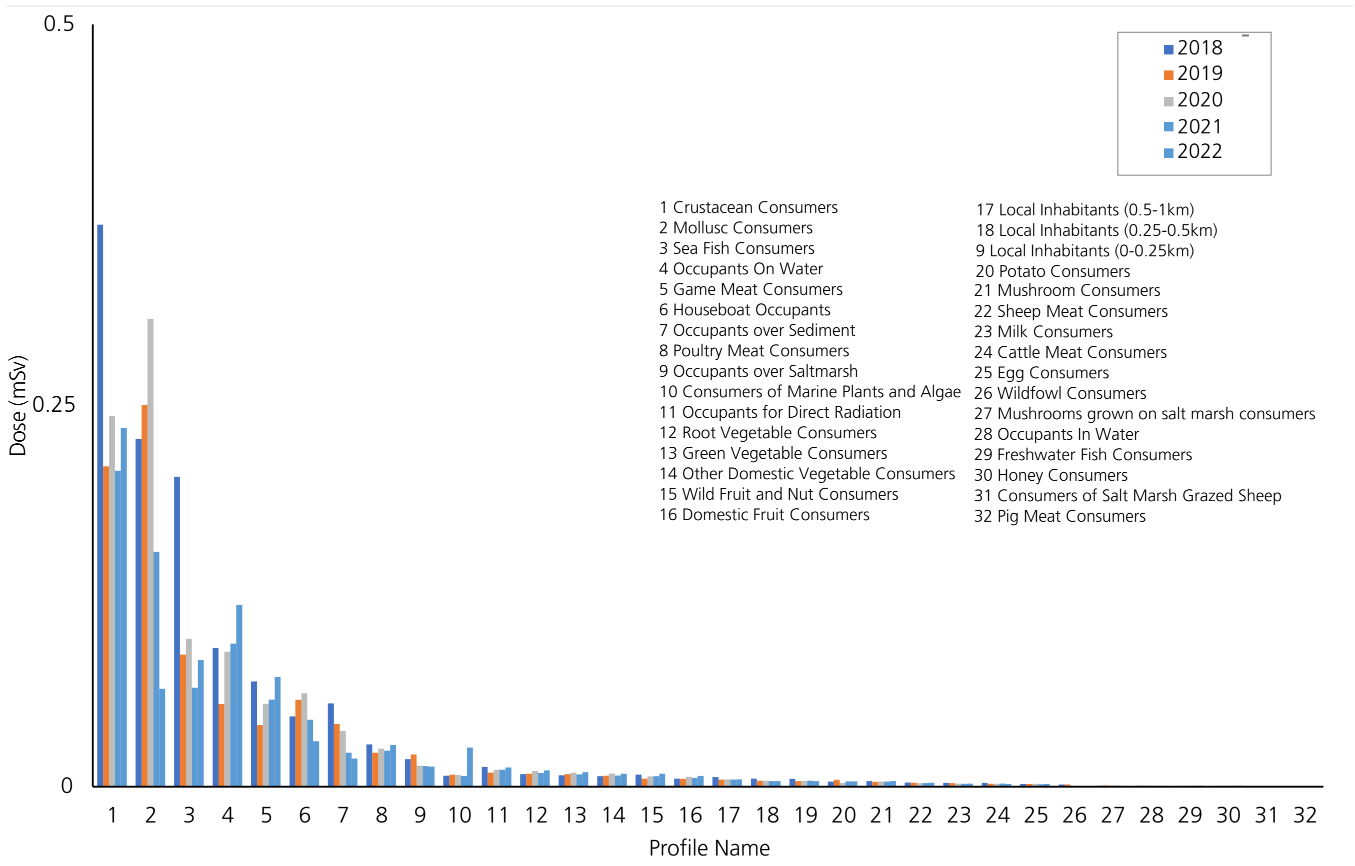


Figure 3.8 Contributions from each pathway of exposure to the 'total dose' from all sources, 2018 to 2022



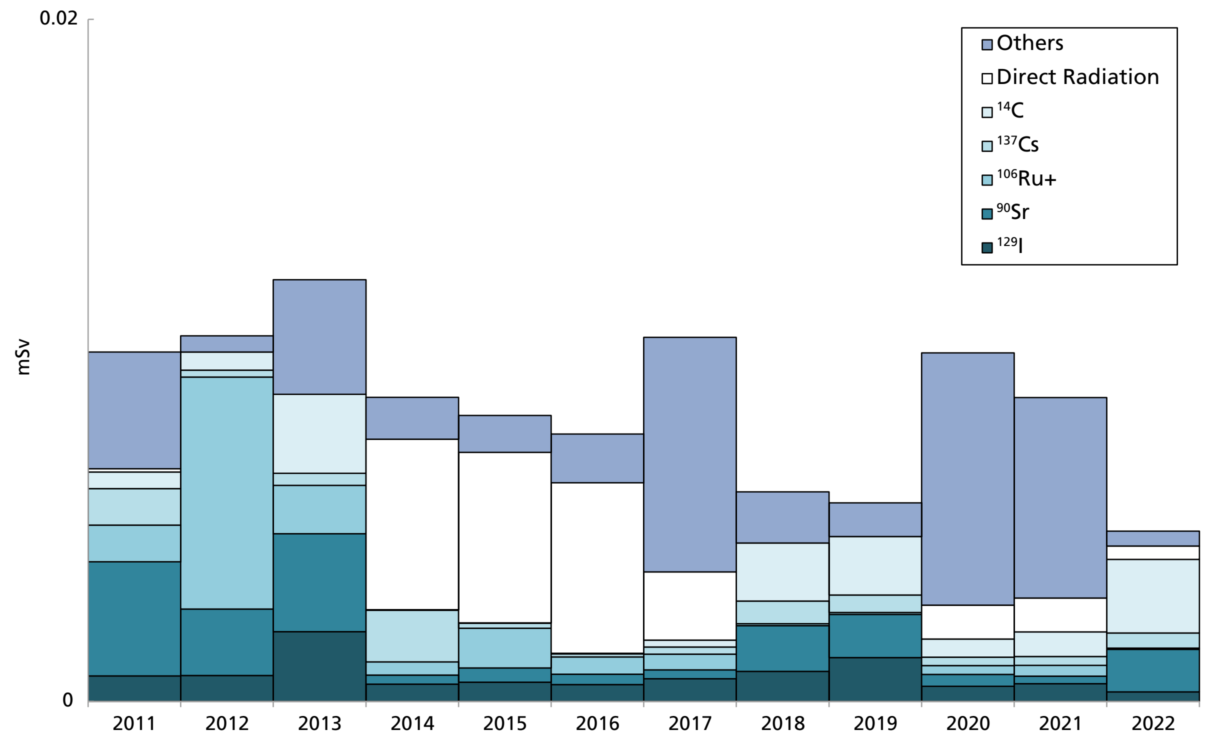
Other age groups received less exposure than the adults 'total dose' of 0.24mSv in 2022 (10-year-old children: 0.12mSv; 1-year-old infants: 0.083mSv; prenatal children: 0.021mSv). 'Total doses' estimated for each age group may be compared with the dose for each person of approximately 2.3mSv to members of the UK population from exposure to natural radiation in the environment [1] and to the annual dose limit to members of the public of 1mSv.

'Total dose' from gaseous discharges and direct radiation

In 2022, the dose to the representative person receiving the highest 'total dose', which includes contributions from artificial and naturally occurring radionuclides, from the pathways predominantly relating to gaseous discharges and direct radiation was 0.011mSv (Table 3.16) and up from 0.009mSv in 2021. The most exposed age group in 2022 was adults consuming root vegetables and unchanged from 2021. The increase in the 'total dose' was mostly due to a higher contribution from americium-241 in root vegetables (reported at lower limit of detection (LoD)). The most significant contributors in 2022 to the 'total dose' for adults were from consumption of root vegetables (37%), external exposure over sediments (23%), and occupancy for direct radiation (9%). The most important radionuclides were americium-241 (34%), polonium-210 (in seafood,10%), carbon-14 (8%), strontium-90 (4%) and iodine-129 (4%). other age groups received lower exposure than the 'total dose' for adults of 0.010mSv (10-year-old children: 0.007mSv, 1-year-old infants: 0.007mSv and prenatal children: <0.005mSv).

Contributions to the highest annual 'total dose', from gaseous discharge and direct radiation sources and by specific radionuclides, are given in Figure 3.9 over the period 2011 to 2022. Over a longer period, the trend is of declining dose (Figure 2.9, [47]) due to a general reduction in concentrations of radionuclides in food and the environment caused, in part, by reductions in discharges in this period. Over the period 2011 to 2019, 'total doses' were generally similar between years. The lower 'total dose' values after 2014 were mostly due to changes in the monitoring programme [156]. In 2018, the decrease in 'total dose' was mostly attributed to the revision of habits information following the full habits survey undertaken that year. From 2020, the relative changes in dose were largely due to variations in americium-241 concentrations (at limits of detection) in root vegetables.

Figure 3.9 Contributions to 'total dose' from gaseous discharge and direct radiation sources at Sellafield, 2011 to 2022 (+ based on limits of detection for concentrations in foods)



'Total dose' from liquid discharges

The people receiving the highest 'total dose' from the pathways predominantly relating to liquid discharges are given in Table 3.16. Each 'total dose' is the same as that giving their maximum 'total dose' for all sources and pathways.

Source specific doses

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

Doses from terrestrial food consumption

In 2022, infants (1-year-old) consuming milk at high rates and exposed to external and inhalation pathways from gaseous discharges received the highest dose for all ages. The estimated dose was 0.012mSv in 2022 (Table 3.16), or approximately 1% of the dose limit to members of the public and up from 0.010mSv in 2021. Other age groups received less exposure than the infants (1-year-old) dose of 0.012mSv in 2022 (adults: 0.011mSv; 10-year-old children: 0.009mSv; prenatal children: 0.005mSv).

Doses from seafood consumption

Two sets of habits data are used in these dose assessments. One is based on the habits information seen in the area each year (2022 habits survey). The second is based on a five-year rolling average using habits data gathered from 2018 to 2022. Some changes were found in the amounts (and mixes) of species consumed compared to those in the 2021 and the 2017 to 2021 rolling average. For crustaceans (crab, lobster, and other crustaceans), the total consumption rate decreased in 2022, and in the 2018 to 2022 rolling average. For fish (cod, other fish), the total consumption rate decreased in 2022 and in the 2018 to 2022 rolling average. For molluscs (winkles and other molluscs), the total consumption rates decreased in 2022 and in the 2018 to 2022 rolling average. The total mollusc consumption (2022) rate decreased for the Sellafield coastal community (mollusc consumption) group (mollusc consumption) For the 2018 to 2022 rolling average, the total mollusc consumption rate also decreased. The occupancy rate over sediments increased in the 2022 habits information and decreased in the 2018 to 2022 rolling average. The revised habits data are given in Appendix 4 (Table A4.2).

Aquatic pathway habits are normally the most important in terms of dose near Sellafield and are surveyed every year (for example [150]). This allows generation of a unique yearly set of data and also rolling five-year averages. The rolling averages are intended to smooth the effects of sudden changes in habits and provide an assessment of dose that follows more closely changes in radioactivity concentrations in food and the environment. These are used for the main assessment of doses from liquid discharges and follow the recommendations of the report of the consultative exercise on dose assessments (CEDA) [135].

Table 3.16 summarises source specific doses to seafood consumers in 2022. The doses from artificial radionuclides to people who consume a large amount of seafood (excluding molluscan consumption) were 0.027mSv (0.032mSv in 2021) and 0.045mSv (0.058mSv in 2021) using the annual and five-year rolling average habits data, respectively. Doses to mollusc consumers, in 2022, was 0.005mSv. These doses each include a contribution due to external radiation exposure over sediments.

The dose to a local person (high-rate consumer of seafood), due to the enhancement of concentrations of naturally occurring radionuclides resulting from discharges from the former phosphate works near Whitehaven (using maximising assumptions for the dose coefficients and the five-year rolling average habits data), is estimated to have been 0.33mSv in 2022 and up from 0.19mSv in 2021. Most of this was due to polonium-210 (99%). For comparison (with the assessment using the five-year rolling average habits data), the dose from the single-year assessment for the Cumbrian coastal community seafood consumer (excluding mollusc consumption) from naturally occurring radionuclides (based on consumption rates and habits survey data in 2022) was 0.21mSv (Table 3.16). The dose to mollusc consumers (2022 data only) was 0.009mSv.

Taking artificial and enhanced natural radionuclides together, the source specific doses were 0.24mSv and 0.37mSv for the annual and five-year rolling average habits data, respectively. The dose to mollusc consumers (2022 data only) was 0.014mSv. These estimates are slightly higher or similar than the estimate of 'total dose' from all sources of 0.24mSv. The main reason for this is a difference in the approach to selecting consumption rates for seafood for the representative person. The differences in dose are expected and are within the uncertainties in the assessments (see Section 2.13).

Exposures typical of the wider communities associated with fisheries in Whitehaven, Dumfries and Galloway, the Morecambe Bay area, Northern Ireland and North Wales have been kept under review in 2022 (Table 3.15). Those for fisheries in the Isle of Man and Fleetwood have been shown to be generally lower and dose data are available in earlier RIFE reports (for example [62]). Where appropriate, the dose from consumption of seafood is summed with a contribution from external exposure over intertidal areas. The doses received in the wider communities were significantly lower than for the Cumbrian coastal community because of the lower concentrations and dose rates further afield. There were generally small changes in the doses (and contribution to doses) in each area in 2022 (Table 3.15), in comparison to those in 2021. For example, on the Dumfries and Galloway coast, the decrease in dose, in 2022, to 0.024mSv (from 0.056mSv in 2021) was mostly due to the average of americium-241 (and other transuranic elements) results determined using radiochemical methods in North Solway Coast Mussels and Kirkcudbright Scallops in 2022). All annual doses of the wider communities were well within the dose limit for members of the public of 1mSv.

The dose to a person, who typically consumes 15kg of fish per year from landings at Whitehaven is also given in Table 3.16. This dose was less than 0.005mSv in 2022. The consumption rate used represents an average for a typical consumer of seafood from the north-east Irish Sea.

Doses from sediments

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

Gamma radiation dose rates over areas of the Cumbrian coast and further afield in 2022 are given in Table 3.9. The results of the assessment of external exposure pathways are included in Table 3.16. The highest whole-body exposures due to external radiation resulting from Sellafield discharges, past and present, was received by a local houseboat dweller at Barrow, Cumbria. In 2022, the dose was 0.029mSv, or approximately 3% of the dose limit, and down from 0.043mSv in 2021 (see Section 6.2). Other people received lower external doses in 2022. The dose to a person who spends a long time over the marsh in the Ravenglass Estuary was 0.014mSv in 2022, and a decrease from that in 2021 (0.019mSv). This decrease in dose was due to lower occupancy over salt marsh (Appendix 4, Table A4.2) and to a lesser extent the lower gamma dose rates over salt marsh close to Eskmeals.

The doses to people in 2022 were also estimated for several other activities. Assessments were undertaken for a typical resident using local beaches for recreational purposes at 300 hours per year, and for a typical tourist visiting the coast of Cumbria with a beach occupancy of 30 hours per year. The exposure to residents was assessed for 2 different environments (at several locations) and at a distance from the Sellafield influence. The 2 different environments are 1) residents that visit and use beaches, and 2) residents that visit local muddy areas or salt marsh. Typical occupancy rates [153,154] are assumed and appropriate gamma dose rates have been used from Table 3.9. The activities for the typical tourist include consumption of local seafood and occupancy on beaches. Concentrations of radioactivity in fish and shellfish have been used from Table 3.5 to Table 3.7, and appropriate gamma dose rates used from Table 3.9. The consumption and occupancy rates for activities of a typical resident and tourist are provided in Appendix 4 (Table A4.2).

In 2022, the doses to people from recreational use of beaches varied from less than 0.005 to 0.009mSv (Table 3.16), with the higher doses being closer to the Sellafield source. The doses for recreational use of salt marsh and muddy areas had a similar variation, from less than 0.005 to 0.008mSv. The values for these activities were similar to those in recent years. The annual dose to a typical tourist visiting the coast of Cumbria, including a contribution from external exposure, was estimated to be less than 0.005mSv.

Doses from handling fishing gear and sediment

Exposures can also arise from contact with beta-emitting radionuclides during handling of sediments, or fishing gear on which fine particulates have become trapped. Habits surveys keep under review the amounts of time spent by fishermen handling their fishing gear, and by bait diggers and shellfish collectors handling sediment. For those most exposed, the rates for handling nets and pots and for handling sediments are provided in Appendix 4 (Table A4.2). In 2022, the skin doses to a bait digger and shellfish collector from handling sediment was 0.082mSv (Table 3.16). This was less than 0.5% of the appropriate annual dose limit of 50mSv specifically for skin. The skin dose to a fisherman from handling fishing gear (including a component due to naturally occurring radiation), based on 2019 monitoring data was 0.14mSv. 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 representative person was infants (1-year-old) from consuming terrestrial foods that were potentially affected by radionuclides transported to land by sea spray. In 2022, the dose (including contributions from Chernobyl and fallout from nuclear weapons testing) was estimated to be 0.012mSv, which was approximately 1% of the dose limit for members of the public, and up from 0.009mSv in 2021. The increase in dose is attributed to higher carbon-14 concentrations in milk in 2022. The largest contribution to the dose was from ruthenium-106 in milk, as in recent years. As in previous years, sea-to-land transfer was not of radiological importance in the Ravenglass area.

Doses from seaweed and sea-washed pasture

Estimated annual doses for a high-rate consumer of laverbread (brown seaweed), and a high-rate consumer of vegetables (assuming these foods were obtained from the monitored plots near Sellafield and seaweeds were used as fertilisers and/or soil conditioners), are available in earlier RIFE reports (for example [62]). It has been previously established that the exposure pathway for a high-rate consumer of laverbread is of low radiological significance. Harvesting of Porphyra in west Cumbria, for consumption in the form of laverbread, was reported in the 2018 habits survey [149] - this exposure pathway has remained dormant in previous years. Previously reported doses from the consumption of vegetables using seaweed (as a fertiliser) have remained similar (and low) from year to year, with only minor variations in exposure (due to different foods being grown and sampled from the monitored plots). Exposures of vegetable consumers using seaweed from further afield in Northern Ireland, Scotland and North Wales are expected to be much lower than near Sellafield.

Animals may also graze on seaweeds on beaches in coastal areas. However, there has been no evidence of this taking place significantly near Sellafield. A research study (relevant to the Scottish islands and coastal communities) conducted by UKHSA on behalf of the FSA and SEPA, investigated the potential transfer of radionuclides from seaweed to meat products and also to crops grown on land where seaweed had been applied as a soil conditioner [157]. The study concluded that the highest levels of dose to people using seaweed, as a soil conditioner or an animal feed, were in the range of a few microSieverts (μSv) and most of the doses are at least a factor of 100 lower. The report is available on SEPA's website: http://www.sepa.org.uk/environment/radioactive-substances/environmental-monitoring-and-assessment/reports/.

3.3.2 Gaseous discharges

Regulated discharges to atmosphere are made from a wide range of facilities at the site including the fuel storage ponds, the reprocessing plants and waste treatment plants, as well as from Calder Hall Power Station. Discharges from Calder Hall are now much reduced since the power station ceased generating electricity in 2003. Discharges to atmosphere, during 2022 are summarised in Appendix 1 (Table A1.1). The permit limits gaseous discharges for gross alpha and beta activities, and 10 specified radionuclides. In addition to overall site limits, plant notification levels have been set on discharges from the main contributing plants on site.

Discharges of gaseous wastes from Sellafield were much less than the permit limits in 2022. Gaseous discharges of tritium, krypton-85 and antimony-125, decreased in 2022, however, discharges of carbon-14, ruthenium-106, plutonium-alpha and americium-241/curium-242 increased by small amounts, in comparison to releases in 2021.

Monitoring around the site related to gaseous discharges

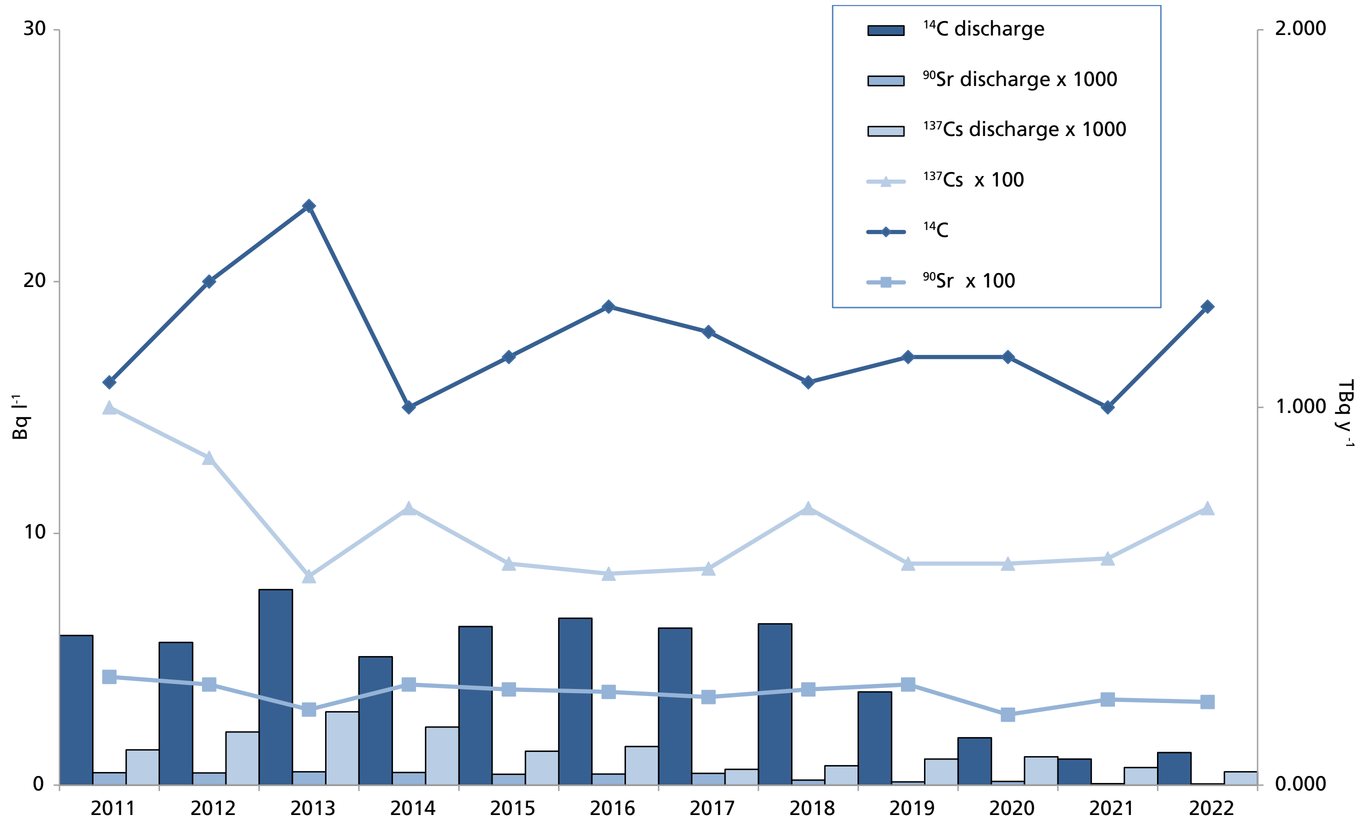
Monitoring of terrestrial foods in the vicinity of Sellafield is conducted by the FSA to reflect the scale and risk of discharges from the site. This monitoring is the most extensive of that for the nuclear licensed sites in the UK. A range of foodstuffs was sampled in 2022 including milk, fruit, vegetables, meat and offal, game, and environmental materials (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 2022 are given in Table 3.4. The activity concentrations of all radionuclides around the site were low. Activity concentrations in terrestrial foodstuffs were generally similar to those in recent years. Activity concentrations of radionuclides in meat and offal (cattle and sheep) were low, with many reported as less than values with only very limited evidence of the effects of Sellafield's gaseous discharges, detected in concentrations of carbon-14 in offal samples.

A range of foods (including fruit and vegetables) and terrestrial indicator materials was sampled in 2022 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 gaseous discharges from Sellafield was found in some of these foods. Strontium-90 was positively detected in a number of food samples (including milk) at low concentrations. In 2022, the maximum iodine-129 and iodine-131 concentrations in milk were reported as less than values. Small enhancements (above the expected background) in concentrations of carbon-14 were found in some food samples (including milk), as in recent years. Concentrations of transuranic radionuclides, when detectable in these foods, were very low. Trends in maximum concentrations of radionuclides in milk (near Sellafield), and corresponding discharges, for more than a decade are shown in Figure 3.10. Over the whole period, concentrations of carbon-14 were relatively constant (with some variation between years, generally consistent with changes in discharges), and caesium-137 concentrations (and strontium-90 to a lesser extent) were declining overall.

Figure 3.10 Discharges of gaseous wastes and monitoring of milk near Sellafield, 2011 to 2022



3.3.3 Liquid discharges

Regulated liquid discharges derive from a variety of sources at the site including the fuel storage ponds, the reprocessing plants, from the retrieval and treatment of legacy wastes, the laundry and general site drainage. Wastes from these sources are treated and then discharged to the Irish Sea via the sea pipelines that terminate 2.1km beyond low water mark. Liquid wastes are also discharged from the factory sewer to the River Ehen Estuary and (since 2015) some liquid wastes are also discharged via the Calder Interceptor Sewer [46]. Discharges from the Sellafield pipelines during 2022 are summarised in Appendix 1 (Table A1.2). The current permit sets limits on gross alpha and beta, and 12 individual radionuclides. In addition to overall site limits, plant notification levels have been set on discharges from the main contributing plants on site (Segregated Effluent Treatment Plant, Site Ion Exchange Effluent Plant (SIXEP), Enhanced Actinide Removal Plant (EARP) and THORP).

All discharges of liquid wastes from Sellafield were much less than the permit limits in 2022. Liquid discharges of all radionuclides decreased, by small amounts in 2022, in comparison to releases in 2021. To date, the discharges continue to reflect the varying amounts of fuel reprocessed in THORP (up to cessation in November 2018) and the Magnox reprocessing facility (which ceased in July 2022), and periods of planned and unplanned reprocessing plant shutdowns that occur from year to year.

The downward trend of technetium-99 discharges from Sellafield is given in Figure 3.11 (2011 to 2022) and Figure 3.12 (1993 to 2022). Technetium-99 discharges have substantially reduced from the peak of 192TBq in 1995. Further information relating to past discharges of technetium-99 is available in earlier RIFE reports (for example [68]).

Figure 3.11 Technetium-99 in UK seaweed ('Fucus vesiculosus') from Sellafield liquid discharges between 2011 to 2022

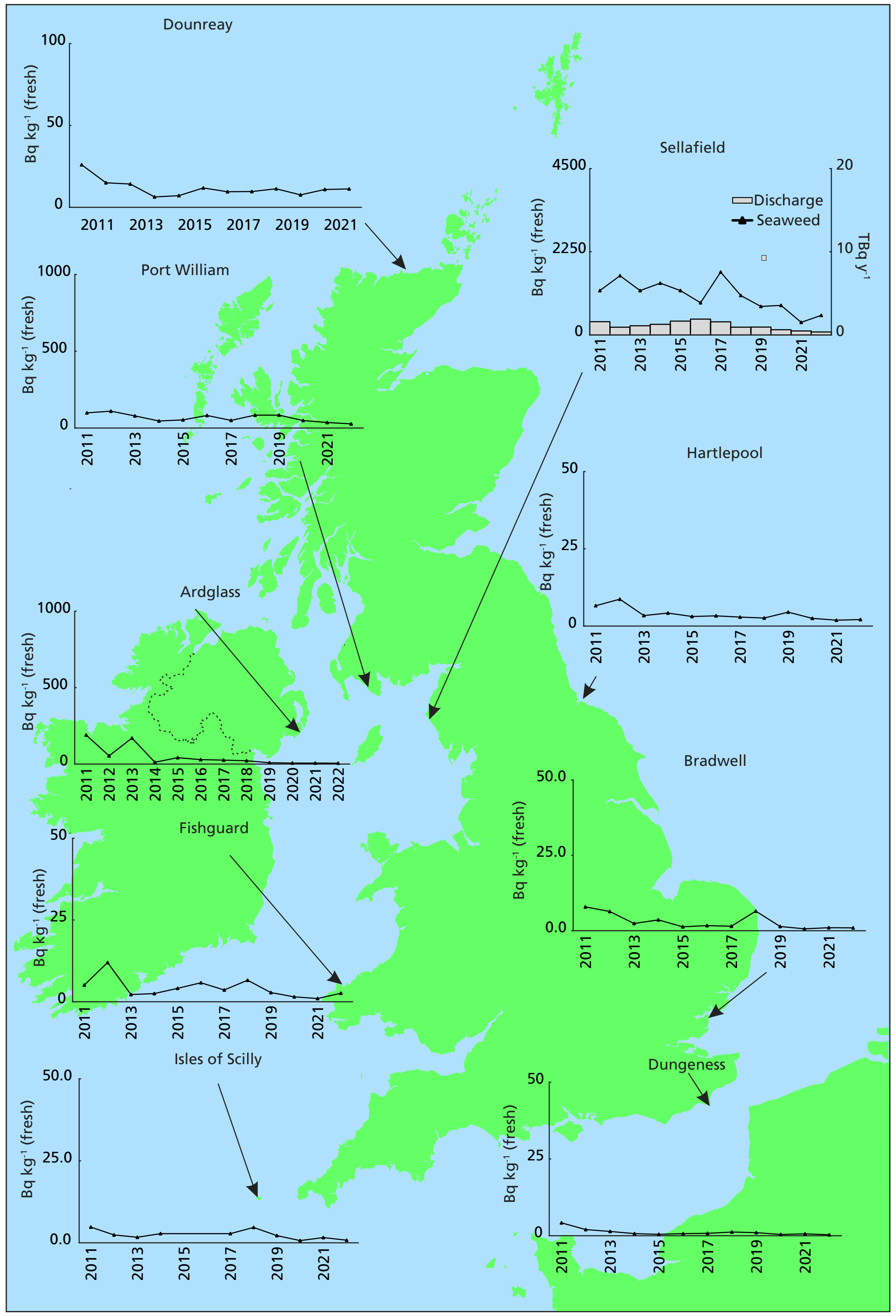
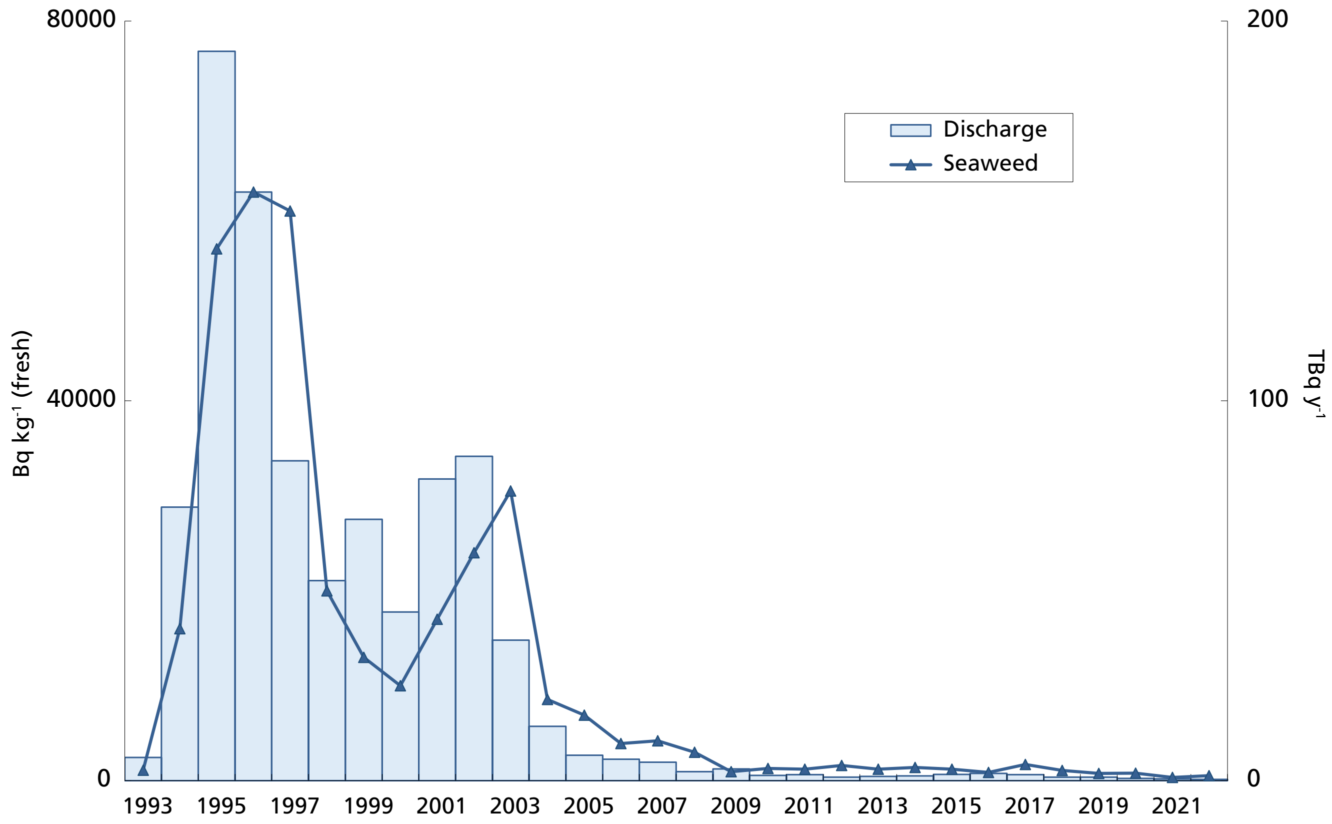


Figure 3.12 Technetium-99 in UK seaweed ('Fucus vesiculosus') from Sellafield liquid discharges between, 1993 to 2022



Monitoring of the marine environment

Regular monitoring of the marine environment near to Sellafield and further afield was conducted during 2022, by the Environment Agency and FSA (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland). The monitoring locations for seafood, water, environmental materials and dose rates near the Sellafield site are shown in Figure 3.13 and Figure 3.14.

Figure 3.13 Monitoring locations in Cumbria, 2022 (not including farms)

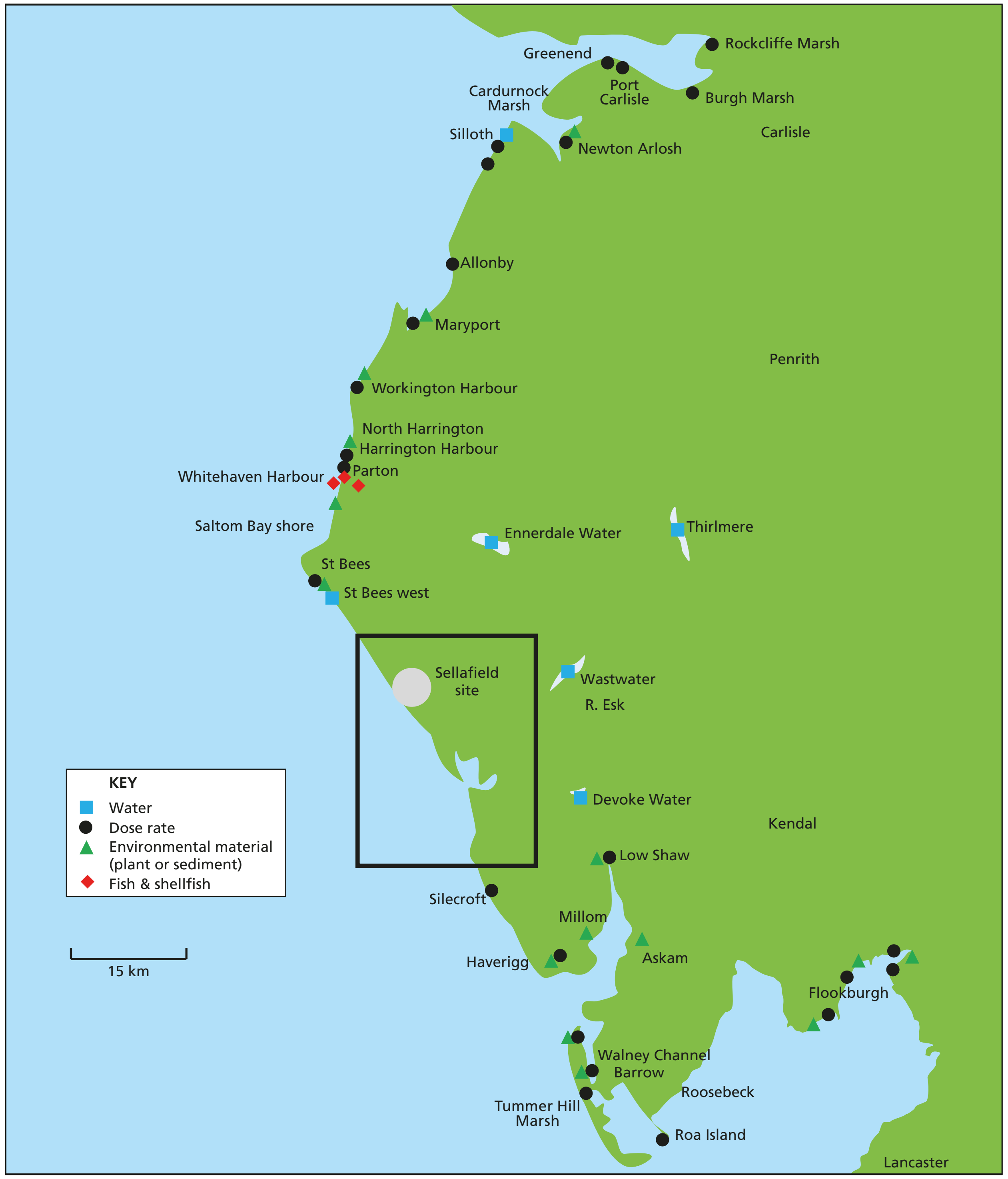


Figure 3.14 Monitoring locations at Sellafield, 2022 (not including farms)

Monitoring of fish and shellfish

Concentrations of beta/gamma activity in fish from the Irish Sea and from further afield are given in Table 3.5. Data are listed by location of sampling or landing point, north to south in Cumbria, then in approximate order of increasing distance from Sellafield. Results are available for previous specific surveys in the "Sellafield Coastal Area" (extending 15km to the north and to the south of Sellafield, from St Bees Head to Selker, and 11km offshore) and the smaller "Sellafield Offshore Area" (consisting of a rectangle, 1.8km wide by 3.6km long, situated south of the pipelines) in earlier RIFE reports (for example, [62]). Concentrations of specific naturally occurring radionuclides in fish and shellfish in the Sellafield area are given in Section 7.

The concentrations of most radionuclides have decreased over the previous decades in response to decreases in discharges (for example Figure 2.8 to Figure 2.13, [158]). Concentrations generally continue to reflect changes in discharges over time periods, characteristic of radionuclide mobility and organism uptake. More recent trends in concentrations of radionuclides, and corresponding discharges, in seafood near Sellafield (over the last decade) are shown in Figure 3.15 to Figure 3.20. There was variability from year to year, particularly for the more mobile radionuclides. Liquid discharges of technetium-99 and concentrations of technetium-99 in fish and shellfish in 2022 (Figure 3.17) were similar, in comparison to their respective values in recent years. Over a longer timescale, technetium-99 concentrations in fish and shellfish have shown a continued reduction, from the relatively elevated values in the previous decade (for example Figure 2.10, [158]). For the transuranic elements (Figure 3.19 and Figure 3.20), the trend of reductions in concentrations is not evident, unlike in earlier decades (for example Figure 2.12, [158]). Over the last decade, discharges and concentrations of americium-241 and plutonium-239+240 in fish and shellfish have continued to show some variations from year to year (Figure 3.19 and Figure 3.20). Overall, these concentrations in shellfish have decreased over the period. The mean concentrations of plutonium-239+240 and americium-241 in crustacean shellfish, and caesium-137 in fish and shellfish, were slightly lower in 2022, in comparison to those in 2021.

Figure 3.15 Carbon-14 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022

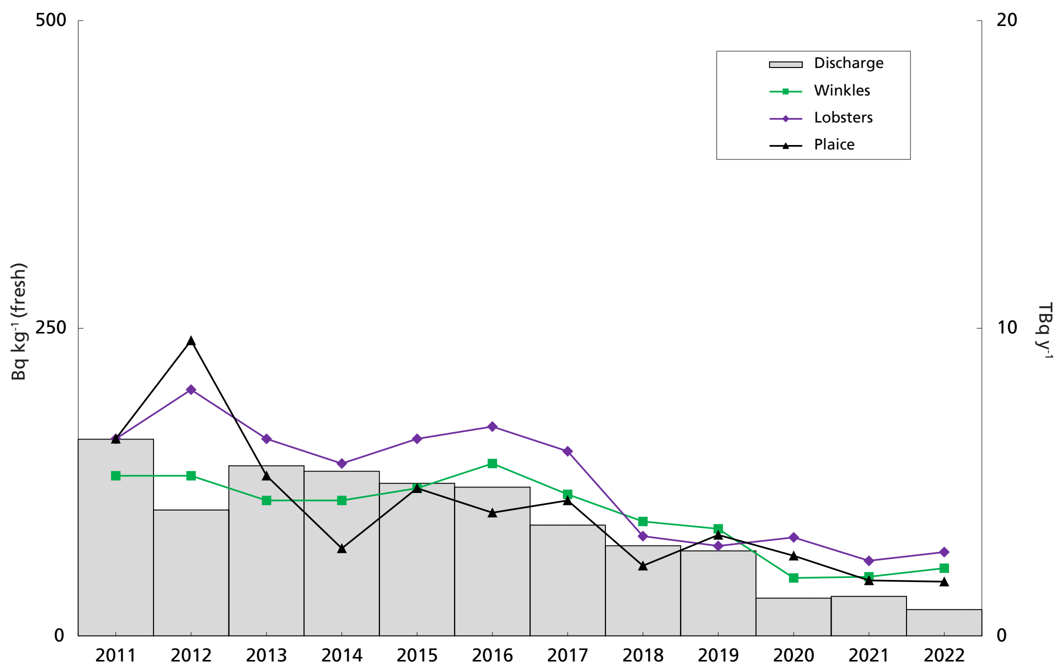


Figure 3.16 Cobalt-60 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022

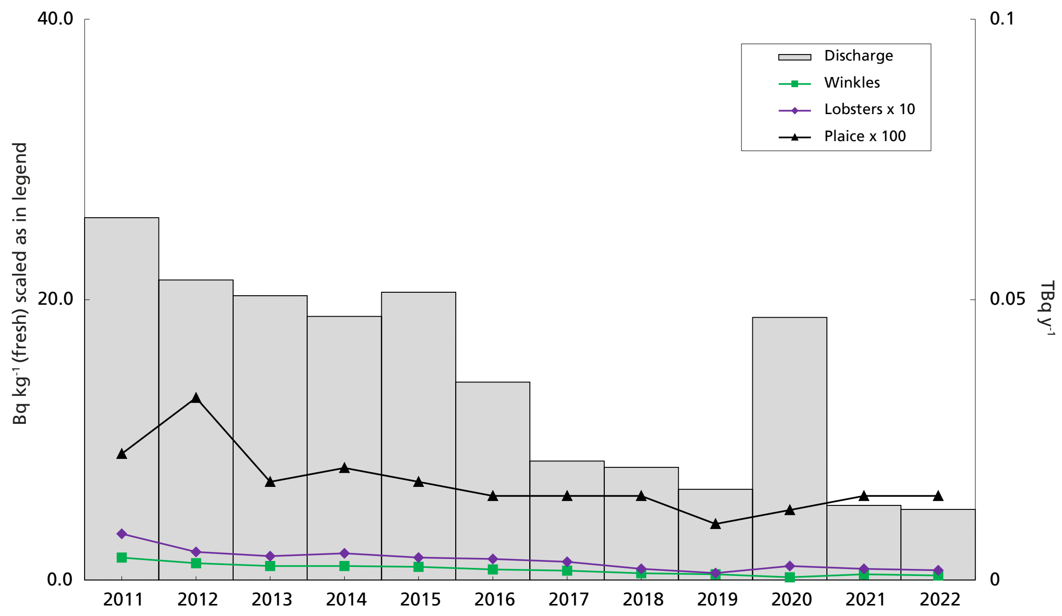


Figure 3.17 Technetium-99 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022

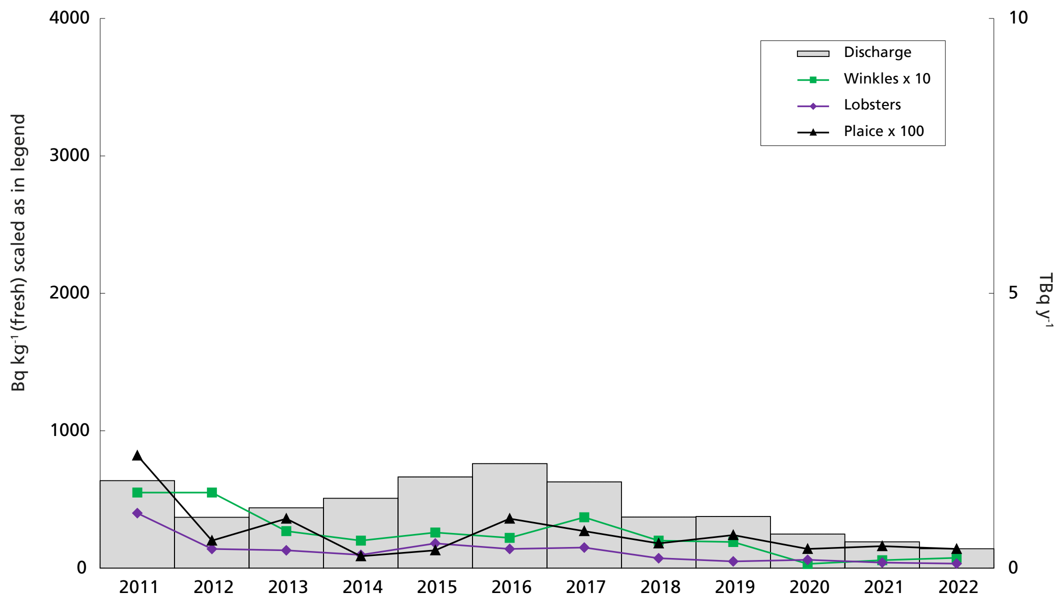


Figure 3.18 Caesium-137 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022

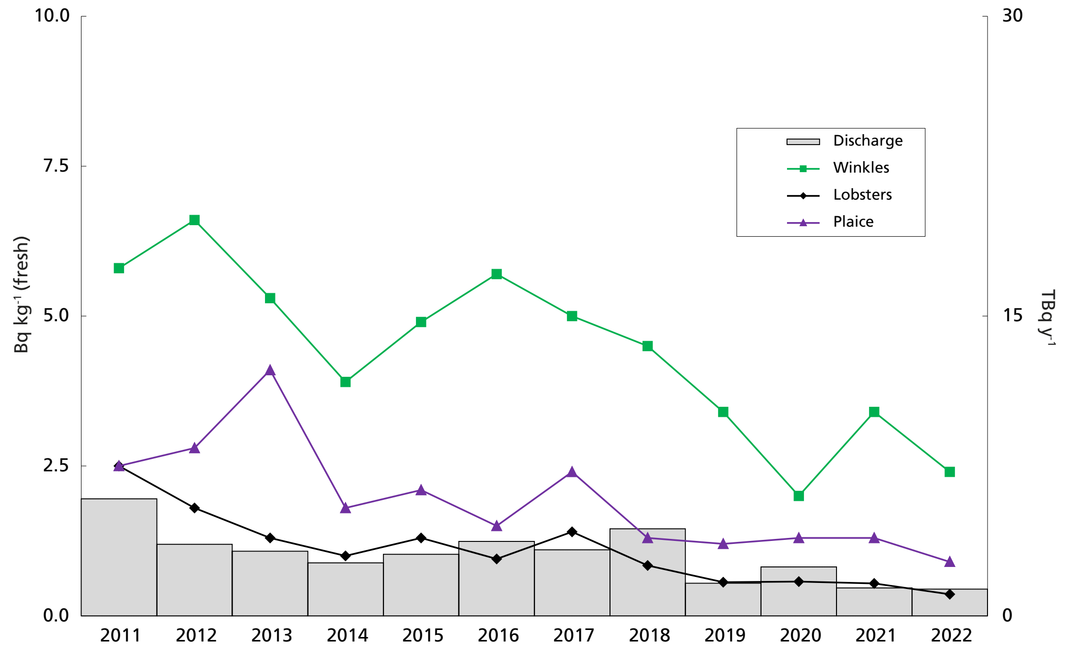


Figure 3.19 Plutonium-239+240 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022

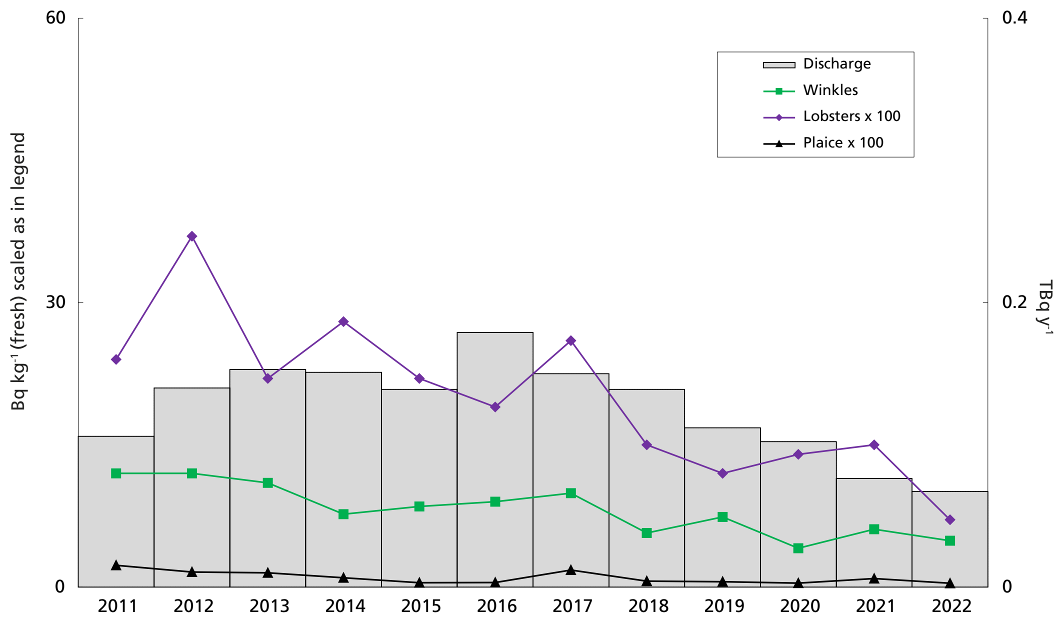
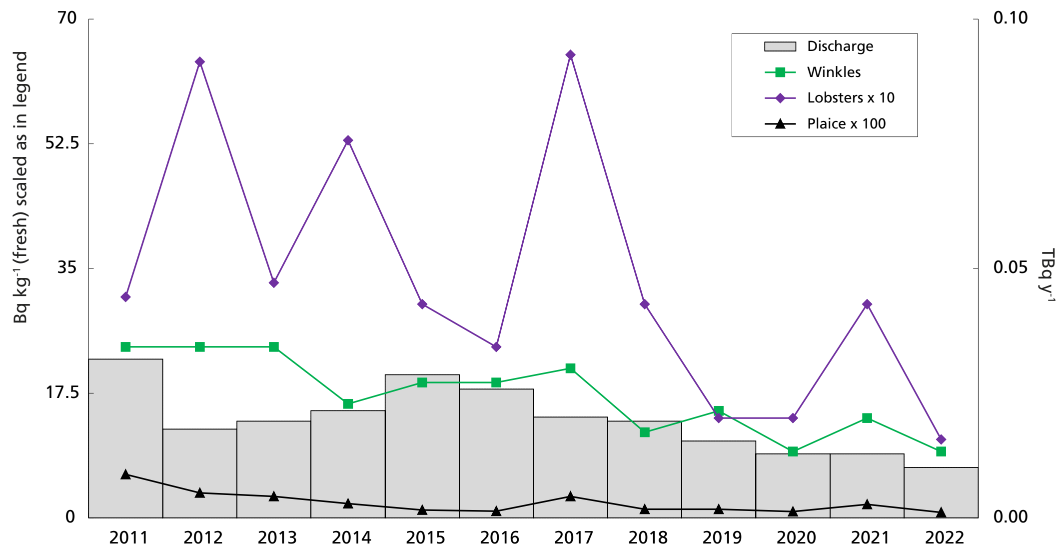


Figure 3.20 Americium-241 liquid discharge from Sellafield and concentrations in plaice, lobsters and winkles near Sellafield, 2011 to 2022



Beta- and gamma-emitting radionuclides detected in fish included tritium, carbon-14, strontium-90 and caesium-137 (Table 3.5). Overall, concentrations of caesium-137 in fish species, across a wide range of sampling locations, were generally similar in 2022, in comparison to those in 2021. Over the longer time period, activity concentrations in fish and shellfish appear to be generally declining (with minor variations) at a slow rate (Figure 3.18). Activity concentrations in fish (and shellfish) generally reflected progressive dilution with increasing distance from Sellafield. However, the rate of decline of caesium-137 concentrations with distance was not as marked as was the case when significant reductions in discharges were achieved in earlier decades.

Other artificial beta- and gamma-emitting radionuclides detected in fish included carbon-14 and tritium (Table 3.5). With an expected carbon-14 concentration from natural sources of about 20Bq kg^{-1} (see Appendix 6, Table A6.1), the data suggest a continued local enhancement of carbon-14 due to discharges from Sellafield. In 2022, carbon-14 is reported as the highest activity concentration in marine fish (plaice, 46Bq kg^{-1}) from Ravenglass. In 2022, the majority of both tritium and organically bound tritium (OBT) values, across all species and locations, were reported as less than values, with a value just above the LoD reported in Whitehaven plaice (26Bq kg^{-1}). Promethium-147 was detected at a very low concentrations (reported as just above the less than value) in fish and shellfish in 2022.

For shellfish, a wide range of radionuclides is detectable, owing to generally greater uptake of radioactivity by these organisms from sediments. Generally, molluscs tend to contain higher concentrations than crustaceans and both contain higher concentrations than fish. Concentrations of beta- and gamma-emitting radionuclides are shown in Table 3.6 (Table 3.7 for plutonium-241). There can be substantial variations between species; for example, lobsters tend to concentrate more technetium-99 than crabs (as shown in references, [159,160]). The highest concentrations in the marine environment from Sellafield discharges were carbon-14, tritium and technetium-99. Comparing 2021 and 2022 data across a wide range of sampling locations and shellfish species (where comparisons can be made), technetium-99 concentrations were similar (with minor variations) but reduced in comparison to those years prior to 2012 due to the progressive reductions in discharges of this radionuclide. Concentrations of other radionuclides (non-transuranic) in 2022 were also broadly similar (where comparisons can be made) to those in 2021.

Transuranic radionuclide data for fish and shellfish samples (chosen on the basis of potential radiological significance) in 2022 are given in Table 3.7. Transuranic elements are less mobile than other radionuclides in seawater and have a high affinity for sediments. This is reflected in higher concentrations of transuranic elements in shellfish compared with fish. Comparing 2021 and 2022 data across a wide range of sampling locations and shellfish species further afield from Sellafield, concentrations in shellfish were generally similar (where comparisons can be made). Those from the north-eastern Irish Sea were the highest transuranic concentrations found in foodstuffs in the UK. In 2022, the concentrations of plutonium and americium-241 in shellfish were generally lower (by small amounts) in comparison to those in 2021 at most of the north-eastern Irish Sea locations (for example, winkles from Nethertown and Parton). Americium-241 concentrations in mussels (near Sellafield) were also generally similar in 2022, in comparison to those in 2021. Overall, plutonium-239+240 and americium-241 concentrations in lobsters (near Sellafield) were generally lower (with minor variations) in 2022, in comparison to those in recent years. The concentrations of plutonium-239+240 and americium-241 in winkles (Nethertown) and plaice (Whitehaven) in 2022 were the lowest reported values in recent years (Figure 3.19 and Figure 3.20). Variations of these observations in previous years were likely to have resulted from a combination of mechanisms including natural environmental variability and redistribution of sediments due to natural processes.

Monitoring of sediments

Radionuclides in Sellafield liquid discharges are taken up into sediments along the Cumbrian Coast, in particular in muddier (fine grained) areas such as estuaries. Some of these areas are used by the public. Concentrations of radionuclides are regularly monitored, both because of their relevance to exposure and to keep distributions of radioactivity under review. The results for 2022 are shown in Table 3.8. Radionuclides positively detected were cobalt-60, strontium-90, caesium-137, europium-154, europium-155, and transuranic elements. The highest concentrations found are close to the site and in fine particulate materials in estuaries and harbours, rather than the coarser grained sands on open beaches. In 2022, the concentrations of caesium-137 and plutonium radionuclides were higher in the River Mite Estuary (an erosional area), in comparison to those in 2021. The concentrations of long-lived radionuclides, particularly caesium-137 and the transuranic elements, largely reflect past discharges from Sellafield, which were considerably higher than in recent years. Over the last 4 decades, discharges have fallen significantly as the site provided enhanced treatment to remove radionuclides prior to discharge. Overall, concentrations in sediments were generally similar in 2022, in comparison to those in 2021.

The trends over time (1993 to 2022) for activity concentrations in mud from Ravenglass and liquid discharges from Sellafield are shown in Figure 3.21 to Figure 3.24. The concentrations of most radionuclides have declined over the time period in response to decreases in discharges, with sustained reductions in discharges of caesium-137 and transuranic elements. Discharges of cobalt-60 have been variable in the earlier years but reduced over the last decade, as reflected in the sediment concentrations at Ravenglass, with some evidence of a lag time between discharge and sediment concentration (Figure 3.23). In 2022, the reported cobalt-60 concentration in mud from Ravenglass (Newbiggin) is the lowest reported value in recent years. Over the last decade, caesium-137 and transuranic concentrations in sediments have remained relatively constant (Figure 3.21, Figure 3.22 and Figure 3.24). Since the mid-1990s, discharges of caesium-137, plutonium isotopes and americium-241 have remained low, but with some variability. There is a suggestion of small progressive increases in caesium-137 and transuranic elements activities in sediments (peaking in both 2006 and 2014). 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 (Figure 3.18 to Figure 3.20) and will continue to be monitored.

Figure 3.21 Caesium-137 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1993 to 2022

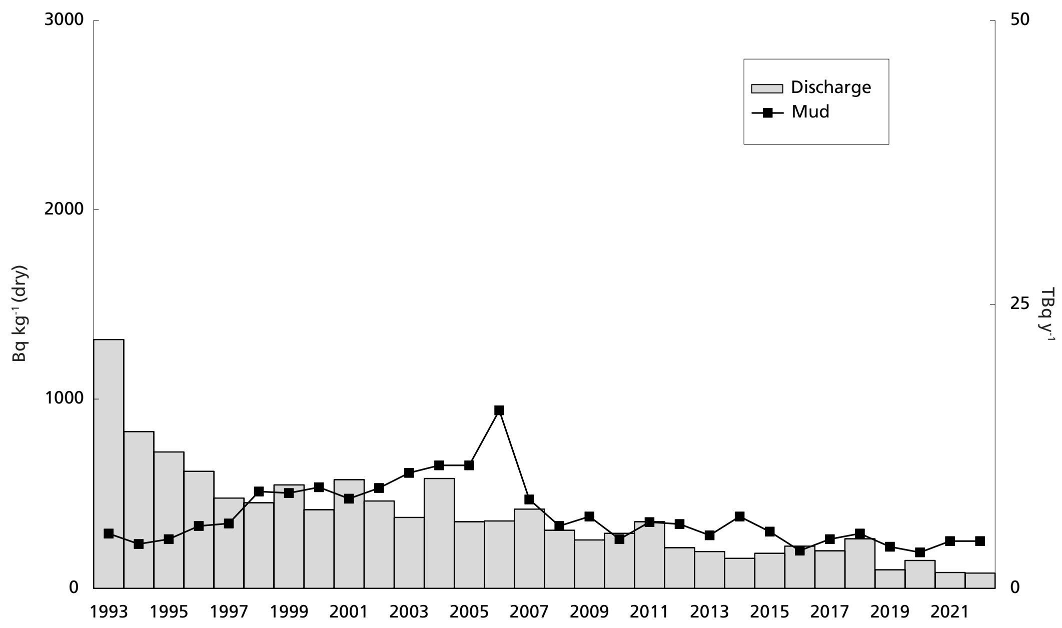


Figure 3.22 Plutonium-alpha liquid discharge from Sellafield and plutonium-239+240 concentration in mud at Ravenglass, 1993 to 2022

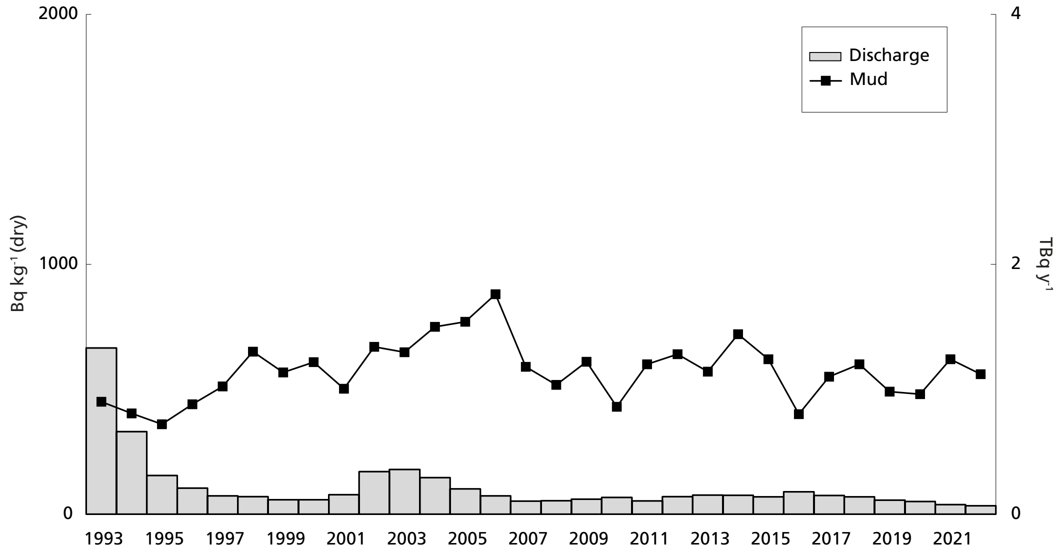


Figure 3.23 Cobalt-60 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1993 to 2022

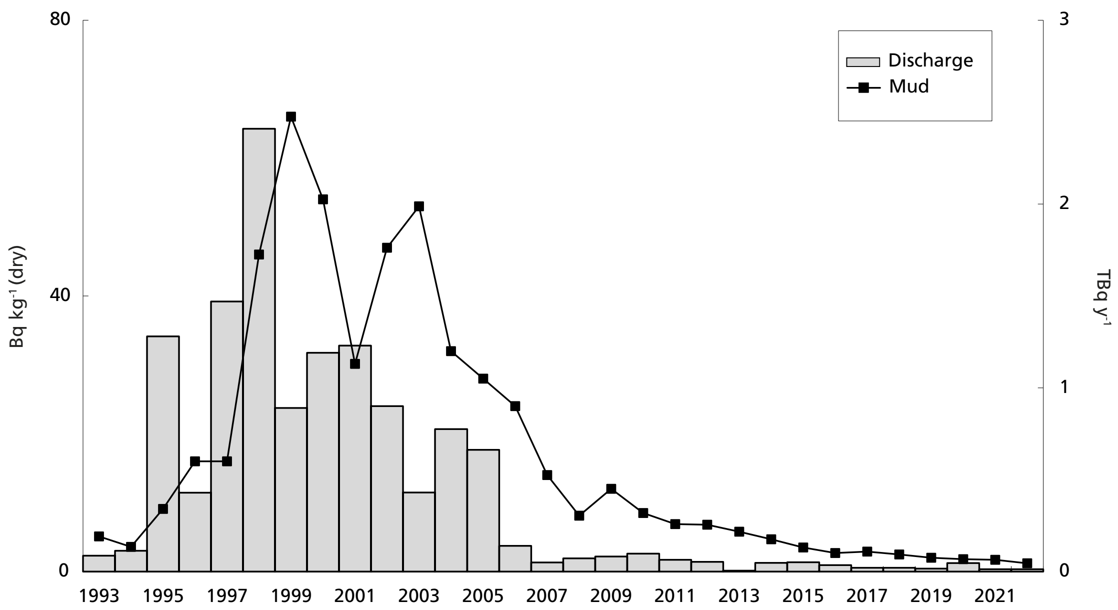
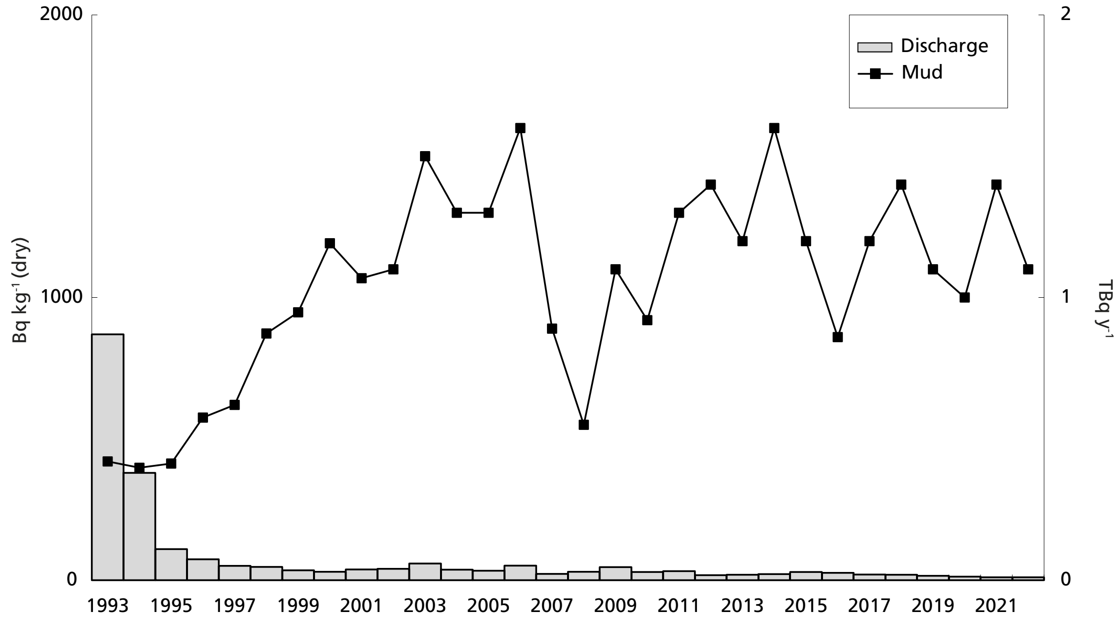
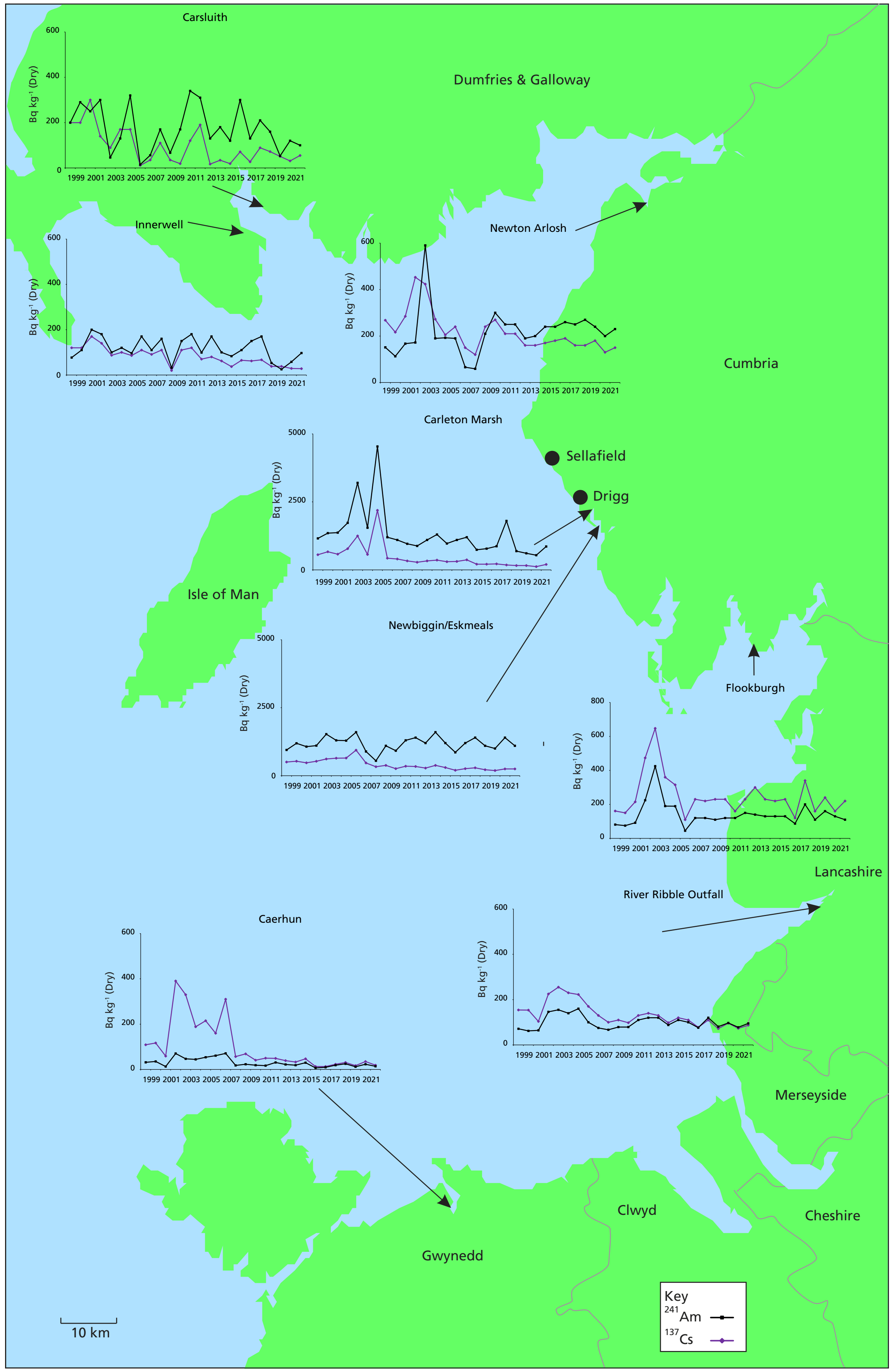


Figure 3.24 Americium-241 liquid discharge from Sellafield and concentration in mud at Ravenglass, 1993 to 2022



Concentrations of caesium-137 and americium-241 in sediments from coastal locations of the north-east Irish Sea are also shown in Figure 3.25. Concentrations of both radionuclides diminish with distance from Sellafield. Overall, concentrations in 2022 at a given location were generally similar to those in recent years, and any fluctuations were most likely due to the normal variability expected to be in the environment.

Figure 3.25 Concentrations of americium-241 and caesium-137 in coastal sediments in North West England,North Wales and South West Scotland between 1999 to 2022. (Note different scales used for Newbiggin and Carleton Marsh)

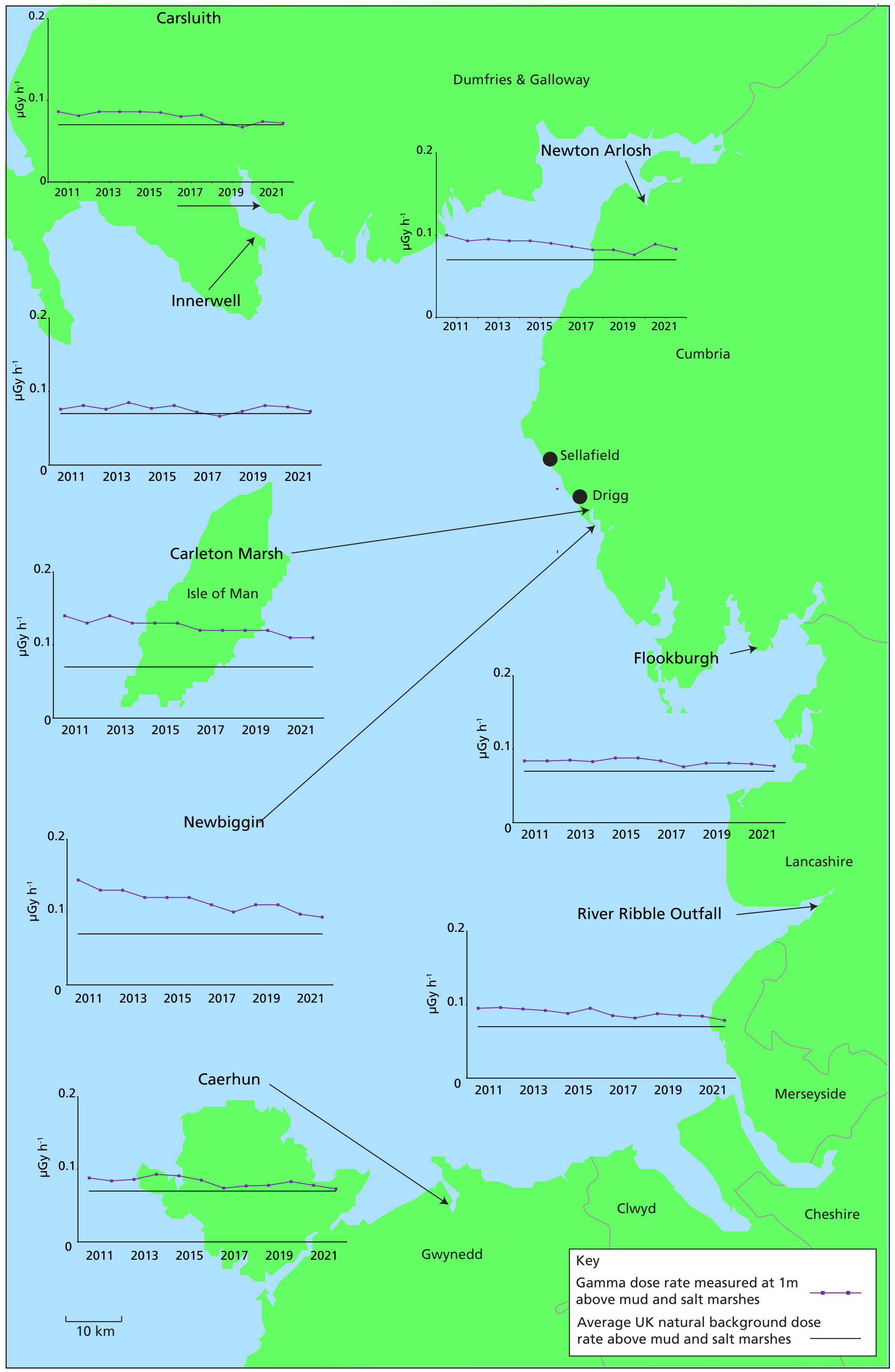


Monitoring of dose rates

Dose rates are regularly monitored at many locations, both in the Sellafield vicinity and further afield, using environmental radiation dosimeters. Table 3.9 provides the locations monitored by the environment agencies and the gamma dose rates in air at 1m above ground. Where comparisons can be made from similar ground types and locations, dose rates over intertidal areas throughout the Irish Sea in 2022 were generally similar to those in recent years (with small variations in comparison to those in 2021). Any variations between years are likely to have been due to normal variability expected to be present in the environment. As in previous years, gamma dose rates were measured on the banks of the River Calder, which flows through the Sellafield site. In 2022, gamma dose rates did not show a significant excess above natural background downstream of the site. Although these dose rates have been locally enhanced in previous years on the banks of the River Calder, occupancy by the public (mainly anglers) is low in this area, this is unlikely to be more than a few tens of hours per year. On this basis, the resulting doses (in previous years) were also 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 3.26 (2011 to 2022). Gamma dose rates at sandy locations are generally lower than those above mud or salt marshes. The general decrease in dose rates with increasing distance from Sellafield, which was apparent under conditions of higher discharges several decades ago, is no longer so prominent in recent years. Spatial variability of dose rates is expected, depending on ground type, with generally higher dose rates 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 some evidence to suggest that dose rates were slowly declining over the time period. Locations that are further afield from Sellafield show dose rate values that only marginally exceeded average UK natural background rates.

Figure 3.26 Gamma dose rates above fine coastal sediments (mud and salt marshes) in North West England, North Wales and South West Scotland between 2011 to 2022



Over the last 4 decades, concentrations of radioactivity in the environment around Sellafield have declined as a result of reduced discharges. In more recent years, the values in the Esk Estuary have shown a less clear trend, with concentrations of some radionuclides fluctuating from year to year (for example, see Figure 3.22). 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 sediment (from depth) containing radioactivity from historical discharges. Due to annual variations and local concerns, the Environment Agency initiated a more detailed study of dose rates in the Esk Estuary in 2007. Further information providing more background information, and describing the objectives and results of this study, is available in earlier RIFE reports (for example [156]).

Monitoring of fishing gear

During immersion in seawater, fishing gear may trap particles of sediment on which radioactivity is adsorbed. Fishermen handling this gear may be exposed to external radiation, mainly to skin from beta particles. Up to 2019, fishing gear was regularly monitored using surface contamination monitors. As in 2021, no monitoring of fishing gear was performed in 2022. Results up to 2019 are included in previous RIFE reports (for example, [23]).

Contact dose-rate monitoring of intertidal areas

Results from measurements of beta dose rates on shoreline sediments (using contamination monitors), to allow estimation of exposure of people who handle sediments regularly, are given in Table 3.10. Overall, positively detected dose rates in 2022 were generally similar to those in 2021 (where comparisons can be made from similar ground types and locations). Beta dose rates in sand were higher at Whitehaven outer harbour, Sellafield beach (north of discharge point), and Tarn Bay in comparison to those in 2021. However, reported beta dose rates are low, with no radiological significance.

More general beta/gamma monitoring for the Environment Agency of radiological 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 2022, no material was found using these probes in excess of the action level equivalent to 0.01mSv h^{-1}.

In 2008, the Environment Agency published a formal programme of work for the assessment of contamination by radioactive particles and objects[18] on and around the west Cumbrian coastline. The assessment was focused on public protection from high activity discrete radioactive particles that have been released to the environment from activities at the Sellafield site [161].

18. “Particles and objects” are terms used which encompass discrete radioactive items which can range in radioactivity concentration, size and origin. “Particles” include radioactive scale, fragments of irradiated nuclear fuel and incinerated waste materials (less than 2mm in diameter). “Objects” are larger radioactive artefacts and stones which have radioactive contamination on their surface and are larger than 2 mm in size. Particles can be compared according to the hazard posed.

Beach survey work using vehicle mounted detectors, by the Sellafield site operator's contractors, began in 2006. The current detection system in use is the Groundhog™ Synergy2 system, which was introduced in mid-2014 and was designed, and introduced, to further improve detection of americium-241 and strontium-90/yttrium-90. This replaced the GroundhogTM Synergy system, which was used from mid-2009 to mid-2014, which had a specific capability in relation to the detection of medium/high energy gamma-emitting radionuclides. The GroundhogTM Synergy system also provided improved detection capability for low energy gamma emissions (in comparison to the original system introduced in 2006), increasing the ability to detect particles containing americium-241.

Further beach monitoring for the 2022 calendar year was completed in line with the Environment Agency's specification. A total area of 117 hectares was surveyed against a programme target of 105 hectares [162]. In 2017, there was a change implemented to the beach finds categories in that the "stone" category is replaced by "larger object". This means that all items larger than 2mm in size (for example granules, gravel, wire, pebbles, and stones) are now classified as objects. The number of radioactive finds identified was 56 in 2022, of which approximately 88% were classified as particles (less than 2mm in size) and the remainder as larger objects. The number of finds were typical of those in recent years. Most of the finds were concentrated on a 5km stretch of beach running northwest from the Sellafield site. All have been removed from the beaches. In 2022, none of the finds detected exceeded the characterisation triggers set within the Environment Agency's intervention trigger levels: https://www.gov.uk/government/publications/sellafield-radioactive-objects-intervention-plan.

Monitoring along the Cumbrian coast will continue for 2023, with the current proposal being a further 105 hectares to be surveyed.

In 2012, UKHSA reported their review of the results and position on risk following the introduction of the improved monitoring (Groundhog™ Synergy system). The report concluded that the increase in particle finds following the introduction of this system was a result of its improved capability and also that advice previously given by UKHSA to the Environment Agency following a detailed assessment of risks in 2010 remained valid [163,164]. The report restated the conclusion that, based on the currently available information, the overall health risks to beach users are very low and significantly lower than other risks people accept when using the beaches. As such, UKHSA advice remained that no special precautionary actions were required to limit access to or use of the beaches. A report by UKHSA describes the assessed health risks from the consumption of seafood (including those to commercial fishermen) from radioactive particles in the vicinity of the Sellafield Site [165]. Based on currently available information, it is concluded that the overall health risks to both seafood consumers and commercial fishermen are very low. More recently, UKHSA were requested by the Environment Agency to update their recommendations, if supported by available evidence. This is to account for the information from the beach monitoring programme and from the further analysis of finds that have been collected since 2012. A summary report of assessing the risk to people's health from radioactive objects on beaches around the Sellafield site was published by UKHSA in February 2020, concluding that the risk is very low [5].

In relation to food safety (and following a previous assessment of the particles frequency and the activity concentrations), FSA's guidance to the Environment Agency supported UKHSA's advice. The Environment Agency will continue to work with relevant authorities to keep the situation under review.

In 2007, SEPA published a strategy document for the assessment of the potential impact of Sellafield radioactive particles on members of the public in south-west Scotland [166] and the beach monitoring programme was temporarily extended to include 2 locations on the north Solway coastline (Kirkcudbright Bay and Southerness). This was based on some limited modelling work on the movement of particles undertaken for the Environment Agency following a request by SEPA. No particles were detected at these locations. SEPA is maintaining a watching brief on the situation in as much as it may affect Scotland.

Further detail on enhanced beach monitoring data compiled so far can be obtained on the UK government website: https://www.gov.uk/government/publications/sellafield-radioactive-objects-intervention-plan/sellafield-radioactive-objects-intervention-plan#monitoring-beaches-near-sellafield.

Monitoring of seaweed

Seaweeds are useful indicator materials, in addition to their occasional use in foods and as fertilisers. Seaweeds have the capability to readily accumulate radionuclides and thereby assist in the detection of these radionuclides in the environment. Table 3.11 gives the results of measurements in 2022 of seaweeds from shorelines of the Cumbrian coast and further afield. Comparing 2021 and 2022 data across a wide range of sampling locations, radionuclide concentrations were generally similar (where comparisons can be made) in seaweeds.

Fucus species of seaweeds are particularly useful indicators of most fission product radionuclides. In particular, samples of 'Fucus vesiculosus' are collected both in the Sellafield vicinity and further afield to show the extent of Sellafield contamination in north European waters. The effects of technetium-99 discharges from Sellafield on concentrations in seaweed are shown in Figure 3.11 (2011 to 2022) and Figure 3.12 (1993 to 2022). In the north-east Irish Sea, technetium-99 concentrations have been reasonably constant over the present decade, consistent with the relatively low discharges; the highest concentrations which were found near Sellafield were much less than those in the mid-1990s and the decade thereafter (in response to the progressive reduction in discharges). In general, there was also a large reduction in concentrations of technetium-99 in 'Fucus vesiculosus' with distance from Sellafield, as the effect of the discharges becomes diluted in moving further afield.

Technetium-99 concentrations in seaweed (Table 3.11) collected from sites in Cumbria were generally higher by small amounts in 2022, in comparison to those in 2021. Over the last 5 years, small variations have been found, year on year, but technetium-99 concentrations in seaweed in 2022 were still low (Figure 3.11). At one specific location (Auchencairn, Scotland), known to have had fluctuating concentrations in previous years, technetium-99 concentrations in seaweed (Fucus) were lower in 2022 compared with those in 2021. The reasons behind these variations have been described in previous RIFE reports (for example [68]).

Monitoring of tide-washed 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 [167]. The maximum potential dose was calculated to be 0.009mSv per year, 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 [168].

Monitoring of sea to land transfer

Terrestrial foodstuffs are monitored near Ravenglass to check on the extent of transfer of radionuclides from sea to land in this area. In 2022, samples of milk and livestock were collected and analysed, for radionuclides which were released in liquid effluent discharges from Sellafield. Results from surveys for activity concentrations in crops, fruit and environmental indicators are available in earlier RIFE reports (for example [62]).

The results of measurements in 2022 are given in Table 3.12. Generally, the activity concentrations, where positively detected, show lower concentrations than were found in the immediate vicinity of Sellafield (Table 3.4). As in previous years, the evidence for sea to land transfer was very limited in 2022. Technetium-99 concentrations are reported as less than values (or close to the less than value). Small concentrations of artificial nuclides were detected in some samples, but the concentrations were very low. As in recent years, where detectable, observed isotopic ratios of plutonium-238 to plutonium-239+240 concentrations were somewhat higher than 0.025, a ratio which might be expected if the source was entirely due to fallout from nuclear weapons testing. This may suggest a Sellafield influence.

Monitoring of fishmeal

A theoretical study has established that any indirect onward transmission of both naturally occurring and artificial radioactivity into the human diet from the fishmeal pathway (that is fed to farmed fish, poultry, pigs, cows and sheep) is unlikely to be of radiological significance [169]. A detailed survey was undertaken to confirm these findings [170]. Samples, obtained from 14 fish farms in Scotland and 3 in Northern Ireland, contained very low radionuclide concentrations, most being less than the limits of detection, and the few positively detected values were all less than 1Bq kg-1. Annually reported RIFE results for activity concentrations in farmed salmon from the west of Scotland confirm the findings of the FSA study (for example, Tables 2.5 and 2.7 [62]).

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 freshwater from rivers and lakes in west Cumbria is conducted as part of the regular environmental monitoring programme around Sellafield. However, other environmental materials are likely to be more indicative of direct site-related effects. Some of the sources monitored provide public drinking water. The results for 2022 are included in Table 3.13. Tritium, gross alpha and gross beta concentrations in public supplies were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Small amounts of radioactivity are discharged from Sellafield under permit via the factory sewer outfall to the River Ehen Estuary, immediately prior to the confluence with the River Calder. In 2022, there was no evidence of tritium downstream or upstream of the outfall (Table 3.13). These are not drinkable waters and any low concentrations observed previously are of no radiological significance. Table 3.13 also includes the results of monitoring from Ehen Spit beach (Figure 3.13) 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 contains high levels of salt so it will not be used as a drinking water source and therefore the only consumption would be inadvertent (incidental). Enhanced gross beta and tritium concentrations were observed in 2022 with concentrations similar to those in recent years. The annual dose from inadvertent consumption of water from Ehen Spit has been shown to be insignificant [171].

Monitoring of unusual pathways

In 1998, high caesium-137 concentrations (up to 110,000Bq kg^{-1}) were found in feral pigeons sampled in Seascale by MAFF [172]. Further background information, describing the consequences of this monitoring, and remedial measures taken by the site operator, is available in earlier RIFE reports (for example [156]). Like in 2021, wood pigeon was not sampled in 2022. In 2020, the maximum caesium-137 concentration in the muscle of wood pigeon was detected just above the less than value (0.49Bq kg^{-1}) and generally similar to those in recent years. These caesium-137 concentrations fluctuated in value prior to 2011, but elevated concentrations have not been sustained thereafter. Concentrations of artificial radionuclides were low and would add little to the exposure of local consumers. The FSA will continue to monitor this pathway.

Following discovery of elevated concentrations in feral pigeons, 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 radiological contamination of urban environments. The results of analyses in 2022 are shown in Table 3.14. Overall, activity concentrations are generally similar to those in recent years, although plutonium-239+240 and americium-241 concentrations decreased, by small amounts, in 2022. Further information of the previously elevated concentrations (of strontium-90, caesium-137, americium-241 and plutonium radionuclides) in road drain sediments is given in earlier RIFE reports (for example [68]).

Table 3.1 Individual doses - Capenhurst and Springfields, 2022

Site	Representative person[a]	Exposure, mSv per year						
		All pathways	Seafood	Other local food	External radiation from intertidal areas, river banks or fishing gear[b]	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
Capenhurst								
'Total dose'	**Local inhabitants (0.5 - 1 km) aged 10y**	**0.14[c]**	**-**	**<0.005**	**<0.005**	**-**	**<0.005**	**0.14**
Source specific doses	Infant inhabitants and consumers of locally grown food	<0.005[c]	-	<0.005	-	-	<0.005	-
	Children playing at Rivacre Brook	0.005[c]	-	-	0.005	<0.005	-	-
Springfields								
'Total dose'	**Local adult inhabitants (0.5 - 1 km)**	**0.032**	**-**	**<0.005**	**-**	**-**	**<0.005**	**0.032**
Source specific doses	Seafood and wildfowl consumers	0.007[c]	<0.005	-	<0.005	-	-	-
	Children playing at Lower Penwortham[c]	<0.005	-	-	<0.005	<0.005	-	-
	External in intertidal areas (farmers)	<0.005	-	-	<0.005	-	-	-
	Infant inhabitants and consumers of locally grown food	<0.005[c]	-	<0.005	-	-	<0.005	-

a. The ‹total dose› is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation. The ‹total dose› for the representative person with the highest dose is presented. Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment. The representative person is an adult unless otherwise stated. Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv

b. Doses (‹total dose› and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)

c. Includes a component due to natural sources of radionuclides

Table 3.2(a) Concentrations of radionuclides in food and the environment near Capenhurst, 2022

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{99}Tc	^{137}Cs	^{234}Th	^{234}U	^{235}U	^{238}U	^{237}Np
Marine samples										
Plaice	Liverpool Bay	1	<25		0.86					
Mussels	Liverpool Bay	1	<25		1.4					
Cockles	Dee Estuary	1	<25	0.71	0.52					
Sediment	Rivacre Brook	2[E]		250	2.8	120	340	17	230	<8.5
Sediment	Rivacre Brook (1.5 km downstream)	2[E]		67	1.5	35	32	1.4	24	<8.5
Sediment	Rossmore (3.1 km downstream)	2[E]		29	<1.1	29	47	1.9	26	<8.5
Sediment	Rivacre Brook (4.3 km downstream)	2[E]		11	<0.42	<9.5	11	<0.75	8.3	<8.5
Freshwater	Rivacre Brook	2[E]	<3.9	<0.024			0.059	<0.0029	0.030	<0.11
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]	<3.8	<0.026			0.023	<0.0013	0.013	<0.11
Freshwater	Rossmore (3.1 km downstream)	2[E]	<3.6	<0.028			0.012	<0.00092	0.0077	<0.11
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]	<3.6	<0.027			0.011	<0.00092	0.0075	<0.11

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Marine samples									
Plaice	Liverpool Bay	1			<0.34				
Mussels	Liverpool Bay	1			2.8				
Cockles	Dee Estuary	1	0.043	0.29	0.62	*	*		
Sediment	Rivacre Brook	2[E]						300	1000
Sediment	Rivacre Brook (1.5 km downstream)	2[E]						230	750
Sediment	Rossmore (3.1 km downstream)	2[E]						220	790
Sediment	Rivacre Brook (4.3 km downstream)	2[E]						76	440
Freshwater	Rivacre Brook	2[E]						0.13	0.39
Freshwater	Rivacre Brook (1.5 km downstream)	2[E]						<0.030	0.22
Freshwater	Rossmore (3.1 km downstream)	2[E]						<0.032	0.18
Freshwater	Rivacre Brook (4.3 km downstream)	2[E]						<0.030	0.15

Table 3.2(a) continued

Material	Location	No. of sampling observ-ations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			$^{3}H^{d}$	^{99}Tc	^{234}U	^{235}U	^{238}U
Terrestrial samples							
Milk		2	<3.8	<0.018	<0.0011	<0.00045	<0.00045
Milk	max		<4.7	<0.023	0.0016	<0.00051	<0.00051
Beetroot		1		<0.046	0.0034	0.00038	0.0026
Silage		1		0.27	0.59	0.016	0.48
Grass/herbage	North of Ledsham	1[E]		<0.35	0.18	<0.028	0.23
Grass/herbage	South of Capenhurst	1[E]		<0.29	0.054	<0.023	0.054
Grass/herbage	East of Capenhurst	1[E]		<0.23	0.072	<0.0056	0.073
Grass	Dunkirk Lane (0.9 km South of Site)	1[E]		<0.41	0.063	<0.028	0.066
Soil	North of Ledsham	1[E]		4.7	23	0.97	23
Soil	South of Capenhurst	1[E]		5.6	21	0.84	22
Soil	East of Capenhurst	1[E]		<0.76	20	0.84	21
Soil	Dunkirk Lane (0.9 km South of Site)	1[E]		<0.94	17	1.1	18

* Not detected by the method used

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

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

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

[d] In distillate fraction of sample

[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 3.2(b) Monitoring of radiation dose rates near Capenhurst, 2022

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
East of railway station	Grass	1	0.072
Dunkirk Lane	Grass	1	0.073
Near Lower Brook Farm	Grass	1	0.070
Rivacre Brook Plant outlet	Grass	1	0.074
Rivacre Brook Plant outlet	Grass and herbage	1	0.078
Rivacre Brook 1.5 km downstream	Grass	2	0.071
Rossmore Road West 3.1 km downstream	Grass	2	0.069
Rivacre Brook 4.3 km downstream	Pebbles and sand	1	0.076
Rivacre Brook 4.3 km downstream	Sand and stones	1	0.075
North of Ledsham	Grass	1	0.077

Table 3.3(a) Concentrations of radionuclides in food and the environment near Springfields, 2022

Material	Location	No. of sampling observa-tions	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{90}Sr	^{99}Tc	^{129}I	^{137}Cs	^{228}Th	^{230}Th	^{232}Th	^{234}Th
Marine samples												
Flounder	Ribble Estuary	1						<1.7				
Sea Bass	Ribble Estuary	1						2.2				
Shrimps[b]	Ribble Estuary	1		18		<0.15		0.68	0.010	0.0027	0.0032	
Mussels[c]	Ribble Estuary	1						0.43	0.31	0.16	0.13	
Wildfowl	Ribble Estuary	1	<3.1	34	0.014		<1.0	0.59		<0.0010	<0.00050	
Samphire	Marshside Sands	1				0.18		0.12				
Sediment	River Ribble outfall	4[E]						87	28	45	27	<29
Sediment	Lower Penwortham Park	4[E]						110	34	57	33	<36
Sediment	River Angler Location 1	4[E]						76	26	44	26	<26
Sediment	Penwortham road bridge - West bank	2[E]						69	22	33	22	53
Sediment	Lytham Yacht Club	1[E]						150	40	71	41	44
Sediment	Becconsall	4[E]						57	26	38	25	41
Sediment	Freckleton	1[E]						140	42	73	42	46
Sediment	Hutton Marsh	1[E]						250	32	110	33	<21
Sediment	Longton Marsh	1[E]						360	43	200	40	<20
Grass (unwashed)	Hutton Marsh	1[E]				<0.34						
Soil	Hutton Marsh	1[E]				27						

Material	Location	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
		^{234}U	^{235}U	^{238}U	^{237}Np	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Marine samples										
Flounder	Ribble Estuary							<0.18		
Sea Bass	Ribble Estuary							<0.06		
Shrimps[b]	Ribble Estuary				0.000047	0.0011	0.0078	<0.014		
Mussels[c]	Ribble Estuary					0.12	0.72	1.3		
Wildfowl	Ribble Estuary					0.00034	0.0027	0.0041		
Samphire	Marshside Sands							0.20		
Sediment	River Ribble outfall	21	1.1	23				95	350	1100
Sediment	Lower Penwortham Park	24	1.7	26				110	380	1100
Sediment	River Angler Location 1	22	<0.98	22				83	290	940
Sediment	Penwortham road bridge - West bank	22	1.1	23				87	310	1000
Sediment	Lytham Yacht Club	26	1.5	30				160	650	1300
Sediment	Becconsall	21	0.89	21				67	320	870
Sediment	Freckleton	26	1.3	27				150	440	1200
Sediment	Hutton Marsh	25	1.2	29				210	600	1500
Sediment	Longton Marsh	32	2.0	32				270	670	1800
Grass (unwashed)	Hutton Marsh									
Soil	Hutton Marsh									

Table 3.3(a) continued

Material	Location	No. of sampling observa-tions	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{14}C	^{90}Sr	^{129}I	^{137}Cs	Cs	^{230}Th	^{232}Th	^{234}Th
Terrestrial samples											
Milk		2									
Milk	Max										
Beetroot		1	<4.7	17	<0.047	<0.018	<0.04	<0.042	<0.00076	<0.00076	
Sediment	Deepdale Brook	2[E]					<0.67				66
Silage		1	<5.5	24	0.17	<0.020	<0.06	<0.056	0.051	0.056	
Grass	Opposite site entrance	1[E]									
Grass	Opposite windmill	1[E]									
Grass	Deepdale Brook	1[E]									
Grass	N of Lea Town	1[E]									
Soil	Opposite site entrance	1[E]									
Soil	Opposite windmill	1[E]									
Soil	Deepdale Brook	1[E]									
Soil	N of Lea Town	1[E]									
Freshwater	Deepdale Brook	4[E]									
Freshwater[f]	Ulnes Walton	1[E]	<3.6				<0.17		<0.0014	<0.00075	

Material	Location	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
		^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Pu	Gross alpha	Gross beta
Terrestrial samples										
Milk		0.0018	<0.00039	<0.0012						
Milk	max		<0.00040	0.0017						
Beetroot		0.0014	<0.00050	0.0023	<0.000080	0.000068	<0.34	0.00011		
Sediment	Deepdale Brook	83	3.9	58					250	1100
Silage		0.062	0.0027	0.064	0.00011	0.0012	<0.42	0.0019		
Grass	Opposite site entrance	0.16	<0.024	0.077						
Grass	Opposite windmill	0.23	<0.023	0.15						
Grass	Deepdale Brook	1.2	0.068	1.2						
Grass	N of Lea Town	0.049	<0.022	0.056						
Soil	Opposite site entrance	160	7.2	130						
Soil	Opposite windmill	120	5.1	110						
Soil	Deepdale Brook	100	4.7	100						
Soil	N of Lea Town	50	2.5	51						
Freshwater	Deepdale Brook	0.41	0.020	0.42					0.83	1.1
Freshwater[f]	Ulnes Walton	0.013	<0.00088	0.011					<0.035	1.2

a. Except for milk and freshwater where units are Bq l^{-1} and for sediment and soil where dry concentrations apply
b. The concentrations of ^{242}Cm and $^{243+244}Cm$ were not detected by the method used
c. The concentrations of ^{242}Cm and $^{243+244}Cm$ were not detected by the method used
d. 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
e. The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime
f. The concentration of ^{228}Th was <0.0035 Bq l^{-1}
E. Measurements are made on behalf of the Food Standards Agency unless labelled "E".
In that case they are made on behalf of the Environment Agency

Table 3.3(b) Monitoring of radiation dose rates near Springfields, 2022

Location	Material or round type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Lytham Yacht Club	Salt marsh	1	0.082
Warton Salt Marsh	Salt marsh	2	0.084
Warton Salt Marsh	Salt marsh[a]	2	0.085
Freckleton	Salt marsh	1	0.082
Naze Point	Salt marsh	2	0.090
Banks Marsh (alternative)[b]	Salt marsh	2	0.091
Banks Marsh (alternative)[b]	Salt marsh[a]	2	0.097
Becconsall Boatyard	Salt marsh	4	0.076
Longton Marsh	Salt marsh	1	0.081
Hutton Marsh	Salt marsh	1	0.10
River Ribble outfall	Mud	1	0.075
River Ribble outfall	Mud and sand	3	0.082
Savick Brook, confluence with Ribble	Salt marsh	2	0.078
Penwortham road bridge	Mud	1	0.077
Penwortham road bridge	Sand	1	0.081
Lower Penwortham Park	Grass	3	0.070
Lower Penwortham Park	Grass and mud	1	0.069
River Darwen	Grass	3	0.077
River Darwen	Grass and herbage	1	0.072
Riverbank Angler Location 1	Grass	2	0.073
Riverbank Angler Location 1	Grass and herbage	1	0.068
Riverbank Angler Location 1	Grass and mud	1	0.077
Ulnes Walton, BNFL area survey	Grass	3	0.075
Mean beta dose rates			**μSv h^{-1}**
Lytham - Granny's Bay	Sand	1	0.072
Banks Marsh (alternative)[b]	Salt marsh	2	0.23
Warton Salt Marsh	Salt marsh	2	0.051

a. 15cm above substrate
b. As in 2021, no monitoring was undertaken at Banks Marsh in 2022 (as reported in earlier RIFE reports)

Table 3.4 Concentrations of radionuclides in terrestrial food and the environment near Sellafield, 2022

Material	Location or selection[a]	No. of sampling observations[b]	Mean radioactivity concentration (fresh)[c], Bq kg^{-1}									
			Organic									
			^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I	^{131}I
Milk		9	<2.4	<2.8	19	<0.04	0.033	0.016	<0.32	<0.09	<0.0040	<0.0019
Milk	max		<2.6	<3.9	20	<0.05	0.049	0.018	<0.35	<0.10	<0.0046	<0.0022
Apple		1	<2.1	<2.1	21	<0.02	0.26	<0.051	<0.21	<0.06	<0.023	
Barley		1	<5.0	<5.0	25	<0.16	0.45		<1.4	<0.37	<0.025	
Beef kidney		1	<3.4	<3.4	27	<0.06	0.064	0.029	<0.25	<0.07	<0.021	
Beef liver		1	6.7	6.7	16	<0.03	0.035	<0.046	<0.24	<0.07	<0.022	
Beef muscle		1	16	16	28	<0.04	0.022	<0.046	<0.29	<0.08	<0.026	
Beetroot		1	<2.9	<2.9	20	<0.03	0.120		<0.24	<0.06	<0.019	
Cabbage		1	<3.8	<3.8	16	<0.06	0.15		<0.41	<0.13	<0.016	
Carrots		1	<3.2	<3.2	20	<0.03	0.058	<0.045	<0.26	<0.07	<0.017	
Duck		2	<3.6	<3.6	47	<0.06	<0.045		<0.40	<0.11	<0.023	
	max		<3.9	<3.9	61		<0.046		<0.42	<0.12		
Eggs		1	<2.7	<2.7	42	<0.04	0.034		<0.33	<0.08	<0.023	
Mushrooms		1	<4.1	<4.1	12	<0.11	<0.084		<1.0	<0.30		
Pheasant		1	<3.5	<3.5	33	<0.12	<0.051	<0.047	<0.44	<0.13	<0.027	
Potatoes		1	<1.9	<1.9	33	<0.06	0.044		<0.39	<0.10	<0.025	
Rabbit		1	<3.8	<3.8	35	<0.06	0.026	<0.047	<0.39	<0.12	<0.036	
Sheep muscle		2	<3.4	<3.4	37	<0.04	0.045	<0.049	<0.27	<0.08	<0.018	
Sheep muscle	max		<3.5	<3.5	39			<0.051	<0.28	<0.09	<0.020	
Sheep offal		2	<7.5	<7.5	32	<0.04	0.044	<0.053	<0.33	<0.10	<0.023	
Sheep offal	max		11	11	39	<0.05	0.052	0.053	<0.41	<0.12		
Grass	Braystones	1[E]		<11	21		<0.19		<11	<5.9		
Grass	River Calder (upstream)	1[E]		<13	14		2.3		<13	<7.2		
Grass	River Calder (downstream)	1[E]		<13	20		1.3		<8.7	<5.0		
Grass	WAMAC Access gate	1[E]		<12	20		1.7		<6.7	<4.2		
Soil		1	<2.3		<10	<0.08	3.7	<0.052	<0.72	<0.25	<0.14	
Soil	Braystones	1[E]		<9.5	12		<0.95		<2.6	<1.5		
Soil	River Calder (upstream)	1[E]		<12	7.6		<1.3		<3.9	<2.2		
Soil	WAMAC Access gate	1[E]		<7.8	9.5		<1.5		<4.8	<2.7		

Table 3.4 continued

Material	Location or selection[a]	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}									
			^{134}Cs	^{137}Cs	Total Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Pu	^{241}Am
Milk		9	<0.04	<0.09	<0.11				<0.000054	<0.000046	<0.29	<0.000025
Milk	max		<0.05	<0.12	0.14				<0.000066	<0.000049		<0.000030
Apple		1	<0.02	0.17	0.17				<0.00011	0.00019	<0.50	0.00024
Barley		1	<0.10	0.32	0.32				0.00020	0.0033	0.11	0.0025
Beef kidney		1	<0.05	0.07	0.074	0.0063	0.00033	0.0040	<0.00012	0.000087	<0.49	0.00024
Beef liver		1	<0.03	0.080	0.078				0.00044	0.0023	<1.2	0.0016
Beef muscle		1	<0.03	0.22	0.22				<0.00098	0.000021	<0.42	0.00014
Beetroot		1	<0.02	<0.05	<0.048	<0.00089	0.00028	<0.00052				<0.77
Cabbage		1	<0.08	<0.05	<0.048				0.000062	0.000099	<0.71	0.000095
Carrots		1	<0.03	0.090	0.087							<0.55
Duck		2	<0.04	0.35	0.36				<0.000056	<0.000084	<0.44	0.000098
	max			0.39	0.39				<0.000083	0.000086	<0.49	0.00016
Eggs		1	<0.04	<0.04	<0.036				0.00034	0.0019	<0.25	0.0014
Mushrooms		1	<0.08	0.25	0.25				0.010	0.068	0.90	0.11
Pheasant		1	<0.05	<0.05	<0.050				<0.000093	0.0000096	<0.55	0.000044
Potatoes		1	<0.05	<0.05	<0.048	0.010	0.00046	0.010	0.00011	0.0010	<0.48	0.00070
Rabbit		1	<0.04	0.10	0.10				<0.000074	0.000016	<0.44	0.000072
Sheep muscle		2	<0.03	0.30	0.30				<0.000059	0.00013	<0.38	0.00031
Sheep muscle	max			0.32	0.32				0.000089	0.00021		0.00046
Sheep offal		2	<0.03	0.08	0.084	0.0024	0.00030	<0.0011	0.00068	0.0050	<0.56	0.0043
Sheep offal	max		<0.04	0.10	0.10	0.0034	0.00036	0.0018	0.00090	0.0059	<0.71	0.0053
Grass	Braystones	1[E]		<1.4					<0.0099	<0.046	<1.6	<1.5
Grass	River Calder (upstream)	1[E]		<1.6					<0.0067	0.035	<1.1	<1.4
Grass	River Calder (downstream)	1[E]		<1.2					<0.0087	0.088	<1.4	<1.7
Grass	WAMAC Access gate	1[E]		1.8					<0.0094	<0.041	<1.6	<2.4
Soil		1	<0.07	18	18				0.028	0.9	<58	0.46
Soil	Braystones	1[E]		33					0.65	6.0	<12	6.6
Soil	River Calder (upstream)	1[E]		37					0.67	17	<14	5.5
Soil	WAMAC Access gate	1[E]		51					0.89	15	<13	8.0

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

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

c. Except for milk where units are Bq l^{-1}

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

Table 3.5 Beta/gamma radioactivity in fish from the Irish Sea vicinity and further afield, 2022

Location	Material	No. of sampling observa-tions	Mean radioactivity concentration (dry), Bq kg^{-1}								
			Organic ^{3}H	^{3}H	^{14}C	^{59}Fe	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc
Cumbria											
Parton	Cod[a]	2			30		<0.05	<0.033	<0.59	<0.32	<0.14
Whitehaven	Cod[a]	2			27		<0.06	<0.030	<0.49	<0.26	<0.14
Whitehaven	Plaice[a,b]	2	<25	26	44		<0.06	<0.046	<0.13	<0.11	1.4
Ravenglass	Plaice[a,c]	2	<25	<25	46		<0.07	<0.029	<0.34	<0.29	1.4
Lancashire and Merseyside											
Morecambe Bay (Morecambe)	Flounder	2	<25	<30	43		<0.06	<0.036	<0.22	<0.28	<0.16
Ribble Estuary	European Sea Bass	1					<0.05		<0.33	<0.22	
Ribble Estuary	Flounder	1					<0.07		<0.41	<0.59	
Liverpool Bay	Plaice	1		<25			<0.05		<0.07	<0.10	
Scotland											
The Minch	Herring	1[S]				<0.21	<0.10		<0.12	<0.11	
The Minch	Mackerel	1[S]				<0.24	<0.10		<0.13	<0.12	
Shetland	Fish meal (herring)	1[S]				<0.32	<0.10		<0.17	<0.22	
Shetland	Fish oil (herring)	1[S]				<0.28	<0.10		<0.17	<0.21	
Ardrossan South Bay	Mackerel	1[S]				<0.26	<0.10		<0.14	<0.13	
Ardrossan South Bay	Salmon	1[S]				<0.23	<0.10		<0.12	<0.12	
Annan	Salmon	1[S]		<5.0		<0.58	<0.10		<0.39	<0.24	
Inner Solway	Trout	1[S]		<5.0		<0.55	<0.10		<0.38	<0.23	
Kirkcudbright	Plaice	2[S]			<15	<0.21	<0.10		<0.12	<0.13	0.17
Wales											
North Anglesey	Plaice	1	<25	<25	33		<0.10		<0.23	<0.26	
Northern Ireland											
North coast	Lesser spotted dogfish	3[N]					<0.11		<1.5	<0.71	
Ardglass	Herring	2[N]					<0.07		<3.2	<0.91	
Kilkeel	Cod	3[N]			22		<0.04		<0.26	<1.9	
Kilkeel	Plaice	2[N]					<0.04		<0.14	<0.13	
Kilkeel	Skates / rays	2[N]					<0.10		<0.46	<0.35	
Kilkeel	Skates / dogfish	1[N]					<0.12		<3.4	<1.2	
Kilkeel	Haddock	3[N]					<0.06		<0.43	<0.26	
Further afield											
Norwegian Sea	Haddock	2					<0.06		<0.15	<0.15	

Table 3.5 continued

Location	Material	No. of sampling observa-tions	Mean radioactivity concentration (dry), Bq kg^{-1}					
			^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce	Gross beta
Cumbria								
Parton	Cod[a]	2	<0.46	<0.10	<0.05	1.9	<0.30	120
Whitehaven	Cod[a]	2	<0.53	<0.13	<0.07	1.6	<0.34	130
Whitehaven	Plaice[a,b]	2	<0.37	<0.10	<0.06	0.90	<0.24	63
Ravenglass	Plaice[a,c]	2	<0.50	<0.12	<0.07	0.89	<0.32	94
Lancashire and Merseyside								
Morecambe Bay (Morecambe)	Flounder	2	<0.51	<0.13	<0.05	3.9	<0.31	
Ribble Estuary	European Sea Bass	1	<0.44	<0.11	<0.06	2.2	<0.26	
Ribble Estuary	Flounder	1	<0.63	<0.15	<0.06	<1.7	<0.39	
Liverpool Bay	Plaice	1	<0.43	<0.12	<0.04	0.86	<0.29	
Scotland								
The Minch	Herring	1[S]	<0.29	<0.10	<0.10	0.10	<0.22	
The Minch	Mackerel	1[S]	<0.31	<0.10	<0.10	0.15	<0.21	
Shetland	Fish meal (herring)	1[S]	<0.84	<0.27	<0.10	0.20	<0.56	
Shetland	Fish oil (herring)	1[S]	<0.77	<0.23	<0.10	<0.10	<0.41	
Ardrossan South Bay	Mackerel	1[S]	<0.31	<0.10	<0.10	0.47	<0.21	
Ardrossan South Bay	Salmon	1[S]	<0.28	<0.10	<0.10	<0.10	<0.19	
Annan	Salmon	1[S]	<0.40	<0.11	<0.10	0.52	<0.29	
Inner Solway	Trout	1[S]	<0.39	<0.10	<0.10	0.12	<0.28	
Kirkcudbright	Plaice	2[S]	<0.45	<0.13	<0.10	<0.10	<0.27	
Wales								
North Anglesey	Plaice	1	<0.93	<0.23	<0.07	0.58	<0.77	
Northern Ireland								
North coast	Lesser spotted dogfish	3[N]	<1.1	<0.25	<0.09	0.98	<0.84	
Ardglass	Herring	2[N]	<0.85	<0.19	<0.09	0.19	<0.64	
Kilkeel	Cod	3[N]	<0.51	<0.10	<0.05	0.31	<0.35	
Kilkeel	Plaice	2[N]	<0.40	<0.10	<0.04	0.20	<0.28	
Kilkeel	Skates / rays	2[N]	<0.85	<0.19	<0.08	0.67	<0.45	
Kilkeel	Skates / dogfish	1[N]	<1.3	<0.29	<0.21	0.42	<0.86	
Kilkeel	Haddock	3[N]	<0.55	<0.13	<0.06	0.31	<0.35	
Further afield								
Norwegian Sea	Haddock	2	<0.48	<0.12	<0.07	0.10	<0.28	

a. Data for natural radionuclides for some of these samples may be available in Table 7.6
b. The concentrations of ^{129}I and ^{147}Pm were <0.98 Bq kg^{-1} and 0.020 Bq kg^{-1} respectively
c. The concentrations of ^{129}I and ^{147}Pm were <0.97 Bq kg^{-1} and 0.017 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 3.6 Beta/gamma radioactivity in shellfish from the Irish Sea vicinity and further afield, 2022

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1} Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb
Cumbria									
Parton	Crabs[a]	2			67	<0.06	<0.14	0.080	<0.22
Parton	Lobsters[a]	2			58	<0.08	<0.21	0.028	<0.40
Parton	Winkles[a]	2			39	0.15	<0.15	0.17	<0.19
Whitehaven	Nephrops[a, b]	2	<25	<25	34	<0.03	<0.10	0.080	<0.11
Whitehaven outer harbour	Mussels[a]	2			45	0.14	<0.14	0.48	<0.10
Nethertown	Winkles[a, c]	4	<25	<25	55	0.33	<0.16	0.99	<0.27
Sellafield coastal area	Crabs[a,d]	2	27	<25	67	<0.09	<0.15	0.11	<0.41
Sellafield coastal area	Lobsters[a]	2	28	<25	68	<0.07	<0.12	<0.037	<0.19
Ravenglass	Winkles[a]	2			40	0.16	<0.17	0.23	<0.11
Seascale Area	Common prawns[a]	2	<25	<25	44	<0.05	<0.14	0.028	<0.13
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Shrimps	2	<25	<25	39	<0.04	<0.10	0.19	<0.20
Morecambe Bay (Morecambe)	Mussels	2	<25	<25	44	<0.10	<0.13	0.10	<0.21
Morecambe Bay (Middleton Sands)	Cockles/Winkles	2	25	<25	34	<0.06	<0.17	0.072	<0.13
Ribble Estuary	Shrimps	1			18	<0.04	<0.11		<0.27
Ribble Estuary	Mussels	1				<0.09	<0.17		<0.13
Liverpool Bay	Mussels	1		<25		<0.12	<0.43		<0.17
Dee Estuary	Cockles	1		<25		<0.06	<0.17		<0.32

Location	Material	No. of sampling observations	^{95}Zr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	Gross beta
Cumbria										
Parton	Crabs[a]	2	<0.29	1.3	<0.55	<0.08	0.50	<0.36		89
Parton	Lobsters[a]	2	<0.28	29	<0.74	<0.09	0.72	<0.42		120
Parton	Winkles[a]	2	<0.15	15	<0.59	<0.06	1.1	<0.34		62
Whitehaven	Nephrops[a, b]	2	<0.10	7.1	<0.30	<0.03	0.91	<0.19	0.023	85
Whitehaven outer harbour	Mussels[a]	2	<0.12	13	<0.68	<0.05	1.4	<0.26		87
Nethertown	Winkles[a, c]	4	<0.22	7.5	<0.46	<0.04	2.4	<0.30	0.20	100
Sellafield coastal area	Crabs[a,d]	2	<0.26	3.3	<0.57	<0.07	0.51	<0.39	0.074	93
Sellafield coastal area	Lobsters[a]	2	<0.16	33	<0.48	<0.05	0.36	<0.32		140
Ravenglass	Winkles[a]	2	<0.14	11	<0.43	<0.06	1.4	<0.26		88
Seascale Area	Common prawns[a]	2	<0.12	<0.18	<0.45	<0.09	0.83	<0.47		61
Lancashire and Merseyside										
Morecambe Bay (Morecambe)	Shrimps	2	<0.17	0.33	<0.43	<0.05	1.5	<0.28		
Morecambe Bay (Morecambe)	Mussels[a]	2	<0.24	35	<0.51	<0.10	0.64	<0.33		62
Morecambe Bay (Middleton Sands)	Cockles[a]	2	<0.13	3.0	<0.38	<0.05	1.2	<0.23		60
Ribble Estuary	Shrimps	1	<0.18	<0.15	<0.44	<0.04	0.68	<0.32		
Ribble Estuary	Mussels	1	<0.18		<0.77	<0.08	0.43	<0.66		
Liverpool Bay	Mussels	1	<0.59		<1.1	<0.12	1.4	<0.69		
Dee Estuary	Cockles	1	<0.31	0.71	<0.48	<0.04	0.52	<0.24		

Table 3.6 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1} Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb
Scotland									
Kinlochbervie	Crabs	1[S]				<0.10	<0.24		<0.75
Lewis	Mussels	1[S]				<0.10	<0.25		<0.38
Skye	Lobsters	1[S]				<0.10	<0.20		<0.48
Skye	Mussels	1[S]				<0.10	<0.13		<0.41
Islay	Crabs	1[S]				<0.10	<0.27		<0.84
Islay	Scallops	1[S]				<0.10	<0.11		<0.27
Kirkcudbright	Crabs[a]	1[S]				<0.10	<0.10		<0.10
Kirkcudbright	Lobsters[a]	1[S]				<0.10	<0.13		<0.30
Kirkcudbright	Winkles	2[S]				<0.10	<0.23		<0.67
Kirkcudbright	Scallops	2[S]				<0.10	<0.12		<0.28
Kirkcudbright	Queens	2[S]				<0.10	<0.12		<0.22
Cutters Pool	Limpets[a]	1[S]				<0.10	<0.16		<0.67
Cutters Pool	Winkles	1[S]				<0.10	<0.14		<0.10
Southerness	Winkles	2[S]		<5.0		<0.10	<0.19		<0.65
North Solway coast	Mussels	2[S]		<5.0	19	<0.10	<0.23	0.19	<0.57
Inner Solway	Shrimps	2[S]		<5.0		<0.10	<0.11	<0.10	<0.27
Wales									
North Anglesey	Crabs	1	<25	<25	40	<0.08	<0.20		<0.15
North Anglesey	Lobster	1	<25	<25	39	<0.10	<0.35		<0.33

Location	Material	No. of sampling observations	^{95}Zr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	Gross beta
Scotland										
Kinlochbervie	Crabs	1[S]	<0.43	<0.27	<0.74	<0.10	<0.10	<0.41		
Lewis	Mussels	1[S]	<0.33		<0.87	<0.10	0.14	<0.46		
Skye	Lobsters	1[S]	<0.33	1.0	<0.69	<0.10	<0.10	<0.38		
Skye	Mussels	1[S]	<0.25		<0.45	<0.10	<0.10	<0.28		
Islay	Crabs	1[S]	<0.52		<0.88	<0.10	<0.10	<0.54		
Islay	Scallops	1[S]	<0.17		<0.31	<0.10	<0.10	<0.24		
Kirkcudbright	Crabs[a]	1[S]	<0.10	<0.27	<0.28	<0.10	<0.10	<0.19		
Kirkcudbright	Lobsters[a]	1[S]	<0.21	17	<0.42	<0.10	0.29	<0.21		
Kirkcudbright	Winkles	2[S]	<0.39		<0.79	<0.10	<0.24	<0.41		
Kirkcudbright	Scallops	2[S]	<0.18	<0.11	<0.32	<0.10	<0.10	<0.22		
Kirkcudbright	Queens	2[S]	<0.16	<0.22	<0.31	<0.10	<0.11	<0.21		
Cutters Pool	Limpets[a]	1[S]	<0.35		<0.55	<0.10	3.2	<0.33		
Cutters Pool	Winkles	1[S]	<0.14		<0.54	<0.10	2.4	<0.27		
Southerness	Winkles	2[S]	<0.38		<0.63	<0.10	1.6	<0.32		
North Solway coast	Mussels	2[S]	<0.40	21	<0.84	<0.11	0.82	<0.50		
Inner Solway	Shrimps	2[S]	<0.16	<0.096	<0.35	<0.10	<0.10	<0.21		
Wales										
North Anglesey	Crabs	1	<0.19		<0.69	<0.14	0.38	<0.40		
North Anglesey	Lobster	1	<0.30	18	<0.93	<0.19	0.31	<0.55		60

Table 3.6 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1} Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{65}Zn	^{90}Sr	^{95}Nb
Northern Ireland									
Ballycastle	Lobsters	1[N]				<0.08	<0.15		<0.34
County Down	Scallops	2[N]				<0.05	<0.12		<0.13
Kilkeel	Crabs	3[N]				<0.05	<0.15		<0.24
Kilkeel	Lobsters	3[N]				<0.07	<0.14		<0.17
Kilkeel	Nephrops	3[N]				<0.08	<0.22		<0.90
Minerstown	Limpets	2[N]				<0.06	<0.22		<0.24
Minerstown	Toothed winkles	1[N]				<0.09	<0.28		<0.13
Minerstown	Winkles	1[N]				<0.04	<0.11		<0.06
Carlingford Lough	Mussels	2[N]				<0.10	<0.50		<3.7
Further afield									
Cromer	Crabs	1				<0.07	<0.22		<0.24
Cromer	Lobsters	1				<0.06	<0.22		<0.24
Southern North Sea	Cockles	2				<0.03	<0.11		<0.12

Location	Material	No. of sampling observations	^{95}Zr	^{99}Tc	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Ce	^{147}Pm	Gross beta
Northern Ireland										
Ballycastle	Lobsters	1[N]	<0.22	6.3	<0.50	<0.05	0.13	<0.32		
County Down	Scallops	2[N]	<0.13		<0.42	<0.05	<0.05	<0.27		
Kilkeel	Crabs	3[N]	<0.20		<0.50	<0.06	<0.08	<0.34		
Kilkeel	Lobsters	3[N]	<0.14	7.4	<0.54	<0.06	0.12	<0.34		
Kilkeel	Nephrops	3[N]	<0.41	1.4	<0.65	<0.09	0.31	<0.42		
Minerstown	Limpets	2[N]	<0.15		<0.59	<0.08	0.14	<0.37		
Minerstown	Toothed winkles	1[N]	<0.16		<0.76	<0.09	0.16	<0.45		
Minerstown	Winkles	1[N]	<0.09		<0.36	<0.05	0.15	<0.22		
Carlingford Lough	Mussels	2[N]	<1.2	3.1	<1.1	<0.12	0.39	<0.74		
Further afield										
Cromer	Crabs	1	<0.22		<0.62	<0.07	<0.06	<0.35		
Cromer	Lobsters	1	<0.14		<0.49	<0.08	<0.05	<0.28		
Southern North Sea	Cockles	2	<0.16		<0.30	<0.04	0.08	<0.19		

[a] Data for natural radionuclides for some of these samples may be available in Table 7.6
[b] The concentration of ^{129}I was <1.0 Bq kg^{-1}
[c] The concentration of ^{129}I was <1.1 Bq kg^{-1}
[d] The concentration of ^{129}I was <1.0 Bq kg^{-1}
[N] Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency
[S] Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency

Table 3.7 Concentrations of transuranic radionuclides in fish and shellfish from the Irish Sea vicinity and further afield, 2022

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1} ^{237}Np	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm
Cumbria									
Parton	Cod	2		0.00037	0.0023	<0.31	0.0050	*	*
Parton	Crabs	2		0.017	0.11	<0.33	0.70	*	*
Parton	Lobsters	2		<0.021	<0.13	0.54	1.5	*	*
Parton	Winkles	2		0.48	2.6	10	5.2	*	*
Whitehaven	Cod	2		0.00036	0.0020	<0.25	0.0044	*	*
Whitehaven	Plaice	2	<0.000021	0.00063	0.0041	<0.31	0.0076	*	*
Whitehaven	'Nephrops'	2	0.00044	0.020	0.14	0.45	0.77	*	0.0013
Whitehaven outer harbour	Mussels	2		0.46	3.0	12	6.3	*	*
Nethertown	Winkles	4	0.012	0.87	4.9	20	9.3	*	*
Sellafield coastal area	Crabs	2	0.0010	0.038	0.22	0.92	0.95	*	*
Sellafield coastal area	Lobsters	2		0.015	0.071	<0.41	1.1	*	0.0050
Ravenglass	Plaice	2	<0.000022	0.00083	0.0048	<0.17	0.0090	*	*
Ravenglass	Winkles	2		0.40	2.5	9.1	5.0	*	*
Seascale	Prawns	2		0.0027	0.016	0.61	0.038	*	0.000037
Lancashire and Merseyside									
Morecambe Bay (Morecambe)	Flounder	2		0.00048	0.0031		0.0063	0.000048	0.000018
Morecambe Bay (Morecambe)	Shrimps	2		0.021	0.14		0.25	*	0.00041
Morecambe Bay (Morecambe)	Mussels	2		0.24	1.40	5.4	3.2	*	*
Morecambe Bay (Middleton Sands)	Cockles	2		0.22	1.4	4.7	4.2	*	*
Ribble Estuary	Flounder	1					<0.18		
Ribble Estuary	Sea Bass	1					<0.06		
Ribble Estuary	Shrimps	1	0.000047	0.0011	0.0078		0.014	*	*
Ribble Estuary	Mussels	1		0.12	0.72		1.3	*	*
Liverpool Bay	Flounder	1					<0.34		
Liverpool Bay	Mussels	1					2.8		
Dee Estuary	Cockles	1		0.043	0.29		0.61	*	*
Scotland									
The Minch	Herring	1[S]		0.0028	0.0086		0.012		
The Minch	Mackerel	1[S]		0.0020	0.0067		0.0047		
Shetland	Fish meal (herring)	1[S]		0.0087	0.0076		0.012		
Shetland	Fish oil (herring)	1[S]		0.0020	0.0039		0.014		
Kinlochbervie	Crabs	1[S]					<0.10		
Lewis	Mussels	1[S]					<0.11		
Skye	Lobsters	1[S]					<0.10		
Skye	Mussels	1[S]					<0.10		
Islay	Crabs	1[S]					<0.11		
Islay	Scallops	1[S]					<0.11		
Ardrossan South Bay	Mackerel	1[S]		0.0020	0.0039		0.036		
Ardrossan South Bay	Salmon	1[S]		0.0023	0.0088		0.0073		
Kirkcudbright	Plaice	1[S]		0.00056	0.0026		0.00075		
Kirkcudbright	Scallops	1[S]		0.0014	0.0030		0.0011		
Kirkcudbright	Queens	1[S]		0.0023	0.0078		0.0076		
Kirkcudbright	Crabs	1[S]					<0.10		

Table 3.7 continued

Location	Material	No. of sampling observations	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
Kirkcudbright	Lobsters	1[S]					0.40		
Kirkcudbright	Winkles	2[S]					0.62		
Cutters Pool	Limpets	1[S]					12		
Cutters Pool	Winkles	1[S]					7.4		
Southerness	Winkles	2[S]					5.4		
North Solway coast	Mussels	2[S]		0.24	1.7	5.6	3.1		
Annan	Shrimps	2[S]		0.0041	0.012		0.022		
Annan	Salmon	1[S]					<0.12		
Inner Solway	Trout	1[S]					<0.12		
Wales									
North Anglesey	Plaice	1					<0.34		
North Anglesey	Crabs	1					<0.22		
North Anglesey	Lobsters	1		0.0067	0.040	0.12	0.59	*	0.00062
Northern Ireland									
North coast	Lesser spotted dogfish	3[N]					<0.40		
Ballycastle	Lobsters	1[N]					0.32		
County Down	Scallops	2[N]					<0.14		
Ardglass	Herring	2[N]					<0.28		
Kilkeel	Cod	3[N]					<0.09		
Kilkeel	Plaice	2[N]					<0.17		
Kilkeel	Skates / rays	2[N]					<0.14		
Kilkeel	Skates / dogfish	1[N]					<0.39		
Kilkeel	Haddock	3[N]					<0.16		
Kilkeel	Crabs	3[N]					<0.15		
Kilkeel	Lobsters	3[N]					<0.24		
Kilkeel	'Nephrops'	1[N]		0.0014	0.0090		0.024	*	*
Minerstown	Limpets	2[N]					<0.22		
Minerstown	Toothed Winkles	1[N]					<0.47		
Minerstown	Winkles	1[N]		0.030	0.19		0.13	*	*
Carlingford Lough	Mussels	2[N]					<0.43		
Further afield									
Norwegian Sea	Haddock	2					<0.10		
Cromer	Crabs	1					<0.07		
Cromer	Lobsters	1					<0.06		
Southern North Sea	Cockles	1		0.0018	0.014		0.016	*	*

* Not detected by the method used
N Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency
S Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency

Table 3.8 Concentrations of radionuclides in sediment from the Cumbrian coast and further afield, 2022

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg⁻¹									
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Cumbria												
Newton Arlosh	Sediment	2		<1.1		<2.1	<1.3	<8.4	<4.3	<1.2	150	<3.7
Maryport Outer Harbour	Sediment	2		<0.53		<0.81	<0.57	<3.4	<1.8	<0.47	61	<1.8
Workington Harbour	Sediment	2		<0.47		<1.0	<0.57	<3.0	<1.7	<0.46	29	<2.1
Harrington Harbour	Sediment	2		<0.46		<0.76	<0.63	<2.9	<1.6	<0.44	39	<1.8
Whitehaven Outer Harbour	Sediment	4		<0.47	<1.2	<0.91	<0.51	<3.1	<1.7	<0.46	43	<1.8
St Bees beach	Sediment	4		<0.36		<0.66	<0.32	<2.4	<1.3	<0.34	46	<1.7
Ehen spit	Sediment	4		<0.42		<0.81	<0.51	<2.8	<1.6	<0.41	70	<2.2
Sellafield beach, S of former pipeline	Sediment	4		<0.48		<0.74	<0.39	<2.9	<1.6	<0.41	41	<1.5
River Calder - downstream	Sediment	4		<0.39		<0.67	<0.39	<2.5	<1.4	<0.41	56	<1.7
River Calder - upstream	Sediment	4		<0.67		<1.0	<0.67	<3.8	<2.0	<0.60	28	<2.3
Seascale beach	Sediment	4		<0.38		<0.62	<0.36	<2.3	<1.2	<0.34	19	<1.4
Ravenglass - Carleton Marsh	Sediment	4		<1.4	38	<1.8	<0.99	<7.0	<3.7	<0.98	200	<3.5
River Mite Estuary (erosional)	Sediment	4		<1.6	31	<2.2	<1.1	<8.8	<4.7	<1.1	210	<4.4
Ravenglass - Raven Villa	Sediment	4		<0.57		<1.0	<0.65	<3.8	<2.0	<0.51	110	<2.1
Newbiggin (Eskmeals)	Sediment	4		<1.2	31	<1.1	<0.76	<4.7	<2.6	<0.69	250	<3.1
Haverigg	Sediment	2		<0.60		<1.0	<0.62	<3.6	<1.9	<0.62	39	<1.8
Millom	Sediment	2		<0.54		<1.3	<0.86	<3.5	<1.9	<0.50	46	<2.3
Askam Pier	Sediment	2		<0.55		<1.0	<0.92	<3.4	<1.8	<0.57	48	<1.8
Low Shaw	Sediment	2		<0.64		<1.2	<0.61	<3.9	<2.0	<0.52	49	<1.8
Walney Channel - N of discharge point	Sediment	2		<0.53		<1.2	<0.63	<3.5	<1.8	<0.50	70	<2.0
Sand Gate Marsh	Sediment	1		<0.46		<1.3	<0.30	<3.1	<1.5	<0.42	35	<1.7
Kents Bank	Sediment	1		<0.60		<1.7	<0.43	<5.2	<2.6	<0.58	220	<2.5
Arnside	Sediment	1		<1.3		<2.9	<1.1	<11	<5.5	<1.4	220	<4.7
Lancashire												
Morecambe	Sediment	2		<0.30							9.5	
Half Moon Bay	Sediment	2		<0.67							92	
Red Nab Point	Sediment	2		<0.46							66	
Potts Corner	Sediment	2		<0.41							17	
Shore adjacent to Northern Outfall	Sediment	1		<0.45							37	
Sunderland Point	Sediment	1		<0.74		<1.3	<0.70	<4.7	<2.5	<0.67	63	<2.2
Conder Green	Sediment	1		<0.36		<0.60	<0.43	<2.6	<1.5	<0.38	81	<2.1
Hambleton	Sediment	1		<0.66		<1.1	<0.59	<4.4	<2.3	<0.61	130	<2.5
Skippool Creek	Sediment	1		<0.89		<1.5	<0.79	<6.1	<3.2	<0.77	170	<2.7
Fleetwood	Sediment	1		<0.34		<0.54	<0.24	<2.1	<1.1	<0.32	7.4	<1.6
Blackpool	Sediment	1		<0.21		<0.36	<0.19	<1.3	<0.69	<0.21	1.5	<0.97
Crossens Marsh	Sediment	1		<1.3		<2.2	<0.96	<8.9	<5.1	<1.3	190	<5.6
Ainsdale	Sediment	1		<0.34		<0.52	<0.22	<2.0	<1.1	<0.31	2.4	<1.1
Rock Ferry	Sediment	1		<0.41		<0.69	<0.37	<2.7	<1.5	<0.40	78	<2.1

Table 3.8 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{54}Mn	^{60}Co	^{90}Sr	^{95}Zr	^{95}Nb	^{106}Ru	^{125}Sb	^{134}Cs	^{137}Cs	^{144}Ce
Scotland												
Nigg Bay	Sediment	1[S]	<0.10	<0.10		<0.10	<0.10	<0.51	<0.17	<0.10	0.16	<0.56
Campbeltown	Sediment	1[S]	<0.10	<0.10		<0.15	<0.19	<0.47	<0.15	<0.10	4.5	<0.52
Garlieston	Sediment	1[S]	<0.10	<0.10		<0.10	<0.10	<0.20	<0.10	<0.10	12	<0.22
Innerwell	Sediment	2[S]	<0.10	<0.10		<0.20	<0.24	<0.53	<0.18	<0.10	28	<0.54
Carsluith	Sediment	1[S]	<0.10	<0.10		<0.16	<0.14	<0.65	<0.26	<0.10	55	<0.65
Skyreburn	Sediment	2[S]	<0.10	<0.10		<0.12	<0.13	<0.36	<0.11	<0.10	18	<0.36
Kirkcudbright	Sediment[a]	2[S]	<0.10	0.18		<0.24	<0.25	<0.70	<0.25	<0.11	58	<0.80
Balcary Bay	Sediment[a]	1[S]	<0.10	<0.10		<0.13	<0.10	<0.53	<0.19	<0.10	21	<0.59
Palnackie Harbour	Sediment	2[S]	<0.10	<0.18		<0.36	<0.71	<0.96	<0.34	<0.11	72	<1.0
Gardenburn	Sediment	2[S]	<0.10	<0.27		<0.23	<0.37	<0.71	<0.28	<0.10	140	<0.75
Kippford Slipway	Sediment	2[S]	<0.10	0.23		<0.27	<0.45	<0.87	<0.32	<0.11	77	<0.90
Kippford Merse	Sediment	1[S]	<0.10	0.14		<0.46	<1.2	<0.57	<0.19	<0.10	58	<0.65
Kirkconnell Merse	Sediment	1[S]	<0.10	<0.26		<0.30	<0.61	<1.1	<0.42	<0.12	170	<1.1
Southerness	Sediment	1[S]	<0.10	<0.10		<0.17	<0.20	<0.59	<0.20	<0.10	17	<0.62
Wales												
Rhyl	Sediment	1		<0.34		<0.56	<0.59	<2.3	<1.3	<0.36	25	<1.8
Llandudno	Sediment	1		<0.35		<0.51	<0.38	<1.9	<1.1	<0.31	1.5	<1.1
Caerhun	Sediment	1		<0.67		<1.1	<1.0	<4.1	<2.2	<0.87	19	<1.9
Northern Ireland												
Carrichue	Mud	1[N]	<0.30	<0.15		<1.6	<2.7	<1.7	<0.44	<0.12	1.5	<1.5
Carrichue	Sandy mud	1[N]	<0.26	<0.14		<1.3	<0.81	<1.5	<0.39	<0.16	2.5	<2.0
Portrush	Sand	2[N]	<0.18	<0.11		<1.3	<1.2	<1.3	<0.33	<0.16	0.39	<1.9
Oldmill Bay	Sandy mud	2[N]	<0.17	<0.15		<0.98	<3.1	<1.6	<0.39	<0.17	5.8	<1.4
Ballymacormick	Mud	1[N]	<0.28	<0.14		<1.5	<1.4	<1.6	<0.41	<0.27	12	<1.0
Ballymacormick	Sandy mud	1[N]	<0.18	<0.15		<1.9	<2.1	<1.7	<0.43	<0.26	7.8	<2.4
Strangford Lough - Nicky's Point	Mud	2[N]	<0.47	<0.24		<2.1	<3.6	<2.6	<0.62	<0.34	12	<2.6
Dundrum Bay	Mud	1[N]	<0.35	<0.20		<1.5	<1.1	<1.9	<0.48	<0.15	4.7	<2.4
Carlingford Lough	Mud	2[N]	<0.47	<0.25		<1.9	<1.7	<2.6	<0.67	<0.35	30	<2.9

Table 3.8 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Cumbria												
Newton Arlosh	Sediment	2	<3.1	<4.9				230			490	1200
Maryport Outer Harbour	Sediment	2	<1.5	<0.79				200			440	800
Workington Harbour	Sediment	2	<1.3	<0.86				47			250	1100
Harrington Harbour	Sediment	2	<1.3	<0.79				52			310	880
Whitehaven Outer Harbour	Sediment	4	<1.3	<0.77	8.1	50	160	70			230	610
St Bees beach	Sediment	4	<0.95	<0.73				130			170	500
Ehen spit	Sediment	4	<1.1	<1.0				70			250	1100
Sellafield beach, S of former pipeline	Sediment	4	<1.3	<0.67				92			170	640
River Calder - downstream	Sediment	4	<1.0	<0.82				73			200	890
River Calder - upstream	Sediment	4	<1.9	<1.6							300	1600
Seascale beach	Sediment	4	<1.0	<0.64				99			160	580
Ravenglass - Carleton Marsh	Sediment	4	<2.0	<1.6	63	380	1300	860			1200	1500
River Mite Estuary (erosional)	Sediment	4	<3.3	<2.0	65	420	1300	790			1000	1300
Ravenglass - Raven Villa	Sediment	4	<1.4	<0.94				510			680	1100
Newbiggin (Eskmeals)	Sediment	4	<1.9	<1.3	85	560	1700	1100			1400	1200
Haverigg	Sediment	2	<1.7	<0.76				180			270	780
Millom	Sediment	2	<1.4	<0.95				190			350	820
Askam Pier	Sediment	2	<1.5	<0.75				160			240	750
Low Shaw	Sediment	2	<1.8	<0.76				110			160	810
Walney Channel - N of discharge point	Sediment	2	<1.4	<0.92				210			280	900
Sand Gate Marsh	Sediment	1	<1.2	<0.70				48			170	690
Kents Bank	Sediment	1	<1.7	<0.98				110			270	980
Arnside	Sediment	1	<3.8	<2.1				150			770	1100
Lancashire												
Morecambe	Sediment	2						12				
Half Moon Bay	Sediment	2			11	68		200				
Red Nab Point	Sediment	2						99				
Potts Corner	Sediment	2						24				
Shore adjacent to Northern Outfall	Sediment	1						65				
Sunderland Point	Sediment	1	<2.1	<0.96				86			370	770
Conder Green	Sediment	1	<1.0	<0.97				130			360	1000
Hambleton	Sediment	1	<1.8	<1.2				190			420	1100
Skippool Creek	Sediment	1	<2.5	<1.2				210			550	1300
Fleetwood	Sediment	1	<0.81	<0.73				14			68	470
Blackpool	Sediment	1	<0.54	<0.50				3.9			<70	270
Crossens Marsh	Sediment	1	<3.4	<2.5				180			490	1200
Ainsdale	Sediment	1	<0.93	<0.50				2.4			<80	270
Rock Ferry	Sediment	1	<1.1	<1.1				72			490	1100

Table 3.8 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1}									
			^{154}Eu	^{155}Eu	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Scotland												
Nigg Bay	Sediment	1[S]	<0.16	<0.21				<0.32				
Campbeltown	Sediment	1[S]	<0.14	<0.25				1.0				
Garlieston	Sediment	1[S]	<0.10	0.37	2.1	15		18				
Innerwell	Sediment	2[S]	<0.12	<0.77	9.7	58		97				
Carsluith	Sediment	1[S]	<0.14	0.67	11	69		100			260	1100
Skyreburn	Sediment	2[S]	<0.11	0.91	3.2	21		24				
Kirkcudbright	Sediment[a]	2[S]	<0.14	2.4				<54				
Balcary Bay	Sediment[a]	1[S]	<0.18	0.54				75				
Palnackie Harbour	Sediment	2[S]	<0.21	<0.72	13	90		150				
Gardenburn	Sediment	2[S]	<0.45	1.2	26	160		280				
Kippford Slipway	Sediment	2[S]	<0.19	0.80	16	100		180				
Kippford Merse	Sediment	1[S]	<0.14	1.1	9.6	52		84			190	1600
Kirkconnell Merse	Sediment	1[S]	0.45	1.3	15	86		180				
Southerness	Sediment	1[S]	<0.16	0.99	2.6	17		28				
Wales												
Rhyl	Sediment	1	<0.94	<0.92				23			260	780
Llandudno	Sediment	1	<0.96	<0.51				1.9			<65	230
Caerhun	Sediment	1	<1.9	<0.78				14			220	700
Northern Ireland												
Carrichue	Mud	1[N]	<0.46	<1.4	0.059	0.36		0.66	*	*		
Carrichue	Sandy mud	1[N]	<0.46	<1.4				<2.1				
Portrush	Sand	2[N]	<0.35	<0.81				<1.4				
Oldmill Bay	Sandy mud	2[N]	<0.46	<0.71				6.1				
Ballymacormick	Mud	1[N]	<0.45	<0.57				14				
Ballymacormick	Sandy mud	1[N]	<0.46	<1.1				8.9				
Strangford Lough - Nicky's Point	Mud	2[N]	<0.75	<1.2				7.6				
Dundrum Bay	Mud	1[N]	<0.69	<1.1				2.7				
Carlingford Lough	Mud	2[N]	<0.84	<1.4	1.4	9.8		8.0	*	*		

* Not detected by the method used
[S] Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency
[N] Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency, all other measurements are made on behalf of the Environment Agency
[a] Data for natural radionuclides for some of these samples may be available in Table 7.6

Table 3.9 Gamma radiation dose rates over areas of the Cumbrian coast and further afield, 2022

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Cumbria, Rockcliffe-Harrington			
Rockcliffe Marsh	Salt marsh	2	0.071
Burgh Marsh	Grass and salt marsh	1	0.070
Burgh Marsh	Salt marsh	1	0.067
Port Carlisle 1	Mud and sand	2	0.075
Port Carlisle 2	Grass	1	0.078
Port Carlisle 2	Salt marsh	1	0.073
Newton Arlosh	Salt marsh	2	0.083
Silloth harbour	Sand and stones	2	0.088
Allonby	Pebbles and sand	1	0.093
Allonby	Sand	1	0.075
Maryport harbour	Mud and sand	1	0.078
Maryport harbour	Sand	1	0.077
Workington harbour	Pebbles and sand	1	0.093
Workington harbour	Shingle	1	0.093
Harrington harbour	Sand and stones	1	0.095
Harrington harbour	Shingle	1	0.095
Cumbria, Whitehaven-Drigg			
Whitehaven - outer harbour	Pebbles and sand	1	0.085
Whitehaven - outer harbour	Sand	3	0.087
St Bees	Sand	4	0.066
Nethertown beach	Shingle	4	0.11
Ehen spit	Pebbles and sand	1	0.10
Ehen spit	Sand and shingle	3	0.10
Braystones	Grass	1	0.084
Braystones beach	Shingle	4	0.10
WAMAC Access gate	Grass	1	0.090
Sellafield dunes	Grass	4	0.086
North of former pipeline on foreshore	Sand	3	0.081
North of former pipeline on foreshore	Sand and stones	1	0.088
South of former pipeline on foreshore	Pebbles and sand	1	0.082
South of former pipeline on foreshore	Sand	3	0.083
River Calder downstream of site	Grass	2	0.087
River Calder downstream of site	Grass and pebbles	1	0.086
River Calder downstream of site	Grass and sand	1	0.088
River Calder upstream of site	Grass	1	0.088
Seascale beach	Pebbles and sand	1	0.077
Seascale beach	Sand	3	0.072
Cumbria, Ravenglass-Askam			
Ravenglass - Carleton Marsh	Salt marsh	4	0.11
Ravenglass - River Mite estuary (erosional)	Salt marsh	4	0.11
Ravenglass - Raven Villa	Salt marsh	4	0.10
Ravenglass - boat area	Pebbles and sand	2	0.096
Ravenglass - boat area	Sand	1	0.095
Ravenglass - boat area	Sand and stones	1	0.093
Ravenglass - ford	Sand	4	0.087

Table 3.9 continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h⁻¹
Cumbria, Ravenglass-Askam			
Muncaster Bridge	Grass	2	0.094
Muncaster Bridge	Grass and salt marsh	1	0.094
Muncaster Bridge	Salt marsh	1	0.096
Ravenglass - salmon garth	Mud and sand	1	0.097
Ravenglass - salmon garth	Sand	2	0.099
Ravenglass - salmon garth	Sand and stones	1	0.097
Ravenglass - Eskmeals Nature Reserve	Salt marsh	4	0.095
Newbiggin/Eskmeals Bridge	Salt marsh	4	0.093
Newbiggin/Eskmeals viaduct	Salt marsh	4	0.095
Tarn Bay	Sand	4	0.067
Silecroft	Shingle	2	0.11
Haverigg	Mud and sand	1	0.078
Haverigg	Pebbles and sand	1	0.090
Millom	Mud and sand	2	0.083
Low Shaw	Salt marsh	2	0.073
Askam	Mud and sand	1	0.066
Askam	Sand	3	0.060
Askam Pier	Mud and sand	3	0.069
Askam Pier	Salt marsh	1	0.069
Cumbria, Walney-Arnside			
Walney Channel, N of discharge point	Mud and sand	4	0.076
Tummer Hill Marsh	Salt marsh	2	0.092
Roa Island	Mud and sand	2	0.088
Sand Gate Marsh	Salt marsh	2	0.076
Kents Bank 2	Salt marsh	2	0.076
Arnside 2	Salt marsh	2	0.077
Lancashire and Merseyside			
Morecambe Central beach	Sand	2	0.068
Half Moon Bay	Sand	1	0.078
Half Moon Bay	Mud and sand	1	0.075
Pipeline (Heysham)	Sand	1	0.071
Pipeline (Heysham)	Mud and sand	1	0.069
Red Nab Point	Sand	1	0.081
Red Nab Point	Sand and stones	1	0.074
Middleton Sands	Sand	2	0.071
Sunderland Point	Mud and sand	2	0.085
Colloway Marsh	Salt marsh	2	0.095
Lancaster	Grass	1	0.073
Lancaster	Salt marsh	1	0.068
Aldcliffe Marsh	Salt marsh	2	0.079
Conder Green	Salt marsh	2	0.074
Pilling Marsh	Salt marsh	2	0.082
Knott End	Mud and sand	1	0.072
Knott End	Sand	1	0.070
Height o' th' hill - River Wyre	Salt marsh	2	0.091
Hambleton	Salt marsh	2	0.079

Table 3.9 continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h⁻¹
Lancashire and Merseyside			
Skippool Creek	Salt marsh	2	0.089
Skippool Creek (mud)	Salt marsh	2	0.087
Fleetwood shore 1	Sand and pebbles	1	0.064
Fleetwood shore 1	Sand and stones	1	0.078
Fleetwood shore 2	Salt marsh	2	0.097
Blackpool	Sand	2	0.059
Crossens Marsh	Salt marsh	2	0.075
Ainsdale	Sand	2	0.056
Rock Ferry	Mud and sand	1	0.077
Rock Ferry	Sand	1	0.075
West Kirby	Sand	1	0.064
West Kirby	Tarmac	1	0.062
Scotland			
Piltanton Burn	Sediment	2[S]	0.059
Garlieston	Sediment	2[S]	0.075
Innerwell	Sediment	2[S]	0.073
Bladnoch	Sediment	2[S]	0.067
Carsluith	Sediment	2[S]	0.072
Skyreburn Bay (Water of Fleet)	Salt marsh	1[S]	0.073
Skyreburn Bay (Water of Fleet)	Sediment	1[S]	0.073
Kirkcudbright	Salt marsh	2[S]	0.064
Cutters Pool	Sediment	4[S]	0.079
Balcary Bay	Sediment	2[S]	0.089
Gardenburn	Sediment	2[S]	0.076
Palnackie Harbour	Sediment	2[S]	0.071
Kippford - Slipway	Sediment	2[S]	0.090
Kippford - Merse	Salt marsh	2[S]	0.087
Kirkconnell Marsh	Salt marsh	1[S]	0.071
Kirkconnell Marsh	Sediment	1[S]	0.066
Southerness	Sediment	2[S]	0.060
Wales			
Flint 1	Mud	1	0.078
Flint 2	Salt marsh	1	0.081
Rhyl	Salt marsh	2	0.072
Llandudno	Shingle	2	0.087
Caerhun	Salt marsh	2	0.073
Llanfairfechan	Sand and shells	2	0.066
Northern Ireland			
Lisahally	Mud	1[N]	0.056
Donnybrewer	Shingle	1[N]	0.052
Carrichue	Mud	1[N]	0.069
Bellerena	Mud	1[N]	0.056
Benone	Sand	1[N]	0.054

Table 3.9 continued

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Northern Ireland			
Castlerock	Sand	1[N]	0.055
Portstewart	Sand	1[N]	0.055
Portrush, Blue Pool	Sand	1[N]	0.055
Portrush, White Rocks	Sand	1[N]	0.055
Portballintrae	Sand	1[N]	0.055
Giant`s Causeway	Sand	1[N]	0.051
Ballycastle	Sand	1[N]	0.052
Cushendun	Sand	1[N]	0.055
Cushendall	Sand and stones	1[N]	0.057
Red Bay	Sand	1[N]	0.057
Carnlough	Sand	1[N]	0.055
Glenarm	Sand	1[N]	0.055
Half Way House	Sand	1[N]	0.056
Ballygally	Sand	1[N]	0.072
Drains Bay	Sand	1[N]	0.057
Larne	Sand	1[N]	0.057
Whitehead	Sand	1[N]	0.061
Carrickfergus	Sand	1[N]	0.057
Jordanstown	Sand	1[N]	0.057
Helen`s Bay	Sand	1[N]	0.058
Groomsport	Sand	1[N]	0.061
Millisle	Sand	1[N]	0.070
Ballywalter	Sand	1[N]	0.072
Ballyhalbert	Sand	1[N]	0.065
Cloghy	Sand	1[N]	0.061
Portaferry	Shingle and stones	1[N]	0.078
Kircubbin	Sand	1[N]	0.069
Greyabbey	Sand	1[N]	0.085
Ards Maltings	Mud	1[N]	0.072
Island Hill	Mud	1[N]	0.079
Nicky`s Point	Mud	1[N]	0.076
Strangford	Shingle & Stone	1[N]	0.097
Kilclief	Sand	1[N]	0.067
Ardglass	Mud	1[N]	0.076
Killough	Mud	1[N]	0.080
Ringmore Point	Sand	1[N]	0.071
Tyrella	Sand	1[N]	0.069
Dundrum	Sand	1[N]	0.097
Newcastle	Sand	1[N]	0.097
Annalong	Sand	1[N]	0.10
Cranfield Bay	Sand	1[N]	0.082
Mill Bay	Sand	1[N]	0.082
Greencastle	Sand	1[N]	0.082
Rostrevor	Sand	1[N]	0.10
Narrow Water	Mud	1[N]	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, all other measurements are made on behalf of the Environment Agency

Nuclear fuel production and reprocessing

Table 3.10 Beta radiation dose rates over intertidal areas of the Cumbrian coast, 2022

Location	Ground type	No. of sampling observations	Mean beta dose rate in tissue μSv h^{-1}
Whitehaven - outer harbour	Sand	3	0.16
Whitehaven - outer harbour	Sand and pebbles	1	0.20
St Bees	Sand	4	0.11
Sellafield beach, N of discharge point	Sand	3	0.14
Sellafield beach, N of discharge point	Sand and stones	1	0.13
Ravenglass - Raven Villa	Salt marsh	4	0.21
Tarn Bay	Sand	4	0.20

Table 3.11 Concentrations of radionuclides in aquatic plants from the Cumbrian coast and further afield, 2022

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Cumbria											
Silloth	Seaweed	2	<0.59			<0.83	<0.46	42	<3.6	<0.64	<2.1
Harrington Harbour	Seaweed	2	<0.67			<0.87	<0.48	54	<4.0	<0.66	<2.3
St Bees[a]	Seaweed	2	<1.1		<0.084	<1.4	<0.78	190	<6.3	<1.1	<3.4
Sellafield[b]	Seaweed	2	<0.68		<0.090	<0.84	<0.47	530	<4.0	<0.64	<2.4
Ravenglass	Samphire	1[F]	0.06	<0.09		<0.06	<0.05	0.38	<0.27	<0.03	<0.07
Ravenglass[c]	Seaweed	2	<0.57		<0.56	<0.80	<0.45	68	<4.0	<0.62	<2.3
Lancashire											
Half Moon Bay[d]	Seaweed	2	<0.98			<1.2	<0.63	130	<5.6	<0.96	<3.3
Marshside Sands	Samphire	1[F]	<0.02	<0.05		<0.06	<0.06	0.18	<0.20	<0.03	<0.05

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-}							
			^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Cumbria										
Silloth	Seaweed	2	<0.56	<0.53	2.8	<1.4				<0.75
Harrington Harbour	Seaweed	2	<0.56	<0.58	<0.84	<1.7				<0.95
St Bees[a]	Seaweed	2	<0.96	<0.95	<1.4	<2.4		0.83	4.5	3.2
Sellafield[b]	Seaweed	2	<1.9	<0.58	2.4	<2.1		0.73	4.1	5.7
Ravenglass	Samphire	1[F]		<0.03	0.85	<0.18	<0.09			5.6
Ravenglass[c]	Seaweed	2	<1.5	<0.59	3.7	<2.1		1.3	7.4	13
Lancashire										
Half Moon Bay[d]	Seaweed	2	<5.5	<0.83	2.9	<2.4				<1.6
Marshside Sands	Samphire	1[F]		<0.04	0.12	<0.14	<0.06			0.20

Table 3.11 continued

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Scotland											
Lerwick	Fucus vesiculosus	1[S]	<0.10	<0.12		<0.20	<0.38	4.0	<0.30	<0.10	<0.10
Kinlochbervie	Fucus vesiculosus	2[S]	<0.10	<0.22		<0.23	<0.23	8.7	0.64	<0.11	<0.20
Lewis	Fucus vesiculosus	1[S]	<0.10	<0.10		<0.10	<0.10	16	<0.18	<0.10	<0.10
Islay	Fucus vesiculosus	1[S]	<0.10	<0.15		<0.17	<0.20	27	<0.37	<0.10	<0.10
Campbeltown	Fucus vesiculosus	1[S]	<0.10	<0.10		<0.10	<0.10	16	<0.19	<0.10	<0.10
Nigg Bay Aberdeen	Fucus vesiculosus	1[S]	<0.10	<0.13		<0.13	<0.11	5.2	<0.41	<0.10	<0.12
Port William	Fucus vesiculosus	2[S]	<0.10	<0.10		<0.10	<0.10	27	<0.21	<0.10	<0.10
Garlieston	Fucus vesiculosus	2[S]	<0.10	<0.12		<0.11	<0.10	20	<0.31	<0.10	<0.12
Auchencairn	Fucus vesiculosus	3[S]	<0.10	<0.15		<0.14	<0.12	58	<0.42	<0.11	<0.14
Wales											
Cemaes Bay	Seaweed	2	<1.0			<1.3	<0.69	14	<5.8	<1.0	<3.3
Porthmadog	Seaweed	2	<0.69			<1.0	<0.56	0.74	<4.5	<0.72	<2.5
Lavernock Point	Seaweed	2	<0.72			<0.86	<0.49	0.25	<4.3	<0.68	<2.4
Fishguard	Seaweed	2	<0.40			<0.62	<0.36	2.6	<2.6	<0.47	<1.5

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-}							
			^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Scotland										
Lerwick	Fucus vesiculosus	1[S]		<0.10	<0.10	<0.25	<0.11			<0.12
Kinlochbervie	Fucus vesiculosus	2[S]		<0.10	0.12	<0.42	<0.18			<0.12
Lewis	Fucus vesiculosus	1[S]		<0.10	0.14	<0.15	<0.10			<0.10
Islay	Fucus vesiculosus	1[S]		<0.10	<0.10	<0.25	<0.11			<0.11
Campbeltown	Fucus vesiculosus	1[S]		<0.10	<0.13	<0.15	<0.10			<0.10
Nigg Bay Aberdeen	Fucus vesiculosus	1[S]		<0.10	<0.10	<0.25	<0.12			<0.10
Port William	Fucus vesiculosus	2[S]		<0.10	0.32	<0.13	<0.10			0.61
Garlieston	Fucus vesiculosus	2[S]		<0.10	1.5	<0.20	<0.13			3.7
Auchencairn	Fucus vesiculosus	3[S]		<0.10	1.2	<0.25	<0.13			1.8
Wales										
Cemaes Bay	Seaweed	2		<0.90	<0.72	<1.9				<0.69
Porthmadog	Seaweed	2		<0.67	<0.58	<1.6				<0.57
Lavernock Point	Seaweed	2		<0.62	<0.51	<2.1	<1.1			<1.0
Fishguard	Seaweed	2		<0.38	<0.33	<1.1				<0.33

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}								
			^{60}Co	^{65}Zn	^{90}Sr	^{95}Zr	^{95}Nb	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Northern Ireland											
Portrush	Fucus species	2[N]	<0.05	<0.21		<0.14	<0.28		<0.40	<0.07	<0.10
Portrush	Fucus serratus	2[N]	<0.04	<0.18		<0.13	<0.14		<0.39	<0.06	<0.10
Strangford Lough (Island Hill)[e]	Rhodymenia species	4[N]	<0.05	<0.20		<0.20	<0.25	0.15	<0.51	<0.08	<0.12
Ardglass	Fucus spiralis	2[N]	<0.04	<0.12		<0.20	<0.33	5.8	<0.33	<0.05	<0.08
Ardglass	Fucus vesiculosus	1[N]	<0.04	<0.41		<3.4	*		<0.68	<0.13	<0.12
Carlingford Lough	Fucus spiralis	2[N]	<0.06	<0.13		<0.72	<2.9		<0.38	<0.06	<0.08
Carlingford Lough	Fucus species	1[N]						9.2			
Isles of Scilly											
	Seaweed	1	<0.86			<1.2	<0.61	0.80	<5.4	<0.90	<3.1

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-}							
			^{129}I	^{134}Cs	^{137}Cs	^{144}Ce	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Northern Ireland										
Portrush	Fucus species	2[N]		<0.03	<0.04	<0.24	<0.11			<0.10
Portrush	Fucus serratus	2[N]		<0.03	<0.05	<0.25	<0.11			<0.17
Strangford Lough (Island Hill)[e]	Rhodymenia species	4[N]		<0.07	0.4	<0.35	<0.13	0.076	0.48	1.1
Ardglass	Fucus spiralis	2[N]		<0.03	0.20	<0.28	<0.09			<0.16
Ardglass	Fucus vesiculosus	1[N]		<0.05	0.67	<0.58	<0.15			0.34
Carlingford Lough	Fucus spiralis	2[N]		<0.04	0.16	<0.45	<0.16			<0.19
Carlingford Lough	Fucus species	1[N]								
Isles of Scilly										
	Seaweed	1		<0.81	<0.65	<2.4	<1.2			<0.78

[a] The concentrations of ^{14}C was <19 Bq kg^{-1}
[b] The concentrations of ^{14}C was 67 Bq kg^{-1}
[c] The concentrations of ^{14}C was 15 Bq kg^{-1}
[d] The concentrations of ^{35}S was <2.2 Bq kg^{-1}
[e] The concentrations of ^{242}Cm and $^{243+244}Cm$ were not detected by the method used
[F] Measurements labelled "F" are made on behalf of the Food Standards Agency
[N] Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency
[S] Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency, all other measurements are made on behalf of the Environment Agency

Table 3.12 Concentrations of radionuclides in terrestrial food and the environment near Ravenglass, 2022

Material and selection[a]		No. of sampling observations[b]	Mean radioactivity concentration (fresh)[c], Bq kg^{-1} Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Nb	^{95}Zr	^{99}Tc	^{106}Ru	^{125}Sb	^{129}I
Milk		3		<3.0	19	<0.04	0.031	<0.05	<0.08	<0.012	<0.33	<0.09	<0.0038
Milk	max						0.044	<0.06		<0.014	<0.34		<0.0043
Beef kidney		1		<7.1	37	<0.02	0.047	<0.14	<0.16	<0.045	<0.24	<0.06	<0.029
Beef liver		1		<2.7	30	<0.06	0.043	<0.40	<0.36	<0.049	<0.43	<0.13	<0.038
Beef muscle		1		<3.8	57	<0.05	0.041	<0.13	<0.12	<0.047	<0.36	<0.09	<0.024
Mixed fruit		1	<2.9	<2.9	20	<0.02	0.081	<0.03	<0.04		<0.21	<0.06	<0.025
Sheep muscle		2		<5.7	28	<0.06	0.036	<0.27	<0.19	<0.048	<0.44	<0.12	<0.023
Sheep muscle	max			8.5	30		0.044	<0.38	<0.23	<0.050	<0.49	<0.13	<0.024
Sheep offal		2		<8.3	43	<0.04	0.046	<0.21	<0.16	<0.046	<0.37	<0.09	<0.022
Sheep offal	max			<9.6	46		0.062	<0.29	<0.20	<0.047	<0.39		<0.024

Material and selection[a]		No. of sampling observations[b]	Mean radioactivity concentration (fresh)[c], Bq kg^{-1} ^{134}Cs	^{137}Cs	Total Cs	^{144}Ce	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu + ^{240}Pu	^{241}Pu	^{241}Am
Milk		3	<0.04	<0.05		<0.29				<0.000053	<0.000036	<0.29	<0.000031
Milk	max			<0.07									
Beef kidney		1	<0.02	0.13	0.13	<0.45	0.0020	<0.00040	0.0016	0.000025	0.00021	<0.49	0.0007
Beef liver		1	<0.06	<0.08	<0.077	<0.36				0.00018	0.0014	<0.58	0.0024
Beef muscle		1	<0.04	0.47	0.48	<0.54				0.000028	0.00012	<0.53	0.000077
Mixed fruit		1	<0.02	0.12	0.13	<0.19				<0.00014	0.00011	<0.48	0.00086
Sheep muscle		2	<0.03	0.81	0.81	<0.33				0.000043	0.00014	<0.48	0.00027
Sheep muscle	max		<0.04	1.2	1.2	<0.37				0.000078	0.00021	<0.50	0.00030
Sheep offal		2	<0.04	0.29	0.29	<0.33				0.00056	0.0036	<0.57	0.0063
Sheep offal	max			0.34	0.35	<0.38				0.0010	0.0065	<0.59	0.012

[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] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime
[c] Except for milk where units are Bq l^{-1}

Nuclear fuel production and reprocessing

Table 3.13 Concentrations of radionuclides in surface waters from West Cumbria, 2022

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1} ^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	Gross alpha	Gross beta
Ehen Spit beach	3	<40	<0.24	<0.059	<0.29	<0.27	<0.23	<0.0016	<0.0030	<4.0	9.6
River Ehen (100m down-stream of sewer outfall)	4	<4.2	<0.30	<0.023		<0.34	<0.26	<0.0013	<0.0012	<0.23	0.61
River Calder (downstream)	4	<3.7	<0.33	<0.074	<0.024	<0.34	<0.28	<0.0012	<0.0012	<0.027	0.23
River Calder (upstream)	4	<3.6	<0.30	<0.023	<0.024	<0.33	<0.27	<0.0013	<0.0012	<0.018	0.028
River Ehen (upstream of site and tidal confluence)	4	<3.7	<0.25	<0.022		<0.29	<0.23	<0.0013	<0.0012	<0.024	0.050
Wast Water	1	<3.7	<0.33				<0.28			<0.033	0.016
Ennerdale Water	1	<3.7	<0.06			<0.07	<0.06			<0.024	0.019
Sellafield Tarn	1	<4.0		<0.026	<0.026		<0.32	<0.0026	<0.0023		
Devoke Water	1	<3.6	<0.06			<0.07	<0.06			<0.041	0.022
Thirlmere	1	<3.7	<0.25				<0.24			<0.031	0.020

Table 3.14 Concentrations of radionuclides in road drain sediments from Whitehaven and Seascale, 2022

Location	No. of sampling observations	Mean radioactivity concentration (dry), Bq kg^{-1} ^{60}Co	^{90}Sr	^{134}Cs	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Seascale SS 204	1	<0.85	<0.76	<0.82	60	1.3	9.1	10
Seascale SS 233	1	<1.2	<0.91	<1.2	34	1.6	9.7	12
Seascale SS 209	1	<0.29	<1.2	<0.30	9.6	1.1	6.4	7.7
Seascale SS 232	1	<0.57	<1.2	<0.54	14	1.3	9.4	11
Seascale SS 231	1	<1.3	<0.93	<1.4	17	2.6	17	23
Whitehaven SS 201	1	<2.0	<0.91	<1.9	16	0.83	6.0	13

Table 3.15 Doses from artificial radionuclides in the Irish Sea, 2009 to 2022

Group	Exposure, mSv per year 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northern Ireland	0.012	0.010	0.010	0.011	0.010	0.009	0.009	0.011	0.010	0.011	0.010	0.009	0.008	0.007
Dumfries and Galloway	0.047	0.040	0.040	0.046	0.044	0.045	0.038	0.044	0.035	0.029	0.031	0.027	0.056	0.024
Whitehaven	0.011	0.010	0.010	0.013	0.010	0.012	0.017	0.016	0.017	0.018	0.014	0.013	0.012	0.010
Sellafield (5 year average consumption)	0.20	0.18	0.15	0.14	0.12	0.089	0.084	0.083	0.085	0.072	0.064	0.062	0.058	0.045
Morecambe Bay	0.041	0.046	0.034	0.034	0.036	0.032	0.031	0.024	0.026	0.015	0.024	0.015	0.019	0.022
North Wales	0.015	0.013	0.014	0.014	0.013	0.018	0.014	0.015	0.014	0.014	0.012	0.010	0.010	0.018

Table 3.16 Individual radiation exposures, Sellafield, 2022

Representative person[a]	Exposure, mSv per year							
	Total	Seafood (nuclear industry discharges)[b]	Seafood (other discharges)[c]	Other local food	External radiation from intertidal areas, river banks or fishing gear[d]	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
'Total dose' - maximum effect of all sources								
Adult crustacean consumers	**0.24[e]**	**0.011**	**0.22**	**<0.005**	**<0.005**	**-**	**<0.005**	**<0.005**
'Total dose' - maximum effect of gaseous release and direct radiation sources								
Adult root vegetable consumer	**<0.011**	**<0.005**	**<0.005**	**<0.006**	**<0.005**	**-**	**<0.005**	**<0.005**
'Total dose' - maximum effect of liquid release source								
Adult crustacean consumers	**0.24[e]**	**0.011**	**0.22**	**<0.005**	**<0.005**	**-**	**<0.005**	**<0.005**
Source specific doses Seafood consumers								
Local seafood consumers (habits averaged 2018-22)	0.37[f]	0.030	0.33	-	0.015	-	-	-
Local seafood consumers (habits for 2022)	0.24[g]	0.012	0.21	-	0.015	-	-	-
Local mollusc consumers (habits for 2022)	0.014[l]	0.005	0.009	-	-	-	-	-
Whitehaven seafood consumers	0.010	0.010	-	-	-	-	-	-
Dumfries and Galloway seafood and wildfowl consumers	0.024	0.013	-	-	0.011	-	-	-
Morecambe Bay seafood consumers	0.022	0.007	-	-	0.015	-	-	-
Northern Ireland seafood consumers	0.008	0.007	-	-	<0.005	-	-	-
North Wales seafood consumers	0.018	0.016	-	-	<0.005	-	-	-
Other groups								
Ravenglass Estuary, marsh users	0.014	-	-	-	0.011	<0.005	-	-
Bait diggers and shellfish collectors[h]	0.082	-	-	-	0.082	-	-	-
Barrow Houseboats[k]	0.029	-	-	-	0.029	-	-	-
Local infant consumers of locally grown food at Ravenglass	0.012[i]	-	-	0.012	-	-	-	-
Local infant consumers of locally grown food at LLWR near Drigg	0.006[i]	-	-	0.006	-	-	-	-
Infant inhabitants and consumers of locally grown food	0.012[i]	-	-	0.012	-	-	<0.005	-

Table 3.16 continued

Representative person[a]	Exposure, mSv per year							
	Total	Seafood (nuclear industry discharges)[b]	Seafood (other discharges)[c]	Other local food	External radiation from intertidal areas, river banks or fishing gear[d]	Intakes of sediment and water	Gaseous plume related pathways	Direct radiation from site
Groups with average consumption or exposure								
Average seafood consumer in Cumbria	<0.005	<0.005	-	-	-	-	-	-
Average consumer of locally grown food[j]	<0.005	-	-	<0.005	-	-	-	-
Typical visitor to Cumbria	<0.005	<0.005	<0.005	-	<0.005	-	-	-
Recreational user of beaches								
Dumfries and Galloway	0.005	-	-	-	0.005	-	-	-
North Cumbria	0.009	-	-	-	0.009	-	-	-
Sellafield	0.009	-	-	-	0.009	-	-	-
Lancashire	0.005	-	-	-	0.005	-	-	-
North Wales	<0.005	-	-	-	<0.005	-	-	-
Recreational user of mud/saltmarsh areas								
Dumfries and Galloway	<0.005	-	-	-	<0.005	-	-	-
North Cumbria	<0.005	-	-	-	<0.005	-	-	-
Sellafield	0.008	-	-	-	0.008	-	-	-
Lancashire	<0.005	-	-	-	<0.005	-	-	-
North Wales	<0.005	-	-	-	<0.005	-	-	-

a. The 'total dose' is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.
The 'total dose' for the representative person with the highest dose is presented.
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the total dose assessment.
The representative person is an adult unless otherwise stated
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv
b. May include a small contribution from LLWR near Drigg
c. Enhanced naturally occuring radionuclides from Whitehaven
d. Doses ('total dose' and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)
e. The dose due to nuclear industry discharges was 0.014 mSv
f. The dose due to nuclear industry discharges was 0.045 mSv
g. The dose due to nuclear industry discharges was 0.027 mSv
h. Exposure to skin for comparison with the 50 mSv dose limit
i. Includes a component due to natural sources of radionuclides
j. Only the adult age group is considered for this assessment
k. Exposures at Barrow are largely due to discharges from the Sellafield site
l. The dose due to nuclear industry discharges was 0.005 mSv

4 Nuclear power stations

Highlights

- 'total doses' for the representative person were less than 2% of the dose limit for all sites assessed

Operating sites

Hartlepool, County Durham

- 'total dose' for the representative person was 0.011mSv and decreased in 2022
- gaseous discharges of carbon-14 decreased in 2022
- liquid discharges of tritium increased in 2022

Heysham, Lancashire

- 'total dose' for the representative person was 0.016mSv and increased in 2022
- gaseous discharges of argon-41 from Heysham 2 increased in 2022

Hinkley Point, Somerset

- 'total dose' for the representative person was 0.015mSv and decreased in 2022

Hunterston, North Ayrshire

- 'total dose' for the representative person was less than 0.005mSv and decreased in 2022
- gaseous discharges of carbon-14 and sulphur-35 from Hunterston B decreased in 2022
- liquid discharges of tritium and sulphur-35 from Hunterston B decreased in 2022

Sizewell, Suffolk

- 'total dose' for the representative person was less than 0.005mSv and decreased in 2022
- gaseous discharges of tritium and carbon-14 from Sizewell B increased in 2022

Torness, East Lothian

- 'total dose' for the representative person was 0.006mSv and increased in 2022

Decommissioning sites

Berkeley, Gloucestershire and Oldbury, South Gloucestershire

- 'total dose' for the representative person was 0.006mSv and decreased in 2022

Bradwell, Essex

- 'total dose' for the representative person was less than 0.005mSv and decreased in 2022

Chapelcross, Dumfries and Galloway

- 'total dose' for the representative person was 0.008mSv and decreased in 2022

Dungeness, Kent

- 'total dose' for the representative person was 0.011mSv and decreased in 2022

Trawsfynydd, Gwynedd

- 'total dose' for the representative person was 0.009mSv and decreased in 2022

Wylfa, Isle of Anglesey

- 'total dose' for the representative person was 0.014mSv and increased in 202

This section considers the results of environment and food monitoring, under the responsibility of the Environment Agency, FSA, FSS, NRW and SEPA, undertaken near nuclear power stations (both operating stations and decommissioning sites). There are a total of 19 nuclear power stations (which may contain more than 1 reactor and reactor type) at 14 locations in the UK as listed below:

- England
  - Berkeley, Oldbury, Bradwell, Calder Hall, Dungeness, Hartlepool, Heysham, Hinkley Point and Sizewell
- Scotland
  - Chapelcross, Hunterston and Torness
- Wales
  - Trawsfynydd and Wylfa

Eleven of the 19 nuclear power stations are older, first generation, Magnox power stations, owned by the NDA. The NDA was set up under the Energy Act 2004 and is a non-departmental public body (sponsored and funded by DESNZ). Its remit is to secure the decommissioning and clean-up of the UK's civil public sector nuclear licensed sites. All Magnox stations are now in the process of decommissioning.

All of the first-generation nuclear reactors are now fuel free. In April 2023, the NDA published its annual business plan (2023 to 2026) and a new strategy. The plan summarises the programme of work at each of the sites [71].

In 2013, Magnox Limited managed 10 nuclear sites and was owned and operated by Energy Solutions on behalf of the NDA. In 2014, the NDA formally appointed Cavendish Fluor Partnership (a joint venture between Cavendish Nuclear and Fluor Corporation) as the PBO for Magnox Limited and Research Sites Restoration Limited (RSRL). Thereafter, the 10 Magnox sites were re-licensed into a single site licensed company alongside the Harwell and Winfrith sites. In 2015, Harwell and Winfrith sites, previously operated by RSRL, merged to be part of Magnox Limited. In September 2019, Magnox Limited became a wholly owned subsidiary of the NDA, replacing the previous PBO management model of ownership by the private sector. In April 2023, Dounreay joined with Magnox Limited (see more information in Section 5). Calder Hall is being decommissioned, it is operated by Sellafield Limited and discharges from this Magnox power station are considered in Section 3 as it is located at Sellafield.

Seven AGR power stations and one PWR power station are owned and operated by EDF Energy Nuclear Generation Limited in 2022 these are: Dungeness B, Hartlepool, Heysham 1 and 2, Hinkley Point B, Sizewell B Power Stations in England, and Hunterston B and Torness Power Stations in Scotland. In June 2021, EDF decided to move Dungeness B into defueling phase following an extended outage since September 2018. In June 2021, the UK government and EDF signed an agreement to transfer control of the AGR power stations to the NDA after cessation of generation and defueling of the reactors. Hunterston B and Hinkley Point B stopped generating electricity in January and August 2022, respectively. The decommissioning process of these two plants will be carried out by Magnox Limited after used fuel has been fully removed by EDF.

Gaseous and liquid discharges from each of the power stations are regulated by the Environment Agency and NRW in England and Wales, respectively and by SEPA in Scotland. In 2022, gaseous and liquid discharges were below regulated limits for each of the power stations (see Appendix 1, Table A1.1 and Table A1.2). Solid waste transfers in 2022 from nuclear establishments in Scotland (Chapelcross, Hunterston A, Hunterston B and Torness) are also given in Appendix 1 (Table A1.4). Independent monitoring of the environment around each of the power stations is conducted by the FSA and the Environment Agency in England and Wales, and by SEPA in Scotland. In Wales, this is conducted on behalf of NRW and the Welsh Government.

In this section, sites are grouped according to their status of power generation (operating and decommissioning power stations). Nuclear sites that have both operating (in 2022) and decommissioning power plants (Hinkley Point, Hunterston and Sizewell) are considered under operating sites because, for the purposes of environmental monitoring, the effects of both sites contribute to the same area. Therefore, Hartlepool, Heysham (1 and 2), Hinkley Point (A and B), Hunterston (A and B), Sizewell (A and B) and Torness are included under operating power stations (Section 4.1). Berkeley, Bradwell, Chapelcross, Dungeness (A and B), Oldbury, Trawsfynydd and Wylfa are included under decommissioning power stations (Section 4.2).

4.1 Operating sites

4.1.1 Hartlepool, County Durham

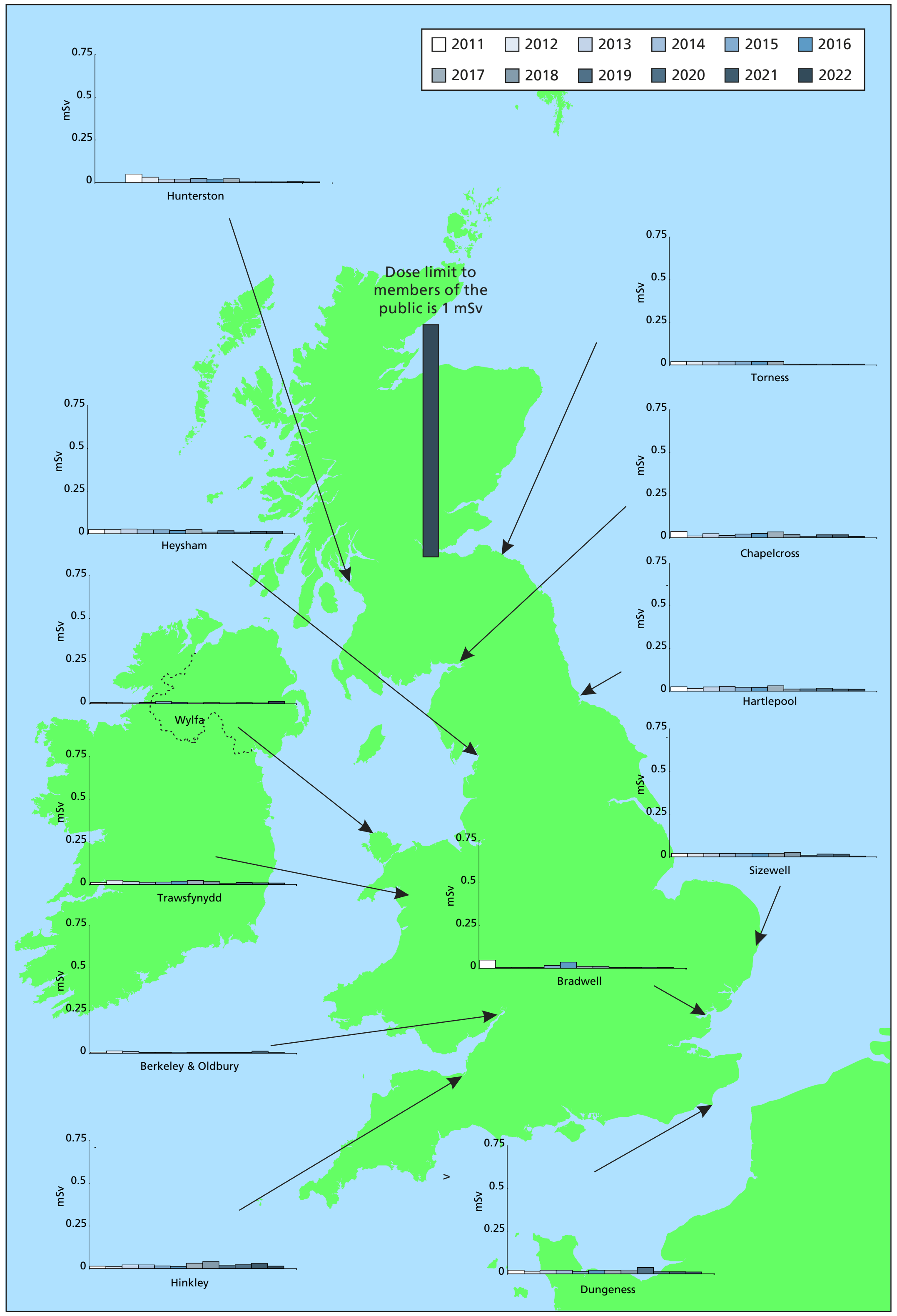
Hartlepool Power Station is situated on the mouth of the Tees Estuary, on the north-east coast of England. This station, which is powered by twin AGRs, began operation in 1983. In March 2023, EDF decided to extend the generating life of the Hartlepool power station by 24 months until March 2026, depending on results from routine inspections of the reactor. The most recent habits survey was undertaken in 2014 [173].

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.011mSv in 2022 (Table 4.1), which was approximately 1% of the dose limit, and down from 0.012mSv in 2021. The small decrease in 'total dose' was mainly attributed to lower direct radiation from the site in 2022, in comparison to that in 2021. The representative person was adults spending time over sand and sea coal and a change from 2021 (adults living near the site). The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. 'Total doses' remained broadly similar, from year to year, and were low.

A source specific assessment for high-rate consumers of locally grown foodstuffs gave an exposure that was less than the 'total dose' in 2022 (Table 4.1). The estimated dose was less than 0.005mSv and down from 0.005mSv in 2021. The small decrease in dose was mostly due to a lower carbon-14 concentration in the potato sample collected in 2022. The dose to a local fish and shellfish consumer (including external radiation but excluding naturally occurring radionuclides) was 0.013mSv in 2022, and up from 0.010mSv in 2021. The reason for the increase in dose was mostly due to higher gamma dose rates measured over sand and sea coal at Carr House in 2022.

Figure 4.1 'Total dose' at nuclear power stations, 2011 to 2022. (Small doses less than or equal to 0.005 mSv are recorded as being 0.005 mSv)



As in recent years, a source specific assessment was not undertaken to determine the exposure from naturally occurring radionuclides in 2022, as a consequence of reported polonium-210 concentrations in mollusc samples. Prior to 2019, winkle samples collected from South Gare (inside the Tees Estuary entrance) also included some winkles taken from the estuary entrance near Paddy's Hole. The area in close proximity to Paddy's Hole is polluted with oil and other wastes and therefore a potential reason for enhanced naturally occurring radionuclides in molluscs. As in recent years, due to limited availability, a winkle sample was not collected from Paddy's Hole in 2022. This estimate assumes that the median concentrations for naturally occurring radionuclides at background (Appendix 6, Table A6.1) be subtracted from the total concentrations as measured in 2022.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. Gaseous discharges of carbon-14 decreased in 2022, in comparison to those in 2021. This decrease is mainly due to the completion of the valve seat replacement programme undertaken on the Secondary Shutdown System (SSD). The programme has reduced the leakage of nitrogen into the reactor gas circuit which was being converted into carbon-14. Analyses of tritium, carbon-14, sulphur-35 and gamma-emitting radionuclides were carried out in milk and crop samples. Samples of freshwater were also taken from boreholes. Data for 2022 are given in Table 4.2(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs, although a small enhancement of carbon-14 concentrations was measured in food (barley and potato) in 2022. As in 2021, carbon-14 was also detected in locally produced milk at concentrations slightly above the default value used to represent background, but at slightly lower concentration. Tritium, and gross beta concentrations in freshwater were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Liquid waste discharges and aquatic monitoring

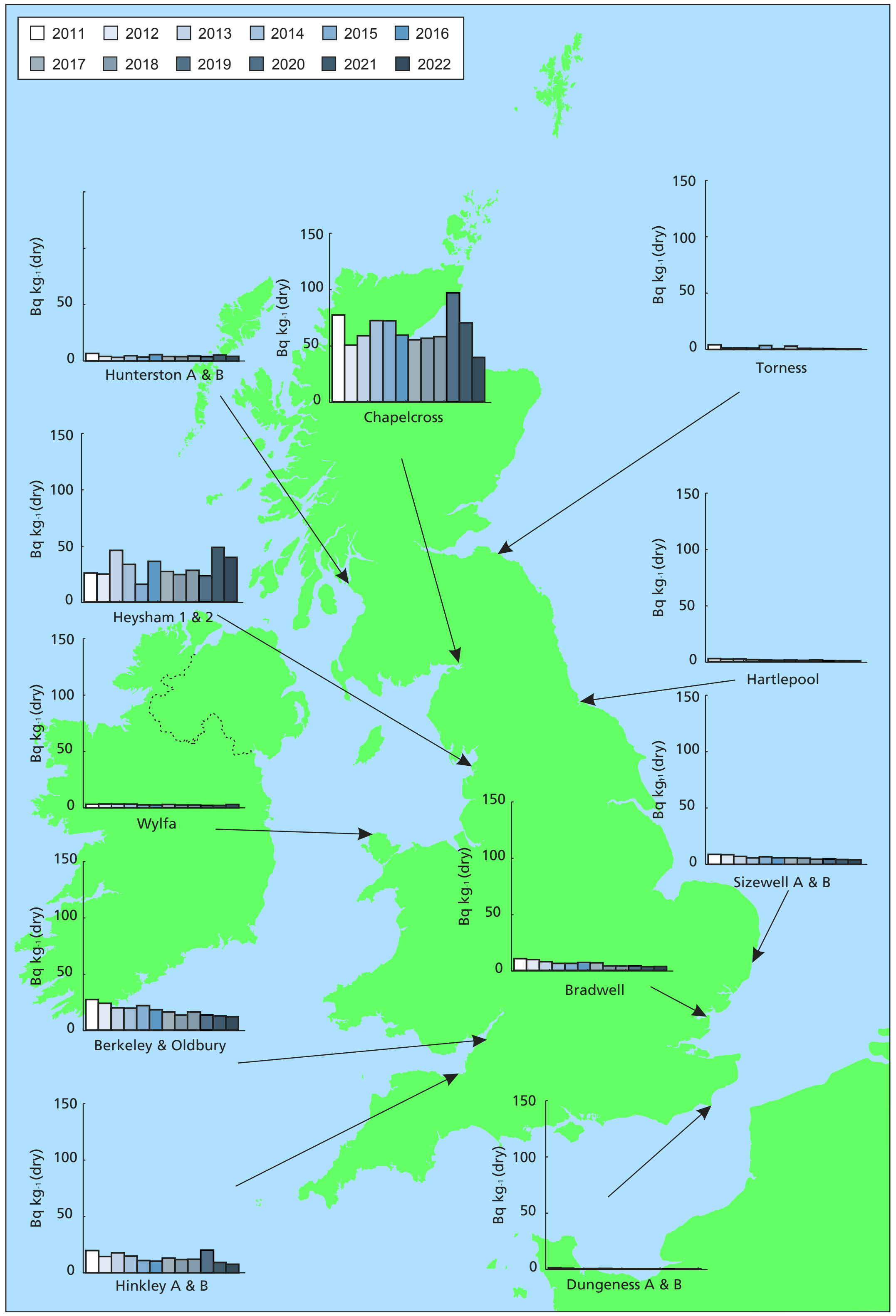
Regulated discharges of radioactive liquid effluent are made to Hartlepool Bay with a minor component being discharged directly to the River Tees. Aqueous discharges of tritium increased in 2022, in comparison to those in 2021. This is mainly due to the return of the two reactors to full operation following an extended double reactor outage towards the end of 2021, which reduced that year's liquid discharges of tritium.

Results of the aquatic monitoring programme conducted in 2022 are shown in Table 4.2(a) and Table 4.2(b). Unlike in previous years, the carbon-14 concentration measured in the mollusc samples (winkles) were not above the expected background (Table A6.1). Carbon-14 concentrations in fish and crustaceans were generally similar in 2022, in comparison to those in recent years.

The analysis of technetium-99 in seaweed is used as a specific indication of the far-field effects of disposals to sea from Sellafield. As in recent years, technetium-99 in seaweed was low and much less than the peak concentration observed in 2008 (see Figure 2.11, [68]). Technetium-99 concentrations in seaweed are less than 1% of the equivalent concentrations near Sellafield. As in recent years, apart from 2020, iodine-131 was positively detected in seaweed samples collected around the mouth of the River Tees Estuary in 2022.

The detected values, as in previous years, are believed to originate from the therapeutic use of this radionuclide in a local hospital. Detectable concentrations of caesium-137 were mainly due to disposals from Sellafield and fallout from nuclear weapons testing. However, caesium-137 concentrations in sediment have remained low for several years (Figure 4.2). Overall, gamma dose rates over intertidal sediment in 2022 were higher (where comparisons can be made from similar ground types and locations), to those observed in 2021.

Figure 4.2 Caesium-137 concentration in marine sediments near nuclear power stations between 2011 to 2022



In 2022, the reported polonium-210 and lead-210 concentrations in winkles from South Gare are values expected due to naturally occurring sources (given in Appendix 6, Table A6.1). As in recent years, a winkle sample could not be collected from the estuary entrance near Paddy's Hole in 2022.

4.1.2 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 of 2 separate nuclear power stations, Heysham 1 and Heysham 2, each powered by twin AGRs. Heysham 1 commenced operation in 1983 and Heysham 2 began operating in 1988. It is estimated that Heysham 1 and 2 will continue to generate electricity until 2024 and 2028, respectively. Disposals of radioactive waste from both stations are permitted via separate and adjacent outfalls to Morecambe Bay and via stacks. However, in RIFE, both stations are considered together for purposes of environmental monitoring, because the discharge effects from both sites impact on the same area.

The most recent habits survey was conducted in 2016 [174].

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.016mSv in 2022 (Table 4.1) or less than 2% of the dose limit for members of the public, and up from 0.015mSv in 2021. As in recent years, the representative person was adults spending time over sediments. The small increase in 'total dose' in 2022 was mostly due to higher gamma dose rates measured over sand in comparison to those in 2021.

The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. Between 2011 and 2015, relatively lower 'total doses' were estimated due to lower occupancy rates over local beaches. In 2016, a lower 'total dose' was due to both a reduction in the rate of mollusc consumption (from the revised habits data) and lower concentrations of plutonium radionuclides and americium-241 in molluscs. In 2017, the increase in 'total dose' was mostly attributed to a higher estimate of direct radiation from the site. The variation observed since 2018 has been directly related to variation of gamma dose rates over substrates.

Source specific assessments for high-rate terrestrial food consumption, and from external exposure for turf cutting over salt marsh, give exposures that were less than the 'total dose' in 2022 (Table 4.1). The estimated dose for terrestrial food consumption was 0.005mSv and down from 0.006mSv in 2021. The small decrease in dose for the terrestrial food consumption was mostly attributed to a lower maximum concentration of carbon-14 in milk measured in 2022. The estimated dose to the turf cutters was less than 0.005mSv in 2022 and unchanged from 2021. The dose to a local fisherman, who was considered to consume a large amount of seafood and was exposed to external radiation over intertidal areas, was 0.022mSv in 2022, which was approximately 2% of the dose limit for members of the public of 1mSv (Table 4.1). The dose in 2021 was 0.019mSv. The main reason for the increase in dose was the same as that contributing to the maximum 'total dose'.

Gaseous discharges and terrestrial monitoring

Both stations discharge gaseous radioactive waste via stacks to the atmosphere. Gaseous discharges of argon-41 from Heysham 2 increased in 2022, in comparison to those in 2021. The increase was mainly due to a higher power output from Heysham 2 in 2022. The monitoring programme for determining the effects of gaseous disposals was similar to that for other power stations. Data for 2022 are given in Table 4.3(a). The effects of gaseous disposals from the site were not easily detectable in foodstuffs in 2022. As in 2021, the carbon-14 concentrations in milk were above the default value used to represent background in 2022 but were lower than those observed in 2021. Tritium, gross alpha and gross beta concentrations in freshwater were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made via outfalls into Morecambe Bay.

The monitoring programme for the effects of liquid disposals included sampling of fish, shellfish, sediment, seawater and measurements of gamma dose rates. For completeness, the data considered in this section include all of those for Morecambe Bay. A substantial part of the programme is in place to monitor the effects of Sellafield disposals. The results for 2022 are given in Table 4.3(a) and Table 4.3(b). In general, activity concentrations in 2022 were similar (in comparison to those in recent years) and the effect of liquid disposals from Heysham was difficult to detect above the Sellafield background. As in 2021, tritium was not positively detected in mussels. Plutonium radionuclides and americium-241 concentrations in mussels were slightly higher in 2022, in comparison to those in 2021. Concentrations of technetium-99 in marine samples originating from Sellafield discharges were similar to those in recent years. As in recent years, strontium-90 was detected at low concentrations (reported as just above, or close to, the less than value) in food samples collected in 2022. Gamma dose rates measured over sand were higher in 2022 (in comparison to 2021).

4.1.3 Hinkley Point, Somerset

The Hinkley Point Power Station sites are situated on the Somerset coast, west of the River Parrett estuary. There are 2 separate stations, A and B, that include twin Magnox reactors and twin AGRs, respectively. Hinkley Point A started electricity generation in 1965 and ceased in 2000. This station completed de-fuelling in 2004 and is undergoing decommissioning. Hinkley Point B ended power generation in August 2022 and has now entered the de-fuelling phase. In RIFE, a single environmental monitoring programme covers the effects of the 2 power stations, because the discharge effects from both sites impact on the same area. The most recent habits survey was conducted in 2017 [175].

The construction of the two new generation EPRTM reactors continues at Hinkley Point C. Summary details of earlier environmental permits issued (by the Environment Agency), the pre-construction safety case (approved by the ONR), the planning consents granted and other approvals, are available in earlier RIFE reports (for example [69]) and from https://www.gov.uk/government/publications/hinkley-point-decisions-on-environmental-permit-applications-for-a-proposed-new-nuclear-power-station.

Hinkley Point C is now expected to begin electricity generation in June 2027. The latest information on Hinkley Point C can be found at: https://www.gov.uk/government/collections/hinkley-point.

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was 0.015mSv (Table 4.1), or less than 2% of the dose limit, and down from 0.030mSv in 2021. The representative person was prenatal children of adults spending time over sediments, a change from 2021 (adults spending time over sediments). The decrease in 'total dose' was mostly because lower gamma dose rates were measured over mud substrates at Stolford, from one year to the next.

The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. The large decrease in 'total dose' in 2011 (and continued thereafter, up to 2016) was attributed to relatively lower gamma dose rates over local beaches. The increase in 'total dose' from 2017 to 2018 was mostly due to the increase in occupancy rates (over sand) reported in the most recent habits survey. The variation observed between 2019 and 2022 is mainly due to changes of gamma dose rates over mud substrates.

Source specific assessments for a high-rate consumer of locally grown food, and local people who consume high-rates of seafood and are exposed to external radiation over intertidal area, gave exposures that were less than the 'total dose' in 2022 (Table 4.1). The dose to this consumer of locally grown food was 0.007mSv in 2022 and up from 0.005mSv in 2021. The main reason for the increase in dose was mostly due to higher concentrations of carbon-14 in milk in 2022, in comparison to those in 2021.

The dose to the local fisherman was 0.010mSv in 2022, or 1% of the dose limit for members of the public of 1mSv. The reason for the decrease in dose from 0.018mSv (in 2021) was the same as that contributing to the maximum 'total dose'. This dose estimate also includes the effects of discharges (historical) of tritium from the former GE Healthcare Limited plant at Cardiff and uses an increased dose coefficient (see Appendix 5). The estimated dose for a houseboat occupant was 0.013mSv in 2022 and down from 0.022mSv in 2021. The main reason for the decrease was mostly due to lower gamma dose rates measured over different substrates at Blue Anchor Bay in comparison to 2021. This estimate is determined as a cautious value (due to direct measurements beneath houseboats not being available) and therefore not included in the 'total dose' assessment.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via separate stacks to the local environment. Analyses of milk, fruit, honey and crops were undertaken to measure activity concentrations of tritium, carbon-14, sulphur-35 and gamma-emitting radionuclides. Local reservoir water samples were also analysed. Data for 2022 are given in Table 4.4(a). Activity concentrations of tritium and gamma-emitting radionuclides (cobalt-60 and caesium-137) in all terrestrial materials were reported as less than values. Unlike in 2021, sulphur-35 was not positively detected in food samples (blackberries and honey) in 2022. The carbon-14 concentrations in locally produced milk were higher than values observed in 2021. Carbon-14 was also detected in blackberries (as in previous years) above the expected background value in 2022.

Tritium, gross alpha and gross beta concentrations in reservoir water were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

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. Analyses of seafood and marine indicator materials and measurements of external radiation were conducted over intertidal areas. The environmental results for 2022 are given in Table 4.4(a) and Table 4.4(b). Overall, activity concentrations observed in seafood and other materials from the Bristol Channel were generally similar to those in previous years. Unlike in 2021, tritium was positively detected in shrimps and limpets in 2022. 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, and fallout from Chernobyl and nuclear weapons testing. Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. The concentrations of transuranic nuclides in seafoods were of negligible radiological significance. There is continuing evidence to suggest that caesium-137 concentrations in sediment have been generally decreasing over the reported years (Figure 4.2). Overall, gamma dose rates over intertidal substrates in 2022 were generally lower (where comparisons can be made for similar ground types and locations), in comparison to those observed in 2021.

4.1.4 Hunterston, North Ayrshire

Hunterston Power Station is located on the Ayrshire coast near West Kilbride and consists of 2 separate nuclear power stations - Hunterston A and Hunterston B.

Hunterston A was powered by twin Magnox reactors until it ceased electricity production in 1990 and is now being decommissioned by Magnox Limited. De-fuelling was completed in 1995. Decommissioning activities continue to focus on 2 major areas: the ongoing decommissioning of the cartridge (nuclear fuel) cooling pond; and making progress towards ensuring that all higher activity waste is stored in a passively safe manner.

Most of the radioactivity in liquid effluent discharged from the Hunterston A site over the last few years has arisen from the cartridge cooling pond. The draining of the cartridge cooling pond is now largely complete. However, there is still a need to manage the remaining radioactive sludges from several areas associated with the pond.

In terms of safe management of legacy higher activity waste at Hunterston A, Magnox Limited are in the process of commissioning the Solid Intermediate Level Waste Encapsulation plant (SILWE). The Wet Intermediate Level Waste Retrieval and Encapsulation Plant (WILWREP) underwent active commissioning in early 2017 and is currently undergoing modifications in order to process radioactively contaminated acid wastes. Processing of the legacy higher activity waste, present at the Hunterston A site has begun and will be processed through either SILWE or WILWREP, with the current plans being to make safe by encapsulating it in a grout mixture. The encapsulated waste will then be transferred to the Intermediate Level Waste Store (ILWS) for storage.

Hunterston B was powered by a pair of AGRs, referenced as Reactors 3 and 4 until it ceased electricity production in January 2022. The station is currently being defueled by EDF Energy Nuclear Generation Limited, and once it has achieved Fuel Free Verification, it will be transferred to the NDA Estate to be decommissioned by Magnox Limited. Both gaseous and liquid discharges are much lower during defueling than in the operational phase.

In terms of safe management of legacy higher activity waste at Hunterston B, the preferred option is to use the ILWS on Hunterston A. Optioneering exercises are being carried out on the optimal solution for the Operational Waste Processing Facility (OWPF), which will manage the higher activity wastes arising from the station's operational life and the Decommissioning Waste Processing Facility (DWPF), which will be used to manage the lower activity waste arising from the decommissioning phase.

Environmental monitoring in the area considers the effects of both Hunterston A and Hunterston B sites together. The most recent habits survey was conducted in 2017 [176]. A new habits survey is scheduled to be undertaken in 2024.

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv in 2022 or less than 0.5% of the dose limit (Table 4.1), and down from 0.006mSv in 2021. The decrease in dose was mostly due to a lower concentration of plutonium-239+240 measured in mollusc species. The representative person was adults living near the site and a change from that in 2021 (adults consuming molluscs). The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1.

The estimated dose for seafood consumption was less than 0.005mSv in 2022, and down from that in 2021 (0.011mSv). The reason for this decrease in dose is the same as that contributing to the maximum 'total dose'.

The estimated dose for a terrestrial food consumer was 0.007mSv in 2022, which was less than 1% of the dose limit for members of the public of 1mSv and slightly down in comparison to that in 2021 (0.008mSv).

Gaseous discharges and terrestrial monitoring

Gaseous discharges are made via separate discharge points from the Hunterston A and Hunterston B stations. Hunterston A is in the decommissioning phase, and gaseous discharges from the site are low. Hunterston B began defueling Reactor 3 in May 2022 after a period of outage. As a consequence of being shut down, the gaseous discharges of carbon-14 and, to a lesser extent, sulphur-35, decreased in 2022, in comparison to those in 2021.

There is a substantial terrestrial monitoring programme which includes the analyses of a comprehensive range of wild and locally produced foods. In addition, air, freshwater, grass and soil are sampled to provide background information. The results of terrestrial food and air monitoring in 2022 are given in Table 4.5(a) and Table 4.5(c). The concentrations of radionuclides in air, milk, crops and fruit were generally low and similar to those in previous years (where comparisons can be made). Sulphur-35 was positively detected in grass at 2 different locations samples. As in recent years, europium-155 was positively detected in soil in 2022.

Tritium, gross alpha and gross beta concentrations in freshwater were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Most of the activity concentrations in air at locations near to the site (Table 4.5(c)) were reported as less than values. Solid waste transfers in 2022 are also given in Appendix 1 (Table A1.4).

Liquid waste discharges and aquatic monitoring

Authorised liquid discharges from both Hunterston stations are made to the Firth of Clyde via the Hunterston B station's cooling water outfall. Hunterston B began defueling Reactor 3 in May 2022 after a period of outage. As a consequence of being shut down, the liquid discharges of tritium and, to a lesser extent, sulphur-35, decreased in 2022, in comparison to those in 2021.

The main part of the aquatic monitoring programme consists of sampling of fish and shellfish and the measurement of gamma and beta dose rates on the foreshore. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials.

The results of aquatic monitoring in 2022 are shown in Table 4.5(a) and Table 4.5(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. As in recent years, the concentrations of technetium-99 from Sellafield in crabs and lobsters around Hunterston were low in 2022. As in 2021, all cobalt-60 concentrations in sediments were reported as less than value in 2022. The plutonium-239+240 concentration in the scallop sample collected was significantly lower than the one observed in 2021. Gamma dose rates were generally similar in 2022, in comparison to those observed in recent years. Measurements of the beta dose rates over sand are reported as less than values in 2022. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2).

4.1.5 Sizewell, Suffolk

The two Sizewell Power Stations are located on the Suffolk coast, near Leiston. Sizewell A is a Magnox twin reactor site that ceased electricity generation in 2006. De-fuelling commenced in 2007 and was completed in 2014. Sizewell B, powered by one reactor, is the only commercial PWR power station in the UK. The Sizewell B power station began operation in 1995 and whilst the end of power generation is currently scheduled for 2035, the site operator is investigating extending operations to 2055 and potentially longer. The most recent habits survey was conducted in 2015 [177]. The permit for Sizewell B was varied (in 2021) to increase the annual permitted limit of carbon-14 to the atmosphere. The variation returned the limit from 500GBq to the original authorisation limit of 600GBq, due to changing plant behaviour.

Further information on the variation, public consultation and our decision can be found in Appendix 1 (Table A1.1).

In 2020, NNB GenCo (SZC) applied to the ONR for a nuclear site license for Sizewell C, the Environment Agency for a radioactive substances activities permit and the Planning Inspectorate for a Development Consent Order (DCO) for Sizewell C where EDF Energy have proposed construction of 2 EPRTM reactors. Examination of the DCO application concluded in October 2021. In July 2022, the Secretary of State for the Department of Business, Energy and Industrial Strategy announced that the Sizewell C project had been granted its DCO. In March 2023, the Environment Agency granted the permit for discharging and disposing of radioactive waste in the environment. The latest information can be found at: https://www.gov.uk/guidance/sizewell-nuclear-regulation.

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv in 2022 (Table 4.1) or less than 0.5% of the dose limit, and down from 0.016mSv in 2021. This decrease in dose (from 2021) was mostly due to a lower estimate of direct radiation from the site in 2022 (Table 1.1). Unlike in recent years, the dominant contribution to 'total dose' in 2022 was from exposure to gamma dose rates over sediments and the representative person was adults spending time over sediments, a change from 2021 (adults living in the vicinity of the site). The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. Any variation in 'total dose' from year to year was due to a change in the contribution from direct radiation from the site. The 'total dose' has declined (reduced by a factor of 5 or 6), following the closure of the Magnox reactors at Sizewell A in 2006 (Figure 4.1, [47]).

As in 2021, source specific assessments for both a high-rate consumer of locally grown foodstuffs, and of fish and shellfish, and of external exposure for houseboat occupancy, gave exposures that were also less than 0.005mSv in 2022 (Table 4.1).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. The discharges of tritium and carbon-14 increased from Sizewell B in 2022, in comparison to those in 2021. This is a result of there being no reactor outage during 2022, with extended periods at full power. The increase in carbon-14 is also attributable to a change in behaviour of carbon delay-beds.

The results of the terrestrial monitoring in 2022 are shown in Table 4.6(a). As in 2021, gamma-ray spectrometry and radiochemical analysis of tritium and sulphur-35 in milk and crops generally showed very low concentrations of artificial radionuclides near the power stations in 2022. In 2022, carbon-14 concentrations in locally produced milk were just above the default value used to represent background level. Sulphur-35 was positively detected at a very low concentration in wheat. Tritium concentrations in local freshwater were reported as less than values in 2022. Tritium, gross alpha and gross beta concentrations in surface water were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent are made via outfalls to the North Sea. The project to drain the fuel storage pond at Sizewell A was completed in 2019. This has resulted in a significant reduction in liquid effluent generation at Sizewell A. Small volumes of effluent were discharged by the foul sewer route via the sewage treatment works that is shared with Sizewell B. This route is monitored at quarterly intervals for tritium and caesium-137 for reassurance purposes. In the aquatic programme, analysis of seafood, sediment, and seawater, and measurements of gamma dose rates were conducted in intertidal areas. Data for 2022 are given in Table 4.6(a) and Table 4.6(b). Concentrations of artificial radionuclides were low and mainly due to the distant effects of Sellafield discharges and fallout from Chernobyl and nuclear weapons testing. Unlike in 2021, tritium was not positively detected in seafood (herring sample in 2021). Concentrations of strontium-90 observed in sediment samples were all reported as less than values. Caesium-137 concentrations in sediment have remained low over the last decade and are generally decreasing over time (Figure 4.2). Overall, gamma radiation dose rates over intertidal areas were difficult to distinguish from the natural background and were similar to those reported in recent years.

4.1.6 Torness, East Lothian

Torness Power Station is located near Dunbar on the east coast of Scotland. The station is powered by twin AGRs and began operation at the end of 1987. The expected end of generation date for Torness remains as 2028. EDF keeps operational dates under constant review which has allowed them to provide the additional clarity on lifetime expectations.

SEPA has completed the determination of the application submitted by EDF to cover the receipt and management of debris found in fuel transport flask. A permit variation was granted in July 2022.

There has been a change to the process used to refuel the reactors such that the reactors are taken offload and depressurised. This has had an impact on the profile of discharges notably carbon-14, sulphur-35 and tritium. However, there has been no significant impact to the magnitude of the annual discharges.

The gaseous and liquid discharges from the site are given in Appendix 1.

The most recent habits survey, to determine the consumption and occupancy rates by members of the public, was undertaken in 2016 [178]. A new survey is scheduled in 2023.

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was 0.006mSv (Table 4.1), or less than 1% of the dose limit, and slightly increased from 0.005mSv in 2021. As in recent years, the representative person was prenatal children of local inhabitants consuming wild fruits and nuts. The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. The decrease in 'total dose' in the earlier years reflected a downward trend in the reported direct radiation, thereafter 'total doses' have remained broadly similar, from year to year, and were low.

The source specific assessment for a high-rate consumer of terrestrial food gave an exposure that was also 0.006mSv in 2022 (Table 4.1) and down from 0.008mSv in 2021. The decrease in dose was mostly due to a lower limit of detection for strontium-90 measured in milk used in the dose assessment. The estimated dose to a high consumer of local fish and shellfish was less than 0.005mSv in 2022, or less than 0.5% of the dose limit for members of the public of 1mSv, and unchanged from that in recent years.

Gaseous discharges and terrestrial monitoring

A variety of foods, including milk, crops, fruit, and game as well as grass, soil and freshwater samples, were measured for a range of radionuclides. Air sampling at 3 locations was undertaken to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2022 are given in Table 4.7(a) and Table 4.7(c). Activity concentrations in many terrestrial foods are reported as less than values (or close to the less than value). The carbon-14 concentrations in locally produced milk were close to the default value used to represent background. Caesium-137 was positively detected in partridge, venison, wild mushrooms and in soil, but at low concentrations. As in 2021, americium-241 concentrations in all terrestrial food and soil samples (measured by gamma–ray spectrometry) were reported as less than values in 2022. The tritium, gross alpha and gross beta concentrations in freshwater were well below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51). Measured concentrations of radioactivity in air, at locations near to the site, were all reported as less than values or close to the less than values in 2022 (Table 4.7(c)). Solid waste transfers in 2022 are also given in Appendix 1 (Table A1.4).

Liquid waste discharges and aquatic monitoring

Discharges of authorised liquid radioactive wastes are made to the Firth of Forth. Seafood, seaweed, sediment, and seawater samples were collected in 2022. Measurements were also made of gamma dose rates over intertidal areas, supported by analyses of sediment, and a beta dose rate on fishing gear.

The results of the aquatic monitoring in 2022 are shown in Table 4.7(a) and Table 4.7(b). Concentrations of artificial radionuclides were mainly due to the distant effects of Sellafield discharges, and fallout from Chernobyl and nuclear weapons testing. As in recent years, cobalt-60 was detected in environmental indicator samples at low concentrations. It was also detected positively in winkles in 2022. This activation product was likely to have originated from the station. Technetium-99 concentrations in marine samples were similar to those in recent years. Overall, caesium-137 concentrations in sediments have remained low over the last decade (Figure 4.2). Gamma dose rates over intertidal areas were generally indistinguishable from natural background and were similar to those measured in recent years. A measurement of the contact beta dose rate on fishermen's pots was reported as less than values in 2022.

4.2 Decommissioning sites

4.2.1 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 twin Magnox reactors. Berkeley was the first commercial power station in the UK to enter into decommissioning. Electricity generation started in 1962 and ceased in 1989. De-fuelling was completed in 1992. Decommissioning is still in progress and small amounts of radioactive wastes are still generated by these operations. Recently, a modular encapsulation plant went into service to treat intermediate level waste to make it safe. The annual permitted limit of tritium to the atmosphere was increased to 1TBq in 2021 to progress with some decommissioning operations. Further details can be found in Appendix 1 (Table A1.1).

Oldbury Power Station is located on the south bank of the River Severn close to the village of Oldbury-on-Severn and has 2 Magnox reactors. Electricity generation started in 1967 and ceased in 2012. De-fuelling was completed in 2016 and the site is now prioritising the retrieval, treatment and storage of intermediate level waste.

Berkeley and Oldbury sites are considered together for the purposes of environmental monitoring because the discharge effects from both sites impact on the same area. The most recent habits survey was undertaken in 2014 [179].

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was 0.006mSv (Table 4.1), or less than 1% of the dose limit, and down from 0.013mSv in 2021. The representative person was infants consuming milk and a change from that in 2021 (infants living near the site). The decrease in 'total dose' was mostly attributed to lower direct radiation from the Berkeley site in 2022. The trend in the 'total dose' over the period 2011 to 2022 is given in Figure 4.1. Any longer-term variations in 'total doses' over time are attributable to changes in the contribution from direct radiation.

As in 2021, the source specific assessments for a high-rate consumer of fish and shellfish, in the vicinity of the Berkeley and Oldbury sites, gave exposures that was less than 0.005mSv in 2022 (Table 4.1). The dose to a consumer of fish and shellfish includes external gamma radiation and a component due to the tritium historically discharged from the former GE Healthcare Limited plant at Cardiff. The estimated dose for a high-rate consumer (infant) of locally grown foods gave an exposure of 0.007mSv and was up from less than 0.005mSv in 2021. The increase in dose was mostly due to higher concentrations of carbon-14 in milk, in comparison to those observed in 2021. The estimated dose for houseboat dwellers was 0.009mSv in 2022, and a decrease from 2021 (0.025mSv). The reason for the decrease in estimated dose for houseboat dwellers was because the gamma dose rates recorded at Sharpness were lower on average in 2022, in comparison to the dose rate over mud observed in 2021. The estimate for this pathway is determined as a cautious value (and therefore not included in the 'total dose' assessment), because gamma dose rate measurements used were not necessarily representative of the categories of ground type and houseboat location (as identified in the habits survey [179]).

Gaseous discharges and terrestrial monitoring

The Berkeley and Oldbury sites discharge gaseous radioactive wastes via separate stacks to the atmosphere. The focus of the terrestrial sampling was for the analyses of tritium, carbon-14 and sulphur-35 in milk and crops. Local freshwater samples were also analysed. Data for 2022 are given in Table 4.8(a). Unlike in 2021, sulphur-35 was not detected positively in any terrestrial food samples in 2022. Carbon-14 concentrations in milk were higher than those reported in recent years and above the default value used to represent background. Tritium, gross alpha and gross beta concentrations in surface water were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Liquid waste discharges and aquatic monitoring

Liquid radioactive wastes are discharged to the Severn Estuary. Oldbury has ceased generation and was verified by the ONR as fuel free in 2016.

Analyses of seafood and marine indicator materials as well as measurements of external radiation were conducted over muddy intertidal areas. Data for 2022 are given in Table 4.8(a) and Table 4.8(b). Most of the artificial radioactivity detected was due to caesium-137, representing the combined effect of discharges from the sites, other nuclear establishments discharging into the Bristol Channel and fallout from nuclear weapons testing, and possibly a small Sellafield-derived component. Caesium-137 concentrations in sediment have been generally decreasing over the period between 2011 to 2022 (Figure 4.2). As in recent years, the tritium concentrations in fish and seawater were reported as less than values in 2022. In earlier decades, concentrations of tritium in seafood were relatively high and were likely to be mainly due to historical discharges from the former GE Healthcare Limited, Cardiff. Very small concentrations of other radionuclides were detected but taken together, were of low radiological significance. Gamma dose rates over mud were generally lower to those observed in recent years.

4.2.2 Bradwell, Essex

The Bradwell site is located on the south side of the Blackwater Estuary. This Magnox power station ceased electricity production in 2002 after 40 years of operation, and de-fuelling was completed in 2006. In 2018, Bradwell became the UK's first Magnox site to reach the interim end-stage of passive Care and Maintenance, following an accelerated decommissioning programme. The most recent permit was issued in 2019.

At the adjacent Bradwell B site, the Bradwell B Power Generation Company Limited (BrB) is in the early stages of developing its proposals for a new nuclear power station. In February 2022, the Environment Agency confirmed the HPR-1000 design (proposed for this site) was suitable for use in the United Kingdom.

Following the cessation of intermediate level waste (fuel element debris) treatment at Bradwell, the enhanced environmental monitoring reverted to the baseline monitoring programme in 2018. The results of the enhanced monitoring programme (2015 to 2017) are described in earlier RIFE reports (for example [47]).

The most recent habits survey was undertaken in 2015 [180].

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv 2022 (Table 4.1), or less than 0.5% of the dose limit for members of the public of 1mSv, and down from 0.006mSv 2021. The representative person was adults living in a houseboat and a change from 2021 (prenatal children of near to the site). The decrease in 'total dose' was mostly attributed to lower estimate of direct radiation from the site in 2022.The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. Any significant variations in 'total dose' over time were attributed to changes in the estimate of direct radiation.

As in recent years, the source specific assessment for a high-rate consumer of fish and shellfish gave an exposure that was less than 0.005mSv in 2022. The dose to a high-rate consumer of locally grown foods was less than 0.005mSv in 2022 and down from less 0.006mSv in 2021. The small decrease in dose was mostly due to lower carbon-14 concentrations measured in milk samples collected in 2022.

Gaseous discharges and terrestrial monitoring

The power station is permitted to discharge gaseous wastes to the local environment via stacks to the atmosphere. Terrestrial sampling is similar to that for other power stations including analyses of milk and crop samples. Samples of freshwater are also taken from a coastal ditch. Data for 2022 are given in Table 4.9(a). Activity concentrations were low in terrestrial samples. Unlike in 2021, carbon-14 was detected in locally produced milk at concentrations close to the expected background concentration and tritium was not positively detected in the grass sample (lucerne) and strontium-90 was positively detected in the coastal ditch freshwater sample collected near the turbine hall in 2022. The gross beta activities in water from the coastal ditch were similar to those reported in 2021 and continued to be enhanced above background concentrations, and in excess of the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51). However, 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. The source of this effluent is rainwater which is discharged to the estuary via the main drains pit at Bradwell site. The main drains pit is sampled at quarterly intervals. The site is also permitted to discharge non-radioactive effluent from the turbine hall voids to the main drains pit, and from there to the estuary. However, no effluent from this source was discharged in 2022. Effluent was last discharged to the estuary via Bradwell site's active effluent system in 2017. This route has since been decommissioned and was removed from the site's permit when the permit was last varied in 2019.

Aquatic sampling was directed at the consumption of locally caught fish and shellfish and external exposure over intertidal sediments. Seaweeds were also analysed as an environmental indicator material. Data for 2022 are given in Table 4.9(a) and Table 4.9(b). Low concentrations of artificial radionuclides were detected in marine samples as a result of discharges from the station, discharges from Sellafield and fallout from nuclear weapons testing.

Due to the low concentrations detected, it is generally difficult to attribute the results to a particular source. There has been an overall decline in caesium-137 concentrations in sediments over the last decade (Figure 4.2). The caesium-137 concentrations observed in sediment samples collected in 2022 were similar to those reported in 2021 and were amongst the lowest reported values in recent years. Gamma dose rates on beaches were difficult to distinguish from natural background and were generally similar to those in recent years.

4.2.3 Chapelcross, Dumfries and Galloway

Chapelcross was Scotland's first commercial nuclear power station. It has 4 Magnox reactors and is 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 since been undergoing decommissioning. De-fuelling of the reactors began in 2008 and was completed during 2013. The major hazards remaining on the site are being addressed during the decommissioning phase.

Habits surveys have been undertaken to investigate aquatic and terrestrial exposure pathways. The most recent habits survey for Chapelcross was conducted in 2022 [181]. In 2017, a separate habits survey was also conducted to determine the consumption and occupancy rates by members of the public on the Dumfries and Galloway coast [151]. The results of this survey are used to determine the potential exposure pathways relating to permitted liquid discharges from the Sellafield nuclear licensed site in Cumbria (see Section 3.3.1).

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.008mSv in 2022 (Table 4.1), which was less than 1% of the dose limit, and down from 0.018mSv in 2021. As in recent years, the representative person was infants consuming locally produced milk at high rates. The decrease in dose was mainly due to the exclusion of the concentrations of americium-241 in milk samples from the calculation of the 'total dose'. The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1.

Source specific assessments for a high-rate consumer of locally grown food, for a seafood consumer (crustaceans), and for a seafood (fish and mollusc) and wildfowl consumer, gave exposures that were less than the 'total dose' in 2022 (Table 4.1). The dose for the terrestrial food consumer was estimated to be 0.007mSv in 2022, down from 0.015mSv in 2021. The decrease in dose was mostly due to the same reason as for the 'total dose'. The dose for the seafood and wildfowl consumer was less than 0.005mSv in 2022 and decreased from 0.006mSv in 2021, mostly due to lower americium-241 concentrations in molluscs (mussels collected at North Solway). As in recent years, the dose for the high-rate consumer of crustacean was less than 0.005mSv in 2022.

Doses from the presence 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.

Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks to the local environment. In June 2022 Magnox Ltd contacted SEPA to inform them that the annual activity limit for gaseous 'all radionuclides other than tritium' associated with the Advanced Vacuum Drying System (AVDS) had been exceeded in May 2022. The AVDS serves to condition packaged ILW that has been removed from the pond facility prior to storage in the site's Interim Storage Facility (ISF). Following an investigation conducted by SEPA, it was concluded that the exceedance constituted a small fraction of the site's relevant Site Limit, and that the exceedance did not result in harm to the public or the environment.

Terrestrial monitoring consisted of the analysis of a variety of foods, including milk, fruit, crops as well as grass, soil and freshwater samples, for a range of radionuclides. Air samples at 3 locations were also monitored to investigate the inhalation pathway. The results of terrestrial food and air monitoring in 2022 are given in Table 4.10(a) and Table 4.10(c). Carbon-14 concentrations in milk were similar to those values used to represent background concentrations. As in 2021, americium-241 concentrations in all terrestrial food, and grass samples were all reported as less than values.

As in recent years, the tritium concentration was measured above the detection limit in one freshwater sample (Gullielands Burn), but also just above the less than value at Black Esk. However, tritium, gross alpha and gross beta concentrations in all freshwater samples were well below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51). Activity concentrations in air samples at locations near to the site (Table 4.10(c)) are reported as less than values (or close to the less than value). Solid waste transfers in 2022 are also given in Appendix 1 (Table A1.4).

Liquid waste discharges and aquatic monitoring

Radioactive liquid effluents are discharged to the Solway Firth. As in previous years, discharges continued at very low rates in 2022 (most reported as <1% of the annual limit). Samples of seawater and seaweed ('Fucus vesiculosus'), as environmental indicators, were collected in addition to shrimps, mussels, fish, sediments and measurements of gamma dose rates. Data for 2022 are given in Table 4.10(a) and Table 4.10(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 similar to those detected in recent years. As in 2021, low concentrations of europium-155 were positively detected (reported as just above the less than value) in sediment samples.

As in previous years, concentrations of caesium-137, plutonium radionuclides and americium-241 were enhanced in sediment samples taken close to the pipeline in 2022. The average concentration of caesium-137 in sediments analysed in 2022 was slightly lower than in 2021 and is known to be largely due to Sellafield discharges (Figure 4.2). In 2022, gamma dose rates over intertidal sediment were similar to those in 2021 (where comparisons can be made). As in recent years, measurements of the contact beta dose rate on fishing nets and sediment were reported as less than values in 2022.

Between 1992 and 2009, several particles were found at the end of the discharge outfall consisting of limescale originating from deposits within the pipeline. Magnox Limited continues to monitor this area frequently and no particles were found during 2022 (as for the previous years). The relining of the pipeline and grouting at strategic points, which was undertaken between 2009 and 2010, has reduced the potential for particles to be released.

4.2.4 Dungeness, Kent

The Dungeness power stations are located on the south Kent coast between Folkestone and Rye. There are 2 separate A and B nuclear power stations on neighbouring sites: station A was powered by twin Magnox reactors and station B has twin AGRs. Discharges are made via separate and adjacent outfalls and stacks, but for the purposes of environmental monitoring these are considered together. Dungeness A ceased generating electricity in 2006. De-fuelling of both Magnox reactors was completed in 2012. The Dungeness A site is currently undergoing decommissioning. In June 2021, EDF Energy Nuclear Generation Limited decided to move Dungeness B nuclear power station into the defueling phase with immediate effect, following over two years of outage to deal with a range of technical issues. The most recent habits survey was conducted in 2019 [182].

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was 0.011mSv (Table 4.1), which was approximately 1% of the dose limit of 1mSv, and down from 0.012mSv in 2021. As in recent years, this was almost entirely due to direct radiation from the site and the representative person was adults living near the site in 2022. The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. 'Total doses' ranged between 0.011 and 0.037mSv over this time period and were dominated by direct radiation. Over a longer time-series, this dose has declined more significantly from the peak value of 0.63mSv, following the shutdown of the Magnox reactors in 2006 (Figure 4.1, [47]).

As in 2021, source specific assessments for a high-rate consumer of locally grown foodstuffs and a local bait digger, who consumes large quantities of fish and shellfish and spends long periods of time in the location being assessed for external exposure, give exposures that were less than the 'total dose' in 2022 (Table 4.1). The dose to a high-rate consumer of locally grown foods was estimated to be less than 0.005mSv and unchanged from 2021. The dose to a local seafood consumer was estimated to be 0.006mSv in 2022, and down from 0.008mSv in 2021. The decrease in dose was mostly attributed to gamma dose rates which were measured over different substrates year on year. As in recent years, the estimation of dose for a houseboat occupant (from external exposure) was not required in 2022 (consistent with information identified in the latest habits survey).

Gaseous discharges and terrestrial monitoring

Gaseous wastes are discharged via separate stacks to the local environment. The focus of the terrestrial sampling was the analyses of tritium, carbon-14 and sulphur-35 in milk and crops. The results of monitoring for 2022 are given in Table 4.11(a). Activity concentrations in many terrestrial foods are reported as less than values (or close to the less than value). Unlike in recent years, tritium and sulphur-35 were positively detected in potatoes and milk samples, respectively in 2022. As in 2021, tritium, gross alpha and gross beta concentrations in freshwater were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51) in 2022.

Liquid waste discharges and aquatic monitoring

Regulated discharges of radioactive liquid effluent from both power stations are made via separate outfalls to the English Channel. Dungeness B has been in double reactor outage since the second half of 2018 until it entered the defueling phase in June 2021. The draining of fuel ponds at Dungeness A was completed in 2019 and this removed the main source of aqueous waste discharges on site. Marine monitoring included gamma dose rate measurements, and analysis of seafood and sediments. The results of monitoring for 2022 are given in Table 4.11(a) and Table 4.11(b). The caesium-137 concentrations in seafood are attributable to discharges from the stations, fallout from nuclear weapons testing and a long-distance contribution from Sellafield and La Hague. Due to the low concentrations detected in foods and marine materials, it is generally difficult to attribute the results to a particular source. The low concentrations of transuranic nuclides in molluscs (scallop sample collected in 2022) were typical of values expected at sites remote from Sellafield. As in 2021, all tritium results in seafood were reported as less than values in 2022. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2) and reported as less than values in recent years. Gamma dose rates were generally difficult to distinguish from the natural background.

4.2.5 Trawsfynydd, Gwynedd

Trawsfynydd Power Station is located inland on the northern bank of a lake in the heart of Snowdonia National Park, North Wales and was powered by twin Magnox reactors. Trawsfynydd ceased to generate electricity in 1991. De-fuelling of the reactors was completed in 1995 and the station is being decommissioned. As part of NDA's site-specific approach to decommissioning, Trawsfynydd was selected as the lead location, where the reactors will be dismantled without achieving an interim site state [70]. The most recent habits survey was undertaken in 2018 [183].

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.009mSv in 2022 (Table 4.1), which was less than 1% of the dose limit, and down from 0.010mSv in 2021. The representative person in 2022 was adults exposed to external radiation over lake sediments and unchanged from 2021. The small decrease in 'total dose' was mostly attributed to lower estimate of direct radiation in 2022. The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1.

The dose to an angler (who consumes large quantities of fish and spends long periods of time in the location being assessed) was 0.008mSv in 2022 (Table 4.1), which was less than 1% of the dose limit for members of the public of 1mSv and unchanged from 2021. The activity concentrations observed 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 rates. The dose to infants (1-year-old) consuming terrestrial food was 0.038mSv, or less than 4% of the dose limit. This was slightly than in 2021 (0.040mSv) and the main reason for the small decrease in dose was because of lower concentrations of carbon-14 in milk samples collected in 2022.

Gaseous discharges and terrestrial monitoring

The results of the terrestrial programme, for local food (including milk) and grass samples in 2022, are shown in Table 4.12(a). Results from surveys, providing activity concentrations in sheep samples, are available in earlier RIFE reports (for example [62]). Concentrations of activity in all terrestrial samples were low. Tritium concentrations in all milk samples were reported as less than values. Like in 2021, carbon-14 concentrations in milk were at reported just above the background concentration for milk. Measured activities for caesium-137 were reported as less than values (or close to the less than value) in 2022. The most likely source of small amounts of caesium-137 is fallout from Chernobyl and nuclear weapons testing, though it is conceivable that a small contribution may be made by re-suspension of lake activity. In recognition of this potential mechanism, monitoring of transuranic radionuclides was also conducted in a potato sample. In 2022, detected activities in potatoes were low and generally similar to observations in other areas of England and Wales, where activity was attributable to fallout from nuclear weapons testing. Therefore, there was no direct evidence of re-suspension of activity in sediment from the lake shore contributing to increased exposure from transuranic radionuclides in 2022.

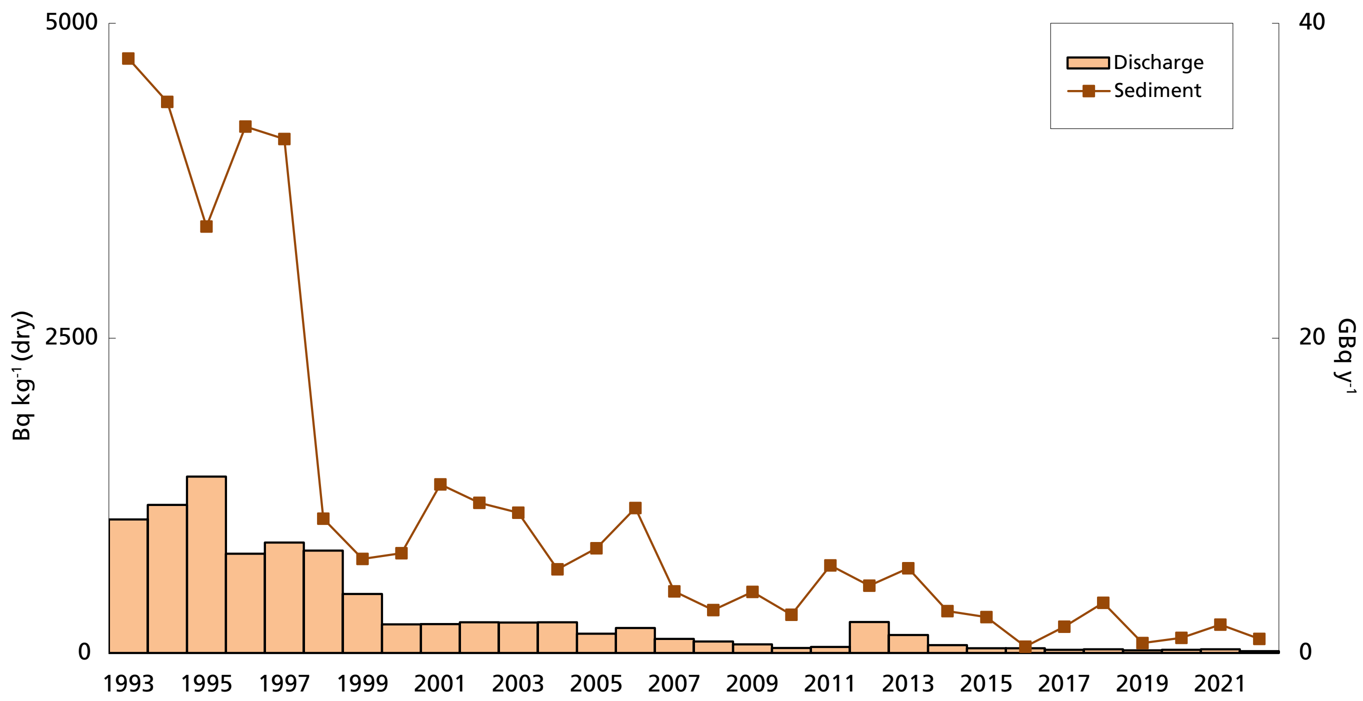
Liquid waste discharges and aquatic monitoring

Discharges of liquid radioactive waste are made to a freshwater lake, making the power station unique in UK terms. 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 caesium-137 and, to a lesser extent, strontium-90. Freshwater and sediment samples were also analysed in 2022. Habits surveys have established that the species of fish regularly consumed are brown and rainbow trout. Most brown trout are indigenous to the lake, but rainbow trout are introduced from a hatchery. Due to the limited period that they spend in the lake, introduced fish generally exhibit lower caesium-137 concentrations than indigenous fish.

Data for 2022 are given in Table 4.12(a) and Table 4.12(b). The majority of activity concentrations in fish and sediments result from historical discharges. As in recent years, due to sample availability, only rainbow trout samples were collected in 2022. The most recent brown trout sample to be collected was in 2015 and the concentration of caesium-137 was the lowest reported value for fish indigenous to the lake [46]. As in previous years, caesium-137 concentrations in water samples are reported as less than values in 2022. Concentrations in the water column are predominantly maintained by processes that release activity (such as remobilisation) from near surface sediments. Caesium-137 concentrations in lake sediments were lower than those in 2021 at all sampling locations. In 2022, the highest caesium-137 concentration was in a sediment sample collected on the lake shore near a café (200Bq kg^{-1}) and was lower than in 2021 (300Bq kg^{-1} collected 1.5km Southeast of the power station). Americium-241 was positively detected in one sediment sample only (2.5Bq kg^{-1} near pipeline). In previous years' monitoring, it has been demonstrated that these concentrations increase with depth beneath the sediment surface. Sediment concentrations of strontium-90, plutonium-238 and plutonium-239+240 in 2022 were all reported as less than values and were similar to those in recent years. Strontium-90 and transuranic concentrations in fish continued to be very low in 2022 and it is the effects of caesium-137 that dominate the external radiation pathways.

In the lake itself, there remains clear evidence for the effects of liquid discharges from the power station (activity concentrations of caesium-137, and other radionuclides, in sediments). However, gamma dose rates measured on the shoreline (where anglers fish) were difficult to distinguish from background dose rates in 2022 and were generally lower (where comparison could be made) to those in 2021. The predominant radionuclide was caesium-137. The time trends of concentrations of caesium-137 in sediments and discharges are shown in Figure 4.3. A substantial decline in concentrations was observed in the mid to late 1990s in line with reducing discharges. Since 2000, the discharges of caesium-137 have generally decreased, but with some variability. Concentrations have generally decreased over the period 2000 to 2022, with fluctuations due to environmental variability (and short periods of increased discharges, particularly in 2012 and 2013) being observed over this period.

Figure 4.3 Caesium-137 liquid discharge from Trawsfynydd and concentration in sediment in Trawsfynydd lake, 1993 to 2022



4.2.6 Wylfa, Isle of Anglesey

Wylfa Power Station is located on the north coast of Anglesey and has 2 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 and ceased in 2015. De-fueling operations were completed in 2019 [184]. This milestone marked the end of de-fueling operations at all the UK's first-generation nuclear reactors.

The most recent habits survey was undertaken in 2013 [185].

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.014mSv in 2022 (Table 4.1), which was approximately 1% of the dose limit, and up from 0.005mSv in 2021. The increase in dose was almost entirely due to higher direct radiation from the site. The representative person was infants (1-year old) living near the site and unchanged from 2021. The trend in 'total dose' over the period 2011 to 2022 is given in Figure 4.1. 'Total doses' remained broadly similar, from year to year, and were generally very low.

Source specific assessments for a high-rate consumer of locally grown foods, and for a high-rate consumer of fish and shellfish (including external radiation) gave exposure levels that were lower than the 'total dose' (Table 4.1). The dose to a high-rate consumer of fish and shellfish (including external radiation) was 0.008mSv in 2022. The main reason for a small increase in dose (from 0.007mSv in 2021) was because of the higher limit of detection associated with the gamma measurement of americium-241 in the fish sample (plaice) in 2022. The dose to a high-rate consumer of locally grown foods was less than 0.005mSv in 2022 and down from 0.006mSv in 2021. The main reason for the decrease in dose was because of lower concentrations of carbon-14 in milk samples collected in 2022.

Gaseous discharges and terrestrial monitoring

In October 2022, Magnox Limited discovered an error in the calculation of gaseous discharges of tritium and sulphur-35. This resulted in an underestimate of some of these discharges by up to 23.3 % between 2002 and 2022. Some beta particulate discharges to air may have also been calculated incorrectly, however this would have resulted in a slight over-estimation of the discharges. The consequences and actions taken by NRW are detailed in Table A1.5.

The focus of the terrestrial sampling was for the analyses of tritium, carbon-14 and sulphur-35 in milk and crops. Data for 2022 are given in Table 4.13(a). Sulphur-35 was detected positively in a milk sample. Unlike in 2021, carbon-14 concentrations measured in locally produced milk were just above background levels.

Liquid waste discharges and aquatic monitoring

The aquatic monitoring programme consists of sampling of fish and shellfish, and the measurement of gamma dose rates. Samples of sediment, seawater and seaweed are analysed as environmental indicator materials. The results of the programme in 2022 are given in Table 4.13(a) and Table 4.13(b). The data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges. The activity concentrations in 2022 were similar to those in previous years. The reported concentration of technetium-99 in seaweed in 2022 (due to the distant effects of discharges to sea from Sellafield) was similar to levels observed in recent years. Caesium-137 concentrations in sediment have remained low over the last decade (Figure 4.2). Overall, gamma dose rates in 2022 were generally similar to those measured in 2021.

Table 4.1 Individual doses - nuclear power stations, 2022

Site	Representative person[a]	Exposure, mSv per year					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or shoreline[b]	Gaseous plume related pathways	Direct radiation from site
Operating sites							
Hartlepool							
'Total dose' - all sources	**Adult occupants over sediment**	**0.011**	**<0.005**	**-**	**0.010**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers[c]	0.013	<0.005	-	0.010	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	0.005	-	<0.005	-
Heysham							
'Total dose' - all sources	**Adult occupants over sediment**	**0.016**	**<0.005**	**<0.005**	**0.016**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers	0.022	0.007	-	0.015	-	-
	Turf cutters	<0.005	-	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	0.005	-	<0.005	-	<0.005	-
Hinkley Point							
'Total dose' - all sources	**Prenatal children of occupants over sediment**	**0.015**	**<0.005**	**<0.005**	**0.015**	**-**	**-**
Source specific doses	Seafood consumers	0.010	<0.005	-	0.009	-	-
	Infant inhabitants and consumers of locally grown food	0.007	-	0.007	-	<0.005	-
Hunterston							
'Total dose' - all sources	**Prenatal children of local inhabitants (0.5 -1km)**	**<0.005**	**-**	**<0.005**	**<0.005**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	0.007	-	0.007	-	<0.005	-
Sizewell							
'Total dose' - all sources	**Adult occupants over sediment**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**<0.005**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Torness							
'Total dose' - all sources	**Prenatal children of wild fruit and nut consumers**	**0.006**	**<0.005**	**0.006**	**<0.005**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	0.006	-	0.006	-	<0.005	-

Table 4.1 continued

Site	Representative person[a]	Exposure, mSv per year					
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or shoreline	Gaseous plume related pathways	Direct radiation from site
Decommissioning sites							
Berkeley and Oldbury							
'Total dose' - all sources	**Infant milk consumers**	**0.006**	**-**	**0.006**	**-**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Houseboat occupants	0.009	-	-	0.009	-	-
	Infant inhabitants and consumers of locally grown food	0.007	-	0.007	-	<0.005	-
Bradwell							
'Total dose' - all sources	**Adult houseboat occupants**	**<0.005**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Chapelcross							
'Total dose' - all sources	**Infant milk consumers**	**0.009**	**<0.005**	**0.009**	**<0.005**	**-**	**-**
Source specific doses	Fish, mollusc and wildfowl consumers	<0.005	<0.005	-	<0.005	-	-
	Crustacean consumers	<0.005	<0.005	-	-	-	-
	Infant inhabitants and consumers of locally grown food	0.007	-	0.007	-	<0.005	-
Dungeness							
'Total dose' - all sources	**Local adult inhabitants (0.25 - 0.5km)**	**0.011**	**<0.005**	**<0.005**	**<0.005**	**<0.005**	**0.010**
Source specific doses	Seafood consumers	0.006	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-
Trawsfynydd							
'Total dose' - all sources	**Adult occupants over sediment**	**0.009**	**<0.005**	**-**	**0.007**	**<0.005**	**<0.005**
Source specific doses	Anglers	0.008	<0.005	-	0.007	-	-
	Infant inhabitants and consumers of locally grown food	0.038	-	0.038	-	<0.005	-
Wylfa							
'Total dose' - all sources	**Infant local inhabitants (0.25-0.5km)**	**0.014**	**-**	**<0.005**	**-**	**<0.005**	**0.013**
Source specific doses	Seafood consumers	0.008	<0.005	-	<0.005	-	-
	Infant inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	<0.005	-

[a] The 'total dose' is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.
The 'total dose' for the representative person with the highest dose is presented.
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the 'total dose' assessment.
The representative person is an adult unless otherwise stated
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv

[b] Doses ('total dose' and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)

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

Table 4.2 (a). Concentrations of radionuclides in food and the environment near Hartlepool nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{99}Tc	^{131}I	^{137}Cs	^{210}Pb
Marine samples										
Plaice	Pipeline	1	<25	<25	26	<0.04		*	0.13	
Crabs	Pipeline	1	<25	30	23	<0.08		*	<0.07	
Winkles	South Gare	2	<25	<26	19	<0.12		*	<0.18	1.9
Seaweed	Pilot Station	2[E]				<0.72	2.1	19	<0.54	
Sediment	Old Town Basin	2[E]				<0.53			<0.77	
Sediment	Seaton Carew	2[E]				<0.31			<0.26	
Sediment	Paddy's Hole	2[E]				<0.30			<0.70	
Sediment	North Gare	2[E]				<0.33			<0.26	
Sediment	Greatham Creek	2[E]				<0.53			2.0	
Sediment	Redcar Sands	2[E]				<0.22			<0.19	
Sea coal	Old Town Basin	2[E]				<0.52			<0.45	
Sea coal	Carr House Sands	2[E]				<0.36			1.3	
Seawater[b]	North Gare	2[E]		<4.6		<0.42			<0.34	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{210}Po	^{238}Pu	^{239}Pu+^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Marine samples										
Plaice	Pipeline	1				<0.16				
Crabs	Pipeline	1				<0.17				
Winkles	South Gare	2	12	0.0060	0.046	0.022	*	*		
Seaweed	Pilot Station	2[E]				<0.59				
Sediment	Old Town Basin	2[E]				<1.0				
Sediment	Seaton Carew	2[E]				<0.39				
Sediment	Paddy's Hole	2[E]				<1.2				
Sediment	North Gare	2[E]				<0.40				
Sediment	Greatham Creek	2[E]				<1.0				
Sediment	Redcar Sands	2[E]				<0.75				
Sea coal	Old Town Basin	2[E]				<0.59				
Sea coal	Carr House Sands	2[E]				<1.2				
Seawater[b]	North Gare	2[E]				<0.35			<3.7	14

Table 4.2 (a). continued

Material	Location or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{35}S	^{60}Co	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples										
Milk		2	<2.2	18	<0.29	<0.05	<4.0	<0.04		
Milk	max		<2.3	20	<0.30		<4.9			
Potatoes		1	4.5	27	<0.10	<0.08	<0.11	<0.06		
Barley		1	<5.8	150	<0.30	<0.18	<2.3	<0.15		
Grass	0.8km NW of site	2[E]	<23	5.8	<0.43	<1.1		<0.93		
Grass	0.6km NE of site	2[E]	<16	18	<0.39	<0.70		<0.59		
Freshwater	Boreholes, Dalton Piercy	2[E]	<3.8		<0.15	<0.28		<0.26	<0.17	0.24

* 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 The concentration of ^{35}S was <0.23 Bq l^{-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 4.2(b) Monitoring of radiation dose rates near Hartlepool nuclear power station, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Fish Sands	Sand and stones	2	0.067
Old Town Basin	Sand and sea coal	2	0.070
Carr House	Sand	1	0.058
Carr House	Sand and sea coal	1	0.075
Seaton Carew	Sand	2	0.060
North Gare	Sand	2	0.062
Paddy's Hole	Sand and pebbles	1	0.15
Paddy's Hole	Sand and stones	1	0.16
Greatham Creek nature reserve	Mud and sand	2	0.077
Redcar Sands	Sand	1	0.055
Redcar Sands	Sand and stones	1	0.060

Table 4.3(a) Concentrations of radionuclides in food and the environment near Heysham nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic							
			^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples										
Flounder	Morecambe	2	<25	<30	43	<0.06	<0.036	<0.16	3.9	0.00048
Shrimps	Morecambe	1	<25	<25	29	<0.04	0.035	0.33	1.3	0.0018
Cockles[b]	Middleton Sands	2	25	<25	34	<0.06	0.072	3.0	1.2	0.22
Mussels[c]	Morecambe	2	<25	<25	44	<0.10	0.10	35	0.64	0.24
Wildfowl	Morecambe	1				<0.06			0.31	
Seaweed[d]	Half Moon Bay	2[E]				<0.98		130	2.9	
Sediment	Half Moon Bay	2[E]				<0.67			92	11
Sediment	Potts' Corner	2[E]				<0.41			17	
Sediment	Morecambe central beach	2[E]				<0.30			9.5	
Sediment	Red Nab Point	2[E]				<0.46			66	
Sediment	Shore adjacent to Northern Outfall	2[E]				<0.45			37	
Seawater[e]	Shore adjacent to Northern Outfall	2[E]		11		<0.33			<0.27	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic						
			^{239}Pu+^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Marine samples									
Flounder	Morecambe	2	0.0031		0.0063	0.000048	0.000018		
Shrimps	Morecambe	1	0.013		0.022	*	0.00041		
Cockles[b]	Middleton Sands	2	1.4	4.7	4.2	*	*		60
Mussels[c]	Morecambe	2	1.4	5.4	3.2	*	*		62
Wildfowl	Morecambe	1			<0.15				
Seaweed[d]	Half Moon Bay	2[E]			<1.6				
Sediment	Half Moon Bay	2[E]	68		200				
Sediment	Potts' Corner	2[E]			24				
Sediment	Morecambe central beach	2[E]			12				
Sediment	Red Nab Point	2[E]			99				
Sediment	Shore adjacent to Northern Outfall	2[E]			65				
Seawater[e]	Shore adjacent to Northern Outfall	2[E]			<0.50			<4.9	14

Table 4.3(a) continued

Material	Location or selection[f]	No. of sampling observations[g]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<2.4	18	<0.23	<0.03	<0.07		
Milk	max		<2.7	19			0.10		
Beetroot		1	<2.6	20	<0.20	<0.05	<0.04		
Silage		1	<1.8	29	<0.30	<0.11	<0.20		
Grass	Half Moon Bay, recreation ground	2[E]	<19	<14	<0.47	<1.2	<1.0		
Grass	Overton	2[E]	<17	<11	<0.66	<1.4	<1.0		
Freshwater	Damas Gill reservoir	2[E]	<3.7	<1.9	<0.12	<0.29	<0.26	<0.026	0.046
Freshwater	Lower Halton Weir	2[E]	<3.9	<1.8	<0.12	<0.44	<0.34	<0.029	0.055

* 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. The concentration of ^{210}Po was 40 Bq kg^{-1}

d. The concentrations of ^{35}S was <2.2 Bq kg^{-1}

e. The concentrations of ^{35}S was <0.19 Bq kg^{-1}

f. 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

g. 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 Heysham nuclear power stations, 2022

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sand Gate Marsh	Salt marsh	2	0.076
Arnside 2	Salt marsh	2	0.077
Morecambe central beach	Sand	2	0.068
Half Moon Bay	Mud and sand	1	0.075
Half Moon Bay	Sand	1	0.078
Pipeline	Mud and sand	1	0.069
Pipeline	Sand	1	0.071
Red Nab point	Sand	1	0.081
Red Nab point	Sand and stones	1	0.074
Middleton Sands	Sand	2	0.071
Sunderland Point	Mud and sand	2	0.085
Colloway Marsh	Salt marsh	2	0.095
Lancaster	Grass	1	0.073
Lancaster	Salt marsh	1	0.068
Aldcliffe Marsh	Salt marsh	2	0.079
Conder Green	Salt marsh	2	0.074

Table 4.4(a) Concentrations of radionuclides in food and the environment near Hinkley Point nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic							
			^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu
Marine samples										
Grey Mullet	Stolford	1			31	<0.05			0.08	
Shrimps	Stolford	1	<25	33	31	<0.10			0.11	0.00014
Limpets	Stolford	1	<25	35	20	<0.08			<0.07	
European Oyster	Stolford	1	<25	<25	11	<0.04			<0.04	
Seaweed	Pipeline	2^E				<0.90		0.70	<0.63	
Sediment	Pipeline	2^E				<0.50	<0.87		1.8	
Sediment	Stolford	2^E				<0.63	<0.92		8.1	
Sediment	Steart Flats	2^E				<0.65	<1.0		7.4	
Sediment	River Parrett	1^E				<0.64	<0.94		13	
Sediment	River Parrett Central 2	2^E				<0.54	<0.96		7.7	
Sediment	Weston-Super-Mare	2^E				<0.36	<1.1		0.62	
Sediment	Burnham-On-Sea	2^E				<0.36	<0.81		0.78	
Sediment	Kilve	2^E				<0.41	<1.1		0.72	
Sediment	Helwell Bay	1^E				<0.53	<0.97		<0.60	
Sediment	Blue Anchor Bay	2^E				<0.31	<0.84		<0.65	
Seawater	Pipeline	1^E		<3.7		<0.29	<0.060		<0.25	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			Organic					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples								
Grey Mullet	Stolford	1		<0.07				
Shrimps	Stolford	1	0.00053	0.00073	*	*		
Limpets	Stolford	1		<0.12				
European Oyster	Stolford	1		<0.32				
Seaweed	Pipeline	2^E		<1.2				
Sediment	Pipeline	2^E		<0.98				
Sediment	Stolford	2^E		<0.75				
Sediment	Steart Flats	2^E		<0.71				
Sediment	River Parrett	1^E		<1.4				
Sediment	River Parrett Central 2	2^E		<1.1				
Sediment	Weston-Super-Mare	2^E		<0.75				
Sediment	Burnham-On-Sea	2^E		<0.45				
Sediment	Kilve	2^E		<0.86				
Sediment	Helwell Bay	1^E		<0.91				
Sediment	Blue Anchor Bay	2^E		<0.95				
Seawater	Pipeline	1^E		<0.48			<3.4	14

Table 4.4(a) continued

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<2.3	22	<0.25	<0.05	<0.04		
Milk	max		<2.5	24	<0.30				
Blackberries		1	<3.8	27	<0.20	<0.03	<0.02		
Honey		1	<3.6	110	<0.20	<0.04	<0.04		
Wheat		1	<12	130	<0.20	<0.10	<0.10		
Grass	Gunter's Grove	2^E	<22	16		<2.0	<1.5		
Grass	Wall Common	2^E	<23	25		<2.1	<1.8		
Freshwater	Durleigh Reservoir	2^E	<3.8		<0.14	<0.33	<0.27	<0.035	0.13
Freshwater	Ashford Reservoir	2^E	<3.7		<0.13	<0.31	<0.26	<0.041	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

[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 Hinkley Point nuclear power stations, 2022

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weston-super-Mare	Sand	1	0.061
Weston-super-Mare	Sand and mud	1	0.064
Burnham-on-Sea	Sand	2	0.057
River Parrett	Mud	2	0.076
River Parrett Bridgwater Central 2	Mud	1	0.076
River Parrett Bridgwater Central 2	Mud and reeds	1	0.071
Steart Flats	Mud	2	0.067
Stolford	Mud	1	0.060
Stolford	Mud and rock	1	0.082
Pipeline	Rock and shingle	2	0.081
Kilve	Mud and rock	1	0.074
Kilve	Sand and rock	1	0.11
Helwell Bay	Sand and rock	1	0.091
Helwell Bay	Mud and rock	1	0.082
Blue Anchor Bay	Pebbles and shingle	1	0.064
Blue Anchor Bay	Sand	1	0.069

Table 4.5(a) Concentrations of radionuclides in food and the environment near Hunterston nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{35}S	^{54}Mn	^{60}Co	^{95}Nb	^{99}Tc
Marine samples								
Cod	Millport	2			<0.10	<0.10	<0.16	
Hake	Millport	2			<0.10	<0.10	<0.19	
Crabs	Millport	2			<0.10	<0.10	<0.10	<0.18
Nephrops	Millport	2			<0.10	<0.10	<0.10	
Lobsters	Largs	1			<0.10	<0.10	<0.10	7.6
Squat lobsters	Largs	2			<0.10	<0.10	<0.12	3.3
Scallops	Largs	2			<0.10	<0.10	<0.13	
Oysters	Hunterston	1			<0.10	<0.10	<0.10	
Winkles	Hunterston	2			<0.10	<0.15	<0.47	
Fucus vesiculosus	N of pipeline	2			<0.10	<0.12	<0.32	
Fucus vesiculosus	S of pipeline	2			<0.10	<0.13	<0.53	
Sediment	Largs	1			<0.10	<0.10	<0.13	
Sediment	Millport	1			<0.10	<0.10	<0.10	
Sediment	Gull's Walk	1			<0.10	<0.10	<0.15	
Sediment	Ardneil Bay	1			<0.10	<0.10	<0.10	
Sediment	Fairlie	1			<0.10	<0.10	<0.33	
Sediment	Pipeline	1			<0.10	<0.10	<0.11	
Sediment	Ardrossan North Bay	1			<0.10	<0.10	<0.15	
Sediment	Ardrossan South Bay	1			<0.10	<0.10	<0.15	
Seawater	Pipeline	2	<0.10	<1.1	<0.10	<0.10	<0.10	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{110m}Ag	^{137}Cs	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am
Marine samples								
Cod	Millport	2	<0.10	0.61	<0.12			<0.10
Hake	Millport	2	<0.10	0.49	<0.12			<0.10
Crabs	Millport	2	<0.10	<0.10	<0.10	0.0069	0.039	0.022
Nephrops	Millport	2	<0.10	0.21	<0.10			<0.10
Lobsters	Largs	1	<0.10	0.16	<0.10			<0.10
Squat lobsters	Largs	2	<0.10	0.16	<0.10	0.0087	0.035	0.047
Scallops	Largs	2	<0.10	<0.10	<0.11	0.022	0.12	0.17
Oysters	Hunterston	1	<0.10	<0.10	<0.10			<0.10
Winkles	Hunterston	2	<0.10	0.25	<0.15	0.034	0.15	0.079
Fucus vesiculosus	N of pipeline	2	<0.10	0.31	<0.12			<0.11
Fucus vesiculosus	S of pipeline	2	<0.11	0.28	<0.16			<0.11
Sediment	Largs	1	<0.10	2.6	<0.24			0.50
Sediment	Millport	1	<0.10	2.4	<0.17			0.20
Sediment	Gull's Walk	1	<0.10	11	0.36			1.1
Sediment	Ardneil Bay	1	<0.18	1.6	<0.16			<0.18
Sediment	Fairlie	1	<0.10	3.7	<0.18			<0.18
Sediment	Pipeline	1	<0.10	2.0	0.31			0.29
Sediment	Ardrossan North Bay	1	<0.10	2.0	0.48			0.31
Sediment	Ardrossan South Bay	1	<0.10	2.0	<0.24			0.92
Seawater	Pipeline	2	<0.10	<0.10	<0.10			<0.10

Table 4.5(a) continued

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{95}Nb	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples												
Milk		2	<5.0	<16	<0.50	<0.10	<0.12	<0.05		<0.05		
Milk	max			<17								
Apple		2	<5.0	<15	<0.50	<0.10	<0.23	<0.05		<0.06		
	max						<0.28					
Beef		1	<5.0	33	<0.50	<0.10	<0.10	0.07		<0.11		
Cabbage		1	<5.0	<15	<0.50	<0.10	<0.05	<0.05		<0.05		
Carrots		1	<5.0	<15	<0.50	<0.10	<0.17	<0.05		<0.06		
Cauliflower		1	<5.0	<15	<0.50	<0.10	<0.27	<0.05		<0.06		
Honey		1	<5.0	75	<0.56	<0.10	<0.05	0.60		<0.11		
Lamb		1	<5.0	38	2.6	<0.10	<0.09	0.14		<0.10		
Onions		1	<5.0	<15	<0.50	<0.10	<0.12	<0.05		<0.05		
Potatoes		2	<5.0	<15	<0.50	<0.10	<0.18	<0.05		<0.06		
Potatoes	max						<0.22					
Rosehips		1	<5.0	22	<0.50	0.16	<0.19	0.07		<0.14		
Turnips		1	<5.0	<15	0.73	<0.10	<0.08	<0.05		<0.05		
Venison		1	<5.0	30	<0.50	<0.10	<0.41	1.7		<0.11		
Grass		6	<5.0	<19	<1.2	<0.16	<0.16	<0.07	<0.09	<0.09	6.9	700
Grass	max			27	2.0	0.27	<0.24	0.10	<0.14	<0.14	23	2200
Soil		3	<5.0	<15	<1.4	0.35	<0.20	7.8	0.71	<0.21	150	1200
Soil	max				<1.6	0.37	<0.26	9.2	0.77	<0.24	180	1500
Freshwater	Busbie Muir	1	<1.0				<0.01	<0.01		<0.01	<0.010	0.040
Freshwater	Loch Ascog	1	<1.1				<0.01	<0.01		<0.01	<0.010	0.072
Freshwater	Camphill	1	<1.0				<0.02	<0.01		<0.01	<0.010	0.036
Freshwater	Knockendon Reservoir	1	<1.1				<0.01	0.02		<0.01	<0.010	0.064
Freshwater	Outerwards	1	<1.0				<0.01	<0.01		<0.01	<0.010	0.019

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

Table 4.5(b) Monitoring of radiation dose rates near Hunterston nuclear power stations, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Meigle Bay	Sediment	2	0.054
Largs Bay	Rocks	2	0.062
Millport	Sediment	2	<0.048
Kilchattan Bay	Sediment	2	<0.047
Gull's Walk	Sediment	2	0.059
Hunterston	Sediment	2	<0.050
0.5 km north of pipeline	Sediment	2	0.057
0.5 km south of pipeline	Sediment	2	0.059
Ardneil Bay	Sediment	2	<0.047
Ardrossan North Bay	Sand	1	<0.047
Ardrossan North Bay	Sediment	1	0.048
Ardrossan South Bay	Sand	1	<0.047
Ardrossan South Bay	Sediment	1	<0.047
Milstonford	Grass	1	0.056
Biglies	Grass	1	0.069
Carlung House	Grass	1	0.055
Beta dose rates			**µSv h^{-1}**
Millport	Sediment	2	<1.0
0.5km north of pipeline	Sediment	1	<1.0
0.5 km south of pipeline	Sediment	1	<1.0

Table 4.5(c) Radioactivity in air near Hunterston nuclear power stations, 2022

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}			
		^{131}I	^{137}Cs	Gross alpha	Gross beta
Fairlie	12	<0.010	<0.010	<0.020	<0.22
West Kilbride	12	<0.010	<0.010	<0.017	<0.20
Low Ballees	12	<0.025	<0.010	0.025	<0.23

Table 4.6(a) Concentrations of radionuclides in food and the environment near Sizewell nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}											
			Organic											
			^{3}H	^{3}H	^{14}C	^{90}Sr	^{137}Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples														
Seabass	Sizewell	1	<25	<25			0.22			<0.17				
Sole	Sizewell	1	<25	<25			0.07			<0.14				
Oysters	Butley Creek	1			12		<0.04	0.00090	0.0053	0.0021	*	0.000025		
Crabs	Sizewell	1	<25	<25			<0.05			<0.31				
Sediment	Aldeburgh	2[E]				<1.4	<0.33			<0.46				
Sediment	Southwold harbour	2[E]				<1.1	4.1			<1.1				1100
Sediment	Minsmere river outfall	2[E]				<1.1	2.3			<0.85				
Seawater	Sizewell beach	2[E]		<3.7	<7.4		<0.21			<0.59			<6.2	12

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples								
Milk		2	<2.5	19	<0.23	<0.04		
Milk	max		<2.9	21	<0.25	<0.05		
Carrots		1	<2.2	17	<0.20	<0.04		
Wheat		1	<3.8	93	1.6	<0.03		
Grass	Sizewell belts	2[E]	<20	23		<1.2		
Grass	Sizewell common	2[E]	<24	46		<2.3		
Freshwater	Minsmere nature reserve	2[E]	<3.8		<0.12	<0.17	<0.032	0.35
Freshwater	The Meare	2[E]	<3.9		<0.11	<0.25	<0.035	0.37
Freshwater	Leisure Park	2[E]	<3.7		<0.12	<0.32	<0.065	0.40
Freshwater	Farm Reservoir	1[E]	<3.7		<0.12	<0.24	<0.048	0.15

[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 4.6(b) Monitoring of radiation dose rates near Sizewell nuclear power stations, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sizewell beach	Sand and pebbles	1	0.046
Sizewell beach	Sand and shingle	1	0.058
Dunwich	Sand and shingle	2	0.049
Aldeburgh	Sand and shingle	2	0.048
Southwold harbour	Mud and salt marsh	2	0.063

Table 4.7(a) Concentrations of radionuclides in food and the environment near Torness nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{14}C	^{54}Mn	^{60}Co	^{99}Tc	^{110m}Ag	^{137}Cs
Marine samples								
Cod	White Sands	2		<0.10	<0.10		<0.10	0.21
Mackerel	Pipeline	2		<0.10	<0.10		<0.10	<0.10
Crabs	Torness	1	30	<0.10	<0.10	<0.38	<0.10	<0.10
Lobsters	Torness	1	23	<0.10	<0.10	1.1	<0.14	<0.10
Nephrops	Dunbar	2		<0.11	<0.10		<0.13	<0.10
Winkles	Pipeline	2		<0.21	0.52		2.7	<0.17
Fucus vesiculosus	Pipeline	2		<0.10	0.30		<0.11	<0.15
Fucus vesiculosus	Thorntonloch	2		<0.10	0.3	12	<0.14	<0.11
Fucus vesiculosus	White Sands	2		<0.10	<0.10		<0.10	<0.10
Fucus vesiculosus	Coldingham Bay	2		<0.10	<0.10		<0.10	0.14
Fucus vesiculosus	Pease Bay	2		<0.10	<0.10		<0.10	<0.12
Sediment	Dunbar	1		<0.10	<0.10		<0.10	0.91
Sediment	Barns Ness	1		<0.10	<0.10		<0.10	1.3
Sediment	Thorntonloch	1		<0.10	<0.10		<0.10	0.78
Sediment	Heckies Hole	1		<0.10	<0.10		<0.12	0.84
Sediment	Belhaven Bay	1		<0.10	<0.10		<0.10	0.26
Sediment	Coldingham Bay	1		<0.10	<0.10		<0.10	0.68
Sediment	Pease Bay	1		<0.10	<0.10		<0.10	0.99
Seawater[b]	Pipeline	2		<0.10	<0.10		<0.10	<0.10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Marine samples								
Cod	White Sands	2	<0.10			<0.11		
Mackerel	Pipeline	2	<0.11			<0.11		
Crabs	Torness	1	<0.10			<0.10		
Lobsters	Torness	1	<0.17			<0.10		
Nephrops	Dunbar	2	<0.19	0.00065	0.0053	0.0079		
Winkles	Pipeline	2	<0.21			<0.12	3.3	160
Fucus vesiculosus	Pipeline	2	<0.12			<0.10		
Fucus vesiculosus	Thorntonloch	2	<0.14			<0.12		
Fucus vesiculosus	White Sands	2	<0.14			<0.11		
Fucus vesiculosus	Coldingham Bay	2	<0.12			<0.11		
Fucus vesiculosus	Pease Bay	2	<0.13			<0.11		
Sediment	Dunbar	1	<0.17			<0.25		
Sediment	Barns Ness	1	0.70			<0.28		
Sediment	Thorntonloch	1	0.23			0.34		
Sediment	Heckies Hole	1	0.71			<0.39		
Sediment	Belhaven Bay	1	<0.20			<0.20		
Sediment	Coldingham Bay	1	0.64			<0.21		
Sediment	Pease Bay	1	0.54			<0.22		
Seawater[b]	Pipeline	2	<0.10			<0.10		

Table 4.7(a) continued

Material	Location or selection[c]	No. of sampling observations[d]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}											
			Organic ^{3}H	^{14}C	^{35}S	^{60}Co	^{90}Sr	^{95}Nb	^{110m}Ag	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples														
Milk		2	<5.0	<15	<0.60	<0.05	<0.10	<0.09	<0.05	<0.05		<0.05		
Milk	max			<16	<0.69					<0.06				
Apples		1	<5.0	<15	<0.50	<0.05	<0.10	<0.21	<0.05	<0.05		<0.05		
Beetroot		1	<5.0	<15	<0.50	<0.05	<0.10	<0.21	<0.05	<0.05		<0.05		
Brussel Sprouts		1	<5.0	<15	<0.50	<0.05	0.12	<0.06	<0.05	<0.05		<0.07		
Cabbage		1	<5.0	<15	<0.50	<0.05	<0.10	<0.06	<0.05	<0.05		<0.09		
Carrots		1	<5.0	<15	<0.50	<0.05	0.14	<0.47	<0.06	<0.05		<0.05		
Chicken		1	<5.0	20	<0.50	<0.05	<0.10	<0.08	<0.05	<0.05		<0.07		
Eggs		1	<5.0	27	<0.50	<0.05	<0.10	<0.36	<0.06	<0.05		<0.05		
Goose		1	<5.0	24	<0.50	<0.05	<0.10	<0.12	<0.05	<0.05		<0.07		
Partridge		1	<5.0	<16	<0.59	<0.05	<0.10	<0.07	<0.05	0.06		<0.11		
Pheasant		1	<5.0	26	<0.57	<0.05	<0.10	<0.05	<0.05	<0.05		<0.05		
Rosehips		1	<5.0	41	<0.50	<0.05	0.15	<0.16	<0.05	<0.05		<0.09		
Turnips		1	<5.0	<15	<0.50	<0.05	0.13	<0.18	<0.05	<0.05		<0.05		
Venison		1	<5.0	<15	<0.50	<0.05	<0.10	<0.16	<0.05	0.08		<0.11		
Wild Mushrooms		1	<5.0	<15	<0.50	<0.05	0.10	<0.34	<0.05	0.05		<0.05		
Grass		6	<5.0	<22	<0.68	<0.06	<0.12	<0.29	<0.06	<0.05	<0.11	<0.07	1.9	250
Grass	max			27	<1.6		0.17	<0.39	<0.07	<0.06	<0.15	<0.09	2.1	310
Soil		3	<5.0	<15	<2.4	<0.07	0.83	<0.51	<0.13	6.8	1.3	0.45	190	1400
Soil	max				<3.7	<0.09	1.4	<0.73	<0.16	9.0	1.6	0.55	210	1600
Freshwater	Hopes Reservoir	1	1.4			<0.01		<0.01	<0.01	<0.01		<0.01	0.013	0.016
Freshwater	Thorter's Reservoir	1	<1.0			<0.01		<0.01	<0.01	<0.01		<0.01	<0.010	0.044
Freshwater	Whiteadder	1	<1.0			<0.01		<0.01	<0.01	<0.01		<0.01	<0.010	0.029
Freshwater	Thornton Loch Burn	1	<1.0			<0.01		<0.01	<0.01	<0.01		<0.01	0.014	0.10

[a] Except for milk and seawater where units are Bq l^{-1} and for sediment where dry concentrations apply
[b] The concentrations of ^{3}H and ^{35}S were 13 Bq l^{-1} and <0.50 Bq l^{-1} respectively
[c] Data are arithmetic means unless stated as 'max' in this column. 'Max' data are selected to be maxima. If no 'max' value is given the mean value is the most appropriate for dose assessments
[d] The number of farms from which milk is sampled. The number of analyses is greater than this and depends on the bulking regime

Table 4.7(b) Monitoring of radiation dose rates near Torness nuclear power station, 2022

Location	Ground type	No. of sampling observations	$\mu Gy\ h^{-1}$
Mean gamma dose rates at 1m over substrate			
Heckies Hole	Sediment	2	0.063
Dunbar Inner Harbour	Sediment	2	0.084
Belhaven Bay	Sediment	2	<0.047
Barns Ness	Sediment	2	<0.051
Skateraw	Sediment	2	0.050
Thorntonloch	Sediment	1	0.069
Thorntonloch beach	Sediment	2	<0.053
Ferneylea	Grass	1	0.067
Pease Bay	Sediment	2	0.050
St Abbs Head	Rocks	2	0.080
Coldingham Bay	Sediment	2	0.050
West Meikle Pinkerton	Grass	1	0.059
Mean beta dose rates on fishing gear			**$\mu Sv\ h^{-1}$**
Torness	Sediment	2	<1.0

Table 4.7(c) Radioactivity in air near Torness nuclear power station, 2022

Location	No. of sampling observations	Mean radioactivity concentration, $mBq\ m^{-3}$				
		^{60}Co	^{131}I	^{137}Cs	Gross alpha	Gross beta
Innerwick	12	<0.010	<0.025	<0.010	0.013	<0.20
Cockburnspath	4	<0.010	<0.044	<0.010	0.016	<0.20
West Barns	3	<0.010	<0.095	<0.011	<0.024	<0.24

Table 4.8(a) Concentrations of radionuclides in food and the environment near Berkeley and Oldbury nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], $Bq\ kg^{-1}$					
			^{3}H	^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$
Marine samples								
Salmon	Beachley	1				0.19		
Elvers	River Severn	1				<0.07		
Mullet	Severn Beach	1	<25			0.13		
Shrimps	Guscar	2	<25	21		0.08	0.00014	0.0017
Seaweed	2km south west of Berkeley	2[E]			0.63	<0.67		
Sediment	0.5km south of Oldbury	2[E]				12		
Sediment	2km south west of Berkeley	2[E]				12		
Sediment	Sharpness	2[E]				11		
Sediment	Ledges	2[E]				9.3		
Seawater	2km south west of Berkeley	2[E]	<3.7			<0.25		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], $Bq\ kg^{-1}$				
			^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples							
Salmon	Beachley	1	<0.31				
Elvers	River Severn	1	<0.25				
Mullet	Severn Beach	1	<0.19				
Shrimps	Guscar	2	0.0017	*	0.000019		
Seaweed	2km south west of Berkeley	2[E]	<0.72				
Sediment	0.5km south of Oldbury	2[E]	<1.2				
Sediment	2km south west of Berkeley	2[E]	<0.85				
Sediment	Sharpness	2[E]	<0.85				
Sediment	Ledges	2[E]	<1.6				
Seawater	2km south west of Berkeley	2[E]	<0.38			<2.8	8.2

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], $Bq\ kg^{-1}$					
			^{3}H	^{14}C	^{35}S	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples								
Milk		4	<2.9	21	<0.31	<0.04		
Milk	max		<3.9	25	<0.43			
Potatoes		1	<3.5	23	<0.20	0.75		
Wheat		1	<3.5	71	<0.20	<0.11		
Freshwater	Gloucester and Sharpness Canal	2[E]	<3.8		<0.13	<0.28	<0.048	0.22

* Not detected by the method used

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

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

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

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

Table 4.8(b) Monitoring of radiation dose rates near Berkeley and Oldbury nuclear power stations, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
0.5km south of Oldbury	Mud	1	0.074
0.5km south of Oldbury	Mud and salt marsh	1	0.070
2km south west of Berkeley	Mud	1	0.073
2km south west of Berkeley	Mud and salt marsh	1	0.067
Guscar Rocks	Mud	1	0.072
Guscar Rocks	Mud and salt marsh	1	0.082
Lydney Rocks	Mud	1	0.086
Lydney Rocks	Mud and salt marsh	1	0.075
Sharpness	Mud	1	0.076
Sharpness	Mud and salt marsh	1	0.067
Ledges	Mud	1	0.071
Ledges	Mud and salt marsh	1	0.071

Table 4.9(a) Concentrations of radionuclides in food and the environment near Bradwell nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}										
			^{3}H	^{90}Sr	^{99}Tc	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marine samples													
Skate	Pipeline	1				<0.06			<0.17				
Lobster	West Mersea	1				<0.05			<0.19				
Pacific oysters	Blackwater Estuary	1				<0.05	0.00025	0.0014	0.00079	0.000057	0.000018		
Samphire	Tollesbury	1			<0.072	<0.10			<0.17				
Seaweed	Waterside	2[E]			0.96	<0.62			<0.62				
Seaweed	West Mersea	1[E]			<0.098	<0.43			<0.70				
Sediment	Pipeline	2[E]				<4.7			<0.53				
Sediment	Waterside	2[E]				3.2			<1.4				
Sediment	N side Blackwater Estuary	2[E]				3.6			<0.78				
Sediment	Maldon Harbour	2[E]				6.5			<0.72				
Sediment	West Mersea Beach Huts	2[E]				0.75			<0.97				
Sediment	West Mersea Boatyard	2[E]				1.8			<0.68				
Seawater	Pipeline	2[E]	<3.8			<0.29			<0.33			<3.5	12

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{90}Sr	^{137}Cs	^{241}Am	Gross alpha	Gross beta
Terrestrial samples									
Milk		2	<3.0	20		<0.04	<0.23		
Milk	max		<3.3	21			<0.28		
Cabbage		1	<2.0	17		<0.06	<0.80		
Lucerne		1	<2.3	20		<0.03	<0.08		
Freshwater	Coastal ditch, between power station and shore	1[E]	<3.8		<0.034	<0.31		<0.77	3.4
Freshwater	Coastal ditch, east face of sector building	1[E]	<4.0			<0.17		<0.64	3.7
Freshwater	Coastal ditch, east face of turbine hall	1[E]	<4.0		0.72	<0.24		<1.2	4.9
Freshwater	Coastal ditch, drain pit overflow	1[E]	<3.8			<0.25		<1.2	5.4

* 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 4.9(b) Monitoring of radiation dose rates near Bradwell nuclear power station, 2022

Location	Ground type	No. of sampling observations	µGy h-1
Mean gamma dose rates at 1m over substrate			
Bradwell Beach	Mud and silt	1	0.066
Bradwell Beach	Sand and shells	1	0.050
Bradwell Beach opposite power station N side of estuary	Mud and salt marsh	2	0.066
Waterside	Mud and stones	1	0.052
Waterside	Mud and silt	1	0.060
Maldon Harbour	Mud and salt marsh	2	0.059
West Mersea Beach Huts	Mud	1	0.053
West Mersea Beach Huts	Mud and shells	1	0.053
SE of West Mersea boatyard	Mud and silt	2	0.061

Table 4.10(a) Concentrations of radionuclides in food and the environment near Chapelcross nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg-1								
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{95}Zr	^{99}Tc	^{106}Ru	^{110m}Ag	^{125}Sb
Marine samples											
Shrimps	Annan	2	<5.0		<0.10	<0.10	<0.16	<0.096	<0.35	<0.10	<0.10
Salmon	Annan	1	<5.0		<0.10		<0.24		<0.40	<0.10	<0.11
Trout	Annan	1	<5.0		<0.10		<0.23		<0.39	<0.10	<0.10
Mussels	North Solway	2	<5.0	19	<0.10	0.19	<0.40	21	<0.84	<0.15	<0.26
Fucus vesiculosus	Pipeline	4			<0.10		<0.29	31	<0.57	<0.13	<0.18
Fucus vesiculosus	Browhouses	2			<0.10		<0.31	23	<0.54	<0.13	<0.18
Fucus vesiculosus	Dornoch Brow	2			<0.10		<0.26	31	<0.50	<0.12	<0.15
Sediment	Priestside Bank	1			<0.10		<0.16		<0.57	<0.10	<0.19
Sediment	Pipeline	4	<5.0		<0.17		<0.18		<0.65	<0.11	<0.24
Sediment	Dornoch Brow	1			<0.10		<0.10		<0.46	<0.10	<0.18
Sediment	Powfoot	1			<0.10		<0.15		<0.52	<0.10	<0.18
Sediment	Redkirk	1			<0.10		<0.15		<0.53	<0.10	<0.18
Sediment	Stormont	1			<0.10		<0.24		<0.77	<0.14	<0.25
Seawater	Pipeline	2	<1.4		<0.10		<0.10		<0.24	<0.10	<0.10

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg-1							
			^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Marine samples										
Shrimps	Annan	2	<0.10	<0.10	<0.10	0.0041	0.012	0.022		
Salmon	Annan	1	0.52	<0.10	<0.12			<0.12		
Trout	Annan	1	0.12	<0.10	<0.11			<0.12		
Mussels	North Solway	2	0.82	<0.12	<0.18	0.24	1.7	3.1		
Fucus vesiculosus	Pipeline	4	6.3	<0.11	<0.26	0.90	4.9	8.2	16	440
Fucus vesiculosus	Browhouses	2	6.4	<0.11	<0.28	0.84	4.5	8.8	18	430
Fucus vesiculosus	Dornoch Brow	2	12	<0.10	<0.29	0.94	6.5	11	29	660
Sediment	Priestside Bank	1	20	<0.14	0.50	1.6	10	17		
Sediment	Pipeline	4	73	<0.23	<0.77	17	100	220		
Sediment	Dornoch Brow	1	39	<0.14	<0.24	2.2	13	7.3		
Sediment	Powfoot	1	24	<0.14	0.86	2.8	15	23		
Sediment	Redkirk	1	21	<0.15	0.55	1.5	14	22		
Sediment	Stormont	1	29	<0.20	0.78	2.8	21	32		
Seawater	Pipeline	2	<0.10	<0.10	<0.10			<0.10		

Table 4.10(a) continued

Material	Location or selection[c]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg-1										
			^{3}H	^{14}C	^{35}S	^{90}Sr	^{95}Nb	^{106}Ru	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Terrestrial Samples													
Milk		10	<5.5	<15	<0.53	<0.10	<0.10	<0.17	<0.05		<0.05		
Milk	max		10		<0.66	<0.12	<0.13	<0.23					
Apples		2	<5.0	<16	<0.50	<0.10	<0.17	<0.28	<0.05		<0.06		
	max			17			<0.26	<0.35			<0.07		
Beef		1	<5.0	<15	<0.50	<0.10	<0.05	<0.29	0.11		<0.10		
Cabbage		1	<5.0	<15	<0.50	<0.10	<0.05	<0.23	<0.05		<0.10		
Carrots		1	<5.0	<15	<0.50	0.13	<0.07	<0.28	0.09		<0.05		
Eggs		1	<5.0	18	<0.50	<0.10	<0.11	<0.30	0.06		<0.05		
Leeks		1	<5.0	<15	<0.50	<0.10	<0.11	<0.25	<0.05		<0.08		
Onions		2	<5.0	<15	<0.50	<0.10	<0.17	<0.36	<0.05		<0.06		
	max						<0.21	<0.48			<0.08		
Pears		1	<5.0	17	<0.50	<0.10	<0.15	<0.36	<0.05		<0.05		
Pork		1	<5.0	39	<0.50	<0.10	<0.12	<0.22	<0.05		<0.07		
Potatoes		1	<5.0	17	<0.50	<0.10	<0.07	<0.20	<0.05		<0.08		
Rosehips		1	<5.0	20	<0.50	<0.10	<0.26	<0.34	0.55		<0.10		
Turnips		1	<5.0	<15	<0.50	<0.10	<0.32	<0.41	<0.05		<0.05		
Grass		4	<5.0	<15	<0.50	<0.14	<0.15	<0.17	<0.06	<0.05	<0.05	2.4	320
Grass	max					0.16	<0.16	<0.18	0.10	<0.06	<0.06	4.9	440
Soil		4	<5.0	<15	<1.6	0.91	<0.65	<2.0	8.0	1.5	<0.33	230	1600
Soil	max					1.1	<0.98	<5.2	9.0	1.7	<0.49	240	1900
Freshwater	Purdomstone	1	<1.0				<0.01	<0.03	<0.01		<0.01	<0.010	0.043
Freshwater	Winterhope	1	<1.0				<0.01	<0.03	<0.01		<0.01	<0.010	0.027
Freshwater	Black Esk	1	1.1				<0.01	<0.03	<0.01		<0.01	<0.010	0.037
Freshwater	Gullielands Burn	1	21				<0.01	<0.03	<0.01		<0.01	0.019	0.20

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 4.10(b) Monitoring of radiation dose rates near Chapelcross nuclear power station, 2022

Location	Material or ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Glencaple Harbour	Sediment	2	0.066
Priestside Bank	Sediment	2	0.061
Powfoot Merse	Sediment	2	0.061
Gullielands	Grass	1	0.066
Seafield	Sediment	2	0.065
Woodhead	Grass	1	0.066
East Bretton	Grass	1	0.054
Pipeline	Salt marsh	2	0.070
Pipeline	Sediment	2	0.071
Dumbretton	Grass	1	0.062
Battlehill	Sediment	2	0.071
Dornoch Brow	Sediment	2	0.072
Dornoch Brow Merse	Salt marsh	2	0.072
Browhouses	Sediment	2	0.072
Redkirk	Sediment	2	0.067
Stormont	Sediment	2	0.063
Mean beta dose rates			μSv h^{-1}
Pipeline	Fishing nets	3	<1.0
Pipeline	Fishing net posts	1	<1.0
500m east of pipeline	Sediment	1	<1.0
500m west of pipeline	Sediment	1	<1.0

Table 4.10(c) Radioactivity in air near Chapelcross nuclear power station, 2022

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}			
		^{131}I	^{137}Cs	Gross alpha	Gross beta
Eastriggs	11	<0.024	<0.010	0.023	0.25
Kirtlebridge	8	<0.016	<0.010	0.025	<0.24
Brydekirk	8	<0.021	<0.010	0.034	0.29

Table 4.11(a). Concentrations of radionuclides in food and the environment near Dungeness nuclear power stations, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic						
			^{3}H	^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{137}Cs
Marine samples									
Cod	Pipeline	1	<25	<25		<0.07			<0.12
Sole	Pipeline	1	<25	<25		<0.05			<0.04
Crabs	Pipeline	1	<25	<25		<0.09			<0.08
Scallop	Pipeline	1	<25	<25	22	<0.07	<0.034		<0.06
Sea kale	Dungeness Beach	1				<0.05			0.11
Seaweed	Folkestone Harbour	2[E]				<0.52		<0.30	<0.37
Sediment	Rye Harbour	2[E]				<0.43			<0.36
Sediment	Camber Sands	2[E]				<0.33			<0.26
Sediment	Pilot Sands	2[E]				<0.24			<0.20
Seawater	Dungeness South	2[E]		<3.9		<0.27			<0.26

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Marine samples									
Cod	Pipeline	1			<0.17				
Sole	Pipeline	1			<0.10				
Crabs	Pipeline	1			<0.29				
Scallop	Pipeline	1	0.00055	0.0034	0.0015	*	0.000056		
Sea kale	Dungeness Beach	1			<0.17				
Seaweed	Folkestone Harbour	2[E]			<0.66				
Sediment	Rye Harbour	2[E]	<0.17	<0.32	<0.76				720
Sediment	Camber Sands	2[E]			<0.60				
Sediment	Pilot Sands	2[E]			<0.73				
Seawater	Dungeness South	2[E]			<0.41			<2.9	13

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{3}H	^{14}C	^{35}S	^{60}Co	^{137}Cs	Gross alpha	Gross beta
Terrestrial Samples									
Milk		2	<2.4	16	<0.50	<0.05	<0.04		
Milk	max		<2.5	18	0.63				
Potato		1	6.7	27	<0.10	<0.03	<0.03		
Grass		1	<8.8	86	<1.3	<0.49	<0.47		
Grass	Lydd	2[E]	<20	26		<2.0	<1.6		
Grass	Denge Marsh	2[E]	<17	<27		<2.4	<1.7		
Freshwater	Long Pits	2[E]	<3.8		<0.11	<0.35	<0.31	<0.026	0.12
Freshwater	Pumping station Well number 1	1[E]	<4.0		<0.14	<0.20	<0.17	<0.029	0.11
Freshwater	Pumping station Well number 2	1[E]	<3.8		<0.12	<0.25	<0.25	<0.025	0.25
Freshwater	Reservoir	1[E]	<3.7		<0.12	<0.17	<0.17	<0.024	0.13

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

Table 4.11(b) Monitoring of radiation dose rates near Dungeness nuclear power stations, 2022

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Littlestone on Sea	Sand and pebbles	1	0.052
Littlestone on Sea	Sand and shingle	1	0.047
Greatstone on Sea	Sand	1	0.050
Greatstone on Sea	Sand and silt	1	0.061
Pilot Sands	Sand and pebbles	1	0.052
Pilot Sands	Sand and silt	1	0.047
Dungeness West	Shingle	2	0.046
Jury's Gap	Sand and pebbles	1	0.054
Jury's Gap	Sand and silt	1	0.057
Rye Bay	Sand	1	0.059
Rye Bay	Sand and silt	1	0.052

Table 4.12(a) Concentrations of radionuclides in food and the environment near Trawsfynydd nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{60}Co	^{90}Sr	^{137}Cs	^{238}Pu
Freshwater samples								
Rainbow trout	Trawsfynydd Lake	2		<13	<0.09	0.27	0.56	0.000017
Sediment	Lake shore near café	2[E]			<0.38	<1.0	200	<0.22
Sediment	1.5km SE of power station	2[E]			<0.44	<0.98	130	<0.31
Sediment	Pipeline	2[E]			<0.54	<1.2	180	<0.29
Sediment	SE of footbridge	2[E]			<0.63	<0.99	100	<0.22
Sediment	Cae Adda	2[E]			<0.47	<0.95	16	<0.30
Freshwater	Pipeline	2[E]	<3.4		<0.36		<0.31	
Freshwater	Gwylan Stream	2[E]	<3.4		<0.42		<0.34	
Freshwater	Afon Prysor	2[E]	<3.4		<0.27		<0.24	
Freshwater	1.5km SE of power station	2[E]	<3.4		<0.06		<0.06	
Freshwater	Afon Tafarn-helyg	2[E]	<3.5		<0.27		<0.24	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross alpha	Gross beta
Freshwater samples								
Rainbow trout	Trawsfynydd Lake	2	0.000071	0.00010	*	*		
Sediment	Lake shore near café	2[E]	<0.32	<0.79				
Sediment	1.5km SE of power station	2[E]	<0.34	<0.88				
Sediment	Pipeline	2[E]	<1.0	2.5				
Sediment	SE of footbridge	2[E]	<0.30	<0.88				
Sediment	Cae Adda	2[E]	<0.35	<0.83				
Freshwater	Pipeline	2[E]					<0.021	0.039
Freshwater	Gwylan Stream	2[E]					<0.018	0.061
Freshwater	Afon Prysor	2[E]					<0.020	0.038
Freshwater	1.5km SE of power station	2[E]					<0.020	0.040
Freshwater	Afon Tafarn-helyg	2[E]					<0.021	0.034

Table 4.12(a) Continued

Material	Selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{14}C	^{90}Sr	^{137}Cs	Total Cs	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am
Terrestrial samples										
Milk		2	<2.9	18	<0.037	<0.06	<0.056			<0.24
Milk	max		<3.5	19	0.051	<0.07	<0.075			<0.28
Potatoes		1	<1.7	41		0.11		0.000014	0.00020	0.00024
Grass		1	<3.4	110		1.9		<0.00010	0.0013	0.00095

* 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 4.12(b) Monitoring of radiation dose rates near Trawsfynydd nuclear power station, 2022

Location	Ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Lake shore (pipeline)	Rock and stones	1	0.084
Lake shore (pipeline)	Stones	1	0.084
Lake shore (SE of footbridge)	Stones	2	0.090
Lake shore (1.5km SE)	Grass and stones	1	0.083
Lake shore (1.5km SE)	Stones	1	0.078
Cae Adda	Stones	2	0.077
Lake shore	Pebbles and stones	1	0.082
Lake shore	Stones	1	0.085

Table 4.13(a) Concentrations of radionuclides in food and the environment near Wylfa nuclear power station, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	^{239}Pu+^{240}Pu
Marine samples									
Plaice	Pipeline	1	<25	<25	33		0.58		
Crabs	Pipeline	1	<25	<25	40		0.38		
Lobsters	Pipeline	1	<25	<25	39	18	0.31	0.0067	0.040
Winkles	Cemaes Bay	1	<25	<25	22	4.5	0.14	0.020	0.15
Seaweed	Cemaes Bay	2[E]				14	<0.72		
Sediment	Cemaes Bay	2[E]					3.0		
Sediment	Cemlyn Bay East	2[E]					0.79		
Sediment	Cemlyn Bay West	2[E]					3.0		
Seawater	Cemaes Bay	2[E]		<3.4			<0.21		

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{241}Pu	^{241}Am	^{242}Cm	^{243}Cm+^{244}Cm	Gross alpha	Gross beta
Marine samples								
Plaice	Pipeline	1		<0.34				
Crabs	Pipeline	1		<0.22				
Lobsters	Pipeline	1	0.12	0.59	*	0.00062		60
Winkles	Cemaes Bay	1	0.35	0.21	*	0.00028		42
Seaweed	Cemaes Bay	2[E]		<0.69				
Sediment	Cemaes Bay	2[E]		1.6				
Sediment	Cemlyn Bay East	2[E]		1.3				
Sediment	Cemlyn Bay West	2[E]		<0.42				
Seawater	Cemaes Bay	2[E]		<0.50			<4.3	13

Material	Location or selection[b]	No. of sampling observations[c]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{14}C	^{35}S	^{137}Cs	^{241}Am
Terrestrial samples							
Milk		2	<3.3	19	<0.34	<0.04	<0.29
Milk	max				0.48		<0.34
Potatoes		1	<2.0	15	<0.10	<0.05	<0.25
Grass		1	<6.7	60	1.0	<0.14	<0.50
Grass	Foel Fawr	2[E]	<18	<10		<0.49	
Grass	Wylfa Head Nature Reserve	2[E]	<17	<14		<0.39	

* 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, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Cemaes Bay	Sand	1	0.059
Cemaes Bay	Sand and rock	1	0.072
Cemlyn Bay East	Sand and shingle	1	0.062
Cemlyn Bay West	Shingle	1	0.072
Porth Yr Ogof	Shingle	2	0.063

5 Research and radiochemical production establishments

Highlights
- 'total doses' (research) for the representative person were less than 3% of the annual dose limit in 2022 (for sites that were assessed)
- 'total doses' (radiochemical production) for the representative person were less than 9% of the annual dose limit in 2022

Dounreay, Highland
- total dose' for the representative person was 0.010mSv and decreased in 2022

GE Healthcare Limited, Grove Centre, Amersham, Buckinghamshire
- 'total dose' for the representative person was 0.086mSv and increased in 2022
- gaseous discharges of radon-222 increased in 2022

Harwell, Oxfordshire
- 'total dose' for the representative person was less than 0.005mSv and unchanged in 2022

Winfrith, Dorset
- 'total dose' for the representative person was 0.028mSv and increased in 2022

Torness, East Lothian
- 'total dose' for the representative person was 0.006mSv and increased in 2022

This section considers the results of monitoring near research establishments (Dounreay, Harwell, Winfrith and 2 minor research sites) and 1 site associated with the radiopharmaceutical industry (Grove Centre, Amersham). One minor research site is considered in this section, the fusion energy research site at Culham which is not a nuclear licensed site.

The NDA owns the licensed nuclear sites at Harwell and Winfrith in England, and Dounreay in Scotland. The Harwell and Winfrith sites, previously operated by RSRL, were re-licensed in 2015 into a single site licensed company and merged to be part of Magnox Limited, also a wholly owned subsidiary of the NDA. In 2022 Dounreay Site Restoration Limited (DSRL) was the site licensed company for Dounreay, responsible for the decommissioning and clean-up of the Dounreay site. On 1st April 2023 Dounreay joined with Magnox Limited.

All the nuclear research 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. Some of this work is carried out by tenants or contractors.

The site at Amersham is operated by GE Healthcare Limited, a company manufacturing radiochemical products for the healthcare and life science research markets. A permit issued by the Environment Agency is in effect at the Amersham site, authorising the discharge of radioactive wastes.

Regular monitoring of the environment was undertaken near all sites to assess the effects of discharges. Independent monitoring of the environment around the sites is conducted by the Environment Agency, FSA and SEPA.

In 2022, gaseous and liquid discharges were below regulated limits for each of the establishments (see Appendix 1, Table A1.1 and Table A1.2). Solid waste transfers in 2022 from nuclear establishments in Scotland (Dounreay) are also given in Appendix 1 (Table A1.4).

5.1 Dounreay, Highland

The Dounreay site was opened in 1955 to develop research reactors. Three reactors were built on the site: the Prototype Fast Reactor, the Dounreay Fast Reactor and the Dounreay Materials Test Reactor. All 3 reactors are now shut down and undergoing decommissioning.

From 2005, the NDA became responsible for the UK's civil nuclear liabilities which included those at Dounreay. Consequently, the 3 existing radioactive waste disposal authorisations were transferred to a new site licensed company (Dounreay Site Restoration Limited, DSRL), before DSRL took over the site management contract. In July 2020, it was announced that DSRL ownership would transfer to the NDA. The official transition of DSRL ownership occurred on 1st of April 2021. On 1st of April 2023 Dounreay joined with Magnox Limited. SEPA transferred all environmental permits falling under its remit from DSRL to Magnox Limited.

In April 2022, DSRL notified SEPA of an incident at a sodium storage facility associated with the Prototype Fast Reactor (PFR) facility. It was established that, during an operation to destroy sodium, there was a very small release of caustic liquid and a release of tritium from an unauthorised and unmonitored route following a tank drainage failure. In September 2022 SEPA issued an Information Notice to DSRL requiring reports detailing a review of the tank drainage and liquid monitoring arrangements. Based on the estimate of the tritium release provided by DSRL, SEPA consider the risk to the public or the environment to be extremely low. SEPA's investigation of the circumstances concluded that DSRL had contravened conditions of its EASR18 radioactive substances authorisation. In January 2023, SEPA issued a Final Warning Letter to DSRL.

In August 2022, SEPA issued a Warning Letter to DSRL. This followed DSRL notifying SEPA that a filter, which is part of the air supply ventilation system for a laundry facility, was not installed. The filter contributes to minimising particulate entering the facility and being entrained with the radioactive discharges. Although there was no harm to the environment as a result of the failure to install the filter, SEPA's investigation of the circumstances concluded that DSRL had contravened conditions of its EASR18 radioactive substances authorisation.

In November 2022, SEPA was notified by DSRL of a potential unplanned release of tritium from an unauthorised and unmonitored route. The source of the potential release was a drum containing sodium with an associated tritium inventory, stored at the PFR facility. Based on the estimate of the tritium release provided by DSRL, SEPA consider the risk to the public or the environment to be extremely low. SEPA's investigation concluded that DSRL had contravened conditions of its EASR18 radioactive substances authorisation. In May 2023, SEPA issued a Warning Letter to DSRL.

In 2022, radioactive waste discharges from the Dounreay site were made by DSRL under an EASR18 radioactive substances authorisation granted by SEPA. The quantities of both gaseous and liquid discharges were generally similar to those releases in recent years (Appendix 1, Table A1.1 and Table A1.2). Solid waste transfers from Dounreay in 2022 are also given in Appendix 1 (Table A1.4).

The most recent habits survey was conducted in 2018 [186]. This habits survey did not identify any occupancy in the area of Oigin's Geo (see Figure 5.2), as an external exposure pathway.

In 2013, SEPA granted an authorisation to DSRL for the Low-Level Radioactive Waste Disposal Facility (LLWF) that is located adjacent to the main Dounreay site. The first phase of the disposal site comprised the construction and operation of 2 concrete vaults that began accepting low level radioactive waste and demolition low level waste from the Dounreay site in 2015. The safety case and planning permission allow for 2 additional construction phases, each comprising 2 vaults. Further phases of construction will be dependent on the progress with the decommissioning of the Dounreay site.

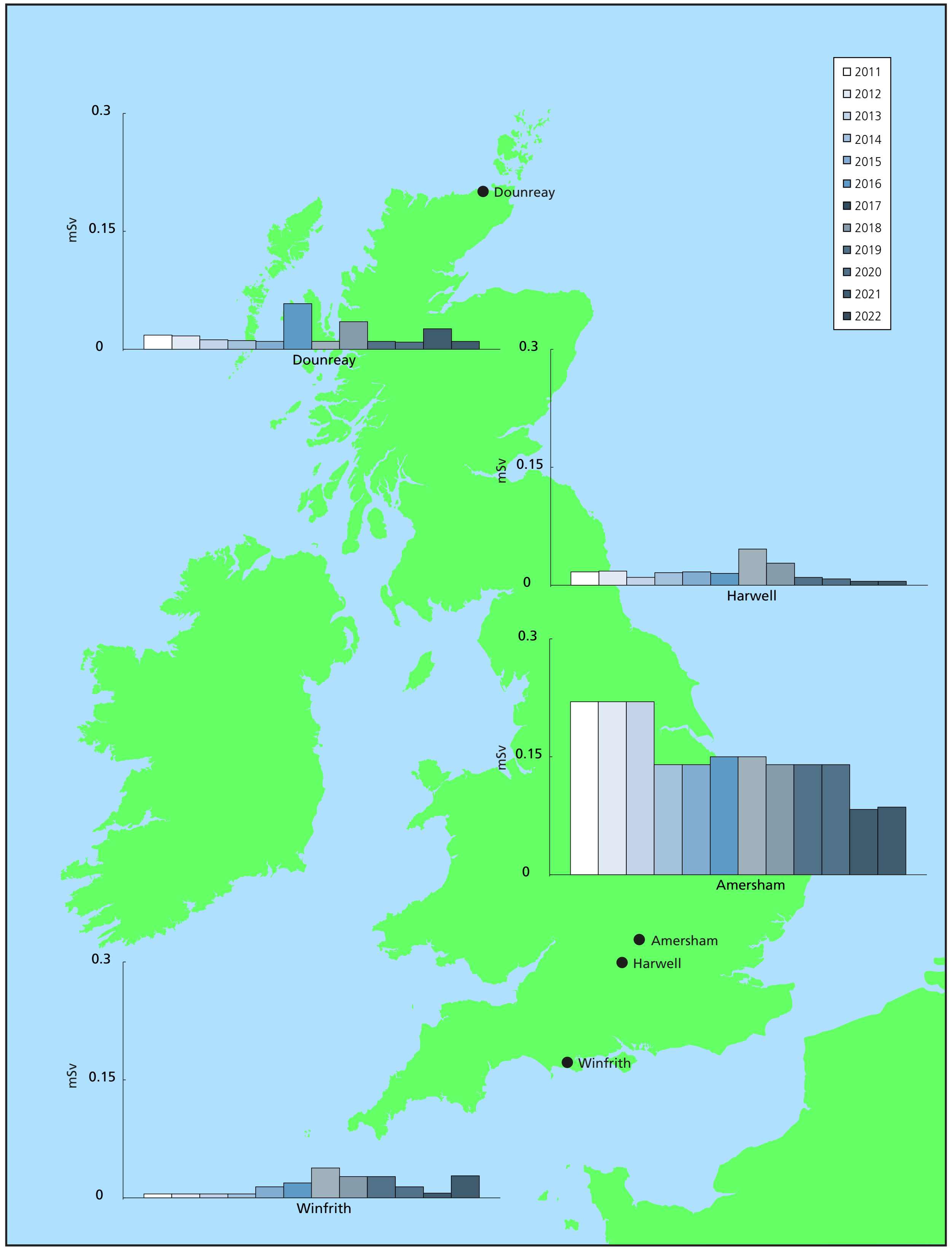
There are no authorised routes for liquid or gaseous discharges from the Dounreay LLWF. The facility is designed to contain the radioactive waste over a long time, allowing radioactive decay to occur while the waste remains isolated from the environment.

Doses to the public

The 'total dose' from all pathways and sources of radiation was 0.010mSv in 2022 (Table 5.1), or 1% of the dose limit, and down from 0.026mSv in 2021. Unlike in recent years, the representative person was adults living near the site (a change from adults consuming game meat at high rates). The decrease in 'total dose' was mostly due to the lack of Cs-137 concentration data in game as samples were not available in 2022.

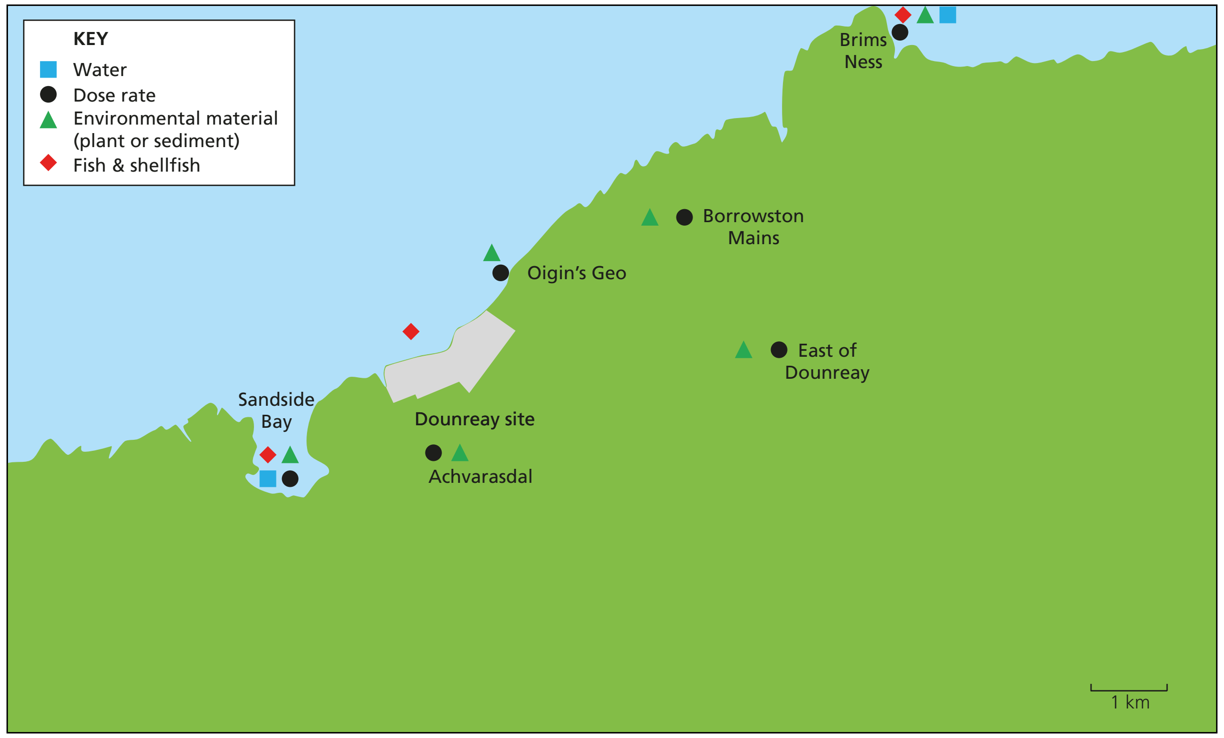
The trend in the annual 'total dose' over the period 2011 to 2022 is given in Figure 5.1. The variations in the earlier years were due to changes in caesium-137 concentrations in game meat and the type of game sampled, but 'total doses' were low. A change in annual 'total dose' between 2013 to 2015 was mostly due to the contribution of goats' milk not being included in the assessment (which has been assessed prior to 2013), as milk samples have not been available in recent years. In 2016, 2018 and 2021, the significant contributor that increased the dose was the concentration of caesium-137 found in venison (game).

Figure 5.1 'Total dose' at research establishments, 2011 to 2022. (Small doses less than or equal to 0.005mSv are recorded as being 0.005mSv).



The annual dose to a consumer of terrestrial foodstuffs was 0.010mSv in 2022, or 1% of the dose limit for members of the public of 1mSv, and down from 0.017mSv in 2021. The reason for the decrease in dose was the same as that contributing to the 'total dose'. As in previous years, adults were identified as the most exposed age group. The annual dose to a consumer of fish and shellfish, including external exposure from occupancy over local beaches, was marginally higher than the 'total dose' in 2022 (0.011mSv) and down from 0.021mSv in 2021. The reason for the decrease in dose was almost entirely due to the lower concentrations of plutonium-239+240 and americium-241 reported in molluscs collected in 2022. The dose (external pathways only) to members of the public visiting Oigin's Geo, based on previously collected habits data [187] and 2019 monitoring data, was less than 0.005mSv. The most recent habits survey was conducted in 2018 [186]. This habits survey did not identify any occupancy in the area of Oigin's Geo, a coastal feature to the east of Dounreay (see Figure 5.2), as an external exposure pathway.

Figure 5.2 Monitoring locations at Dounreay, 2022 (not including farms or air sampling locations).

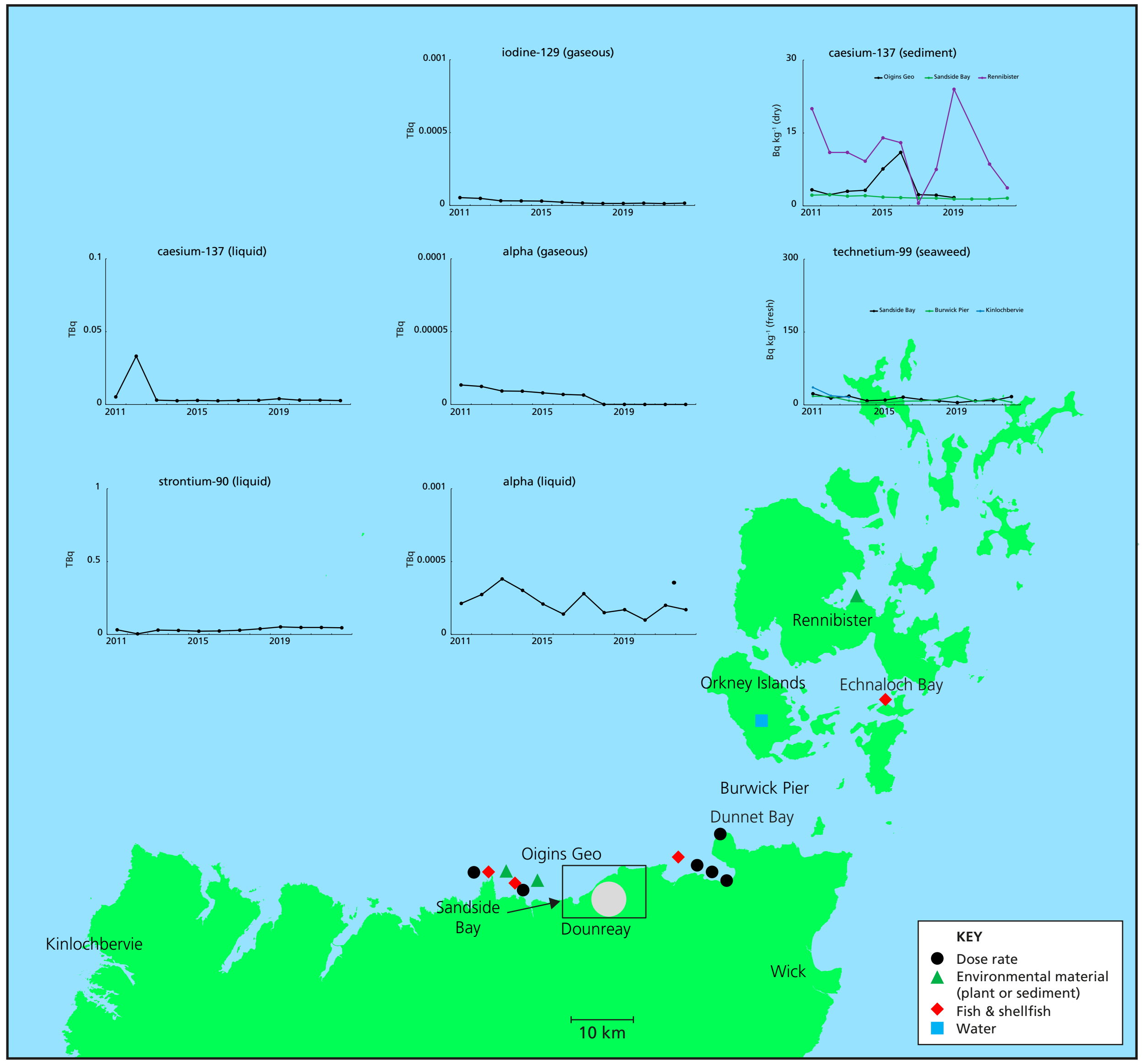


Gaseous discharges and terrestrial monitoring

DSRL is authorised by SEPA to discharge radioactive gaseous wastes to the local environment via stacks to the atmosphere. The discharges also include a minor contribution from the adjoining reactor site (Vulcan naval reactor test establishment (NRTE)), which is operated by the MOD's Submarine Delivery Agency. Monitoring conducted in 2022 included the sampling of air, freshwater, grass, soil and locally grown terrestrial foods including meat (no game) and vegetables as well as wild foods. As there are no dairy cattle herds in the Dounreay area, no milk samples were collected from cattle. As in recent years, goats' milk samples were not sampled, as no milk sample was available in 2022.

The sampling locations for the terrestrial (and marine) monitoring programmes are shown in Figure 5.2 (Dounreay) and Figure 5.3 (north of Scotland). Figure 5.3 also provides time trends of radionuclide discharges (gaseous and liquid). The results for terrestrial samples and radioactivity in air are given in Table 5.2(a) and Table 5.2(c).

Figure 5.3 Monitoring locations, discharges of gaseous and liquid radioactive wastes and monitoring of the environment in the north of Scotland, 2022 (not including farms or air sampling locations). The rectangle around the Dounreay site is the area presented in Figure 5.2.



The concentrations of radionuclides at Dounreay were generally low and relatively similar to those observed in previous years. As in 2021, strontium-90, caesium-137 and americium-241 were positively detected in a few food samples and antimony-125 and iodine-129 concentrations were all reported as less than values in 2022. Activity concentrations in air samples at locations near to the site (Table 5.2(c)) were reported as less than values, apart from gross alpha from the locations near Reay and Balmore (just above the LoD).

In 2022, no game sample was available, however a honey sample was (not collected in 2021). Caesium-137 is likely to be present in terrestrial samples from the Dounreay area due to fallout from weapons testing in the 1960s and from the Chernobyl reactor accident in 1986. Caesium-137 was positively detected in honey but at low concentrations (0.22Bq kg^{-1}) in comparison to those reported in previous years (24, 23 and 38Bq kg^{-1} in 2020, 2019 and 2016, respectively). Earlier RIFE reports have provided results and interpretation of honey monitoring (for example [47]).

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 on-site low level solid waste disposal facility (which operated from 1958 to 2005), and a minor contribution from the adjoining reactor site (Vulcan NRTE).

Routine marine monitoring included sampling of seafood and the measurement of beta and gamma dose rates. Seafood samples from within the zone covered by a FEPA[19] Order are collected under consent granted in 1997 by the Scottish Office and revised in 2011 by the FSS (then FSA in Scotland).

Crab, mussel and winkle samples were collected from areas along the Caithness coastline. Additionally, sediment, seawater and seaweed were sampled in 2022 as indicator materials. The results for marine samples, and gamma and beta dose rates, are given in Table 5.2(a) and Table 5.2(b). Activity concentrations were generally low in 2022 and similar to those in recent years. Technetium-99 concentrations in seaweed remained at the expected levels for this distance from Sellafield and were similar to those in recent years. Figure 5.3 also gives time trend information for technetium-99 concentrations (from Sellafield) in seaweed at Sandside Bay (location shown in Figure 5.2), Kinlochbervie and Burwick. Data indicate a general decline in concentrations over the period at all 3 locations. Overall, gamma dose rates in 2022 were lower than those observed in 2021, apart from those measured over sediment and the winkle bed at Sandside Bay. Beta dose rate measurements were reported as less than values (Table 5.2(b)) in 2022.

During 2022, DSRL continued monitoring of local public beaches, using vehicle mounted detectors, for radioactive fragments in compliance with the requirements of the authorisation granted by SEPA. In 2022, 4 fragments were recovered from Sandside Bay and 15 from the Dounreay foreshore. The caesium-137 activity measured in the fragments recovered from Sandside Bay ranged between 17kBq and 35kBq (similar to ranges observed in recent years).

19. The FEPA Order was made in 1997 following the discovery of fragments of irradiated nuclear fuel on the seabed near Dounreay, by United Kingdom atomic energy authority (UKAEA), and prohibits the collection of seafoods within a 2km radius of the discharge pipeline.

Although there was a relative increase in the number of fragments found on the foreshore in the first three months of 2022, the activities of the fragments found are within the range of those previously found. It should be noted that the foreshore area is physically difficult to access and additionally is an area of extremely low occupancy. No further fragments were found on the foreshore in 2022. The Particles Retrieval Advisory Group (Dounreay) (PRAG(D)) are considering the 2022 recoveries and will report in due course.

Dounreay particle updates are posted on Radioactive particles in the environment around Dounreay - GOV.UK (www.gov.uk) (https://www.gov.uk/government/publications/radioactive-particles-in-the-environment-around-dounreay).

The previously conducted offshore survey work provided data on repopulation rates of particles (fragments) 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 [188]. Since the work of DPAG[20] was concluded, PRAG(D) has published reports in 2010 and 2011 [189,190]. In 2016, PRAG(D) published a further report into the retrieval of offshore particles. This was produced following an extensive research and monitoring programme in 2012 [191]. The report considered the extent and effectiveness of the offshore recovery programme to reduce the numbers of particles. The report concluded that any noticeable change in the rate or radioactive content of the particles arriving on the nearest public beach (Sandside Bay) will take several years to assess and recommended that in the interim the monitoring of local beaches should continue.

In 2007, the FSA reviewed the Dounreay FEPA Order. A risk assessment, that was peer-reviewed by UKHSA, indicated that the food chain risk was very small [192]. The FEPA Order was reviewed with regard to ongoing work to remove radioactive particles from the seabed and the food chain risk. In 2009, the FSA in Scotland (now FSS) announced that the FEPA Order would remain in place and be reviewed again upon completion of the (now completed) seabed remediation work. Following a recommendation in the 2016 PRAG(D) report FSS agreed that the FEPA Order would remain in place and be reviewed following re-evaluation of particle arrival rates.

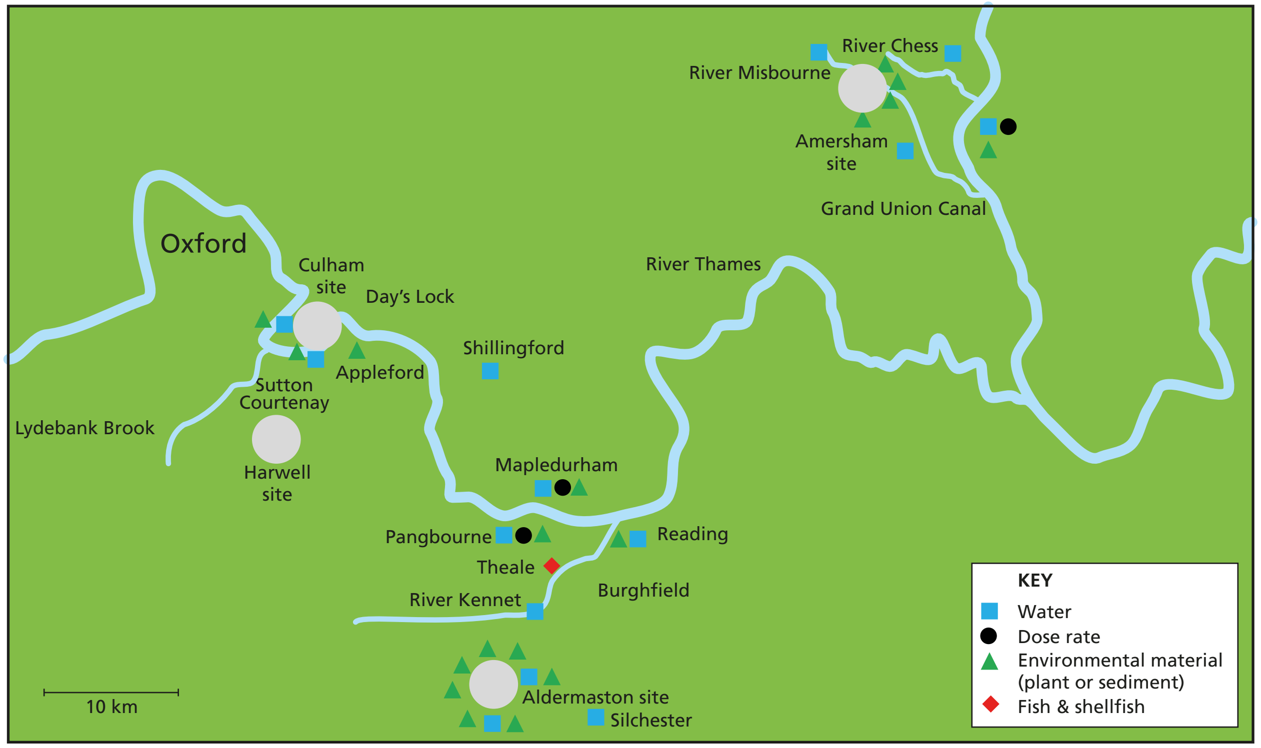
5.2 Grove Centre, Amersham, Buckinghamshire

GE Healthcare Limited's sole remaining nuclear licenced site is located at Amersham, in Buckinghamshire. It consists of a range of plants previously used for manufacturing diagnostic imaging products for use in medicine and research, which are now closed and are being decommissioned.

The monitoring programme consists of analysis of fish, crops, water, sediments and environmental materials, and measurements of gamma dose rates. The monitoring locations are shown in Figure 5.4. The most recent habits survey was undertaken in 2016 [193].

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

Figure 5.4 Monitoring locations at Thames sites, 2022 (not including farms)



Doses to the public

The 'total dose' from all pathways and sources of radiation was conservatively estimated to be 0.086mSv in 2022 (Table 5.1) or less than 9% of the dose limit, and slightly increased from 2021. The dominant contribution to 'total dose' was from direct radiation from stored radioactive waste. The previous dominant contribution (to 'total dose') was from direct radiation associated with radiochemicals manufactured elsewhere and brought to the Grove Centre site for storage and subsequent distribution. The Grove Centre is no longer used as a distribution hub. The representative person was adults living in the vicinity of the site in 2022 and unchanged from 2021. 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 annual 'total dose' over the period 2011 to 2022 is given in Figure 5.1. 'Total doses' remained broadly similar over time (up until 2013) and were dominated by direct radiation. The lower values from 2014 onwards are due to changes in working practices for distribution activities, with products spending less time in the dispatch yard – as well as the construction of a shield wall on the western side of a building that contains legacy radioactive wastes. All distribution activity ceased in 2019. Dose from the site is now dominated by radiation from the waste store. The 'total dose' is expected to be no more than the conservative estimated value of 0.086mSv.

Source specific assessments for a high-rate consumer of locally grown foods, for an angler and for a worker at Maple Lodge Sewage Treatment Works (STW), which serves the sewers to which permitted discharges are made, give exposures that were less than the 'total dose' in 2022 (Table 5.1). The dose for a high-rate consumer of locally grown foods was 0.010mSv in 2022 and up from 2021 (0.006mSv). This increase in dose was mostly due to a higher contribution from the gaseous discharges of radon-222 in 2022. It should be noted that the current assessment methodology uses a conservative dose factor based on this nuclide being in equilibrium with its decay products. As in recent years, the dose to a local angler was less than 0.005mSv in 2022.

The 2016 habits survey at Amersham did not directly identify any consumers of fish, shellfish or freshwater plants. As in previous surveys, however, there were reports of occasional coarse fish and signal crayfish consumption (but no actual consumption rates). To allow for this, a consumption rate of 1kg per year for fish and crayfish has been included in the dose assessment for an angler.

The Grove Centre discharges liquid waste to Maple Lodge STW, and the proximity to raw sewage and sludge experienced by sewage treatment workers is a likely exposure pathway [194]. The dose received by one of these workers was modelled using the methods described in Appendix 3. The dose from a combination of external exposure to contaminated raw sewage and sludge, inadvertent ingestion and inhalation of re-suspended radionuclides was less than 0.005mSv in 2022 and unchanged from recent years.

Gaseous discharges and terrestrial monitoring

The Amersham facility is permitted to discharge gaseous radioactive wastes via stacks on the site. Gaseous discharges of radon-222 increased by an order of magnitude in 2022, in comparison with those in 2021. Increased radon emission in 2022 are believed to be linked to recent changes to the ventilation rate in the glove boxes where radium waste is stored. These changes have been made as part of a project to retrieve and repackage the radium waste, and then decommission the glove boxes. Elevated radium emissions are expected to occur during the retrieval phase, which has an estimated duration of 24 months, and may result in higher annual emissions in 2023 and 2024 than were recorded in 2022. Once retrievals are complete, radon emissions are expected to decrease significantly. The results for the terrestrial monitoring for 2022 are given in Table 5.3(a) and Table 5.3(b). As in 2021, sulphur-35 was positively detected in food (barley) in 2022. As in previous years, caesium-137 was detected in soil near the site and this is likely to be due to fallout from Chernobyl and nuclear weapons testing.

Liquid waste discharges and aquatic monitoring

Radioactive liquid wastes are discharged to sewers serving the Maple Lodge STW; treated effluent subsequently enters the Grand Union Canal and the River Colne. The results of the aquatic monitoring programme for 2022 are given in Table 5.3(a). Activity concentrations in freshwater were mostly reported as less than values in 2022. Samples of effluent and sludge from Maple Lodge STW were collected in 2022 following a 2-year interruption due to the COVID-19 pandemic. The concentration levels observed in these samples were similar to the latest results observed in 2019 [23]. Tritium, gross alpha and gross beta concentrations in water were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51). Gamma dose rates over grass were generally indistinguishable from natural background in 2022 (Table 5.3(b)) and were generally similar to those measured in recent years.

5.3 Harwell, Oxfordshire

The Harwell site was established in 1946 as the UK's first Atomic Energy Research Establishment and is situated approximately 5km southwest of the town of Didcot. Since 2015, the Harwell site has been operated by Magnox Limited on behalf of the NDA. The Harwell nuclear licensed site forms part of Harwell Campus, a science, innovation and business campus. The nuclear licensed site originally accommodated 5 research reactors of various types. Two of the reactors have been completely removed, and the fuel has been removed from the remaining 3 reactors. In 2021, the final remediation work was completed for the decommissioned Liquid Effluent Treatment Plant (LETP) and radiological sampling is now underway to support the permit surrender for this area and the old sewage treatment plant. On completion, this land will be handed back to the Harwell Science Park for future development.

Decommissioning work at the Harwell site is well underway with a project to transfer nuclear materials away from the site expected to be completed by 2025. Intermediate level waste (from Harwell, Winfrith and Culham) will be stored in a designated facility on the Harwell site during a quiescent period of 'care and maintenance'. At the final site clearance stage, the two reactors DIDO and PLUTO are due to be demolished and the remaining radioactive waste transferred to the GDF for final disposal. The most recent habits survey was conducted in 2015 [195].

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv in 2022 (Table 5.1), which was less than 0.5% of the dose limit, and unchanged from 2021. As in 2021, the representative person was prenatal children of adults spending time over sediments. The trend in annual 'total dose' over the period 2011 to 2022 is given in Figure 5.1. The 'total doses' remained broadly similar, from year to year (up to 2016), and were low. The increase in 'total dose' in 2017 (from 2016), and then decrease in 2018, was attributed to changes in the estimate of direct radiation from the site.

As in 2021, source specific assessments for a high-rate consumer of terrestrial foods, and for an angler, give exposures that were also less than 0.005mSv (Table 5.1).

Gaseous discharges and terrestrial monitoring

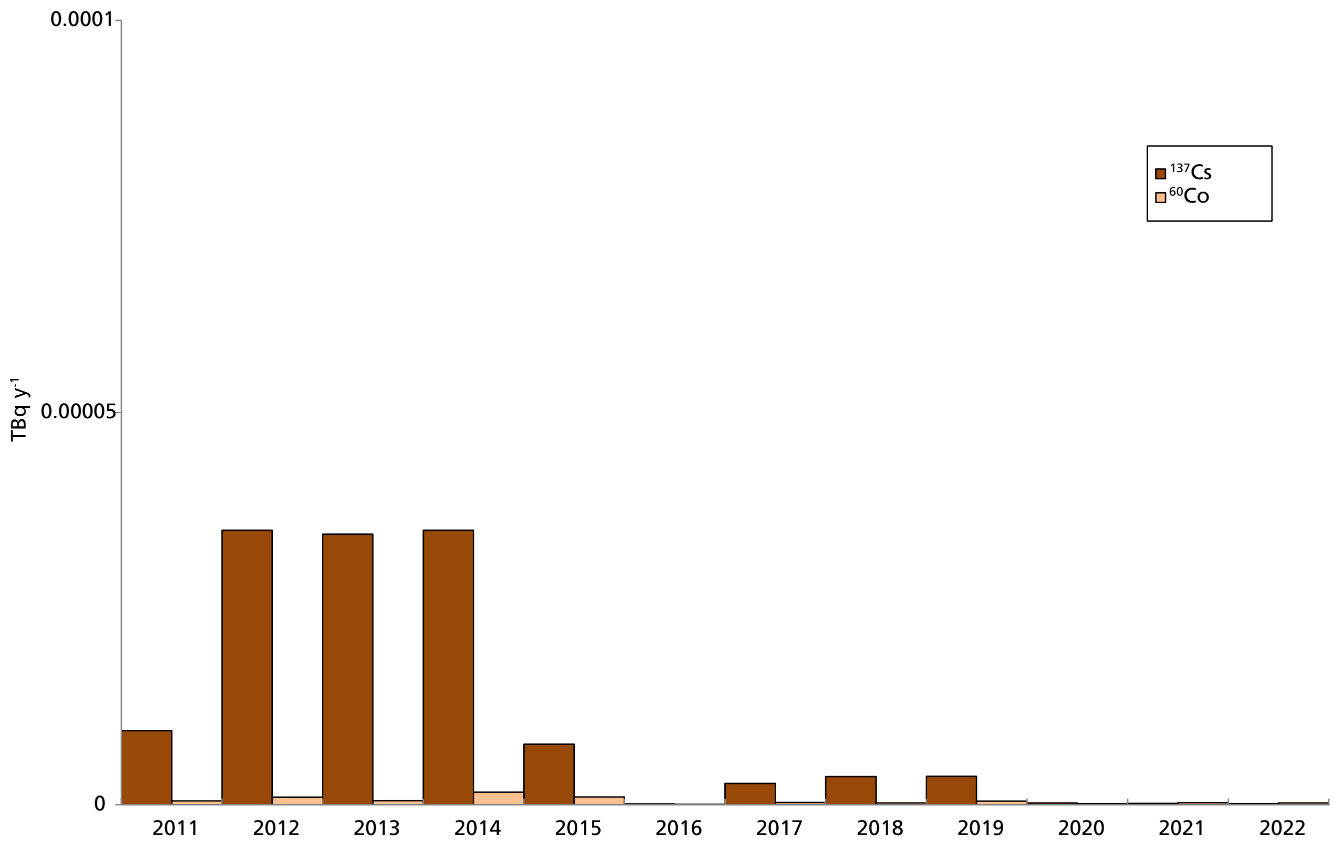
Gaseous wastes are discharged via stacks to the local environment. As in previous years, discharges of radioactive wastes continued at very low rates, with some reported as nil, in 2022. The monitoring programme sampled milk, fruit and cereal. Sampling locations at Harwell and in other parts of the Thames catchment are shown in Figure 5.4. The results of the terrestrial monitoring programme in 2022 are shown in Table 5.4. As in 2021, 2022 tritium and caesium-137 concentrations in terrestrial samples were all reported as less than values.

Liquid waste discharges and aquatic monitoring

Regulated discharges from Harwell are discharged to sewers serving the Didcot STW; treated effluent subsequently enters the River Thames at Long Wittenham. Discharges to the River Thames at Sutton Courtenay ceased in 2013, thereafter the decommissioning of the treated waste effluent discharge point was completed, and the discharge pipeline removed. Further information is available via: https://www.gov.uk/government/publications/decommissioning-of-the-harwell-site-discharge-pipeline.

Discharges of surface water drainage from the Harwell site are made via the Lydebank Brook, north of the site, which is a permitted route. As in recent years, discharges from Lydebank Brook were very low. Figure 5.5 shows trends of discharges over time (2011 to 2022) for cobalt-60 and caesium-137. There was an overall reduction in the discharges over the whole period and very low discharges in most recent years.

Figure 5.5 Trends in liquid discharges of caesium-137 and cobalt-60 from Harwell, Oxfordshire 2011 to 2022



The aquatic monitoring programme is directed at consumers of fish and occupancy (sediment and freshwater samples) close to the liquid discharge point. Due to on-going access issues at Day's Lock, the Environment Agency have replaced this sampling location with River Thames above Shillingford. As in recent years, concentrations of tritium, cobalt-60 and caesium-137 in freshwater were reported as less than values. The caesium-137 concentration in sediment continued to be enhanced above background levels in 2022 but has low radiological impact. As in recent years, plutonium-239+240 was positively detected in the sediment sample collected near Shillingford and the concentrations of all radionuclides in fish (plaice) from the lower reaches of the Thames were reported as less than values in 2022.

5.4 Winfrith, Dorset

The Winfrith site is located near Winfrith Newburgh, Dorset. It was established in 1957 as an experimental reactor research and development site. Since 2015, the Winfrith site has been operated by Magnox Limited on behalf of the NDA. During various times there have been 9 research and development reactors. The last operational reactor at Winfrith closed in 1995. Seven of the reactors have been decommissioned. The final two; steam generating heavy water and 'Dragon' (high temperature gas-cooled) reactors and supporting site facilities, are in the process of being decommissioned. It is the end state intention of Magnox, to return most of the land to a brownfield heathland site with public access.

Magnox Winfrith is located adjacent to the Tradebe-Inutec site. Tradebe-Inutec is an independent nuclear operator (see section 7.3). Magnox Winfrith and Tradebe-Inutec undertake separate site environmental monitoring programmes as required by their respective environmental permits. However, in RIFE, Magnox Winfrith and Tradebe-Inutec are considered together for the purposes of environmental monitoring because, with the exclusion of their liquid discharges (which discharge to different geographic areas), their operational activities and gaseous discharges impact on the same local area.

The most recent habits survey (covering both the Magnox and Tradebe-Inutec sites) was conducted in 2019 [196].

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was 0.028mSv (Table 5.1), or less than 3% of the dose limit, and up from 0.006mSv in 2021. The increase of the dose was almost entirely attributed to a higher estimate of direct radiation from the Magnox Winfrith site in 2022 (Table 1.1). The representative person was adults living near the site and unchanged from 2021. Trends in annual 'total doses' over time are shown in Figure 5.1. At Winfrith, 'total doses' remained broadly similar from year to year (up to 2014) and were generally very low. The variations observed in recent years are mainly due to changes in the estimates of direct radiation from the site. The increase in estimates of 'total dose' at Magnox Winfrith when compared to the previous reporting period, is attributed to the extent of the decommissioning work undertaken at the site during 2022, including removal, temporary storage, and transfer of legacy wastes for off-site disposal. The specific waste transfer activities that occurred during 2022, are time limited in nature, and form part of the routine operational work required to secure the safe decommissioning of the site. Estimates of 'total dose' will fluctuate with operational decommissioning work demands as the site proceeds through to the final stage decommissioning and all radioactive waste management activities cease.

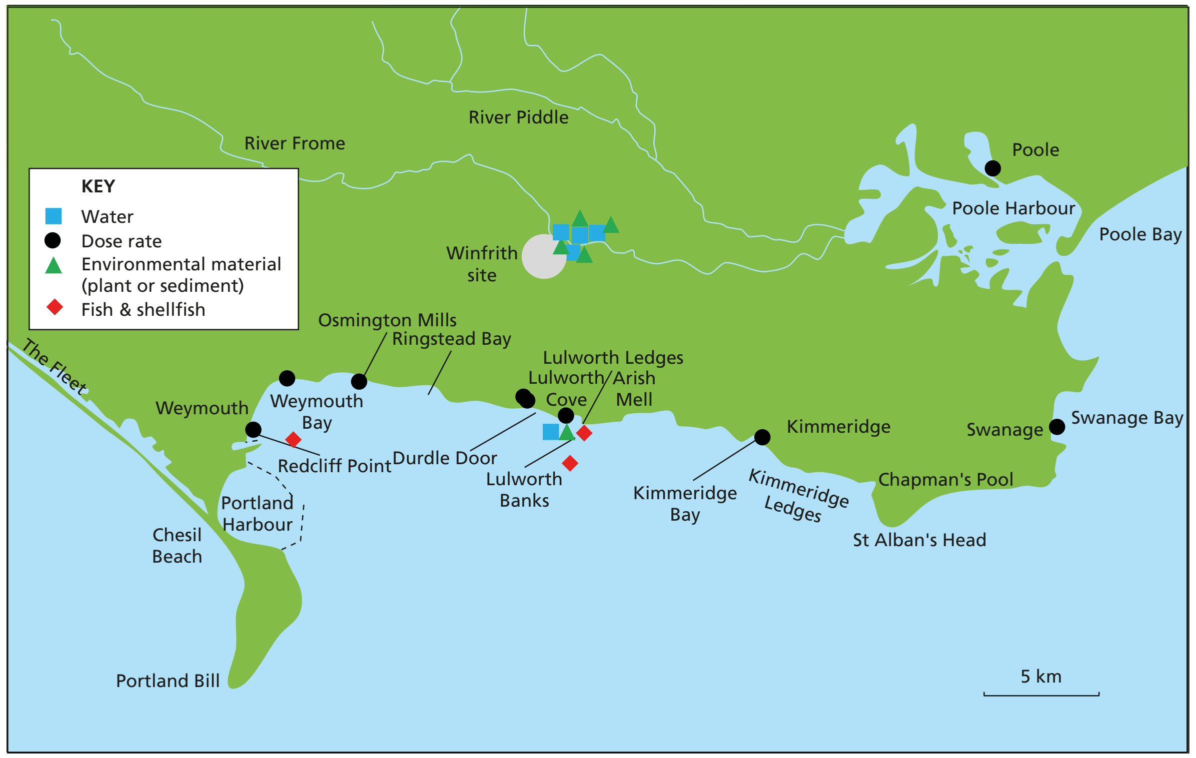
As in 2021, the doses to a high-rate consumer of locally grown food and to a high-rate consumer of fish and shellfish were less than 0.005mSv in 2022.

Gaseous discharges and terrestrial monitoring

At Magnox Winfrith, gaseous radioactive waste is discharged via various stacks to the local environment. As in previous years, discharges were very low in 2022.

The main focus of the terrestrial sampling was the analyses of tritium and carbon-14 in milk and crops. Local freshwater and sediment samples were also analysed. Sampling locations at Winfrith are shown in Figure 5.6. Data for 2022 are given in Table 5.5(a). Results from terrestrial samples provide little indication of an effect due to gaseous discharges. As in recent years, the carbon-14 concentrations in locally produced milk were above values used to represent background concentrations. Low tritium concentrations were measured in surface water to the north of the site, similar to those in previous years. Tritium, gross alpha and gross beta concentrations in freshwater were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

Figure 5.6 Monitoring locations at Winfrith, 2022 (not including farms)

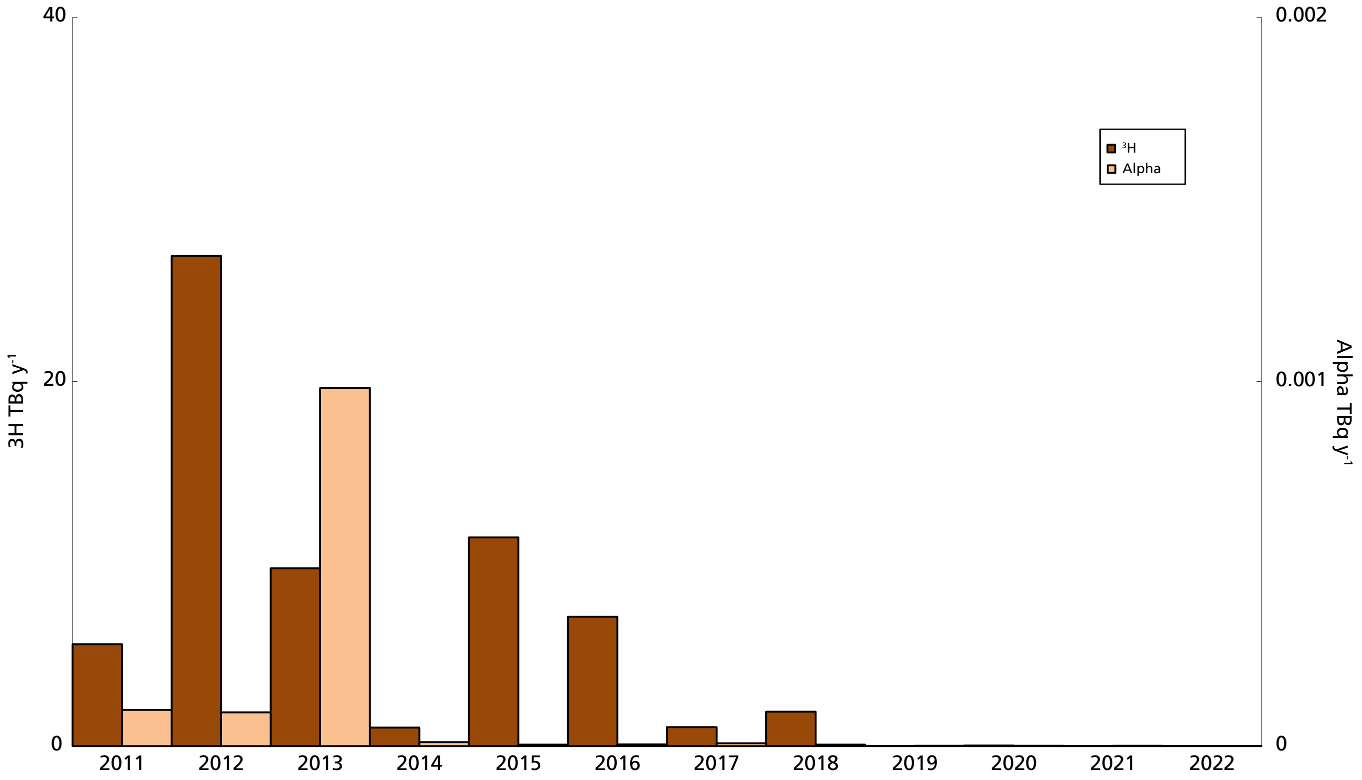


Liquid waste discharges and aquatic monitoring

Liquid wastes, from the Magnox Winfrith site, are disposed via a pipeline to deep water in Weymouth Bay. As in previous years, discharges continued at very low rates in 2022 (reported as <1% of the annual limit or nil).

Figure 5.7 shows trends of liquid discharges over time (2011 to 2022) for tritium and alpha-emitting radionuclides. In recent years, alpha-emitting radionuclide discharges have decreased since the peak observed in 2013. In comparison, tritium discharges have varied more between years, with periodic peaks in releases, due to operations at Tradebe-Inutec, but have also generally declined since 2015.

Figure 5.7 Trends in liquid discharges of tritium and alpha-emitting radionuclides from Winfrith, Dorset 2011 to 2022



Analyses of seafood and marine indicator materials and measurements of external radiation over muddy intertidal areas were conducted. These are primarily to determine the effects of liquid discharges from the Magnox Winfrith site and to a lesser extent, historical (pre-2019) liquid discharges from Tradebe-Inutec. Data for 2022 are given in Table 5.5(a) and Table 5.5(b). Concentrations of radionuclides in the marine environment were low and similar to those in previous years. As in 2021, caesium-137 was positively detected in the fish sample collected from Weymouth Bay (skates and rays). Technetium-99 was also detected in the seaweed sample collected from Bognor Rocks. Gamma dose rates in 2022 were generally similar to those measured in 2021 (where comparison could be made).

5.5 Culham, Oxfordshire

Culham Centre for Fusion Energy (CCFE) operated by the United Kingdom Atomic Energy Authority (UKAEA) is the UK's national laboratory for fusion research. CCFE hosts and is responsible for the operation of two experimental fusion reactors; the Joint European Torus (JET) and the Mega Amp Spherical Tokamak (MAST) Upgrade. The JET operational research programme is due to cease at the end of 2023 followed by a period of decommissioning.

The Culham site also operates several other facilities to support fusion energy and related technologies and should host commercial fusion developers to become a fusion cluster hub in the near future.

An annual 'total dose' is not determined at this site in this report because an integrated habits survey has not been undertaken. As in 2021, the source specific dose (including tritium and caesium-137), from using the River Thames directly as drinking water downstream of the discharge point at Culham, was estimated to be much less than 0.005mSv in 2022 (Table 5.1).

Monitoring of soil and grass around Culham and of sediment and water from the River Thames was undertaken in 2022. Locations and data are shown in Figure 5.4 and Table 5.6, respectively. Historically, the main effect of the site's operation was the increased tritium concentrations found in grass collected near the site perimeter. As in recent years, tritium concentrations in all samples were reported as less than values. Overall, no effects were detected due to site operation. The reported caesium-137 concentration in the downstream sediment (28Bq kg^{-1}) was slightly higher in 2022, in comparison to that in recent years (23 and 19Bq kg^{-1} in 2021 and 2020, respectively). Caesium-137 concentrations in the River Thames sediment are not attributable to Culham but were most likely due to past discharges from Harwell, and fallout from Chernobyl and nuclear weapons testing.

Table 5.1 Individual doses - Research and radiochemical production sites, 2022

Site	Representative person[a]	Exposure, mSv per year						
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks[b]	Intakes of sediment and water[c]	Gaseous plume related pathways	Direct radiation from site
Dounreay								
'Total dose' - all sources	**Adult occupants for direct radiation**	**0.010**	**<0.005**	**-**	**<0.005**	**-**	**<0.005**	**0.010**
Source specific doses	Seafood consumers	0.011	<0.005	-	0.009	-	-	-
	Inhabitants and consumers of locally grown food	0.010	-	0.010	-	-	<0.005	-
Amersham								
'Total dose' - all sources	**Local adult inhabitants (0 - 0.25km)**	**0.086[d]**	**-**	**<0.005**	**<0.005**	**-**	**0.006**	**0.080**
Source specific doses	Anglers	<0.005	<0.005	-	<0.005	-	-	-
	Infant inhabitants and consumers of locally grown food	0.010[d]	-	<0.005	-	-	0.009	-
	Workers at Maple Lodge STW	<0.005	-	-	<0.005[e]	<0.005[f]	-	-
Harwell								
'Total dose' - all sources	**Prenatal children of occupants over riverbank**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Anglers	<0.005	<0.005	-	<0.005	-	-	-
	Infant inhabitants and consumers of locally grown food	<0.005[d]	-	<0.005	-	-	<0.005	-
Winfrith								
'Total dose' - all sources	**Local adult inhabitants (0.5-1km)**	**0.028**	**<0.005**	**<0.005**	**<0.005**	**-**	**<0.005**	**0.028**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-	-
	Infant inhabitants and consumers of locally grown food	0.005	-	0.005	-	-	<0.005	-
Culham								
Source specific dose	Drinkers of river water	<0.005	-	-	-	<0.005	-	-

[a] The 'total dose' is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.
The 'total dose' for the representative person with the highest dose is presented.
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the 'total dose' assessment.
The representative person is an adult unless otherwise stated
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv

[b] Doses ('total dose' and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)

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

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

[e] External radiation from raw sewage and sludge

[f] Intakes of resuspended raw sewage and sludge

Table 5.2(a) Concentrations of radionuclides in food and the environment near Dounreay, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{90}Sr	^{99}Tc	^{125}Sb	^{137}Cs	^{154}Eu	^{155}Eu	^{238}Pu
Marine samples											
Cod	Scrabster	1		<0.10			<0.20	0.20	<0.10	<0.16	0.0042
Crabs	Pipeline	1		<0.10	<0.10	0.19	<0.18	<0.10	<0.10	<0.14	0.24
Crabs	Strathy	2		<0.10			<0.20	<0.10	<0.10	<0.15	0.0072
Crabs	Melvich Bay	2		<0.10		<0.12	<0.18	<0.10	<0.10	<0.12	0.0023
Mussels	Echnaloch Bay	1		<0.11		2.2	<0.27	<0.10	<0.12	<0.19	0.0086
Winkles	Brims Ness	4		<0.10	<0.10		<0.18	<0.10	<0.10	<0.13	0.087
Winkles	Sandside Bay	4		<0.10	<0.10	0.66	<0.21	<0.15	<0.11	<0.15	0.015
Fucus vesiculosus	Brims Ness	4		<0.10			<0.11	<0.10	<0.10	<0.11	
Fucus vesiculosus	Sandside Bay	4		<0.10		17	<0.12	<0.10	<0.10	<0.12	
Fucus vesiculosus	Burwick Pier	4		<0.10		5.5	<0.11	<0.10	<0.10	<0.10	
Sediment	Brims Ness	1		<0.10			<0.15	0.70	<0.13	<0.25	2.0
Sediment	Strathy	1		<0.10			<0.12	0.70	<0.10	<0.19	0.23
Sediment	Melvich Bay	1		<0.10			<0.14	1.1	<0.13	<0.23	0.14
Sediment	Sandside Bay	1		<0.10			<0.12	1.6	<0.11	<0.20	1.8
Sediment	Rennibister	1		<0.10			<0.24	3.7	<0.20	0.66	0.34
Seawater	Brims Ness	2	<1.0	<0.10			<0.10	<0.10	<0.10	<0.10	
Seawater	Sandside Bay	2	<1.0	<0.10			<0.10	<0.10	<0.10	<0.10	

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}			
			^{239}Pu+ ^{240}Pu	^{241}Am	Gross alpha	Gross beta
Marine samples						
Cod	Scrabster	1	0.0013	0.0017		
Crabs	Pipeline	1	0.052	0.39	1.1	180
Crabs	Strathy	2	0.0047	0.0034		
Crabs	Melvich Bay	2	0.0036	0.016		
Mussels	Echnaloch Bay	1	0.070	0.069		
Winkles	Brims Ness	4	0.37	0.44		
Winkles	Sandside Bay	4	0.080	0.081		
Fucus vesiculosus	Brims Ness	4		<0.13	4.7	530
Fucus vesiculosus	Sandside Bay	4		<0.14	5.4	590
Fucus vesiculosus	Burwick Pier	4		<0.10		
Sediment	Brims Ness	1	11	13		
Sediment	Strathy	1	0.82	1.1		
Sediment	Melvich Bay	1	1.1	0.90		
Sediment	Sandside Bay	1	9.7	11		
Sediment	Rennibister	1	2.2	0.55		
Seawater	Brims Ness	2		<0.10		
Seawater	Sandside Bay	2		<0.10		

Research and radiochemical production establishments

Table 5.2(a) continued

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			^{3}H	^{60}Co	^{90}Sr	^{125}Sb	^{129}I	^{137}Cs	^{155}Eu	^{234}U
Terrestrial samples - Annual										
Beef muscle		1	<5.0	<0.05	<0.10	<0.11	<0.050	0.13	<0.10	<0.050
Beef offal		1	<5.0	<0.05	<0.10	<0.06	<0.050	<0.05	<0.07	<0.050
Broccoli		1	<5.0	<0.05	<0.10	<0.07	<0.050	0.05	<0.09	
Cabbage		1	<5.0	<0.05	<0.10	<0.05	<0.050	<0.05	<0.05	
Carrots		1	<5.0	<0.05	<0.10	<0.09	<0.050	<0.05	<0.08	
Cauliflower		1	<5.0	<0.05	<0.10	<0.14		<0.05	<0.10	
Eggs		1	<5.0	<0.05	<0.10	<0.12	<0.050	<0.05	<0.08	
Honey		1	<5.0	<0.05	<0.10	<0.07	<0.20	0.22	<0.09	
Lamb muscle		1	<5.0	0.37	<0.10	<0.18	<0.050	0.44	<0.15	<0.050
Onion		1	<5.0	<0.05	<0.10	<0.12	<0.050	<0.05	<0.10	
Potatoes		1	<5.0	<0.05	<0.10	<0.10	<0.050	<0.05	<0.09	
Rosehips		1	<5.0	<0.05	0.13	<0.13	<0.050	0.25	<0.17	
Rowan Berries		1	<5.0	<0.05	<0.10	<0.09	<0.050	0.06	<0.10	
Swede		1	<5.0	<0.05	0.20	<0.11	<0.050	0.07	<0.08	
Grass		3	<5.0	<0.05	<0.14		<0.088	<0.24	<0.09	<0.25
	max				<0.15		<0.095	0.51	<0.10	<0.52
Soil		3	<5.0	<0.08	0.51		<0.12	15	1.7	27
	max			<0.11	0.56			21	2.1	38
Freshwater	Loch Calder	1	<1.0	<0.01				<0.01		
Freshwater	Loch Shurrery	1	<1.0	<0.01				<0.01		
Freshwater	Loch Baligill	1	<1.0	<0.01				<0.01		
Freshwater	Heldale Water	1	<1.0	<0.01				<0.01		

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Terrestrial samples - Annual									
Beef muscle		1	<0.050	<0.050	<0.050	<0.050	0.050		
Beef offal		1	<0.050	<0.050	<0.050	<0.050	0.050		
Broccoli		1			<0.050	<0.050	0.052		
Cabbage		1			<0.050	<0.050	<0.050		
Carrots		1			<0.050	<0.050	<0.050		
Cauliflower		1			<0.050	<0.050	<0.050		
Eggs		1			<0.050	<0.050	<0.050		
Honey		1			<0.050	<0.050	0.31		
Lamb muscle		1	<0.050	<0.050	<0.050	<0.050	0.050		
Onion		1			<0.050	<0.050	<0.050		
Potatoes		1			<0.050	<0.050	<0.050		
Rosehips		1			<0.050	<0.050	<0.050		
Rowan Berries		1			<0.050	<0.050	0.067		
Swede		1			<0.050	<0.050	<0.050		
Grass		3	<0.051	<0.28	<0.050	<0.051	<0.053		
	max		<0.052	<0.61		<0.054	<0.059		

Table 5.2(a) continued

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{235}U	^{238}U	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Terrestrial samples - Annual									
Soil		3	1.6	26	<0.052	0.39	0.23		
	max		2.9	37	<0.057	0.54	0.29		
Freshwater	Loch Calder	1					<0.01	<0.010	0.053
Freshwater	Loch Shurrery	1					<0.01	0.013	0.044
Freshwater	Loch Baligill	1					<0.01	<0.010	0.043
Freshwater	Heldale Water	1					<0.01	<0.010	0.046

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

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

Table 5.2(b) Monitoring of radiation dose rates near Dounreay, 2022

Location	Material or ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Sandside Bay	Sediment	3	0.082
Sandside Bay	Winkle Bed	1	0.11
Brims Ness	Sediment	2	0.091
Melvich	Salt marsh	2	0.056
Melvich Sands	Sediment	2	0.053
Strathy Sands	Sediment	2	0.051
Thurso riverbank	Grass	1	0.082
Thurso riverbank	Sediment	1	0.067
Achvarasdal	Grass	2	0.074
Thurso Park	Grass	1	0.075
Thurso Park	Sediment	1	0.075
Borrowston Mains	Grass	2	0.074
Castletown Harbour	Sediment	2	0.061
Dunnet Bay	Sediment	2	0.047
Hallam	Grass	2	0.074
Mean beta dose rates			**µSv h^{-1}**
Sandside Bay	Sediment	2	<1.0
Thurso riverbank	Rocks	1	<1.0
Thurso riverbank	Sediment	1	<1.0
Castletown Harbour	Sand	2	<1.0

Table 5.2(c) Radioactivity in air near Dounreay, 2022

Location	No. of sampling observations	Mean radioactivity concentration, mBq m^{-3}			
		^{131}I	^{137}Cs	Gross alpha	Gross beta
Shebster	12	<0.027	<0.010	<0.012	<0.20
Reay	11	<0.064	<0.010	0.013	<0.21
Balmore	9	<0.035	<0.010	0.017	<0.20

Table 5.3(a) Concentrations of radionuclides in food and the environment near Amersham, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}				
			^{3}H	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples - Annual							
Plaice	Woolwich Reach	1	<25	<1.1	<0.04		
Sediment	Upstream of outfall (Grand Union Canal)	2[E]		<1.5	<3.3	<130	290
Sediment	Downstream of outfall (Grand Union Canal)	2[E]		<1.1	3.5	190	400
Freshwater	Downstream of outfall (Grand Union Canal)	1[E]	<3.6	<0.54	<0.12	<0.045	0.69
Freshwater	River Chess	1[E]	<3.6	<0.34	<0.23	<0.046	0.039
Freshwater	River Misbourne - downstream	1[E]	<3.5	<0.40	<0.26	<0.020	0.052
Crude effluent[d]	Maple Lodge Sewage Treatment Works	2[E]	<14		<0.25	<0.084	0.83
Digested sludge[e]	Maple Lodge Sewage Treatment Works	2[E]	<15	1.9	<0.32	4.2	11
Final effluent[f]	Maple Lodge Sewage Treatment Works	2[E]	<13		<0.30	<0.063	0.93

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{35}S	^{131}I	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples - Annual								
Milk		1	<3.1	<0.48	<0.0018	<0.04		
Potato		1	3.2	<0.10		<0.05		
Barley		1	<3.5	1.0		<0.03		
Grass	Orchard next to site	1[E]			<0.96	<1.1	<2.1	210
Grass	Water Meadows (River Chess)	1[E]			<1.2	<1.7	12	330
Soil	Orchard next to site	1[E]			<0.37	5.2	200	600
Soil	Water Meadows (River Chess)	1[E]			<0.48	5.2	180	370

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 <3.4Bq l^{-1}
e. The concentration of ^{3}H as tritiated water and ^{177}Lu were <4.9Bq l^{-1} and 3.8Bq kg^{-1}
f. The concentration of ^{3}H as tritiated water was <3.5Bq 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 5.3(b) Monitoring of radiation dose rates near Amersham, 2022

Location	Material or ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Bank of Grand Union Canal (downstream)	Grass and stones	2	0.061
Downstream of outfall (Grand Union Canal)	Grass and stones	2	0.055
Upstream of outfall (Grand Union Canal)	Grass and sand	1	0.056
Upstream of outfall (Grand Union Canal)	Grass and stones	1	0.058
Water Meadows (River Chess)	Grass	1	0.055
Orchard next to site	Grass	1	0.072

Table 5.4 Concentrations of radionuclides in food and the environment near Harwell, 2022[d]

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}								
			^{3}H	^{60}Co	^{131}I	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	Gross alpha	Gross beta
Freshwater samples											
Plaice	Woolwich Reach	1	<25	<0.04	<1.1	<0.04			<0.15		
Sediment	River Thames (Sutton Courtenay)	1[E]		<0.27		2.0	<0.062	<0.27	<0.63	170	210
Sediment	River Thames (Shillingford)	1[E]		<0.85		6.4	<0.22	0.70	<0.36	260	540
Freshwater	River Thames (Long Wittenham)	4[E]	<3.6	<0.29		<0.24				<0.068	0.32
Freshwater	River Thames (Shillingford)	4[E]	<3.6	<0.24		<0.23				<0.083	0.29

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}		
			Organic ^{3}H	^{3}H	^{137}Cs
Terrestrial samples					
Milk		2	<2.9	<2.9	<0.04
Milk	max				
Oats		1	<3.2	<3.2	<0.18
Strawberries		1	<2.1	<2.1	<0.02

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
d The gamma dose rates in air at 1 m over grass; grass and mud at Sutton Courtney were 0.065 μGy h^{-1} and 0.067 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 5.5(a) Concentrations of radionuclides in food and the environment near Winfrith, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{14}C	^{99}Tc	^{137}Cs	^{238}Pu	$^{239}Pu+^{240}Pu$	^{241}Am	^{242}Cm	$^{243}Cm+^{244}Cm$	Gross alpha	Gross beta
Marinel samples												
Skates/Rays	Weymouth Bay	1			0.08			<0.20				
Crabs	Lulworth Banks	1	19		<0.07			<0.17				
Scallops	Lulworth Ledges	1			<0.05	0.00026	0.0038	0.00052	*	*		
Seaweed	Bognor Rocks	2[E]		0.39	<0.46			<0.55				
Seaweed	Lulworth Cove	1[E]		<0.25	<0.52			<0.63				
Seawater	Lulworth Cove	1[E]			<0.34			<0.36			<5.5	16

Material	Location or selection[b]	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{3}H	^{14}C	^{137}Cs	Gross alpha	Gross beta
Terrestrial samples - Annual								
Milk		2	<2.4	<2.4	21	<0.05		
Milk	max		<2.6	<2.6	22	<0.06		
Barley		1	<7.0	<7.0	110	<0.16		
Potatoes		1	6.1	6.1	14	<0.03		
Grass	Near Newburgh Farm Cottages	2[E]		<17	13	<1.2	<1.8	240
Grass	Adjacent to railway	2[E]		<14	<13	<0.80	5.0	170
Sediment	North of site	1[E]				1.6	<110	<150
Sediment	R Frome (upstream)	1[E]				<0.21	<94	<160
Sediment	R Frome (downstream)	1[E]				1.6	88	<160
Sediment	R Win, east of site	1[E]				0.54	<96	270
Freshwater	North of site	2[E]		<4.8		<0.25	<0.047	0.10
Freshwater	R Frome (upstream)	2[E]		<3.7		<0.26	<0.032	0.086
Freshwater	R Frome (downstream)	2[E]		<3.6		<0.21	<0.036	0.078
Freshwater	R Win, east of site	2[E]		<3.7		<0.27	0.035	0.14

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

Table 5.5(b) Monitoring of radiation dose rates near Winfrith, 2022

Location	Material or ground type	No. of sampling observations	μGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Weymouth Bay	Sand	1	0.052
Osmington Mills	Shingle	1	0.058
Durdle Door	Shingle	1	0.047
Lulworth Cove	Sand and shingle	1	0.052
Kimmeridge Bay	Sand and shingle	1	0.086
Swanage Bay	Sand	1	0.056
Poole Harbour	Sand	1	0.045

Table 5.6 Concentrations of radionuclides in the environment near Culham, 2022

Material	Location	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}					
			^{3}H	^{14}C	^{131}I	^{137}Cs	Gross alpha	Gross beta
Freshwater	River Thames (upstream)	2	<3.6			<0.24	<0.057	0.38
Freshwater	River Thames (downstream)	2	<3.8			<0.23	<0.056	0.36
Grass	0.6km east of site perimeter	2	<19	35		<1.1		320
Sediment	River Thames (upstream)	2				3.2		
Sediment	River Thames (downstream)	2				28		
Soil	1km east of site perimeter	1	<6.6	7.8		2.0		480

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

6 Defence establishments

Highlights

- 'total doses' for the representative person were approximately 3% of the dose limit for all sites assessed

Aldermaston, Berkshire

- 'total dose' for the representative person was less than 0.005mSv and decreased in 2022
- gaseous discharges of volatile beta decreased in 2022

Barrow, Cumbria

- 'total dose' for the representative person was 0.030mSv and decreased in 2022

Derby, Derbyshire

- 'total dose' for the representative person was less than 0.005mSv and unchanged in 2022

Devonport, Devon

- 'total dose' for the representative person was less than 0.005mSv and unchanged in 2022

Faslane and Coulport, Argyll and Bute

- 'total dose' for the representative person was 0.007mSv and unchanged in 2022

Rosyth, Fife

- 'total dose' for the representative person was 0.006mSv and decreased in 2022

This section considers the results of monitoring, under the responsibility of the Environment Agency, FSA, FSS and SEPA, undertaken routinely near 9 defence-related establishments in the UK. In addition, the MOD makes arrangements for monitoring at other defence sites where radiological contamination may occur. The operator at the Atomic Weapons Establishment (AWE) in Berkshire carries out environmental monitoring to determine the effects from discharges at its sites (including low level gaseous and liquid discharges from Burghfield, Berkshire). Monitoring at nuclear submarine berths is also conducted by the MOD (for example [101]).

In 2022, gaseous and liquid discharges were below regulated limits for each of the defence establishments (see Appendix 1, Table A1.1and Table A1.2). Solid waste transfers in 2022 from nuclear establishments in Scotland (Coulport, Faslane, Rosyth and Vulcan) are also given in Appendix 1 (Table A1.4).

6.1 Aldermaston and Burghfield

AWE has two major sites located in Berkshire: AWE Aldermaston and AWE Burghfield. AWE at Aldermaston provides and maintains the fundamental components of the UK's nuclear deterrent (Trident) including component manufacture and radioactive waste management activities. 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 the UK's nuclear stockpile are managed, on behalf of the MOD, by AWE plc (which is a non-departmental public body, wholly owned by the MOD). AWE at Burghfield is responsible for the complex final assembly and maintenance of warheads whilst in service, as well as their decommissioning. Gaseous and liquid discharges are regulated by the Environment Agency, permitting discharges of low concentrations of radioactive waste to the environment.

The most recent habits survey to determine the consumption and occupancy rates by members of the public in the vicinity of the site was undertaken in 2022 [197].

Doses to the public

In 2022, the 'total dose' from all pathways and sources of radiation was less than 0.005mSv (Table 6.1), or less than 0.5% of the dose limit, which has decreased compared to 2021 (0.008mSv). This decrease in dose was mostly due to lower concentrations of uranium isotopes in milk, in comparison to those in 2021. In 2022, the representative person was adults consuming game meat at high rates, this was a change from 2021 (infants (1-year-old) consuming milk at high-rates).

As in 2021, source specific assessments for high-rate consumers of locally grown foods, for sewage workers and for anglers, gave exposures that were also less than 0.005mSv in 2022 (Table 6.1). Estimates of activity concentrations in fish have been based on shellfish samples from the aquatic monitoring programme for the dose determination. A low consumption rate of 1kg per year for fish has been included in the dose assessment for anglers.

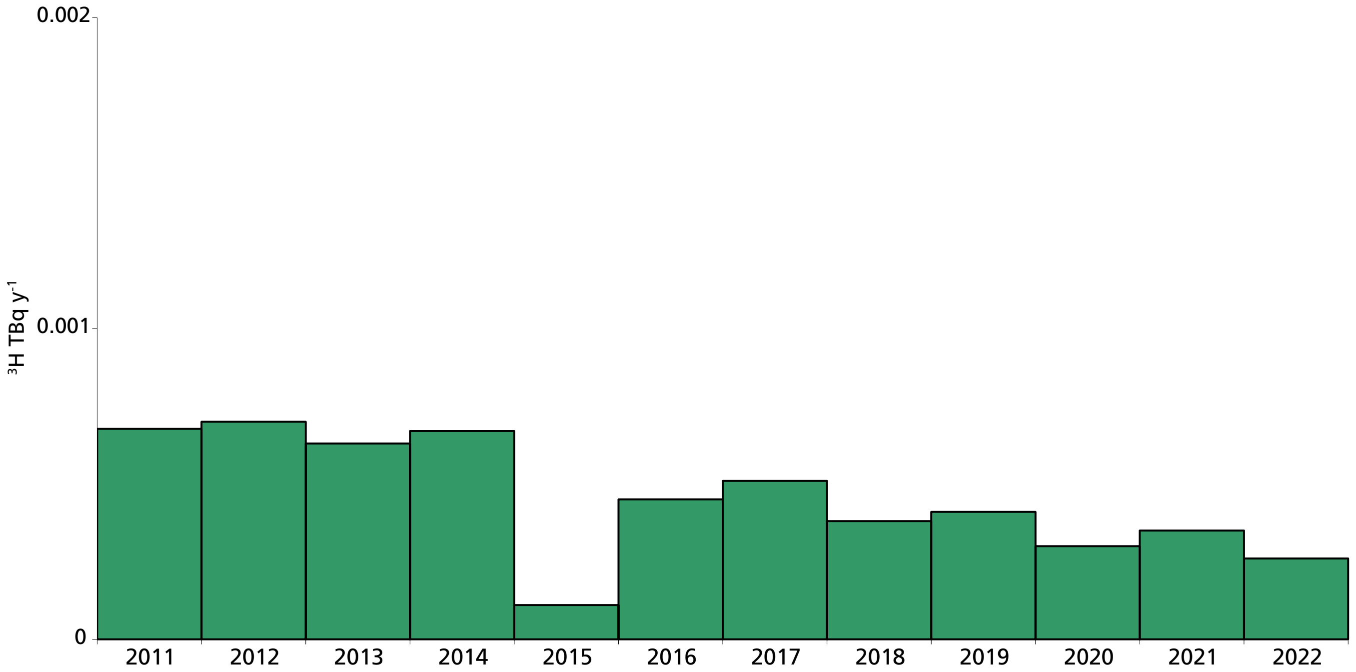
Gaseous discharges and terrestrial monitoring

Gaseous radioactive waste is discharged via stacks from facilities at Aldermaston and Burghfield Sites. Gaseous discharges of volatile beta decreased in comparison to those in 2021. These discharges are related to an nuclear forensics testing campaign, which was limited in 2022. Samples of milk, terrestrial foodstuffs, grass and soil were taken from locations close to the sites (Figure 5.4) and the results of the terrestrial monitoring in 2022 are given in Table 6.2(a). In 2022, tritium concentrations and other radionuclides in foodstuffs (including milk) were very low or reported as less than values. Caesium-137 concentrations were positively detected in soil samples and were generally similar in both 2021 and 2020 (where comparisons can be made). As in 2021, caesium-137 concentrations in all food and grass samples were reported as less than values in 2022. Concentrations of uranium isotopes in milk in 2022 were lower than those values observed in 2021. Natural background or fallout concentrations from global nuclear weapons testing would have made a significant contribution to the detected values.

Liquid waste discharges and aquatic monitoring

Discharges of radioactive liquid effluent are made under permit to the sewage treatment works at Silchester (Figure 5.4), and to the Aldermaston Stream from the Aldermaston Site. A time-series trend of generally decreasing tritium discharges from Aldermaston (2011 to 2022) is shown in Figure 6 1. Tritium discharges have declined more significantly, over a longer period in comparison to the last decade (Figure 5.1, [198]). The longer-term decline in discharges is due to the replacement of the original tritium facility (the replacement facility uses sophisticated abatement technology that has resulted in significantly less tritium discharged into the environment) and the reduction of historical groundwater contamination by radioactive decay and dilution by natural processes. Discharges of radioactive liquid effluent from Burghfield are made to a sewage treatment works located on the Burghfield Site. Environmental monitoring of the River Thames (Pangbourne and Mapledurham) has continued to assess the effect of historical discharges.

Figure 6.1 Trends in liquid discharges of tritium from Aldermaston, Berkshire 2011 to 2022 (including discharges to River Thames at Silchester sewer and Aldermaston Stream)



Activity concentrations for freshwater, fish, sediment samples (including gully pot sediments from road drains), and measurements of gamma dose rates, are given in Table 6.2(a) and Table 6.2(b). As in recent years, the Environment Agency continued their enhanced environmental monitoring of sediments and freshwater samples in 2022. The concentrations of artificial radioactivity detected in the Thames catchment were very low in 2022 and generally similar to those in recent years. Tritium concentrations in freshwater samples were all reported as less than values, but, unlike in 2021, tritium was positively detected in a gully pot sediment sample collected at Falcon Gate (160Bq kg^{-1}). As in 2021, iodine-131 was not positively detected in seafood samples in 2022. Activity concentrations of artificial radionuclides in shellfish were very low in 2022 and similar to those reported in recent years. Analyses of caesium-137 and uranium activity concentrations in River Kennet sediments were broadly consistent with those in recent years. As in 2021, caesium-137 concentrations in gully pot samples were reported as less than values (or just above the less than value) and tritium concentrations in freshwater samples were all reported as less than values. Gross alpha and beta activities in freshwater samples were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (based upon the European Directive 2013/51). Gamma dose rates were below or close to natural background.

6.2 Barrow, Cumbria

At Barrow, BAE Systems Marine Limited builds, tests and commissions new nuclear-powered submarines. Gaseous discharges were reported as nil and liquid discharges of tritium, carbon-14 and cobalt-60 to sewer were all very low (<1% of the annual limit) in 2022. The most recent habits survey was undertaken in 2012 [199].

The 'total dose' from all pathways and sources of radiation was 0.030mSv (Table 6.1) in 2022, or 3% of the dose limit, and down from 0.044mSv in 2021. Virtually all of this dose was due to the effects of Sellafield discharges. As in recent years, the representative person was adults living on a local houseboat. The decrease in 'total dose' was mostly due to gamma dose rates being measured over different substrates at Askam Pier, from one year to the next.

As in 2021, source specific assessments for a high-rate consumer of locally grown food and a person living on a local houseboat gave exposures that were less than the 'total dose' in 2022 (Table 6.1). No assessment of seafood consumption was undertaken in 2022 because of the absence of relevant monitoring data. However, the dose from seafood consumption is less important than that from external exposure on a houseboat [200].

The FSA's terrestrial monitoring is limited to vegetable and grass (or silage) sampling. The Environment Agency monitors gamma dose rates and analysis of sediment samples from local intertidal areas and is directed primarily at the far-field effects of Sellafield discharges. The results are given in Table 6.3(a) and Table 6.3(b). No effects of discharges from Barrow were apparent in the concentrations of radioactivity in vegetables and silage, most reported as less than values. In 2022, the reported gross beta concentration (due to the far-field effects of Sellafield discharges) in Walney Channel sediment was higher in comparison to that in 2021. The gamma dose rates in intertidal areas near Barrow in 2022 are given in Table 6.3(b) and Table 3.9. As in previous years, gamma dose rates were enhanced above those expected due to natural background, and generally lower than those measured in 2021. Any enhancement above natural background is most likely due to the far-field effects of historical discharges from Sellafield.

6.3 Derby, Derbyshire

Rolls-Royce Submarines Limited (RRSL) (formerly Rolls-Royce Marine Power Operations Limited), a subsidiary of Rolls-Royce plc, carries out design, development, testing and manufacture of nuclear-powered submarine fuel at its 2 adjacent sites in Derby at Raynesway. Small discharges of liquid effluent are made via the Megaloughton Lane STW to the River Derwent and very low concentrations of alpha activity are present in releases to the atmosphere. Other wastes are disposed of by transfer to other sites (for example, at a permitted landfill site or by incineration). The most recent habits survey was undertaken in 2021 [201].

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv in 2022 (Table 6.1), which is less than 0.5% of the dose limit, and unchanged from 2021. As in recent years, the representative person was infants consuming locally sourced water. Source specific assessments for consumption of fish, crustaceans and drinking river water at high-rates, and spent time on river-washed areas also gave exposures that were also less than 0.005mSv in 2022 (Table 6.1).

Results of the routine monitoring programme at Derby are given in Table 6.3(a). Concentrations of uranium in samples taken around the site in 2022 were generally similar to those in previous years. More detailed analysis in previous years has shown the activity as being consistent with natural sources. The gross beta activities in water samples from the River Derwent were less than the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (based upon the European Directive 2013/51), but unlike in 2021, the gross alpha activity in the sample collected from the River Derwent upstream was found to be marginally above the 0.1Bq l^{-1} limit. However, this area is not known to be used as a source of drinking water. Caesium-137 detected in sediments from local water courses was most likely from historic fallout from overseas sources (such as nuclear weapons testing).

Table 6.3(a) also includes analytical results for a water sample taken from Fritchley Brook, downstream of Hilts Quarry, near Crich in Derbyshire. RRSL formerly used the quarry for the controlled burial of solid low level radioactive waste. Concentrations of uranium isotopes detected in the sample in 2022 were broadly similar to those reported elsewhere in Derbyshire (Table 8.7).

6.4 Devonport, Devon

The Devonport Royal Dockyard consists of 2 parts and is operated by His Majesty's Naval Base (HMNB) (owned and operated by the MOD) and Devonport Royal Dockyard Limited (owned by Babcock International Group plc). Devonport Royal Dockyard refits, refuels, repairs and maintains the Royal Navy's nuclear-powered submarine fleet 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 to determine the consumption and occupancy rates by members of the public was undertaken in 2017 [202]. The routine monitoring programme in 2022 consisted of measurements of gamma dose rate and analysis of barley, vegetables, fish, shellfish and other environmental indicator materials (Table 6.3(a) and Table 6.3(b)).

Doses to the public

The 'total dose' from all pathways and sources of radiation was less than 0.005mSv in 2022 (Table 6.1), which was less than 0.5% of the dose limit, and unchanged from 2021. The representative person was adults consuming locally collected marine plants at high rates, who also consumed fish (which largely determined the exposure) and spent time on intertidal areas. The trend in annual 'total doses' at Devonport remains less than 0.005mSv (Figure 6.1, [203]).

As in 2021, source specific assessments for a high-rate consumer of locally grown food (including doses from external and inhalation from gaseous discharges), for fish and shellfish, and for an occupant of a houseboat, gave exposures that were also less than 0.005mSv in 2022 (Table 6.1).

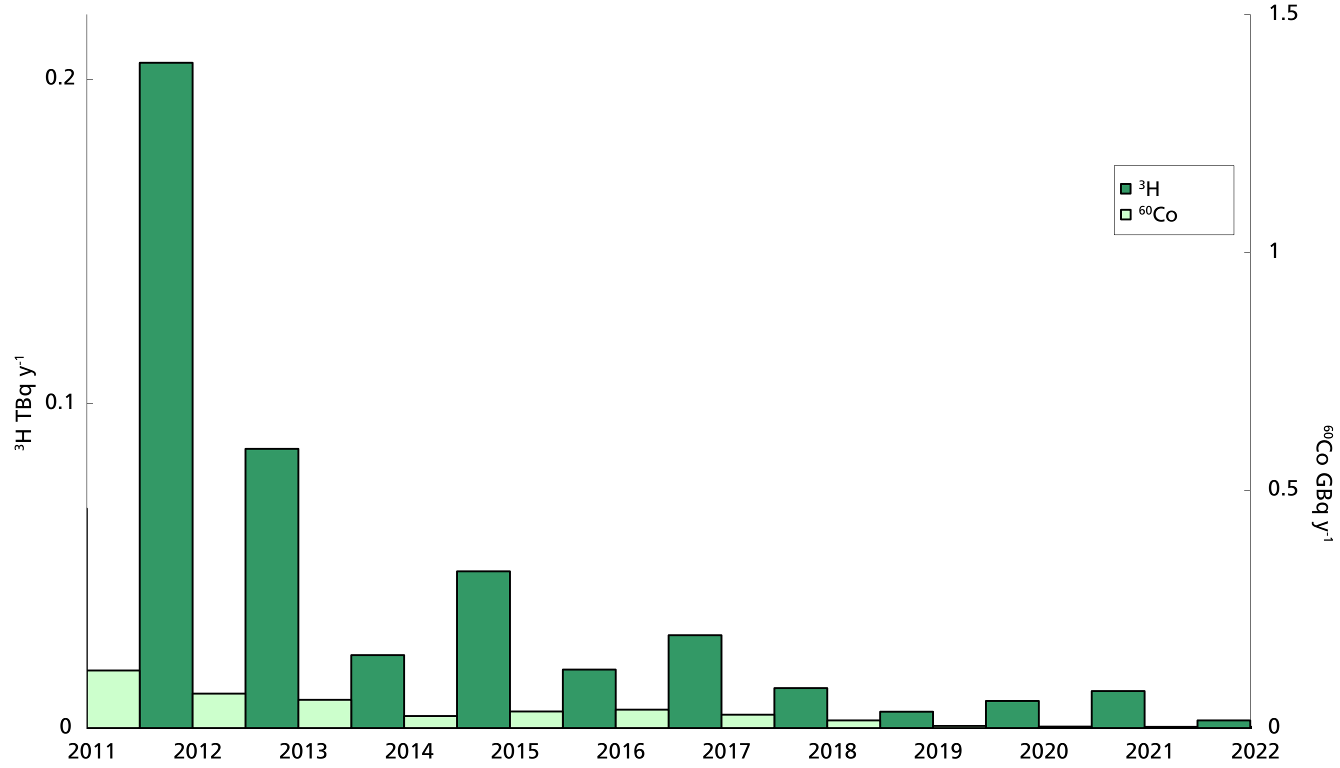
Gaseous discharges and terrestrial monitoring

Terrestrial samples (barley and potatoes) were analysed for a number of radionuclides. Activity concentrations in terrestrial samples were reported as less than values in 2022, apart from a positive tritium result observed in barley.

Liquid waste discharges and aquatic monitoring

Discharges of tritium, cobalt-60 and "other radionuclides" to the Hamoaze (estuary) were generally similar in 2022, in comparison to those releases in 2021. The trends of tritium and cobalt-60 discharges over time (2011 to 2022) are given in Figure 6.2. The main contributor to the variations in tritium discharges over time has been the re-fitting of Vanguard class submarines. These submarines have a high tritium inventory as they do not routinely discharge primary circuit coolant until they undergo refuelling at Devonport. Cobalt-60 discharges have declined more significantly than tritium, since the early 2000s (Figure 5.2, [198]). The underlying reason for the overall decrease in cobalt-60 discharges over nearly 3 decades has been the improvement in submarine reactor design so that less cobalt-60 was produced during operation, and therefore less was released during submarine maintenance operations.

Figure 6.2 Trends in liquid discharges of tritium and cobalt-60 from Devonport, Devon 2011 to 2022



In marine samples, concentrations of tritium and cobalt-60 were reported as less than values in 2022. Low caesium-137 concentrations, likely to originate from other sources (such as nuclear weapons testing), were measured in sediment samples. Carbon-14 concentrations in seafood species were generally similar to those in previous years. Iodine-131 was not detected in fish and shellfish samples in 2022. Gamma dose rates in the vicinity of Devonport in 2022, were similar to those in recent years, and reflect the local effects of enhanced background radiation from natural sources.

In marine samples, concentrations of tritium and cobalt-60 were reported as less than values in 2022. Low caesium-137 concentrations, likely to originate from other sources (such as nuclear weapons testing), were measured in sediment samples. Carbon-14 concentrations in seafood species were generally similar to those in previous years. Iodine-131 was not detected in fish and shellfish samples in 2022. Gamma dose rates in the vicinity of Devonport in 2022, were similar to those in recent years, and reflect the local effects of enhanced background radiation from natural sources.

6.5 Faslane and Coulport, Argyll and Bute

The HMNB Clyde establishment consists of the naval base at Faslane and the armaments depot at Coulport. Babcock Marine, a subsidiary of Babcock International Group plc, operates HMNB Clyde, Faslane in partnership with the MOD. However, the MOD remains in control of the undertaking, through the Naval Base Commander, Clyde (NBC Clyde) in relation to radioactive waste disposal. MOD through NBC Clyde also remains in control of the undertaking at Coulport although many of the activities undertaken at Coulport have been outsourced to an industrial alliance comprising of AWE plc, Babcock and Lockheed Martin UK (known as ABL).

Discharges of liquid radioactive waste, into the 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 (LoA) between SEPA and the MOD. The construction of a new radioactive waste treatment facility at Faslane continued during 2022 and the facility is in the commissioning phase. The expected in-service date is 2024. An application for a revised LoA that includes discharges from the facility was submitted to SEPA in 2019 and SEPA consulted on the application in 2020. Determination of the application was impacted by a cyber-attack on SEPA in December 2020, however work on the determination progressed in 2022.

In 2022, gaseous tritium discharges (from Coulport) and liquid discharges (from Faslane) were broadly similar, in comparison to those releases in 2021 (see Appendix 1, Table A1.1 and Table A1.2, respectively).

The disposal of solid radioactive waste from each site is made under a separate LoA between SEPA and the MOD. Solid waste transfers in 2022 are given in Appendix 1 (Table A1.4).

The most recent habits survey to determine the consumption and occupancy rates by members of the public was undertaken in 2016 [204]. A new habits survey is scheduled to be undertaken in 2024.

The 'total dose' from all pathways and sources of radiation was 0.007mSv in 2022 (Table 6.1), which was less than 1% of the dose limit and unchanged from 2021. The representative person was adults consuming fish at high rates. Activity concentrations in fish (not collected in 2022) were estimated using reported environmental fish data in 2022, sampled outside the aquatic habits survey area of this site (but within the Firth of Clyde). The assessment of this 'total dose' was highly conservative (due to the assumption of fish data). In 2022, source specific assessments for a high-rate consumer of shellfish and a consumer of locally grown food (based on limited data) gave exposures of 0.010mSv and less than 0.005mSv, respectively. The main reason for the change in dose (from 0.008mSv in 2021) to the consumer of shellfish is due to higher gamma dose rates over sediment at Helensburgh and Rhu.

The routine marine monitoring programme consisted of the analysis of shellfish, seawater, seaweed and sediment samples, and gamma dose rate measurements. Terrestrial monitoring included meat, domestic fruit, honey, water, grass and soil sampling. The results in 2022 are given in Table 6.3(a) and Table 6.3(b) and were generally similar to those in 2021. Caesium-137 was positively detected at a low concentration in honey (as in recent years) and domestic fruit. Radionuclide concentrations were generally reported as less than values in 2022. Caesium-137 concentrations in sediment are consistent with the distant effects of discharges from Sellafield, fallout from Chernobyl and nuclear weapons testing.

Gamma dose rates measured in the surrounding area were difficult to distinguish from natural background (Table 6.3(b)). The tritium, gross alpha and gross beta concentrations were much lower than the investigation levels in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51).

6.6 Holy Loch, Argyll and Bute

A small programme of monitoring at Holy Loch continued during 2022 to determine the effects of past discharges from the US submarine support facilities which closed in 1992. Radionuclide concentrations were low (Table 6.3(a)). Gamma dose rate measurements over intertidal areas (Table 6.3(b)) were similar to those values reported in 2021. The most recent habits survey to determine the consumption and occupancy rates by members of the public was undertaken in 1989 [205].

The external radiation dose to a person spending time on the loch shore was 0.006mSv in 2022, which was less than 1% of the dose limit for members of the public of 1mSv and slightly down from 0.007mSv in 2021 (Table 6.1). The decrease in dose was mostly due to lower gamma dose rates measured over sediment (Kilmun Pier and North Sandbank) in 2022.

6.7 Rosyth, Fife

The Rosyth naval dockyard is located on the north bank of the River Forth in Fife, 3km west of the Forth Road Bridge and some 50km from the mouth of the Firth of Forth. It is sited on reclaimed land, with reclamation completed in 1916. From 1916, the site was known as HM Dockyard Rosyth and activities conducted there included refitting and maintaining warships.

In 1997, Rosyth Royal Dockyard Limited (RRDL) - a wholly owned subsidiary of Babcock International Group Marine Division - was set up to be responsible for the decommissioning of the dockyard site and the management of radioactive waste that had arisen from the re-fitting of nuclear submarines which ended in 2003. Site decommissioning started in 2006 and has mainly been completed, except for some small areas of the site where facilities are required to continue managing radioactive wastes.

The MOD sold the site to Babcock International Group Marine Division who now manage and operate the site. However, radioactive waste that was generated by the site, to support the nuclear submarine fleet, is owned by the MOD. Therefore, the MOD has entered into a contract with RRDL to manage all radioactive waste on the dockyard site. As the radioactive waste owner, the MOD maintains an overview of procedures to ensure RRDL fully complies with the terms and conditions of its contract.

In 2016, SEPA granted RRDL an authorisation (under RSA 93) to dispose of radioactive waste arising on the Rosyth dockyard site. This allows RRDL to dispose of LLW that arises from the decommissioning of the Rosyth premises, from former submarine re-fitting operations and from waste transferred from the MOD from the dismantling of the 7 redundant nuclear submarines currently stored afloat at the dockyard site. The authorisation was transitioned to a permit under the Environmental Authorisations (Scotland) Regulations 2018 (EASR18) with a new permit being issued in March 2019. A LoA (effective from 2016) to the MOD allows the transfer of LLW from the 7 nuclear submarines berthed at the Rosyth dockyard site to RRDL. Granting of the LoA and new authorisation to RRDL has permitted the start of the MOD submarine dismantling programme at Rosyth. Work to dismantle and remove radioactive and conventional wastes from each submarine and subsequently clean up the Rosyth site is expected to take up to 15 years to complete.

The most recent habits survey was undertaken in 2022 [206].

The ‘total dose’ from all pathways and sources of radiation was 0.006mSv in 2022 (Table 6.1), which is approximately 1% of the dose limit. In 2022, the representative person was adults consuming crustacean shellfish at high rates. The decrease in ‘total dose’ from 2021 is attributed to lower gamma dose rates over sediment observed in 2022 and to a lesser extent the revision of the habits data. The source specific assessment for marine pathways (fishermen and beach users) was estimated to be less than 0.005mSv in 2022 (a decrease from 0.012mSv in 2021). The reason for the decrease in dose is the same as that contributing to the maximum ‘total dose’.

The gaseous and liquid discharges from Rosyth in 2022 are given in Appendix 1 (Table A1.1 and Table A1.2, respectively), and solid waste transfers in Table A1.4. Gaseous discharges of tritium and carbon-14 were slightly decreased in 2022 compared to 2021. Liquid wastes are discharged via a dedicated pipeline to the Firth of Forth. Liquid discharges of tritium increased in 2022 in comparison to that in 2021. During the reporting year a greater percentage of the effluent discharged arose from the drain down of the submarine undergoing decommissioning. This accounted for the increase in tritium discharged.

The direct radiation from the site was less than 0.001mSv in 2022 (Table 1.1), which is lower than that in 2021 (0.002mSv). This lower value of direct radiation is based upon actual measurements and a more representative background radiation measurement location.
SEPA’s routine monitoring programme included analysis of fish, shellfish, environmental indicator materials and measurements of gamma dose rates in intertidal areas. Results are shown in Table 6.3(a). The radioactivity concentrations in freshwater measured were low in 2022, and similar to those in recent years, and in most part due to the combined effects of Sellafield, weapon testing and Chernobyl. Gamma dose rates were generally similar (in comparison to those in 2021) and difficult to distinguish from natural background.

6.8 Vulcan NRTE, Highland

The Vulcan Naval Reactor Test Establishment (NRTE) is operated by the Submarine Delivery Agency, part of the MOD, and its purpose was to prototype submarine nuclear reactors. It is located adjacent to the Dounreay site, and the impact of its discharges is considered along with those from Dounreay (in Section 5). The site ceased critical reactor operations in 2015 and will not be required for further prototyping. Since the reactor shutdown for the last time, work has focused on post-operational clean out. This includes the de-fuelling of the reactor, clearance of fuel from the site and preparations for future decommissioning. Magnox Limited issued a statement regarding future decommissioning and stated “Magnox, together with Dounreay, will be part of a joint working team exploring the option of transferring the future decommissioning of the MOD’s Vulcan site to the NDA Group. Any transfer would be subject to regulatory approval and sign-off by Government and is unlikely to take place before 2026”.

Gaseous discharges, and solid waste transfers, from Vulcan NRTE in 2022 are given in Appendix 1 (Table A1.1 and Table A1.4, respectively).

Table 6.1 Individual doses - defence sites, 2022

Site	Representative person[a]	Exposure mSv, per year						
		Total	Fish and shellfish	Other local food	External radiation from intertidal areas or river banks[b]	Intakes of sediment or water[c]	Gaseous plume related pathways	Direct radiation from site
Aldermaston and Burghfield								
‘Total dose’ - all sources	**Adult game meat consumers**	**<0.005[d]**	**-**	**<0.005**	**-**	**-**	**<0.005**	**<0.005**
Source specific doses	Anglers	<0.005[d]	<0.005	-	<0.005	-	-	-
	Infant inhabitants and consumers of locally grown food	<0.005[d]	-	<0.005	-	-	<0.005	-
	Workers at Silchester STW	<0.005	-	-	<0.005[e]	<0.005[f]	-	-
Barrow								
‘Total dose’ - all sources	**Adult occupants on houseboats[g]**	**0.030**	**-**	**-**	**0.030**	**-**	**-**	**-**
Source specific doses	Houseboat occupants[g]	0.029	-	-	0.029	-	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-	-	-
Derby								
‘Total dose’ - all sources	**Adult consumers of locally sourced water**	**<0.005**	**<0.005**	**-**	**<0.005**	**<0.005**	**-**	**-**
Source specific doses	Anglers consuming fish, shellfish and drinking water	<0.005	<0.005	-	<0.005	<0.005	-	-
	Children Inhabitants and consumers of locally grown food	<0.005[c]	-	<0.005	-	-	<0.005	-
Devonport								
‘Total dose’ - all sources	**Adult consumers of marine plants and algae**	**<0.005**	**<0.005**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Seafood consumers	<0.005	<0.005	-	<0.005	-	-	-
	Houseboat occupants	<0.005	-	-	<0.005	-	-	-
	Prenatal children of Inhabitants and consumers of locally grown food	<0.005	-	<0.005	-	-	<0.005	-
Faslane								
‘Total dose’ - all sources	**Adult fish consumers**	**0.007**	**0.006**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Seafood consumers	0.010	0.006	-	<0.005	-	-	-
	Consumers of locally grown food	<0.005	-	<0.005	-	-	-	-
Holy Loch								
Source specific doses	Anglers	0.006	-	-	0.006	-	-	-
Rosyth								
‘Total dose’ - all sources	**Adult crustacean consumers**	**0.006**	**<0.005**	**-**	**<0.005**	**-**	**-**	**-**
Source specific doses	Fishermen and beach users	<0.005	<0.005	-	<0.005	-	-	-

a. The ‘total dose’ is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.
The ‘total dose’ for the representative person with the highest dose is presented.
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the ‘total dose’ assessment
The representative person is an adult unless otherwise specified
Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv
b. Doses (‘total dose’ and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)
c. Water is from rivers and streams and not tap water
d. Includes a component due to natural sources of radionuclides
e. External radiation from raw sewage and sludge
f. Intakes of resuspended raw sewage and sludge
g. Exposures at Barrow are largely due to discharges from the Sellafield site

Table 6.2(a) Concentrations of radionuclides in food and the environment near Aldermaston, 2022

Material	Location	No. of sampling observations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			Organic ^{3}H	^{3}H	^{131}I	^{137}Cs	^{234}U	^{235}U	^{238}U
Freshwater samples									
Plaice	Woolwich Reach	1		<25	<1.1	<0.04			
Pike	Ufton Bridge - Theale	1	<25	<25	*	<0.04	<0.00032	<0.00023	<0.00023
Sediment	Pangbourne	2[E]				1.3	15	0.75	16
Sediment	Mapledurham	2[E]				14	11	0.61	10
Sediment	Aldermaston	4[E]				3.4	16	<0.82	16
Sediment	Spring Lane	4[E]				3.0	16	<0.72	16
Sediment	Stream draining south	4[E]				<1.3	18	0.89	17
Sediment	Near Chamber 39 of PPL	2[E]				2.0	10	0.61	8.3
Sediment	Oval pond near Chamber 14	3[E]				<2.2	14	<0.69	13
Sediment	River Kennet	4[E]				3.4	10	<0.61	10
Sediment	Hosehill Lake	3[E]				<1.2	23	<1.2	21
Gully pot sediment	Aldermaston Gate	1[E]		<15		<1.7	20	0.91	21
Gully pot sediment	Falcon Gate	1[E]		160		<1.1	15	0.95	17
Gully pot sediment	Burghfield Gate	1[E]		<17		1.2	19	0.77	19
Freshwater	Pangbourne	2[E]		<3.6		<0.29	0.031	<0.00064	0.0073
Freshwater	Mapledurham	2[E]		<3.8		<0.27	0.013	<0.00058	0.0071
Freshwater	Aldermaston	4[E]		<3.7		<0.30	0.0055	<0.00078	0.0046
Freshwater	Spring Lane	4[E]		<3.7		<0.30	0.0021	<0.00047	<0.0015
Freshwater	Stream draining south	4[E]		<3.7		<0.23	0.0031	<0.00072	<0.0018
Freshwater	Near Chamber 39 of PPL	4[E]		<3.9		<0.28	0.0068	<0.00033	0.0048
Freshwater	Oval pond near Chamber 14	4[E]		<3.7		<0.19	<0.0071	<0.00074	<0.0051
Freshwater	River Kennet	4[E]		<3.8		<0.23	0.0058	<0.0011	0.0038
Freshwater	Hosehill Lake	4[E]		<3.6		<0.29	0.0036	<0.00048	<0.0027
Crude effluent	Silchester treatment works	2[E]		<8.4		<0.30	0.0070	<0.0013	0.0053
Final effluent	Silchester treatment works	2[E]		<3.9		<0.29	0.0074	<0.0011	0.0042
Sewage sludge	Silchester treatment works	2[E]		<18	48	<0.22	0.23	0.011	0.21

Table 6.2(a) continued

Material	Location	No. of sampling observations[a]	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
Freshwater samples									
Plaice	Woolwich Reach	1			<0.16				
Pike	Ufton Bridge - Theale	1	0.0000070	0.000019	0.000044	*	*		
Sediment	Pangbourne	2[E]	<0.053	<0.24	<0.64			210	370
Sediment	Mapledurham	2[E]	<0.14	0.32	<0.54			120	300
Sediment	Aldermaston	4[E]	<0.13	4.2	2.1			270	700
Sediment	Spring Lane	4[E]	<0.077	<0.66	<0.90			250	650
Sediment	Stream draining south	4[E]	<0.064	<0.31	<0.64			<200	480
Sediment	Near Chamber 39 of PPL	2[E]	<0.15	<0.35	<0.49			130	260
Sediment	Oval pond near Chamber 14	3[E]	<0.12	<0.33	<0.60			170	530
Sediment	River Kennet	4[E]	<0.063	<0.27	<0.66			190	450
Sediment	Hosehill Lake	3[E]	<0.089	<0.21	<0.50			290	780
Gully pot sediment	Aldermaston Gate	1[E]	<0.080	<0.22	<2.3			270	980
Gully pot sediment	Falcon Gate	1[E]	<0.050	0.20	<1.6			200	620
Gully pot sediment	Burghfield Gate	1[E]	<0.24	0.28	<0.67			120	640
Freshwater	Pangbourne	2[E]	<0.00090	<0.0014	<0.0024			<0.059	0.32
Freshwater	Mapledurham	2[E]	<0.00089	<0.0014	<0.0020			<0.061	0.34
Freshwater	Aldermaston	4[E]	<0.0015	<0.0024	<0.0031			<0.055	0.18
Freshwater	Spring Lane	4[E]	<0.0011	<0.0019	<0.0028			<0.040	0.15
Freshwater	Stream draining south	4[E]	<0.0015	<0.0020	<0.0026			<0.042	0.21
Freshwater	Near Chamber 39 of PPL	4[E]	<0.00031	<0.0021	<0.0027			<0.048	0.11
Freshwater	Oval pond near Chamber 14	4[E]	<0.00082	<0.0019	<0.0025			<0.031	0.061
Freshwater	River Kennet	4[E]	<0.00092	<0.0020	<0.0025			<0.042	0.12
Freshwater	Hosehill Lake	4[E]	<0.0011	<0.0020	<0.0027			<0.029	0.46
Crude effluent	Silchester treatment works	2[E]	<0.0019	<0.0019	<0.34			0.11	0.63
Final effluent	Silchester treatment works	2[E]	<0.0021	<0.024	<0.42			<0.11	0.59
Sewage sludge	Silchester treatment works	2[E]	<0.0031	<0.0037	<0.58			3.7	4.2

Table 6.2(a) continued

Material	Location or selection[b]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}									
			^{3}H	^{137}Cs	^{234}U	^{235}U	^{238}U	^{238}Pu	^{240}Pu	^{241}Am	Gross alpha	Gross beta
Terrestrial samples												
Milk		2	<2.9	<0.04	0.0056	<0.00047	0.0060	<0.000023	<0.000025	<0.000030		
Milk	max		<3.0		0.0094	<0.00060	0.0090	<0.000024		<0.000031		
Barley		1	<3.2	<0.15	0.0046	0.00045	0.0034	0.000018	0.000079	0.000036		
Potato		1	<1.9	<0.03	0.0056	<0.00041	0.0054	<0.000086	0.00014	0.000084		
Grass and herbage	Kestrel Meads	1[E]	<16	<0.96	0.076	0.022	0.086	0.040	<0.033		<1.1	180
Grass and herbage	Young's Industrial Estate	1[E]	<12	<0.98	0.054	<0.033	0.029	<0.0080	<0.031		<1.8	220
Grass and herbage	Tadley, Perimeter fence	1[E]	<13	<1.2	0.17	<0.018	0.12	<0.018	0.078		2.2	210
Soil	Kestrel Meads	1[E]	<8.2	3.1	13	0.54	14	0.28	0.32		170	540
Soil	Young's Industrial Estate	1[E]	<10	1.8	18	1.1	17	<0.07	0.28		180	450
Soil	Black Pigthle, Perimeter fence	1[E]	<8.2	8.6	14	0.73	15	<0.067	0.32		170	590
Soil	Tadley, Perimeter fence	1[E]	<8.9	<1.3	8.9	0.68	11	<0.086	<0.19		240	450

* Not detected by the method used
[a] Except for milk, sewage effluent and water where units are Bq l^{-1}, and for sediment and soil where dry concentrations apply
[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 6.2(b) Monitoring of radiation dose rates near Aldermaston, 2022

Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate			
Pangbourne, riverbank	Grass	2	0.054
Mapledurham, riverbank	Grass	1	0.055
Mapledurham, riverbank	Grass and stones	1	0.058

Table 6.3(a) Concentrations of radionuclides in food and the environment near defence establishments, 2022

Material	Location or selection[a]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{95}Nb	^{125}Sb	^{131}I	^{137}Cs
Barrow										
Potatoes	Barrow	1[F]		4.5		<0.07	<0.09	<0.14	<0.96	<0.05
Grass	Barrow	1[F]		<4.2		<0.14	<0.52	<0.33	*	0.30
Sediment	Walney Channel - N of discharge point	2				<0.53	<0.63	<1.8		70
Derby										
Barley	Derby	1[F]				<0.15	<0.91	<0.37	*	<0.15
Potatoes	Derby	1[F]				<0.03	<0.05	<0.07	<0.37	<0.03
Sediment	River Derwent, upstream	1				<0.25				1.6
Sediment	Fritchley Brook	1				<0.39				<0.35
Sediment	River Derwent, downstream	4				<0.87				<1.5
Water	River Derwent, upstream	1				<0.31				
Water[c]	Fritchley Brook	1		<3.5		<0.30				<0.26
Water	River Derwent, downstream	4				<0.27				
Devonport										
Ballan wrasse	Plymouth Sound	1[F]	<25	<25	26	<0.07	<0.31	<0.14	*	0.12
Crabs	Plymouth Sound	1[F]			31	<0.04	<0.20	<0.11	*	<0.04
Shrimp	River Lynher	1[F]			27	<0.04	<0.13	<0.11	*	<0.04
Mussels	River Lynher	1[F]	<25	<25	15	<0.07	<0.22	<0.17	<2.3	<0.09
Seaweed[d]	Beach near Royal Albert Bridge	2				<0.69				<0.45
Sediment[e]	Beach near Royal Albert Bridge	2		<15		<0.59				2.0
Sediment	Tor Point South	2		<20		<0.60				1.2
Sediment	Lopwell	2		<14		<0.61				2.6
Seawater	Torpoint South	1		<3.7	<3.4	<0.45				
Seawater	Millbrook Lake	1		<3.8	<2.8	<0.40				
Sludge	Camel's Head sewage treatment works	1		<12		<1.1				
Barley	Devonport	1[F]		9.9		<0.16	<0.27	<0.37	<3.9	<0.15
Potatoes	Devonport	1[F]		<2.7		<0.08	<0.09	<0.14	<0.65	<0.05
Faslane										
Fucus vesiculosus	Garelochhead	1				<0.10	<0.22	<0.20		0.20
Fucus vesiculosus	Carnban	1				<0.10	<1.4	<0.20		0.20
Fucus vesiculosus	Rhu	1				<0.10	<0.51	<0.18		1.0
Fucus vesiculosus	Cairndhu Point	1				<0.10	<0.99	<0.22		0.40
Fucus vesiculosus	Helensburgh	1				<0.10	<0.62	<0.21		0.27
Sediment	Garelochhead	1				<0.15	<0.62	<0.44		3.4
Sediment	Carnban	1				<0.10	<0.10	<0.10		2.1
Sediment	Rhu	1				<0.10	<0.16	<0.10		2.5
Seawater	Carnban	2		<1.0		<0.10	<0.10	<0.10		<0.10
Beef muscle	Faslane	1				<0.05	<0.14			0.08
Blackberries	Faslane	1				<0.05	<0.12			<0.05
Honey	Faslane	1				<0.05	<0.05			1.3
Grass	Auchengaich Reservoir	1		<5.0		<0.05	<0.06			0.37
Grass	Lochan Ghlas Laoigh	1		<5.0		<0.05	<0.24			0.18

Table 6.3(a) continued

Material	Location or selection[a]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1} Organic ^{3}H	^{3}H	^{14}C	^{60}Co	^{95}Nb	^{125}Sb	^{131}I	^{137}Cs
Faslane										
Soil	Auchengaich	1		<5.0		<0.05	<0.08			30
Soil	Lochan Ghlas Laoigh	1		<5.0		<0.10	<1.0			11
Freshwater	Helensburgh Reservoir	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Loch Finlas	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Auchengaich Reservoir	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Lochan Ghlas Laoigh	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Loch Eck	1		<1.1		<0.01	<0.01			<0.01
Freshwater	Loch Lomond	1		<1.0		<0.01	<0.01			<0.01
Holy Loch										
Sediment	Mid-Loch	1				<0.10	<0.15	<0.18		2.8
Rosyth										
Winkles	St David's Bay	1				<0.10	<1.3	<0.23		0.12
Fucus vesiculosus	East of dockyard	1				<0.10	<0.10	<0.10		0.10
Sediment	East of dockyard	1				<0.10	<0.10	<0.13		2.0
Sediment	Port Edgar	1				<0.10	<0.13	<0.22		9.7
Sediment	West of dockyard	1				<0.10	<0.10	<0.13		0.77
Sediment	East Ness Pier	1				<0.10	<0.10	<0.14		8.9
Sediment	Blackness Castle	1				<0.10	<0.10	<0.13		1.0
Sediment	Charlestown Pier	1				<0.10	<0.12	<0.14		0.53
Seawater	East of dockyard	2		<1.0		<0.10	<0.10	<0.10		<0.10
Freshwater	Castlehill Reservoir	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Holl Reservoir	1		1.1		<0.01	<0.02			<0.01
Freshwater	Gartmorn Dam	1		<1.0		<0.01	<0.01			<0.01
Freshwater	Morton No. 2 Reservoir	1		<1.0		<0.01	<0.01			<0.01

Table 6.3(a) continued

Material	Location or selection[a]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1} ^{154}Eu	^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Barrow										
Potatoes	Barrow	1[F]	<0.20	<0.12				<0.13		
Grass	Barrow	1[F]	<0.43	<0.37				<0.51		
Sediment	Walney Channel - N of discharge point	2	<1.4	<0.92				210	280	900
Derby										
Barley	Derby	1[F]	<0.44	<0.48	0.0027	<0.00032	0.0022	<0.65		
Potatoes	Derby	1[F]	<0.10	<0.13	0.0054	0.00031	0.0059	<0.38		
Sediment	River Derwent, upstream	1			16	0.60	19		140	470
Sediment	Fritchley Brook	1			27	1.4	30		150	720
Sediment	River Derwent, downstream	4			23	<0.95	23		240	610
Water	River Derwent, upstream	1							0.12	0.064
Water[c]	Fritchley Brook	1			0.0050	<0.00096	0.0064		<0.035	0.17
Water	River Derwent, downstream	4							<0.053	0.19
Devonport										
Ballan wrasse	Plymouth Sound	1[F]	<0.22	<0.15				<0.16		
Crabs	Plymouth Sound	1[F]	<0.13	<0.14				<0.18		
Shrimp	River Lynher	1[F]	<0.12	<0.13				<0.18		
Mussels	River Lynher	1[F]	<0.20	<0.19				<0.43		
Seaweed[d]	Beach near Royal Albert Bridge	2								
Sediment[e]	Beach near Royal Albert Bridge	2						<0.68		
Sediment	Tor Point South	2								
Sediment	Lopwell	2								
Seawater	Torpoint South	1								
Seawater	Millbrook Lake	1								
Sludge	Camel's Head sewage treatment works	1								
Barley	Devonport	1[F]	<0.45	<0.47				<0.69		
Potatoes	Devonport	1[F]	<0.23	<0.13				<0.13		
Faslane										
Fucus vesiculosus	Garelochhead	1	<0.11	<0.18				<0.12		
Fucus vesiculosus	Carnban	1	<0.10	<0.17				<0.11		
Fucus vesiculosus	Rhu	1	<0.10	<0.15				<0.10		
Fucus vesiculosus	Cairndhu Point	1	<0.11	<0.20				<0.14		
Fucus vesiculosus	Helensburgh	1	<0.12	<0.12				<0.15		
Sediment	Garelochhead	1	<0.27	<0.45				<0.30		
Sediment	Carnban	1	<0.10	0.35				0.39		
Sediment	Rhu	1	<0.10	0.37				0.69		
Seawater	Carnban	2	<0.10	<0.10				<0.10		
Beef muscle	Faslane	1						<0.09		
Blackberries	Faslane	1						<0.05		
Honey	Faslane	1						<0.06		
Grass	Auchengaich Reservoir	1		<0.06				<0.06		
Grass	Lochan Ghlas Laoigh	1		<0.08				<0.05		

Table 6.3(a) continued

Material	Location or selection[a]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{154}Eu	^{155}Eu	^{234}U	^{235}U	^{238}U	^{241}Am	Gross alpha	Gross beta
Faslane										
Soil	Auchengaich	1		1.4				<0.27		
Soil	Lochan Ghlas Laoigh	1		2.2				<0.52		
Freshwater	Helensburgh Reservoir	1						<0.01	<0.010	0.082
Freshwater	Loch Finlas	1						<0.01	<0.010	0.047
Freshwater	Auchengaich Reservoir	1						<0.01	<0.010	0.016
Freshwater	Lochan Ghlas Laoigh	1						<0.01	<0.010	0.040
Freshwater	Loch Eck	1						<0.01	<0.010	0.021
Freshwater	Loch Lomond	1						<0.01	0.011	0.15
Holy Loch										
Sediment	Mid-Loch	1	<0.16	1.0				<0.32		
Rosyth										
Winkles	St David's Bay	1	<0.10	<0.15				<0.10		
Fucus vesiculosus	East of dockyard	1	<0.10	<0.10				<0.10		
Sediment	East of dockyard	1	<0.12	<0.23				<0.23		
Sediment	Port Edgar	1	<0.21	1.2				1.2		
Sediment	West of dockyard	1	<0.11	<0.21				<0.21		
Sediment	East Ness Pier	1	<0.13	<0.20				<0.23		
Sediment	Blackness Castle	1	<0.12	<0.14				<0.23		
Sediment	Charlestown Pier	1	<0.12	0.47				<0.23		
Seawater	East of dockyard	2	<0.10	<0.10				<0.10		
Freshwater	Castlehill Reservoir	1						<0.01	<0.010	0.016
Freshwater	Holl Reservoir	1						<0.01	<0.010	0.039
Freshwater	Gartmorn Dam	1						<0.01	<0.01	0.13
Freshwater	Morton No. 2 Reservoir	1						<0.01	<0.010	0.037

* Not detected by the method used

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

b. Except for sediment and sewage pellets where dry concentrations apply, and for water where units are Bq l^{-1}

c. The concentrations of ^{228}Th, ^{230}Th and ^{232}Th were <0.0036, <0.0014 and <0.00085 Bq l^{-1} respectively

d. The concentration of ^{99}Tc was 0.38 Bq kg^{-1}

e. The concentrations of ^{238}Pu and $^{239+240}$Pu were <0.060 and <0.30 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 6.3(b) Monitoring of radiation dose rates near defence establishments, 2022

Location	Location	Ground type	No. of sampling observations	µGy h^{-1}
Mean gamma dose rates at 1m over substrate				
Barrow	Askam Pier	Mud and sand	3	0.069
Barrow	Askam Pier	Salt Marsh	1	0.069
Barrow	Walney Channel, N of discharge point	Mud and sand	4	0.077
Barrow	Roa Island	Mud and sand	2	0.088
Devonport	Torpoint South	Mud and shingle	1	0.089
Devonport	Torpoint South	Shingle and slate	1	0.11
Devonport	Beach near Royal Albert Bridge	Mud	1	0.088
Devonport	Beach near Royal Albert Bridge	Mud and shingle	1	0.082
Devonport	Lopwell	Mud and shingle	2	0.086
Faslane	Garelochhead	Sediment	2	0.063
Faslane	Gulley Bridge Pier	Sediment	2	0.056
Faslane	Rhu	Sediment	2	0.054
Faslane	Helensburgh	Sediment	2	0.056
Faslane	Carnban	Sediment	2	0.061
Faslane	Rahane	Sediment	2	0.062
Faslane	Rosneath Bay	Sediment	2	<0.047
Faslane	Auchengaich	Grass	1	0.064
Faslane	Lochan Ghlas	Grass	1	0.060
Holy Loch	Kilmun Pier	Sediment	1	0.063
Holy Loch	Mid-Loch	Sediment	1	0.056
Holy Loch	Robertsons Yard	Sediment	1	0.060
Rosyth	Blackness Castle	Sediment	2	0.053
Rosyth	Charlestown Pier	Sediment	2	0.051
Rosyth	East Ness Pier	Sediment	2	0.056
Rosyth	East of Dockyard	Sediment	2	0.052
Rosyth	Port Edgar	Sediment	2	0.054
Rosyth	West of Dockyard	Sediment	2	0.058

7 Industrial, landfill, legacy and other non-nuclear sites

Highlights

- doses (dominated by the effects of legacy discharges from other sources) decreased at the LLWR in 2022
- doses at landfill sites were less than 0.5% of the dose limit in 2022
- doses (dominated by the effects of naturally occurring radionuclides from legacy discharges) decreased at Whitehaven in 2022

This section considers the results of monitoring by the Environment Agency, FSA and SEPA for industrial, landfill, legacy and other non-nuclear sites that may have introduced radioactivity into the environment:

1. the main disposal site for solid radioactive wastes in the UK, at the LLWR near Drigg in Cumbria, as well as a recycling facility and other landfill sites that received small quantities of solid wastes
2. one legacy site in England, near Whitehaven (Cumbria), which was used to manufacture phosphoric acid from imported phosphate ore
3. two legacy sites in Scotland, at Dalgety Bay (Fife) and Kinloss (Moray)
4. other non-nuclear sites

7.1 Low Level Waste Repository near Drigg, Cumbria

The LLWR is the UK's national facility for the disposal of lower activity waste and is located on the west Cumbrian coast, southeast of Sellafield. The main function of the LLWR is to receive low activity solid radioactive wastes from all UK nuclear licensed sites (except Dounreay, where the adjacent disposal facility began accepting waste in 2015) and many non-nuclear sites. Where possible the waste is compacted, and then most waste is grouted within containers before disposal. Wastes are currently 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 owned by the NDA and operated on their behalf by LLWR Limited. In 2018, the NDA awarded the incumbent PBO, UK Nuclear Waste Management Limited (UKNWM), a third (and final) contract for the management of LLWR Limited. In January 2022, NWS was launched. This brought together the operator of the LLWR, GDF developer Radioactive Waste Management Limited and the NDA group's integrated waste management programmes into a single organisation. A five-year plan has been published setting out the long-term future of the site through to final closure, expected in 2129 [207]. LLWR's Plutonium Contaminated Materials (PCM) Decommissioning Programme was completed in 2019 (almost 4 years ahead of schedule). Five decommissioned concrete bunkers which housed legacy PCM, will be demolished and material re-used as in-fill for the final engineered cap over vaults and trenches.

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 1). Marine monitoring of the LLWR is therefore subsumed within the Sellafield programme, described in Section 3.3. 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 2022, be distinguished from those due to Sellafield.

The current permit allows for continued solid radioactive waste disposal at the site, including permission to dispose of further radioactive waste beyond Vault 8, and limits disposals against a lifetime capacity for the site. In financial year 2017/18, the site commenced its long-term Repository Development Programme (RDP) [207]. In 2019, Revised Joint Waste Management Plans (JWMP) were published (in conjunction with LLW Repository Limited) for 3 radioactive waste-producing site licence companies (LLWR Limited, Magnox Limited and Sellafield Limited), covering the financial years, 2019/20 to 2023/24. More information can be found at the UK government's website: https://www.gov.uk/government/collections/joint-waste-management-plans-jwmp.

Waste received at the site will have a final disposal location allocated to it at the appropriate time, consequently, in the future, once the closure of Vault 8 has commenced as part of the RDP works, it is intended to report the quantity of solid radioactive waste finally disposed at the site. In the meantime, while development work progresses on the final waste disposal location and capping arrangements, Table A1.3 records (for financial year 2022/23) both solid radioactive wastes already disposed in Vault 8 and the solid radioactive wastes accepted by the site (with the intention to dispose and currently stored within Vaults 8 and 9, pending disposal). A total of 1040m^3 of waste was received by the site with the intention of disposal in financial year 2022/23, bringing the cumulative total to 254,000m^3. As started in 2016, the radiological data, given in Table A1.3, are recorded by financial year (instead of calendar year). All activities in terms of either disposal or receipt of solid radioactive waste with the intention of disposal have been within the lifetime capacity for the site.

Although the permit for routine disposal to the Drigg Stream has been revoked, reassurance monitoring has continued for samples of water and sediment. The results are given in Table 7.2. The tritium, gross alpha and gross beta concentrations in the stream were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from European Directive 2013/51). 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 3 weeks, the annual dose would be less than 0.005mSv. Concentrations of some radionuclides (plutonium-238 and plutonium-239+240) in sediment from the Drigg stream were similar to those in previous years. They reflect the legacy of direct discharges of leachate from the disposal site into the stream [208]. This practice stopped in 1991.

In the past, groundwater from some of the trenches on the LLWR site migrated eastwards towards a railway drain that runs along the perimeter of the site. Radioactivity from the LLWR was detected in the drain water. The previous operators of the site, British Nuclear Fuels plc (BNFL) took steps in the early 1990s to reduce migration of water from the trenches by building a "cut-off wall" to reduce lateral migration of leachate. The results of monitoring in 2022 show that the activity concentrations have continued to be very low in the railway drain and have reduced significantly since the construction of the "cut-off wall". Tritium, gross alpha and gross beta concentrations in the drain were also below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from European Directive 2013/51).

The monitoring programme of terrestrial foodstuffs at the site was primarily directed at the potential migration of radionuclides from the waste burial site via groundwater, since the disposals of gaseous wastes are very small. Results for 2022 are given in Table 7.2 and these provide very limited evidence in support of the proposition that radioactivity in leachate from the LLWR might be transferring to foods. Concentrations of radionuclides were generally similar to (or lower than) those measured near Sellafield (Section 3.3). A new habits survey for Sellafield was undertaken in 2022 and the results have been included in the dose assessments for the site [155].

The 'total dose' from all pathways and sources of radiation was 0.16mSv in 2022, or 16% of the dose limit for members of the public of 1mSv (Table 1.2 and Table 7.1) and includes a component due to the fallout from Chernobyl and nuclear weapons testing. This dose was dominated by the effects of naturally occurring radionuclides and the legacy of discharges into the sea at Sellafield, which are near to the LLWR site (see Section 3.3.1). If these effects were to be excluded, and the sources of exposure from the LLWR are considered, the 'total dose' from gaseous releases and direct radiation was 0.031mSv in 2022 (Table 1.2). The representative person was infants living near the site. The increase in 'total dose' (from 0.029mSv in 2021) was due to a higher estimate of direct radiation from the site in 2022. A source specific assessment of exposure for consumers of locally grown terrestrial food (animals fed on oats), using 2022 modelled activity concentrations in animal products, gives an exposure that was 0.006mSv in 2022, and similar to that in recent years.

7.2 Metals Recycling Facility, Lillyhall, Cumbria

The Metals Recycling Facility (MRF), operated by Cyclife UK Limited, is a small low hazard facility located at the Lillyhall Industrial Estate near Workington in Cumbria. The MRF receives metallic waste items contaminated with low quantities of radiological contamination from clients within the UK nuclear industry. These items are processed on a batch basis. Techniques used include size reduction (if required) using conventional hot and cold cutting methods, with subsequent decontamination using industrial grit blasting equipment.

The permit for the MRF site allows discharges of gaseous waste to the environment via a main stack and of aqueous waste to the sewer. Low discharge limits are set for both aqueous and gaseous discharges. Very small discharges were released during 2022 (Appendix 1, Table A1.1 and Table A1.2). The permit includes conditions requiring Cyclife UK Limited to monitor discharges and undertake environmental monitoring. As in recent years, direct radiation from the site was less than 0.001mSv in 2022 (Table 1.1) and the radiological impact was very low.

A direct radiation observation survey was undertaken in 2018 [209]. This was the first habits survey to be carried out at the MRF and it was undertaken to ensure consistency with other nuclear licensed sites in the UK. The qualitative survey focussed on the area adjacent to the waste container park that had resulted in the elevated dose rates in 2016. Quantitative habits data were not obtained as the time spent by members of the public undertaking activities in the area was minimal.

7.3 Tradebe-Inutec, Winfrith, Dorset

The Tradebe-Inutec site is a radiological waste processing facility, for the wider nuclear industry, located adjacent to the Magnox Winfrith site. In early 2019, Tradebe-Inutec acquired buildings and land at Winfrith from the NDA and the ONR and Environment Agency granted a new nuclear site licence and environmental permit transfer (respectively) to Inutec Limited (who trade as Tradebe-Inutec). Prior to this, Tradebe-Inutec had been operating as a tenant of Magnox Limited. The impact of its site operations and gaseous discharges is considered along with those from the Magnox Winfrith site (in Section 5.4).

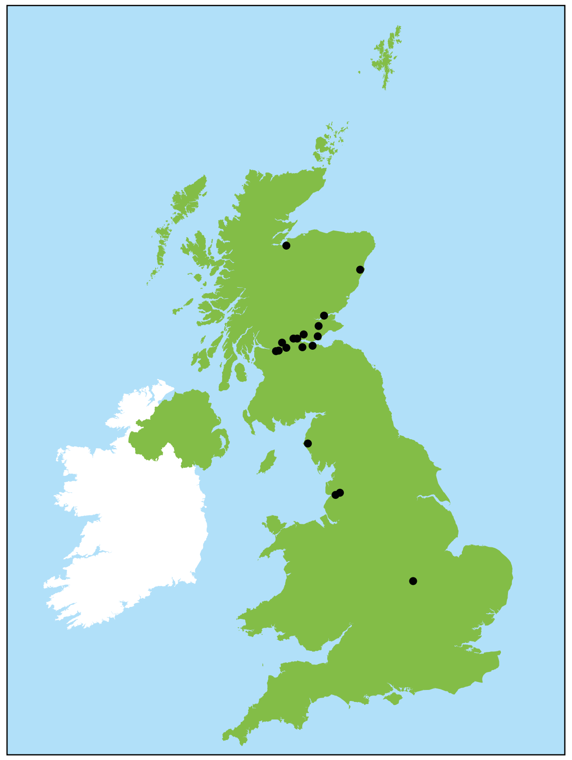
Gaseous discharges from Tradebe-Inutec are also made via stacks to the local environment and are given in Appendix 1 (Table A1.1). As in 2021, discharges of alpha, carbon-14 and other radioelements were less than 1% of the discharge limits, but a small increase of tritium was observed in 2022. The dose from direct radiation from the Tradebe-Inutec site is lower (0.008mSv) than the Magnox Winfrith site (Table 1.1).

Liquid waste from Tradebe-Inutec is transferred off site and discharged into Southampton Water under a non-nuclear permit and therefore, these impacts are not considered in the RIFE report.

7.4 Other landfill sites

Some organisations are granted permits by SEPA (in Scotland), the Environment Agency (in England) and NRW (in Wales) to dispose of solid wastes containing low quantities of radioactivity to approved landfill sites. In Northern Ireland, this type of waste is transferred to Great Britain for incineration. Waste with very low quantities 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 locations of landfill sites considered in 2022 are shown in Figure 7.1 and the results are presented in Table 7.3 and Table 7.4.

Figure 7.1 Landfill sites monitored in 2022



The results, in common with previous years, showed evidence for migration of tritium from some of the disposal sites. The reported tritium concentrations vary from year to year. The variation is thought to be related to changes in rainfall quantity and resulting leachate production and the use of different boreholes for sampling. A possible source of the tritium is thought to be due to disposal of Gaseous Tritium Light Devices [210]. As in recent years, inadvertent ingestion of leachate (2.5l per year) from the Summerston landfill (City of Glasgow) site (with the highest observed concentration of tritium) would result in a dose of less than 0.005mSv in 2022 (Table 7.1), or less than 0.5% of the dose limit for members of the public of 1mSv. Similarly, the annual dose from ingestion of uranium isotopes in leachate from Clifton Marsh was also less than 0.005mSv in 2022.

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

In England and Wales, disposal of LLW at landfill sites requires both landfill companies and nuclear operators to hold permits to dispose of LLW and very low-level waste (VLLW). The 2007 government policy led to applications from landfill operators for permits to dispose of LLW at their sites. The landfill sites were:

- Waste Recycling Group Limited (part of FCC Environmental) at the Lillyhall Landfill Site in Cumbria. Their permit, issued in 2011, allows disposal of VLLW.
- Augean at the East Northants Resource Management Facility (ENRMF), near Kings Cliffe, Northamptonshire. Their permit, issued in 2016, allows the disposal of low activity LLW and VLLW. This permit also requires the operator to carry out periodic environmental monitoring. The results and techniques used are annually audited by the Environment Agency.
- Suez Recycling and Recovery UK Limited (formerly SITA UK) at Clifton Marsh in Lancashire. A permit to dispose of LLW was issued by the Environment Agency in 2012.

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

Disposals of LLW at the ENRMF landfill site, near Kings Cliffe, began in 2011 and were from non-nuclear site remediation works. The first consignment from a nuclear licensed site was in 2012. This comprised soil, concrete, rubble and clay pipes from the drains on the Harwell site. In parallel, the Environment Agency began a programme of monitoring within and around the ENRMF site to provide a baseline and allow detection of any future changes. In 2022, samples were taken, filtered and analysed for radiological composition from groundwater boreholes and off-site watercourses. Both the filtrate and the particulate were analysed for their radioactivity content, along with some bulk water samples. The results are given in Table 7.5. The results were generally reported as less than values. Naturally occurring radionuclides were present at values expected due to natural sources. Gross alpha and gross beta concentrations in off-site watercourses were below the investigation levels for drinking water in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from the European Directive 2013/51) of 0.1 and 1.0Bq l^{-1}, respectively. No use of water for drinking has been observed. Where sampling was repeated, the results were similar to those in previous years. Based on inadvertent ingestion of borehole or surface water at concentrations presented in Table 6.5, the dose in 2022 was estimated to be less than 0.005mSv, or less than 0.5% of the dose limit for members of the public of 1mSv (Table 7.1). The assessment excludes potassium-40 because its presence is homeostatically controlled in the body.

After receiving a permit variation application from FCC Recycling (UK) Limited and subsequent consultation with the local public, professional bodies and stakeholders in 2019, the EA issued a permit variation in July 2021. This allows the site to receive radioactive waste at up to a maximum average activity of 200Bq g^{-1} (previously, a maximum average activity of 4Bq g^{-1}, or 40Bq g^{-1} for tritium). For further information, please visit the following website: (https://consult.environment-agency.gov.uk/cumbria-and-lancashire/lillyhall-landfill-site-rsa-permit-variation/).

SEPA's monitoring programme at the Stoneyhill Landfill Site in Aberdeenshire, authorised to dispose of conditioned NORM waste, ceased in 2016. Results up to 2015 are included in earlier RIFE reports and show no significant radiological impact (for example [46]).

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

7.5 Past phosphate processing, Whitehaven, Cumbria

An important historical man-made source of naturally occurring radionuclides in the marine environment was the chemical plant near Whitehaven in Cumbria, which used to manufacture phosphoric acid (for use in detergents) from imported phosphate ore [211]. Processing of ore resulted in a liquid waste slurry (phosphogypsum) containing most of the thorium, uranium and radioactive decay products (including polonium-210 and lead-210) originally present in the ore, and this was discharged by pipeline to Saltom Bay.

The slurry is regarded as TENORM, meaning that, elevated levels of NORM resulting from industrial activity. Historical discharges continue to have an impact (close to the former discharge point), through the production of the radioactive products. The impact is due to the decay of long-lived parent radionuclides previously discharged to sea. Both polonium-210 and lead-210 are important radionuclides in that small changes in activity concentrations above background significantly influence the dose contribution from these radionuclides. This is due to their relatively high dose coefficient used to convert intake of radioactivity into a radiation dose.

Processing of phosphoric acid at the plant ceased at the end of 2001. The plant was subsequently decommissioned and the authorisation to discharge radioactive wastes was revoked by the Environment Agency.

The results of routine monitoring for naturally occurring radioactivity near the site in 2022 are shown in Table 7.6. Routine analytical effort is focused on polonium-210 and lead-210, which concentrate in marine species and are the important radionuclides in terms of potential dose to the public. As in previous years, polonium-210 and other naturally occurring radionuclides were slightly enhanced near Whitehaven but quickly reduced to background values further away. Figure 7.2 to Figure 7.4 show how concentrations of polonium-210 in winkles, crabs and lobsters have generally decreased since 1998, with larger concentrations variations in lobsters since 2014. Concentrations in the early 1990s were in excess of 100Bq kg^{-1} (fresh weight). There were some small variations in concentrations of polonium-210 in local samples in 2022 (where comparisons can be made), in comparison with those in 2021. Polonium-210 concentrations were generally higher in both crab and lobster samples in 2022, and as in recent years, these concentrations continued to be within or close to the expected range due to natural sources. For crustacean and other seafood samples, it is now difficult to distinguish between the measured radionuclide concentrations and the range of concentrations normally expected from naturally sourced radioactivity. The latter are shown in Figure 7.2 to Figure 7.4 and in Appendix 6. There were small enhancements for some samples at other locations above the expected natural background median values for marine species, however, the majority were within the ranges observed in the undisturbed marine environment. It is considered prudent to continue to estimate doses at Whitehaven whilst there remains an indication that concentrations are higher than natural background. Further analysis has confirmed that this approach is unlikely to underestimate doses [212].

Figure 7.2 Polonium-210 discharge from Whitehaven and concentration in winkles at Patron, 1990 to 2022

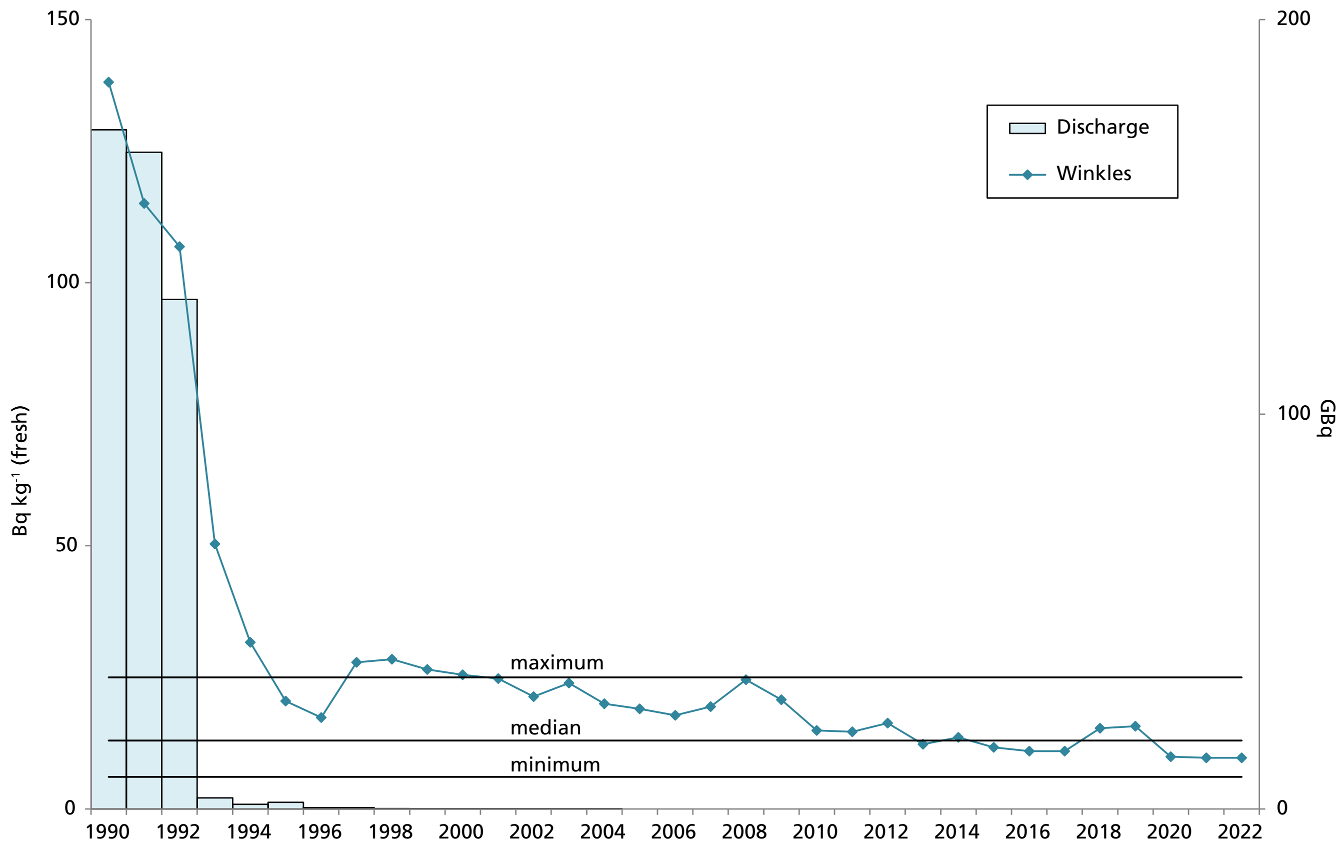


Figure 7.3 Polonium-210 discharge from Whitehaven and concentration in crabs at Parton, 1990 to 2022

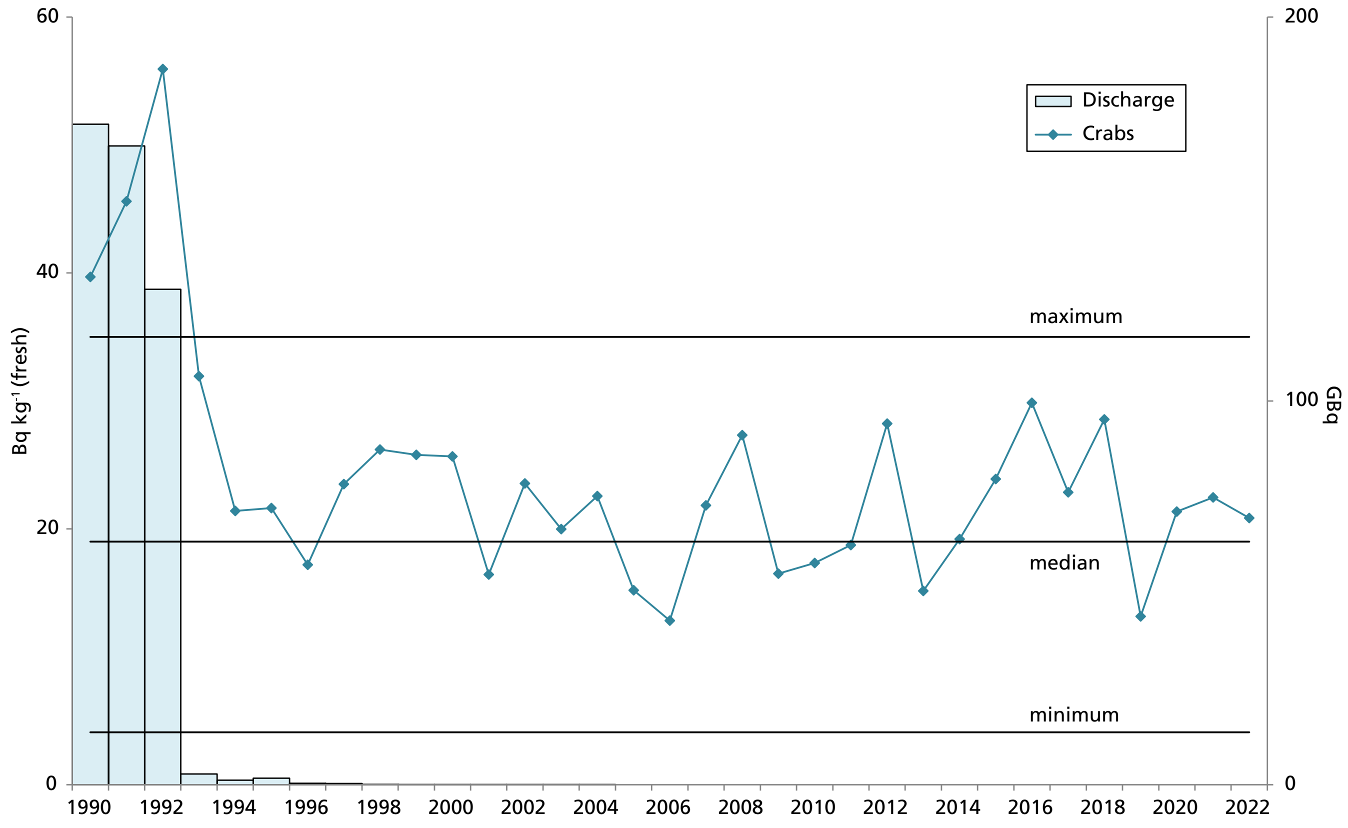
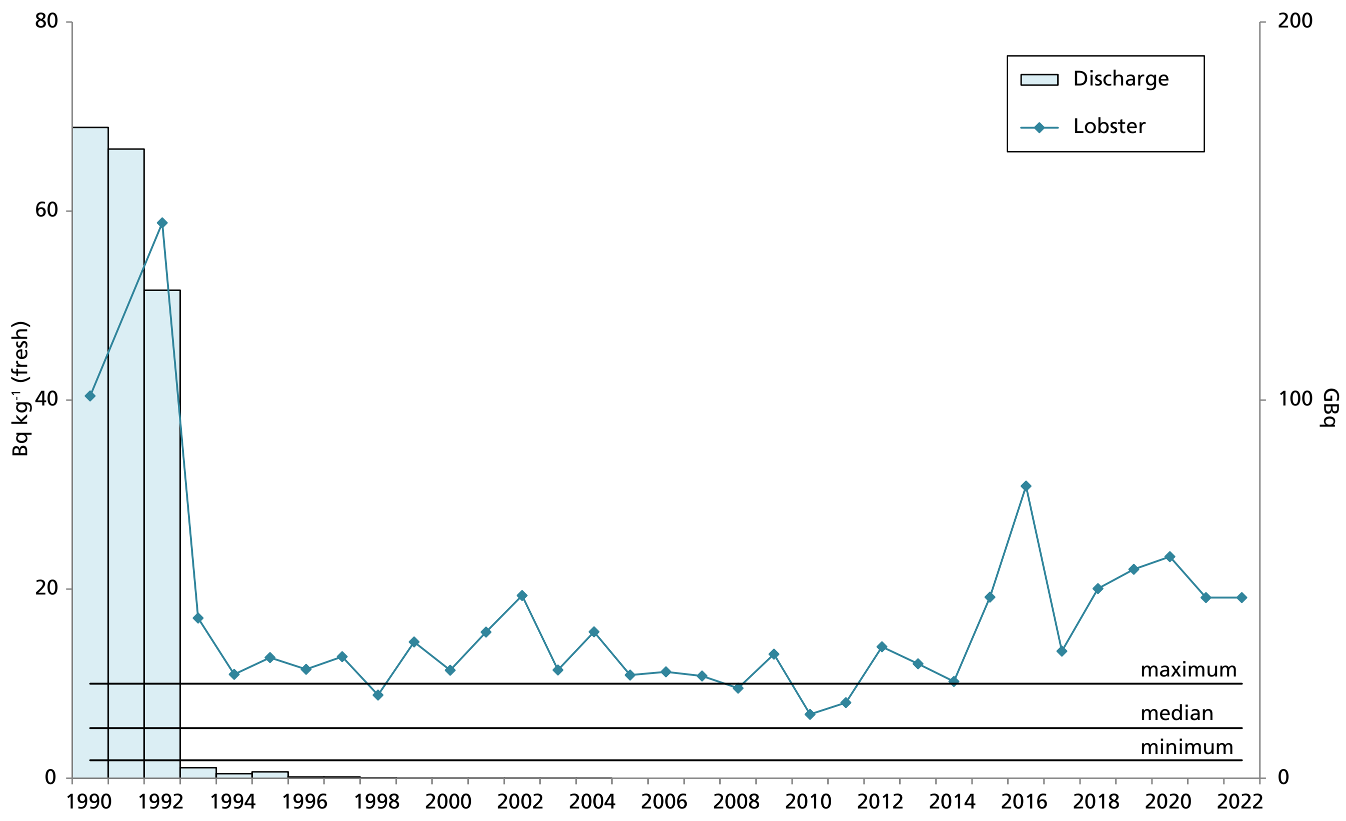


Figure 7.4 Polonium-210 discharge from Whitehaven and concentration in lobsters at Parton, 1990 to 2022



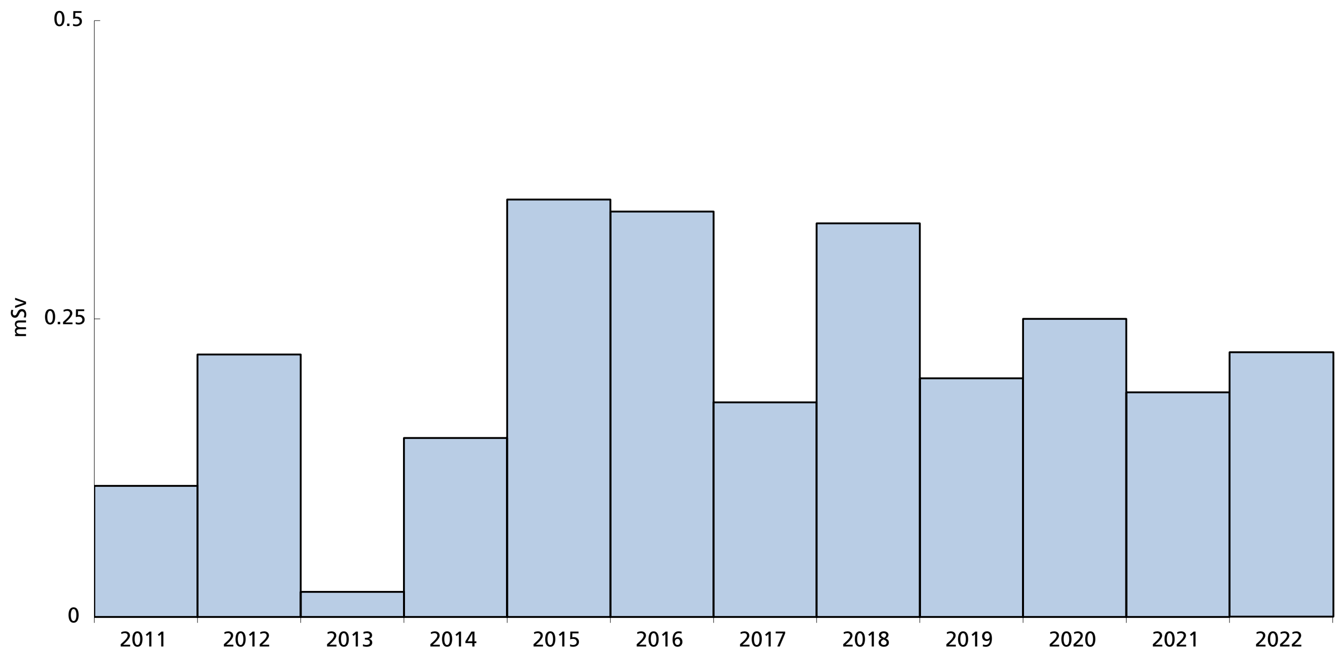
In 2018, the Environment Agency, with the support of the FSA, NIEA and SEPA, performed additional polonium-210 analyses in shellfish samples to obtain baseline data, providing naturally sourced polonium-210 concentrations that are unlikely to be influenced by TENORM in the Irish Sea. Further details are presented in RIFE 24 [68].

The exposure pathway considered for the assessment at Whitehaven was internal irradiation, due to the ingestion of naturally occurring radioactivity in local fish and shellfish. The representative person was a Cumbrian coastal community consumer who, centred on the Sellafield site to the south of Whitehaven, obtained their sources of seafood from locations such as Whitehaven, Nethertown and Parton. This consumer is also considered in the assessment of the marine impacts of the Sellafield and LLWR (near Drigg) sites (Sections 3.3 and 7.1). The estimated contribution due to background median concentrations of naturally occurring radionuclides is subtracted from the measured activity concentration. Consumption rates for people who eat seafood at high rates were reviewed and revised in 2022 [155]. Revised figures for consumption rates, together with occupancy rates, are provided in Appendix 4 (Table A4.2). The dose coefficient for polonium-210 is based on a value of the gut transfer factor of 0.5 for all foods.

The 'total dose' to a local high-rate consumer of seafood was 0.24mSv in 2022 (Table 7.1), or 24% of the dose limit to members of the public, and up from 0.21mSv in 2021. The dose includes the effects of all sources near the site: technically enhanced naturally occurring radionuclides from the non-nuclear industrial activity (in other words, TENORM) and Sellafield operations. The contribution to the 'total dose' from enhanced natural radionuclides was 0.22mSv and was higher in 2022, in comparison to that in 2021 (0.19mSv). The increase in 'total dose' in 2022 was mostly attributed to the increased polonium-210 concentrations in lobsters from Parton. The largest contribution to dose to a Cumbrian coastal community seafood consumer near Whitehaven and Sellafield continues to be from the legacy of historical discharges near Whitehaven. A source specific dose assessment targeted directly at local consumers of seafood (at high rates), gives an exposure of 0.37mSv in 2022 (Table 7.1).

The longer-term trend in annual 'total dose' over the period 2011 to 2022 is shown in Figure 7.5. The variations in 'total dose' over the period 2011 to 2021 reflect changes in polonium-210 concentrations, consumption rates and the range of seafood species consumed by individuals at high-rates, including that of crustaceans. Over a longer period, the trend is of generally declining dose (Figure 7.4, [47]).

Figure 7.5 Trend in 'total dose' to seafood consumers from naturally-occurring radionuclides near Whitehaven, 2011 to 2022



7.6 Former military airbase, Dalgety Bay, Fife

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

In 1990, environmental monitoring showed elevated activity concentrations in the Dalgety Bay area. The monitoring was undertaken as part of the routine environmental monitoring programme for Rosyth Royal Dockyard Limited conducted in accordance with the dockyard's authorisation to dispose of liquid radioactive effluent to the Firth of Forth. Some material was removed for analysis, which indicated the presence of radium-226. Further investigation confirmed that the contamination could not have originated from the dockyard and was most likely to be associated with past practices related to the nearby former RNAS Donibristle/HMS Merlin military airfield. Since this initial discovery, there have been several monitoring exercises to determine the extent of this contamination. In 2017, SEPA issued guidance on monitoring for heterogeneous radium-226 sources resulting from historic luminising activities or waste disposal sites [213].

Additional public protection measures were established following the increased number of particles and the discovery of some high activity particles in 2011. These were maintained between 2020 and 2023. A monthly beach monitoring and particle recovery programme was adopted in 2012 by a contractor working on behalf of the MOD and this remains in place. The fence demarcating the area, where the highest activity particles were detected, remains in place, as well as the information signs advising the public of the contamination and precautions to be taken. In addition, the FEPA Order issued by FSS (then FSA in Scotland) prohibiting the collection of seafood from the Dalgety Bay area remains in force. SEPA undertook a one-year programme of shellfish monitoring from February 2012 during which no particles were detected in the shellfish. All shellfish samples collected were analysed for the presence of radium-226 and all were reported as less than values. During routine monitoring of mussel beds in 2015 a particle was detected in this area (for the first time since 2011) and retrieved, indicating that the continuation of these protection measures is reducing the risks to members of the public whilst further work continues to address the contamination.

The Committee on Medical Aspects of Radiation in the Environment (COMARE) recommended that effective remediation of the affected area be undertaken as soon as is possible. This recommendation followed the publication of the risk assessment in 2013, which was considered alongside the Appropriate Person Report. This Appropriate Person Report included a comprehensive study of the land ownership and history at Dalgety Bay. The COMARE recommendation, amongst others, was subsequently published in 2014 in COMARE's 15th report. The MOD has progressed with addressing the contamination by initially publishing its Outline Management Options Appraisal Report in 2014, followed by a further publication in 2014 of its broad management strategy and timescale for implementation of its preferred management option. Copies of these reports are available on the UK government website: https://www.gov.uk/government/groups/committee-on-medical-aspects-of-radiation-in-the-environment-comare.

The environmental impact assessment (EIA) in support of the planning application for the remediation works was submitted to Fife Council for consideration. In 2017, the planning application for the remediation works was submitted to Fife Council and subsequently approved.

The remediation contract was awarded by MOD in February 2020 and an EASR18 permit to undertake the required work was granted by SEPA in May 2021. Remediation work is now under way and is expected to be completed by the end of 2023.

Further details on the work at Dalgety Bay can be found on the Radioactive Substances pages on SEPA's website: https://www.sepa.org.uk/regulations/radioactive-substances/dalgety-bay/.

7.7 Former military airbase, Kinloss Barracks, Moray

Radioactive items containing radium-226 and associated decay products have been detected on an area of land which used to form part of the former RAF Kinloss, now Kinloss Barracks. The contamination is associated with historical disposals of waste from past military operations at the site resulting from the dismantling of aircraft no longer required by the RAF following World War II. During the late 1940s, the aircraft were stripped for their scrap metal, with the remains being burnt and/or buried at the site. The source of the radium-226 and associated decay products are the various pieces of aircraft instrumentation which were luminised with radium paint.

SEPA has undertaken monitoring surveys at the site which positively identified the presence of radium-226 and has published an assessment of the risks posed to the public [214]. Currently, the site is largely undeveloped open land covered in gorse, with a number of wind turbines and access tracks. The area has a number of informal paths crossing the land that is used by visitors and dog walkers. The contamination detected at the site is all currently buried at depth. Current uses of the site do not involve intrusion into the ground to any significant depth; thus, there is no current pathway for exposure via skin contact, ingestion or inhalation. Exposure via external gamma irradiation is possible but is significantly below the relevant dose criteria detailed in the Radioactive Contaminated Land (RCL) Statutory Guidance [215,216].

The risk assessment of the series of monitoring surveys concluded that, under its current use, there are no viable or credible exposure pathways for the public to be exposed to the contamination and that this site does not currently meet the definition of radioactive contaminated land [214]. However, SEPA will keep this site under review as a change in land use on the site may alter the potential exposure pathways. To access the full risk assessment report please visit the radioactive substances pages available on SEPA's website: https://www.sepa.org.uk.

7.8 Other non-nuclear sites

Small quantities of gaseous and liquid radioactive wastes are routinely discharged from a wide range of other non-nuclear sites in the UK on land (including to the atmosphere from industrial stacks and incinerators), and from offshore oil and gas installations.

A summary of the most recent data for the quantities discharged under regulation for England and Northern Ireland in 2022 is given in Table 7.7 and Table 7.8. Data for Scotland are presented in Table 7.9 and Table 7.10 in terms of OSPAR regions (Region II represents the Greater North Sea and Region III the Celtic Sea). Data for Wales are presented in Table 7.11. This change in format allows easier trend analysis to be performed for OSPAR. 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 (off and onshore)
- education (universities and colleges)
- hospitals
- other (research, manufacturing and public sector)

Discharges may also occur without an authorisation or permit when the quantities are 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 [217].

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

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

In 2022, SEPA continued to undertake a small-scale survey (as part of the annual programme) of the effects of discharges from non-nuclear operators by analysing mussel samples and other materials from the River Clyde, the Firth of Forth and sludge pellets from a sewage treatment works (at Daldowie). The results are given in Table 7.12. The results in 2022 were generally similar to those in 2021. Activity concentrations were typical of the expected effects from Sellafield discharges at this distance and the presence of iodine-131 in sludge pellets (probably from a hospital source). An assessment was undertaken to determine the dose to the representative high-rate mollusc consumer. The dose was estimated to be less than 0.005mSv in 2022, or approximately 0.5% of the dose limit for members of the public, and unchanged from 2021.

Scotoil, in Aberdeen City, operates a cleaning facility for equipment from the oil and gas industry contaminated with enhanced concentrations of radionuclides of natural origin. The facility is authorised to discharge liquid effluent to the marine environment within the limitations and conditions of the authorisation, which includes limits for radium-226, radium-228, lead-210 and polonium-210 discharges. The authorisation includes conditions requiring Scotoil to undertake environmental monitoring. Prior to their operations, a fertiliser manufacturing process was operated on the site and made discharges to sea. Monitoring of seaweed ('Fucus vesiculosus') from Nigg Bay, near Aberdeen Harbour was carried out in 2022 and are reported in Table 3.11. In 2022, the dose rate on sediment was 0.071μGy h^{-1} and similar to background.

Table 7.1 Individual doses - industrial and landfill sites, 2022

Site	Representative person[a,b]	Exposure, mSv per year							
		Total	Seafood (nuclear industry discharg-es)	Seafood (other dis-charges)	Other local food	External radiation from intertidal areas[c]	Intakes of sediment and water[d]	Gaseous plume related pathways	Direct radiation from site
'Total dose' - all sources									
Whitehaven and LLWR near Drigg	**Adult crustacean consumers**	**0.24[e]**	**0.011**	**0.22**	**<0.005**	**<0.005**	**-**	**<0.005**	**<0.005**
Source specific doses									
LLWR near Drigg	Infant consumers of locally grown food	0.006	-	-	0.006	-	-	-	-
	Consumers of water from Drigg stream	<0.005[f]	-	-	-	-	<0.005	-	-
Landfill sites for low-level radioactive wastes	Inadvertent leachate consumers (infants)	<0.005	-	-	-	-	<0.005	-	-
Whitehaven (habits averaged 2018-2022)	Seafood consumers	0.37[e]	0.030	0.33	-	0.015	-	-	-

a. The 'total dose' is the dose which accounts for all sources including gaseous and liquid discharges and direct radiation.
The 'total dose' for the representative person with the highest dose is presented.
Other dose values are presented for specific sources, either liquid discharges or gaseous discharges, and their associated pathways. They serve as a check on the validity of the 'total dose' assessment.
The representative person is an adult unless otherwise stated
'Data are presented to 2 significant figures or 3 decimal places. Data below 0.005 mSv are reported as <0.005 mSv
b. None of the people represented in this table were considered to receive direct radiation from the sites listed
c. Doses ('total dose' and source specific doses) only include estimates of anthropogenic inputs (by substracting background and cosmic sources from measured gamma dose rates)
d. Water is from rivers and streams and not tap water
e. Includes the effects of discharges from the adjacent Sellafield site
f. Includes a component due to natural sources of radionuclides

Table 7.2 Concentrations of radionuclides in terrestrial food and the environment near Drigg, 2022

Material	Location or selection	No. of sampling observ-ations[a]	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	^{134}Cs	^{137}Cs	Total Cs
Milk		1	<3.2	18	<0.04	0.022	<0.08	<0.07	<0.012	<0.30	<0.08	<0.0073	<0.04	0.13	
Deer		1	<3.2	35	<0.04	0.036	<0.12	<0.07	<0.12	<0.27	<0.08	<0.021	<0.03	<0.07	<0.066
Eggs		1	14	45	<0.04	0.029	<0.05	<0.03		<0.24	<0.08	<0.016	<0.02	<0.03	<0.029
Potatoes		1	8.8	6.9	<0.05	0.052	<0.09	<0.07	<0.044	<0.40	<0.09	<0.017	<0.05	0.17	0.17
Sheep muscle		1	<3.1	36	<0.05	0.029	<0.13	<0.14	<0.23	<0.40	<0.10	<0.020	<0.04	0.85	0.85
Sheep offal		1	<6.3	42	<0.04	0.037	<0.09	<0.07	<0.044	<0.33	<0.09	<0.020	<0.05	0.28	0.28
Oats		1	<5.4	100	<0.21	0.47	<0.56	<0.53	<0.054	<1.8	<0.42	<0.025	<0.17	0.50	0.50
Sediment	Drigg Stream	4[E]			<0.48	<1.2	<0.94	<0.44		<3.2	<1.7		<0.45	45	
Freshwater	Drigg Stream	4[E]	<3.8		<0.31	<0.026							<0.34	<0.27	
Freshwater	Railway drain	1[E]	<3.7		<0.32	0.042							<0.35	<0.27	

Material	Location or selection	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}									
			^{144}Ce	^{210}Po	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	^{238}Pu	^{239}Pu+^{240}Pu
Milk		1	<0.24								<0.000051	<0.000039
Deer		1	<0.31								<0.00011	<0.00015
Eggs		1	<0.16								<0.00011	<0.00011
Potatoes		1	<0.25								0.00014	0.0014
Sheep muscle		1	<0.28								<0.000085	0.00012
Sheep offal		1	<0.23								0.00080	0.0056
Oats		1	<0.96								0.00015	0.0014
Sediment	Drigg Stream	4[E]	<1.6	14	13	10	10	22	<1.2	20	2.5	19
Freshwater	Drigg Stream	4[E]		<0.0025	<0.0022	<0.0011	<0.00070	0.023	<0.00090	0.015	<0.0016	<0.0021
Freshwater	Railway drain	1[E]		<0.0030	0.0039	<0.0016	<0.00074	0.0032	<0.00017	0.0025	<0.00060	<0.0029

Material	Location or selection	No. of sampling observations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}			
			^{241}Pu	^{241}Am	Gross alpha	Gross beta
Milk		1	<0.28	<0.000025		
Deer		1	<0.45	0.00021		
Eggs		1	<0.45	0.00010		
Potatoes		1	<0.53	0.0015		
Sheep muscle		1	<0.36	0.00025		
Sheep offal		1	<0.48	0.0068		
Oats		1	<0.54	0.0032		
Sediment	Drigg Stream	4[E]	<50	30	<170	610
Freshwater	Drigg Stream	4[E]	<0.19	<0.0025	<0.072	0.29
Freshwater	Railway drain	1[E]	<0.093	<0.0046	0.025	0.28

a. Except for milk and freshwater where units are Bq l^{-1}, and for sediment where dry concentrations apply
b. 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, 2022

Area	Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}			
			^{3}H	^{14}C	^{137}Cs	^{241}Am
Aberdeen City	Ness landfill	1	<5.0	<15	<0.05	<0.05
City of Glasgow	Summerston landfill	1	63	<15	<0.05	<0.05
City of Glasgow	Cathkin	1	140	<15	<0.05	<0.05
Clackmannanshire	Black Devon	1	<5.0	<15	<0.05	<0.05
Dunbartonshire	Birdston	1	<5.0	<15	<0.05	<0.05
Dundee City	Riverside	1	4.2	<15	<0.05	<0.05
Edinburgh	Braehead	1	<5.0	<15	<0.05	<0.05
Fife	Balbarton	1	51	<15	0.09	<0.05
Fife	Melville Wood	1	280	<15	<0.05	<0.05
Highland	Longman landfill	1	<5.0	<15	<0.05	<0.05
North Lanarkshire	Dalmacoulter	1	140	<15	<0.05	<0.05
North Lanarkshire	Kilgarth	1	<5.0	<15	<0.05	<0.05
Stirling	Lower Polmaise	1	5.0	<15	<0.05	<0.05

Table 7.4 Concentrations of radionuclides in water from landfill sites in England and Wales, 2022

Location	Sample source	No. of sampling observ-ations[a]	Mean radioactivity concentration Bq^{-1}					
			^{3}H	^{40}K	^{60}Co	^{137}Cs	^{228}Th	^{230}Th
Lancashire								
Clifton Marsh	Borehole 6	2	<3.7	<5.2	<0.31	<0.26	<0.0015	<0.00074
Clifton Marsh	Borehole 19	2	<3.6	<6.4	<0.35	<0.31	<0.0017	<0.0027
Clifton Marsh	Borehole 40	2	<3.7	<4.3	<0.25	<0.23	<0.0015	<0.0011
Clifton Marsh	Borehole 59	2	7.8	<3.7	<0.22	<0.20	<0.0017	0.0017

Location	Sample source	No. of sampling observ-ations[a]	Mean radioactivity concentration Bq^{-1}					
			^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
Lancashire								
Clifton Marsh	Borehole 6	2	<0.00078	0.055	0.0027	0.050	0.12	1.1
Clifton Marsh	Borehole 19	2	<0.00075	0.045	<0.0017	0.039	<1.1	5.3
Clifton Marsh	Borehole 40	2	<0.00063	0.0034	<0.00097	0.0027	<0.11	1.2
Clifton Marsh	Borehole 59	2	<0.00076	0.0054	<0.00074	0.0047	<0.11	1.2

Table 7.5 Concentrations of radionuclides in water near the East Northants Resource Management Facility landfill site, 2022

Area	Mean radioactivity concentration[a], Bq kg^{-1}											
	^{3}H	^{40}K	^{137}Cs	^{226}Ra	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U	Gross alpha	Gross beta
K13A Groundwater borehole	<3.7	<5.1	<0.24	0.025	<0.0032	0.0018	0.0011	0.026	<0.0016	0.027	0.20	0.17
K15A Groundwater borehole	<3.7	<3.9	<0.17	0.019	<0.0027	0.0038	<0.011	0.018	<0.00080	0.015	<0.080	0.092
K17 Northern perimeter Groundwater borehole	<3.8	<6.9	<0.28	0.013	<0.0028	<0.0023	<0.00079	0.050	0.0015	0.037	<0.24	2.3
Horse Water spring		<8.2	<0.35								<0.066	0.41
Willow brook		<5.2	<0.25								<0.069	0.53

a. Except for ^{3}H where units are Bq l^{-1}

Table 7.6 Concentrations of naturally occurring radionuclides in the environment, 2022[a]

Material	Location	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}							
			^{210}Po	^{210}Pb	^{228}Th	^{230}Th	^{232}Th	^{234}U	^{235}U	^{238}U
Phosphate processing, Whitehaven										
Winkles	Parton	2	9.3	0.53						
Winkles	Nethertown	4	13	1.2	0.69	0.48	0.43	0.68	0.023	0.62
Winkles	Ravenglass	2	15	1.1						
Mussels	Whitehaven	2	49	1.3						
Prawns	Seascale	2	9.9	<0.019						
Crabs	Parton	2	23	<0.043						
Crabs	Sellafield coastal area	2	16	<0.088	0.11	0.0075	0.0051	0.094	0.0037	0.081
Lobsters	Parton	2	26	0.089						
Lobsters	Sellafield coastal area	2	12	<0.021						
Nephrops	Whitehaven	2	0.96	0.039	0.036	0.017	0.013	0.029	0.00087	0.027
Cod	Parton	2	0.58	0.015						
Cod	Whitehaven	1	0.71	0.013						
Plaice	Whitehaven	2	2.8	0.23	0.055	<0.000065	<0.000065	0.045	0.0013	0.039
Plaice	Drigg	2	2.7	0.20	0.053	<0.000080	<0.00016	0.052	0.0016	0.044
Other samples - Non-Whitehaven										
Winkles	South Gare (Hartlepool)	2	12	1.9						
Cockles	Middleton Sands	2	13							
Mussels	Morecambe	2	40							
Mussels	Ribble Estuary	1			0.31	0.16	0.13			
Limpets	Kirkcudbright	1[S]	8.0							
Shrimps	Ribble Estuary	1			0.010	0.0027	0.0032			
Wildfowl	Ribble Estuary	1				<0.00010	<0.000050			
Sediment	Kirkcudbright	2[S]						14	0.62	14
Sediment	Balcary Bay	1[S]						3.3	0.050	4.0

a. Data for artificial nuclides for some of these samples may be available in the relevant sections for nuclear sites
b. Except for sediment where dry concentrations apply
S Measurements are made on behalf of the Scottish Environment Protection Agency

Table 7.7 Discharges of gaseous radioactive wastes from non-nuclear establishments in England and Northern Ireland, 2022[a]

	Discharges during 2022, Bq					
	Education (Universities and Colleges)		Hospitals		Other (Research, manufacturing and public sector)	
	England	Northern Ireland	England	Northern Ireland	England	Northern Ireland
^{3}H	9.0E+06				3.1E+11	
^{14}C	9.1E+07				2.4E+12	
^{18}F	6.3E+10			1.2E+10	1.1E+12	
^{35}S			6.4E+07		3.6E+07	
^{60}Co					1.7E+07	
^{85}Kr					0.0E+00	
^{90}Sr					8.5E+07	
^{99m}Tc			2.9E+08		6.4E+03	
^{106}Ru					1.3E+06	
^{125}I					1.4E+08	
^{129}I					1.4E+05	
^{131}I			2.3E+08		2.6E+08	
^{137}Cs					1.2E+08	
Uranium Alpha					1.0E+00	
^{241}Pu					9.6E+02	
Plutonium Alpha					1.5E+06	
^{241}Am					4.2E+02	
^{242}Cm					1.0E+00	
Other Alpha Particulate		Nil	4.7E+06	Nil	8.6E+10	Nil
Other Beta/Gamma		Nil		Nil		Nil
Other Beta/Gamma Particulate	6.9E+11	Nil	5.2E+09	Nil	3.0E+12	Nil

a. Excludes nuclear power, defence and radiochemical manufacturing (Amersham) industries. Excludes discharges which are exempt from reporting. England discharge data refers to 2021

Table 7.8 Discharges of liquid radioactive waste from non-nuclear establishments in England and Northern Ireland, 2022[a]

	Discharges during 2022, Bq						
	Education (Universities and Colleges)		Hospitals		Other (Research, manufacturing and public sector)		Oil and gas (off-shore)
	England	Northern Ireland	England	Northern Ireland	England	Northern Ireland	United Kingdom
^{3}H	4.1E+09	2.1E+07	4.6E+07	3.3E+07	2.5E+12		
^{14}C	2.8E+09		1.1E+07		1.5E+11		
^{18}F	7.0E+11		4.1E+12	2.5E+11	5.5E+12		
^{32}P	1.5E+09		1.7E+09		3.1E+07		
^{33}P	1.8E+08		4.6E+08				
^{35}S	2.5E+09		4.8E+08		1.3E+09		
^{51}Cr	2.9E+08		1.2E+07				
^{57}Co	1.2E+05		7.1E+07				
^{58}Co	7.0E+04						
^{60}Co					2.2E+06		
^{67}Ga			2.2E+09				
^{75}Se	2.6E+07		4.6E+09	1.6E+08	1.2E+08		
^{90}Sr	2.6E+07				9.0E+00		
^{90}Y			1.2E+10	9.0E+08			
^{99}Tc	1.0E+06				4.4E+02		
^{99m}Tc	9.5E+09		4.4E+13	1.4E+12	1.0E+12		
^{111}In	3.5E+08		6.5E+10	2.3E+10	6.9E+07		
^{123}I	5.7E+06		1.0E+12	6.7E+10	2.0E+10		
^{125}I	2.4E+09	1.1E+08	4.0E+08	6.9E+09	9.0E+09		
^{129}I					1.0E+00		
^{131}I			8.4E+12	3.8E+11	1.5E+11		
^{134}Cs					1.7E+07		
^{137}Cs	1.3E+06				3.3E+09		
^{153}Sm			5.7E+09	2.1E+09			
^{177}Lu	9.3E+07		9.8E+12	4.0E+10	9.2E+11		
^{201}Tl	2.0E+07		5.1E+09				
^{223}Ra			1.3E+10	4.6E+08	4.8E+06		
^{230}Th					2.4E+08		
^{232}Th					6.1E+08		
^{237}Np					1.0E+00		
Uranium Alpha					9.3E+08		
^{241}Pu					8.7E+03		
Plutonium Alpha					2.0E+03		
^{241}Am					3.8E+03		
^{242}Cm					5.0E+00		
^{243}Cm					2.1E+01		
^{244}Cm					2.1E+01		
Total Alpha	1.1E+05	Nil	1.3E+10	Nil	6.5E+10	Nil	4.6E+09
Total Beta/Gamma (Excl Tritium)	7.6E+11		6.1E+13		7.9E+12		3.3E+09
Other Alpha Particulate	5.8E+04		1.6E+08		9.5E+06		
Other Beta/Gamma[b]	4.3E+10	Nil	1.9E+11	Nil	5.2E+11	Nil	
Other Beta/Gamma Particulate					2.2E+08		

a. Excludes nuclear power, defence and radiochemical manufacturing (Amersham) industries. Excludes discharges which are exempt from reporting. England discharge data refers to 2021

b. Excluding specific radionuclides

Table 7.9 Discharges of gaseous radioactive wastes from non-nuclear establishments in Scotland by OSPAR region, 2022[a]

Area	Discharges during 2022, Bq					
	OSPAR Region II - Greater North Sea			OSPAR Region III - Celtic Seas		
	Education (Universities and Colleges)	Hospitals	Other (Research, manufacturing and public sector)	Education (Universities and Colleges)	Hospitals	Other (Research, manufacturing and public sector)
^{3}H	Nil	Nil	Nil	Nil	Nil	Nil
^{14}C	Nil	Nil	Nil	Nil	Nil	Nil
^{18}F	Nil	Nil	Nil	Nil	1.8E+10	Nil
^{85}Kr	Nil	Nil	Nil	Nil	Nil	Nil
^{125}I	Nil	Nil	Nil	Nil	Nil	Nil
^{131}I	Nil	Nil	Nil	Nil	Nil	Nil
^{133}Xe	Nil	Nil	Nil	Nil	Nil	Nil
^{137}Cs	Nil	Nil	Nil	Nil	Nil	Nil
Group of Two or More Specified Radionuclides	Nil	1.1E+11	Nil	Nil	Nil	5.1E+06
Other Alpha	Nil	Nil	Nil	Nil	Nil	2.0E+00
Other Beta/Gamma	5.6E+05	4.9E+10	Nil	Nil	Nil	6.5E+06
Other Radionuclides Not Listed	Nil	Nil	Nil	Nil	7.8E+09	Nil

a. Excludes nuclear power and defence industries. Excludes discharges which are exempt from reporting.

Table 7.10 Discharges of liquid radioactive waste from non-nuclear establishments in Scotland by OSPAR region, 2022[a]

Area	Discharges during 2022, Bq						
	OSPAR Region II - Greater North Sea				OSPAR Region III - Celtic Seas		
	Education (Universities and Colleges)	Hospitals	Other (Research, manufacturing and public sector)	Oil and gas (on-shore)	Education (Universities and Colleges)	Hospitals	Other (Research, manufacturing and public sector)
^{3}H	2.4E+09	4.6E+07	1.1E+08	Nil	7.4E+08	Nil	2.7E+08
^{14}C	4.8E+05	8.6E+04	1.8E+09	Nil	3.9E+06	Nil	Nil
^{18}F	Nil	1.3E+11	Nil	Nil	Nil	3.2E+11	Nil
^{22}Na	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{32}P	2.1E+08	5.5E+06	Nil	Nil	1.1E+08	Nil	6.6E+08
^{33}P	1.1E+09	Nil	Nil	Nil	Nil	Nil	Nil
^{35}S	4.9E+07	Nil	Nil	Nil	1.3E+09	Nil	Nil
^{51}Cr	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{57}Co	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{60}Co	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{67}Ga	Nil	Nil	Nil	Nil	Nil	4.6E+07	Nil
^{75}Se	Nil	6.6E+07	Nil	Nil	Nil	5.2E+07	Nil
^{89}Sr	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{90}Sr	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{90}Y	Nil	5.5E+08	Nil	Nil	Nil	Nil	Nil
^{99m}Tc	Nil	3.0E+12	Nil	Nil	Nil	2.0E+12	3.3E+08
^{111}In	Nil	3.1E+09	Nil	Nil	Nil	9.4E+08	Nil
^{123}I	Nil	5.0E+10	Nil	Nil	Nil	3.0E+10	Nil
^{125}I	Nil	9.6E+06	Nil	Nil	Nil	4.4E+06	Nil
^{131}I	1.0E+09	2.1E+11	Nil	Nil	Nil	3.3E+11	Nil
^{134}Cs	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{137}Cs	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{153}Sm	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{169}Er	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{201}Tl	Nil	2.5E+07	Nil	Nil	Nil	7.2E+09	Nil
^{210}Pb	Nil	Nil	1.8E+06	2.6E+08	Nil	Nil	Nil
^{210}Po	Nil	Nil	Nil	2.2E+08	Nil	Nil	Nil
^{226}Ra	Nil	Nil	5.5E+05	7.2E+08	Nil	Nil	Nil
^{228}Ra	Nil	Nil	5.2E+05	1.5E+09	Nil	Nil	Nil
^{232}Th	Nil	Nil	Nil	Nil	Nil	Nil	1.2E+06
Uranium Alpha	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{237}Np	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Plutonium Alpha	Nil	Nil	Nil	Nil	Nil	Nil	Nil
^{241}Am	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Group of Two or More Specified Radionuclides	Nil	Nil	Nil	Nil	Nil	Nil	2.5E+07
Other Alpha	Nil	2.8E+08	Nil	Nil	Nil	Nil	1.1E+04
Other Beta/ Gamma[b]	Nil	1.2E+11	Nil	Nil	9.9E+06	7.4E+11	2.7E+06
Other Radionuclide Not Listed	Nil	2.8E+08	Nil	Nil	Nil	4.8E+08	Nil

a. Excludes nuclear power and defence industries. Excludes discharges which are exempt from reporting.
b. Excluding specific radionuclides

Table 7.11 Discharges of gaseous and liquid radioactive wastes from non-nuclear establishments in Wales, 2022a

	Discharges during 2022, Bq		
	Education (Universities and Colleges)	Hospitals	Other (Research, manufacturing and public sector)
Gaseous Discharges			
^{3}H	8.2E+05		2.6E+13
^{14}C			3.8E+12
^{210}Pb			3.3E+10
^{210}Po			4.5E+10
Liquid Discharges			
^{3}H	2.0E+08		7.6E+10
^{14}C	1.6E+06		2.3E+09
^{32}P	4.7E+07		
^{35}S	7.0E+04		1.9E+07
^{125}I	1.2E+07		1.6E+10
^{131}I		3.0E+11	

a. Excludes nuclear power industries. Excludes discharges which are exempt from reporting.

Table 7.12 Monitoring in the Firth of Forth, River Clyde and near Glasgow, 2022[a]

Location	Material and selection[b]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{3}H	^{14}C	^{54}Mn	^{90}Sr	^{95}Nb	^{99}Tc
Between Finlaystone and Woodhall	Mussels	1		<15	<0.15		<0.14	0.96
Between Finlaystone and Woodhall	Fucus vesiculosus	1		<15	<0.11		<0.11	18
Dalmuir Clydebank	Sediment	1		<15	<0.10		<0.10	
Downstream of Dalmuir	Freshwater	4			<0.10		<0.10	
River Clyde	Freshwater	4	<1.0			<0.005		
Firth of Forth	Freshwater	3	<1.0			<0.005		
Daldowie	Sludge pellets	4			<0.10		<0.10	

Location	Material and selection[b]	No. of sampling observ-ations[a]	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}						
			^{125}Sb	^{131}I	^{137}Cs	^{155}Eu	^{241}Am	Gross alpha	Gross beta
Between Finlaystone and Woodhall	Mussels	1	<0.42	<0.15	<0.17	<0.33	<0.20		
Between Finlaystone and Woodhall	Fucus vesiculosus	1	<0.30	9.1	0.22	<0.39	<0.43		
Dalmuir Clydebank	Sediment	1	<0.18	0.14	5.9	<0.32	<0.38		
Downstream of Dalmuir	Freshwater	4	<0.10	<0.10	<0.10	<0.13	<0.12		
River Clyde	Freshwater	4			<0.01				1.0
Firth of Forth	Freshwater	3			<0.02			0.043	1.6
Daldowie	Sludge pellets	4	<0.34	450	2.3	<0.88	<0.89		

a. Results are available for other radionuclides detected by gamma spectrometry,
All such results are less than the limit of detection
No ^{32}P analyses were performed in 2022

b. Except for water where units are Bq l^{-1}, and sludge pellets and sediment where dry concentrations apply

8 Industrial, landfill, legacy and other non-nuclear sites

Highlights
- Doses for the representative person were approximately 1% (or less) of the annual public dose limit in 2022

Regional monitoring in areas remote from nuclear licensed sites has continued in 2022:

1. to establish long distance transport of radioactivity from UK and other nuclear licensed sites
2. to indicate general contamination of the food supply and the environment
3. to provide data under UK obligations under the OSPAR Convention

The routine component parts of this programme are: sampling of seafood and environmental samples from the Channel Islands and Northern Ireland; monitoring UK ports of entry for foodstuffs from Japan and for other non-specific contamination; sampling of the UK food supply, air, rain, sediments, drinking water and seawater.

8.1 Channel Islands

Samples of marine environmental materials were provided by the Channel Island States and measured for a range of radionuclides. The programme monitors the effects of radioactive discharges from the French reprocessing plant at La Hague and the power station at Flamanville. It also monitors any effects of historical disposals of radioactive waste in the Hurd Deep, a natural trough in the western English Channel. Fish and shellfish are monitored to determine exposure from the internal radiation pathway and sediment is analysed for external exposures. Seawater and seaweeds are sampled as environmental indicator materials and, in the latter case, because of their use as fertilisers. A review of marine radioactivity in the Channel Islands from 1990 to 2009 has been published [218].

The results of monitoring for 2022 are given in Table 8.1, as in 2021, no samples were collected or analysed from Alderney. There was evidence of routine releases from the nuclear industry in some food and environmental samples (for example, technetium-99). However, activity concentrations in fish and shellfish were low and similar to those in previous years. It is generally difficult to attribute the results to different sources, including fallout from nuclear weapons testing, due to the low values detected. No evidence for significant releases of activity from the Hurd Deep site was found.

In 2022, the dose to the representative person, consuming large amounts of fish and shellfish was estimated to be less than 0.005mSv, or less than 0.5% 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.

Collection of milk and crop samples from the Channel Island States ceased in 2014. Results up to 2013 are included in earlier RIFE reports (for example [112]) and the data indicated no significant effects from UK or other nuclear installations.

8.2 Isle of Man

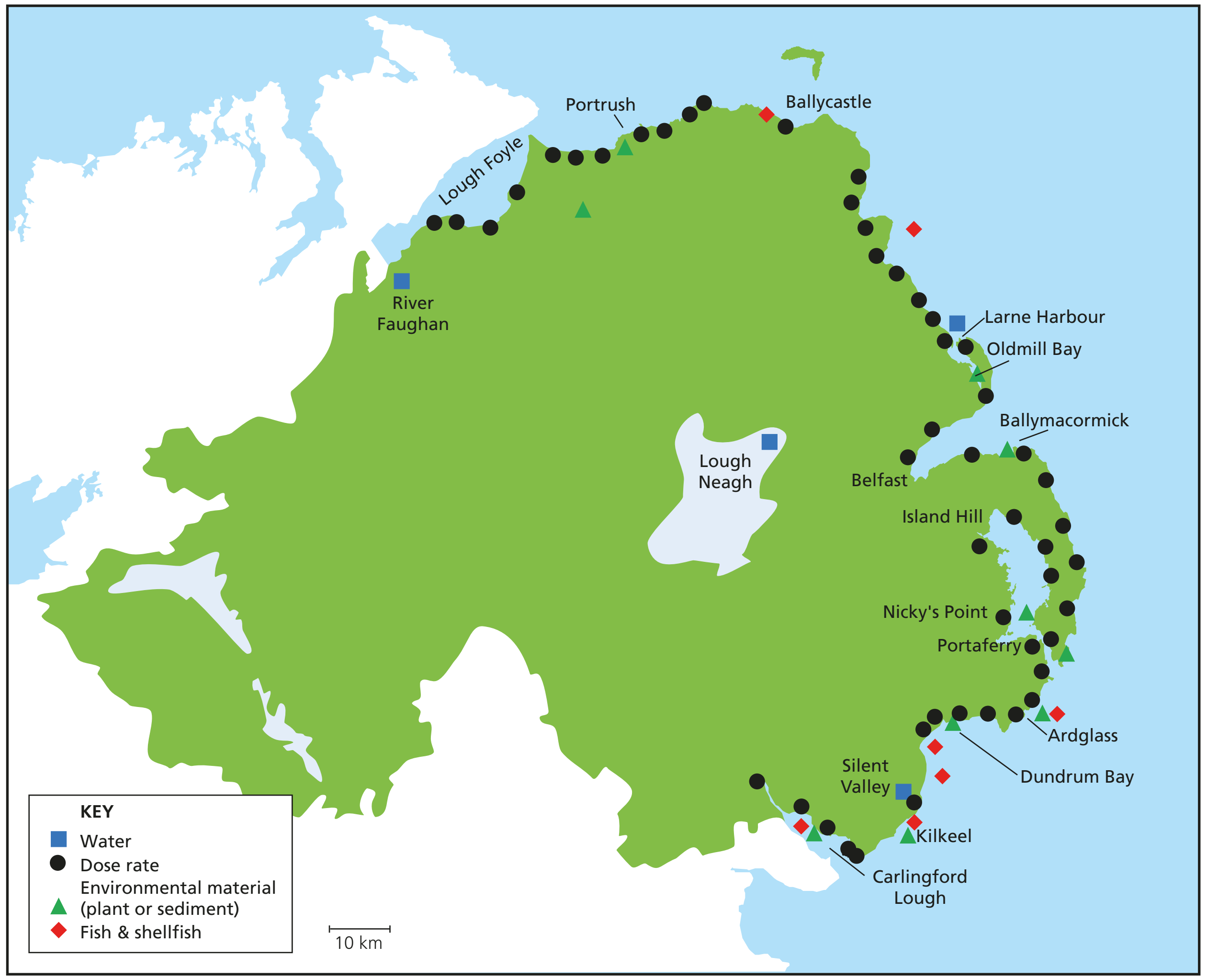
The Environment Agency has carried out a review of its environmental monitoring on the Isle of Man. Following this review, the Environment Agency's marine monitoring on the Isle of Man ceased in 2016. Results up to 2015 are included in earlier RIFE reports (for example [46]). Previous results have demonstrated that there has been no significant impact on the Isle of Man from discharges to sea from mainland nuclear installations in recent years.

The Government of the Isle of Man undertakes their own independent radioactivity monitoring programme and provides an indication of the far-field effects of current and historical discharges from Sellafield and other UK nuclear sites. These are reported annually: https://www.gov.im/about-the-government/departments/environment-food-and-agriculture/regulation-directorate/government-laboratory/environmental-radioactivity/.

8.3 Northern Ireland

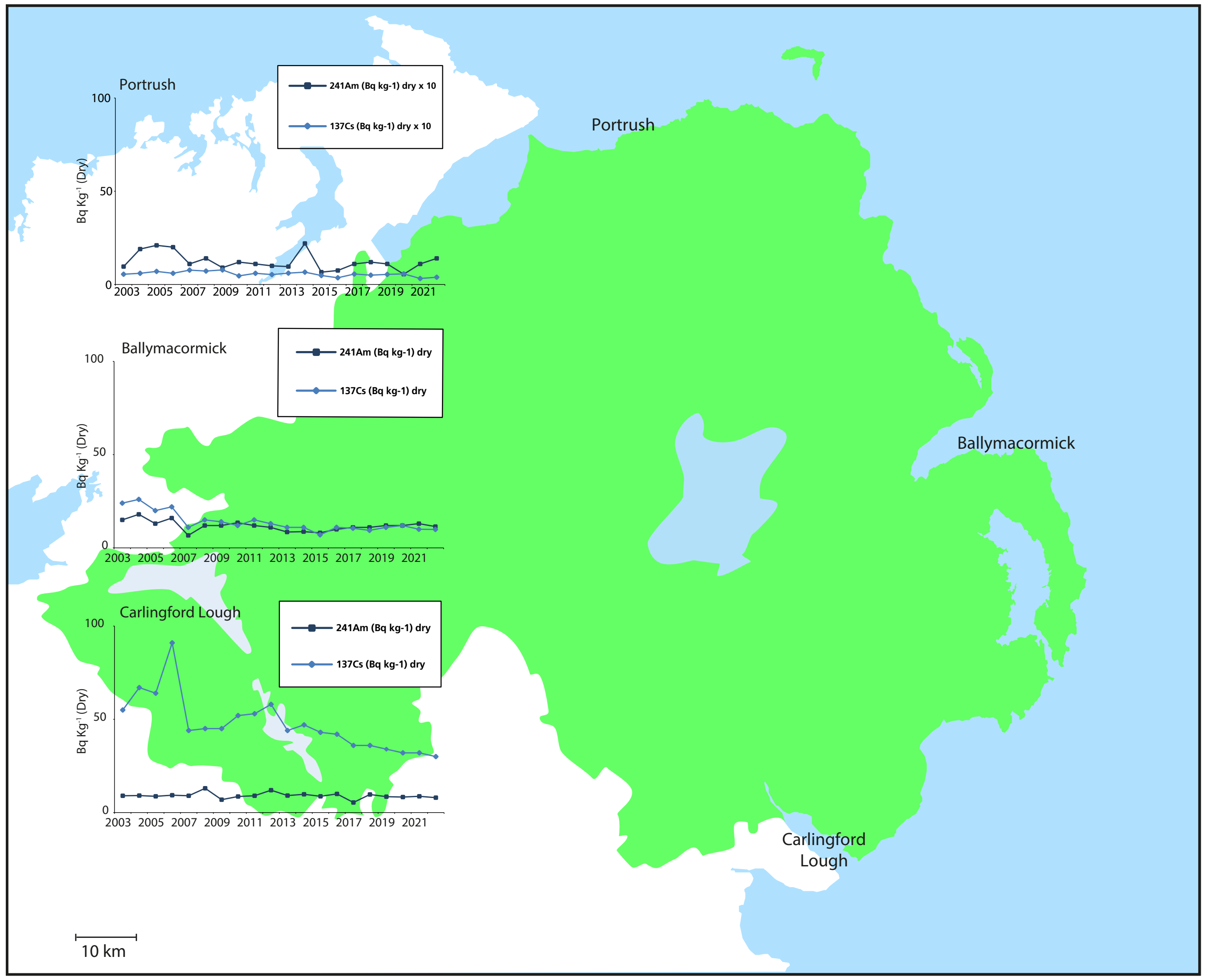
The NIEA monitors the far-field effects of liquid discharges from Sellafield into the Irish Sea. The programme involved sampling fish, shellfish and indicator materials from a range of locations along the coastline (Figure 8.1). Gamma dose rates were measured over intertidal areas to assess the external exposure pathway. The results of monitoring are given in Table 8.2(a) and Table 8.2(b).

Figure 8.1 Monitoring locations in Northern Ireland, 2022



In 2022, the main effect of discharges from Sellafield was observed in concentrations of technetium-99 in shellfish and seaweed samples. These were similar to values reported in recent years, reflecting the considerably decreased inputs to the Irish Sea (see also Section 3.3.3). Caesium-137 concentrations were low and generally similar to those in 2021. As expected, low concentrations of transuranic radionuclides were also detected in 2022. Reported concentrations are less than those found nearer to Sellafield and continued to be low, as in recent years (Figure 8.2). Further information on the trends in radioactivity in the marine environment of Northern Ireland has been published [219]. The gamma dose rates over intertidal areas were similar to those in previous years.

Figure 8.2 Concentrations of americium-241 and caesium-137 in coastal sediments in Northern Ireland, 2003-2022. The dark blues lines represent americium-241 and the light blue lines caesium-137.



A survey of consumption and occupancy in coastal regions of Northern Ireland established the habits of people consuming large quantities of fish and shellfish [220]. Based on the monitoring results from the marine environment in 2022, the annual dose from the consumption of seafood and exposure over intertidal areas was 0.008mSv (Table 3.15), or less than 1% of the dose limit for members of the public.

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

8.4 General diet

As part of the UK government and devolved administrations' general responsibility for food safety, concentrations of radioactivity are determined in regional diets. These data (and data on other dietary components in Sections 8.5 and 8.6) previously formed the basis of the UK submission to the EC under Article 36 of the Euratom Treaty. While these data are no longer supplied to the EC for England, Wales and Northern Ireland, they will continue to be published in the RIFE reports. In 2022, the concentrations found in a survey of radioactivity in canteen meals collected across the UK, and mixed diets in Scotland, were very low or typical of natural sources (Table 8.3). Activity concentrations were generally similar to those in previous years.

8.5 Milk

The programme of milk sampling across dairies in the UK continued in 2022. The aim is to collect and analyse samples on a monthly basis, for their radionuclide content. This programme provides useful information with which to compare data from farms close to nuclear licensed sites and other establishments that may enhance values above background activity concentrations. Prior to the UK's exit from the EU, concentrations of radioactivity in the general diet were reported to the EC by the FSA (for England, Northern Ireland and Wales), and by SEPA (for Scotland). While these data are no longer supplied to the EC for England, Wales and Northern Ireland, they will continue to be published in the RIFE reports.

The results of milk monitoring for 2022 are summarised in Table 8.4. Most results were similar to those in previous years (where comparisons can be made). The mean carbon-14 concentrations in England, Northern Ireland, Wales and Scotland were all close to the expected background concentration in milk (see Appendix 6). The maximum concentrations of carbon-14 in milk for England (Dorset and Kent), Northern Ireland (Co. Tyrone), Wales (Clywd) and Scotland (Dumfriesshire and Nairnshire) were 22, 25, 43 and less than 16Bq l^{-1}, respectively. As in previous years, tritium concentrations were reported as less than values at all remote sites. In 2022, strontium-90 concentrations were reported as less than values (or just above the less than value) and the mean concentration over the UK was less than 0.033Bq l^{-1} in 2022 (0.037Bq l^{-1} in 2021). In the past, the highest concentrations of radiocaesium in milk were from those regions that received the greatest amounts of fallout from Chernobyl. However, the concentrations are now very low, and it is not possible to distinguish this trend.

Radiation dose from consuming milk at average rates was assessed for various age groups. In 2022, the most exposed age group was infants (1-year-old). For the range of radionuclides analysed, the annual dose was less than 0.005mSv or less than 0.5% of the dose limit. Previous surveys (for example, [221]) have shown that if a full range of nuclides were to be analysed and assessed, the dose would be dominated by naturally occurring lead-210 and polonium-210, and artificial radionuclides would contribute less than 10% of the dose.

8.6 Crops

The programme of monitoring naturally occurring and artificial radionuclides in crops (in England, Wales and the Channel Islands) as a check on general food contamination (remote from nuclear sites) ceased in 2014. Further information on previously reported monitoring is available in earlier RIFE reports (for example [62]).

8.7 Airborne particulate, rain, freshwater and groundwater

Radioactivity in rainwater and air was monitored at several UK locations as part of the programme of background sampling managed by the Environment Agency and SEPA. These data are collected on behalf of the DESNZ, NIEA and the Scottish and Welsh Governments. The results of monitoring are given in Table 8.5. The routine programme is comprised of two components:

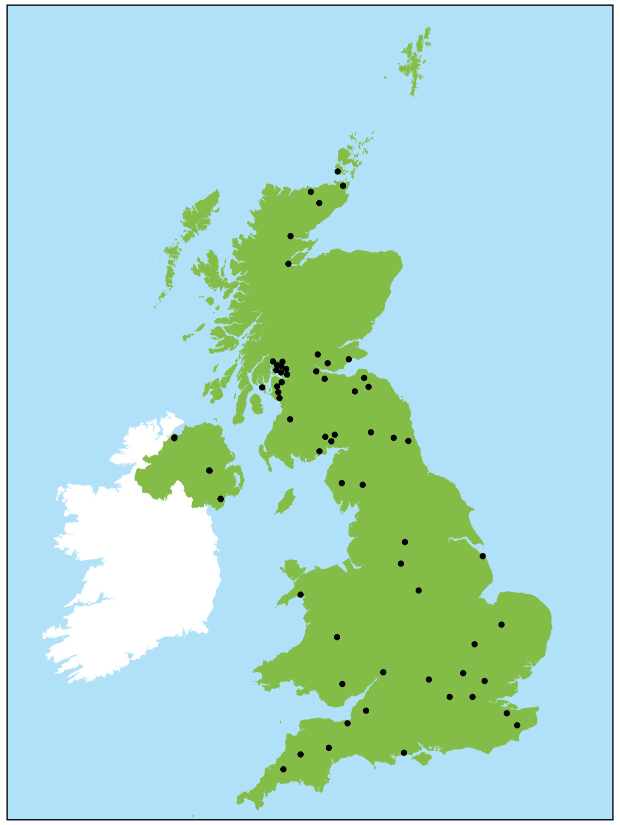
1. regular sampling and analysis on a quarterly basis
2. supplementary analysis on an 'ad hoc' basis

Tritium and caesium-137 concentrations in air and rainwater are reported as less than values in 2022. Caesium-137 concentrations in air, as in recent years, remain less than 0.01% 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 positively detected at similar values 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 [171]. Activity concentrations of the radionuclides reported in air and rainwater were very low and do not currently merit radiological assessment.

Sampling and analysis of freshwater from drinking water sources throughout the UK continued in 2022 (Figure 8.3). These water data are collected by the Environment Agency (for England and Wales), NIEA (for Northern Ireland) and SEPA (for Scotland). Sampling was designed to represent the main drinking water sources, namely reservoirs, rivers and groundwater boreholes. Most of the water samples were representative of natural waters before treatment and supply to the public water system.

Figure 8.3 Drinking water sampling locations, 2022



The results are given in Table 8.6 to Table 8.8 (inclusive). Tritium concentrations were all substantially below the investigation level for drinking water of 100Bq l^{-1} in the Water Supply (Water Quality) (Amendment) 2018 Regulations (retained from European Directive 2013/51) (where applicable) and all are reported as less than values (except for 5 results). At Gullielands Burn (Table 8.6), which is near to the Chapelcross nuclear licensed site, the tritium concentration was 21Bq l^{-1} in 2022 (similar to that in recent years).

The mean annual dose from consuming drinking water in the UK was 0.027mSv in 2022 (Table 8.9), and higher than the mean annual dose in 2021 (0.015mSv). The highest annual dose was estimated to be 0.030mSv for drinking water from Matlock, Derbyshire. The estimated doses were dominated by naturally occurring radionuclides and are generally similar to those in recent years. The annual dose from artificial radionuclides in drinking water was less than 0.001mSv.

Collection and analysis of groundwater samples from across Scotland was not performed in 2022. Results up to 2019 are included in earlier RIFE reports (for example, [23]).

8.8 Overseas incidents

Two overseas accidents have had direct implications for the UK: Chernobyl (1986) and Fukushima Dai-ichi (2011). Earlier RIFE reports have provided detailed results of monitoring by the environment agencies and the FSA [111].

For Chernobyl, the main sustained impact on the UK environment was in upland areas, where heavy rain fell in the days following the accident, but activity concentrations have now reduced substantially. The results of monitoring and estimated doses to consumers are available in earlier RIFE reports.

In 2011, the EC implemented controls (Regulation EU/297/2011) on the import of feed and food originating in or consigned from Japan following the Fukushima Dai-ichi accident [222]. Thereafter, imports of all feed and food originating in or consigned from Japan could only enter the UK through specific ports and airports where official controls will be carried out. Products of animal origin can only enter through border inspection posts (BIPs) and products of non-animal origin can only enter through designated points of entry (DPE).

The legislation was updated in 2016 (Regulation EU/6/2016) and amended in 2017 (Regulation EU/2058/2017) and again in October 2019 (Regulation EU/2019/1787) [223]. This applied certain measures to some feed and food originating in or consigned from specific prefectures of Japan. The 2016 regulation (amended in 2017 and 2019) lifted restrictions on some or all agricultural and fisheries products from 10 Japanese prefectures. Applicable feed and food products from these prefectures intended to be imported to the UK had to be tested before leaving Japan and were subject to random testing in the UK. The exceptions are for certain personal consignments of feed and food. The main requirements of the regulation for imports of feed and food destined for the EU are provided in earlier RIFE reports (for example [47]). The list of applicable feeds and foods from the prefectures can be found in annex II of the legislation. These regulations were retained in the UK following the UK's exit from the EU and amended by the Food and Feed Hygiene and Safety (Miscellaneous Amendments etc.) (EU Exit) Regulations 2020.

There was a requirement in the legislation to review these enhanced import controls on food from Japan in 2021. Following the UK's exit from the EU, the responsibility to review the controls fell to ministers in England, Wales and Scotland based on advice from the FSA and FSS.

In December 2021, the FSA and FSS launched a public consultation as part of this review [224]. The consultation proposed removing the last of the remaining enhanced controls based on the outcome of the FSA and FSS risk assessment, which concluded that the removal of the 100Bq kg 1 maximum level for radiocaesium in imported Japanese food would result in a negligible increase in dose and any associated risk to UK consumers [225]. Following the consultation, the FSA and FSS Boards both agreed to make recommendations to ministers to remove the controls [226,227]. Following agreement from ministers, legislation was laid to revoke retained EU Regulation 2016/6 which came into force on 25 June 2022 (in Scotland) [228] and 29 June 2022 (in England and Wales) [229,230]. From these dates, the enhanced controls, and requirements for testing these food products from Japan were removed for products entering Great Britain.

In Northern Ireland, European Regulations continue to apply under the terms of the UK's withdrawal agreement from the EU. In September 2021, the EU published Commission Implementing Regulation (EU) 2021/1533 [231] which replaced Regulation 2016/6 in the EU. The EU retained enhanced controls on any food where there is a single instance of exceeding the maximum level of 100Bq kg^{-1}, or similar. As a result, some controls will remain in place for food imported into the EU and Northern Ireland. The list of foods covered by the enhanced controls in the EU regulations is now very limited and includes wild mushrooms, foraged foods and some species of fish.

A full description of the legislation, requirements and procedures involved for imports are provided in earlier RIFE reports [66].

A percentage of Japanese imports into the EU were monitored in the UK and this work continued in early 2022 and were discontinued after the revocation of the retained regulations. Monitoring was carried out by local port health authorities (or local authorities in Scotland). Following changes to the regulations in 2016, the FSA and FSS ceased collating routine data on these samples and were only notified in the event of a non-compliant consignment such as exceeding the maximum permitted levels. None of the imports to the UK in 2022 were found to contain radioactivity exceeding the maximum permitted levels (100Bq kg^{-1} for the total of caesium-134 and caesium-137 in food). The doses received due to the imports were of negligible radiological significance.

Screening instruments are used at importation points of entry to the UK as a general check on possible contamination from unknown sources. In 2022, these instruments were not triggered by a food consignment at any point of entry into the UK.

8.9 Seawater surveys

The UK government and devolved administrations are committed to preventing pollution of the marine environment from ionising radiation, with the main aim of reducing concentrations in the environment to near background values for naturally occurring radioactive substances, and close to zero for artificial radioactive substances [3]. Therefore, a programme of surveillance into the distribution of important 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. The programme of radiological surveillance work provided the source data and, therefore, the means to monitor and assess progress in line with the UK's commitments towards OSPAR's 1998 Strategy for Radioactive Substances target for 2020 (part of the North-East Atlantic Environment Strategy adopted by OSPAR for the period 2010 to 2020), see Section 1.3.2 of this report for more details. The surveys also provide information that can be used to distinguish different sources of artificial radioactivity (for example, [232]) and to derive dispersion factors for nuclear licensed sites (for example, [233]). 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.

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 2022 are given in Figure 8.4 to Figure 8.8.

Figure 8.4 Concentrations (Bq l-1) of caesium-137 in surface water from the North Sea, September to October 2022

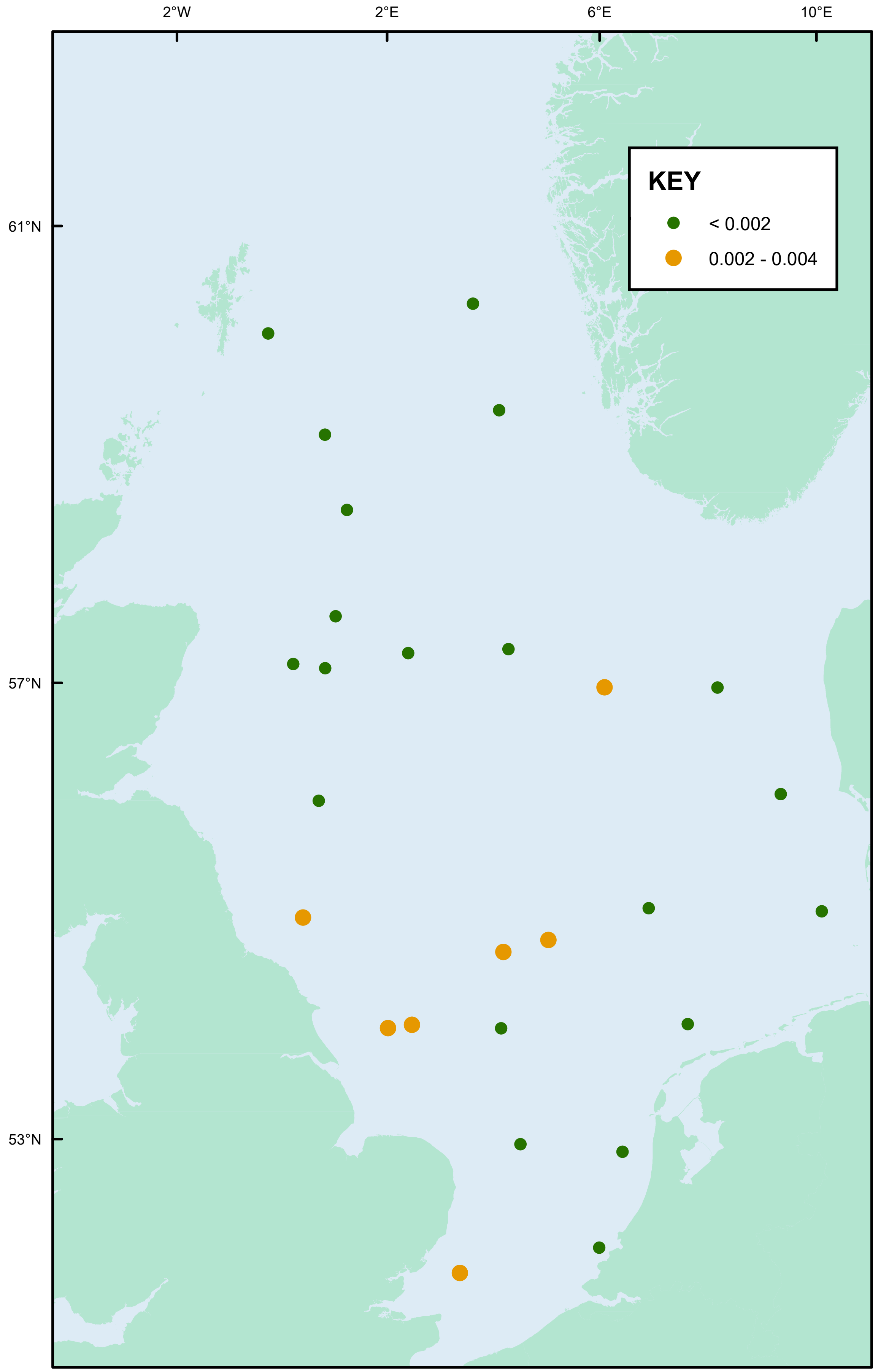


Figure 8.5 Concentrations (Bq l-1) of caesium-137 in surface water from the English Channel, March 2022

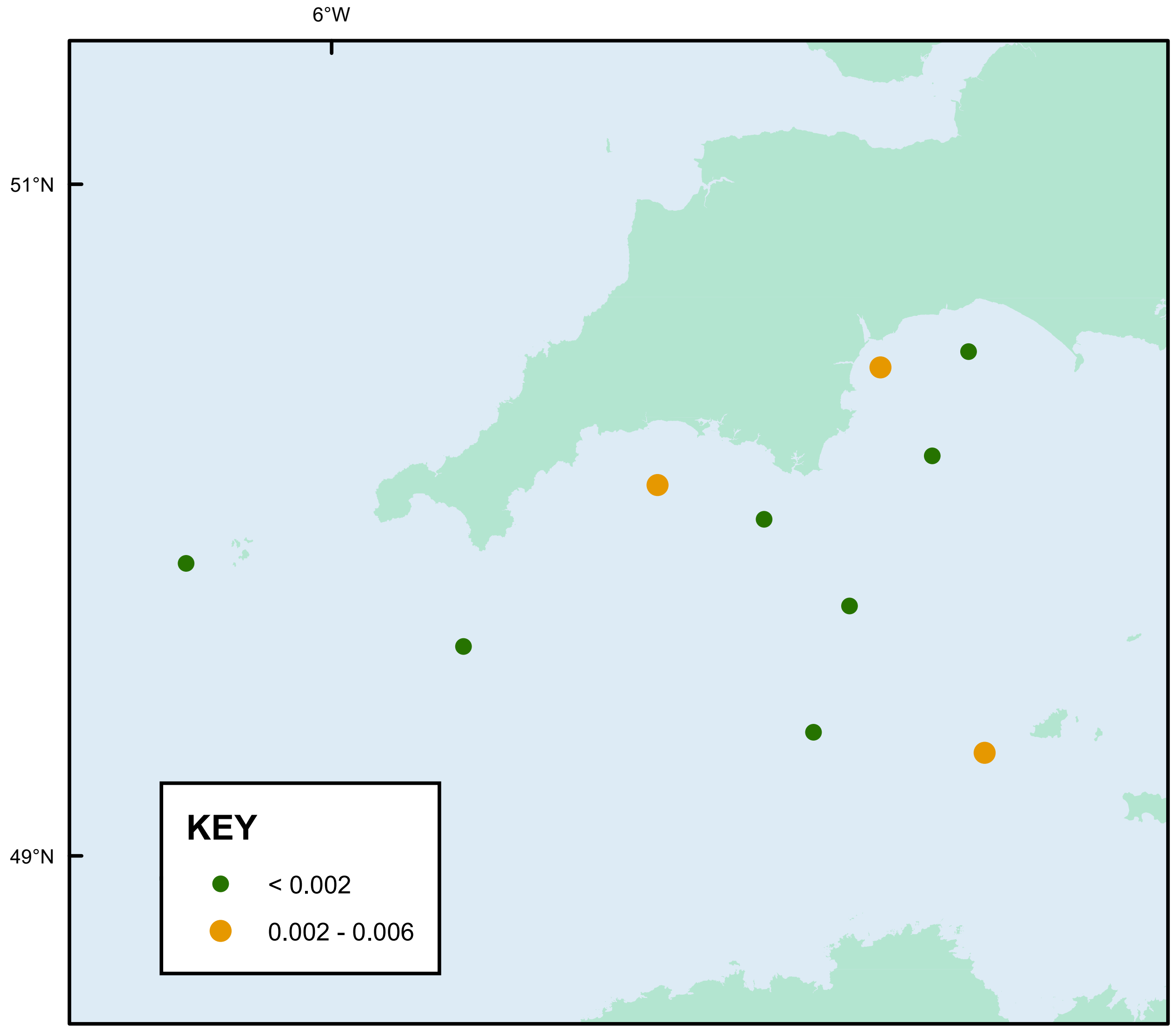


Figure 8.6 Concentrations (Bq l[-1]) of tritium in surface water from the North Sea, September to October 2022

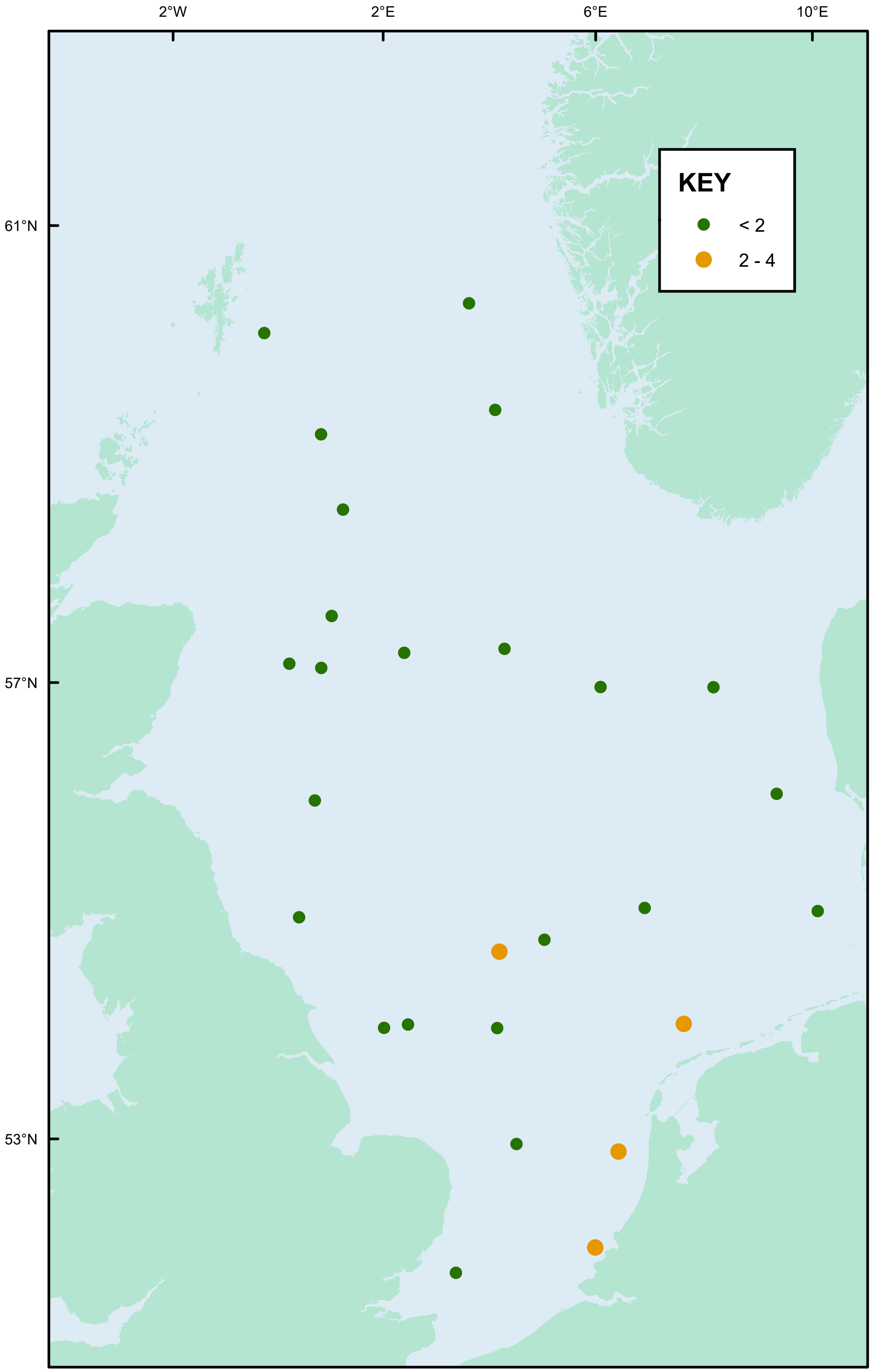


Figure 8.7 Concentrations (Bq l[-1]) of triitum in surface water from the Bristol channel and Irish sea, September 2022

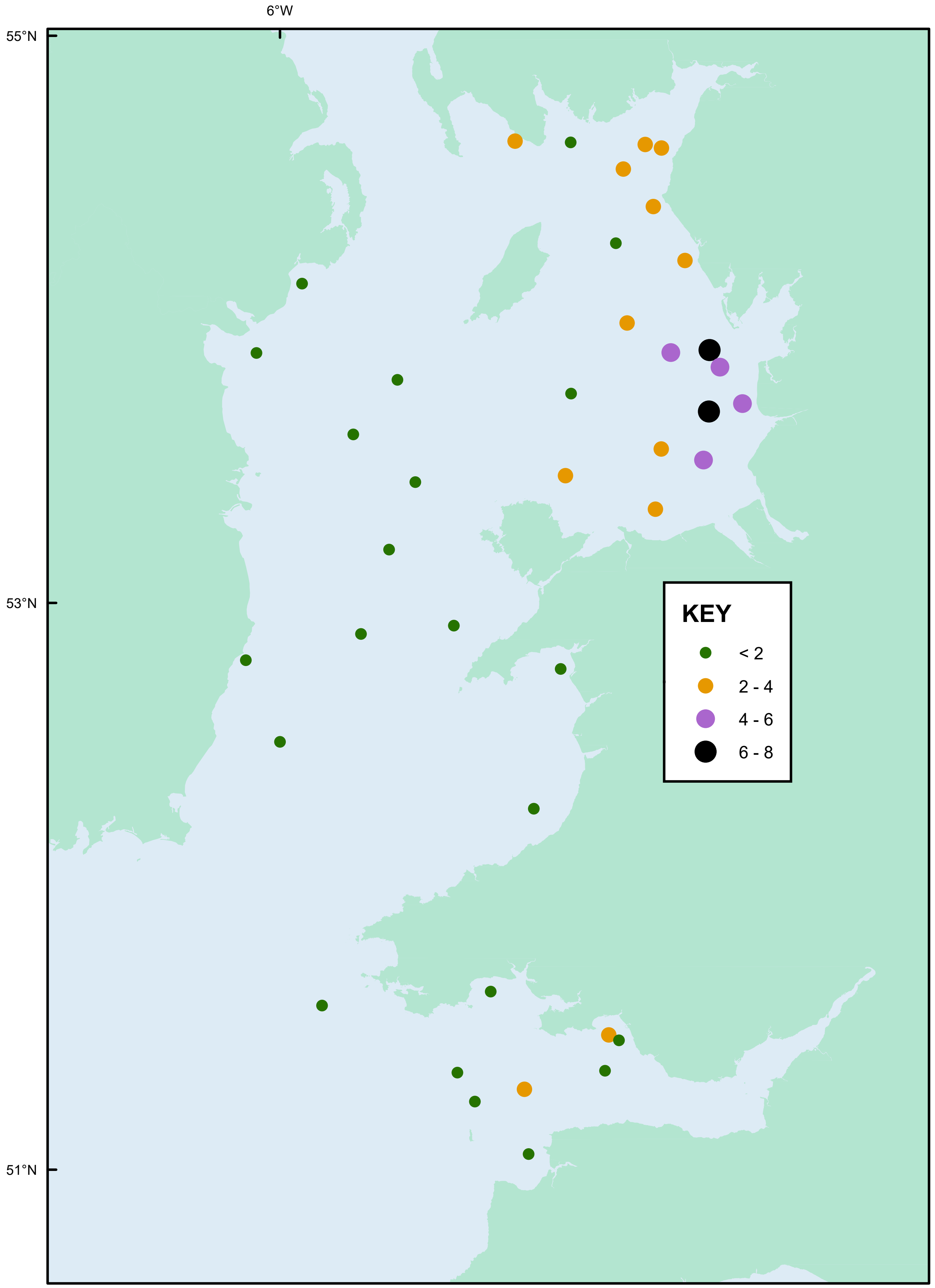
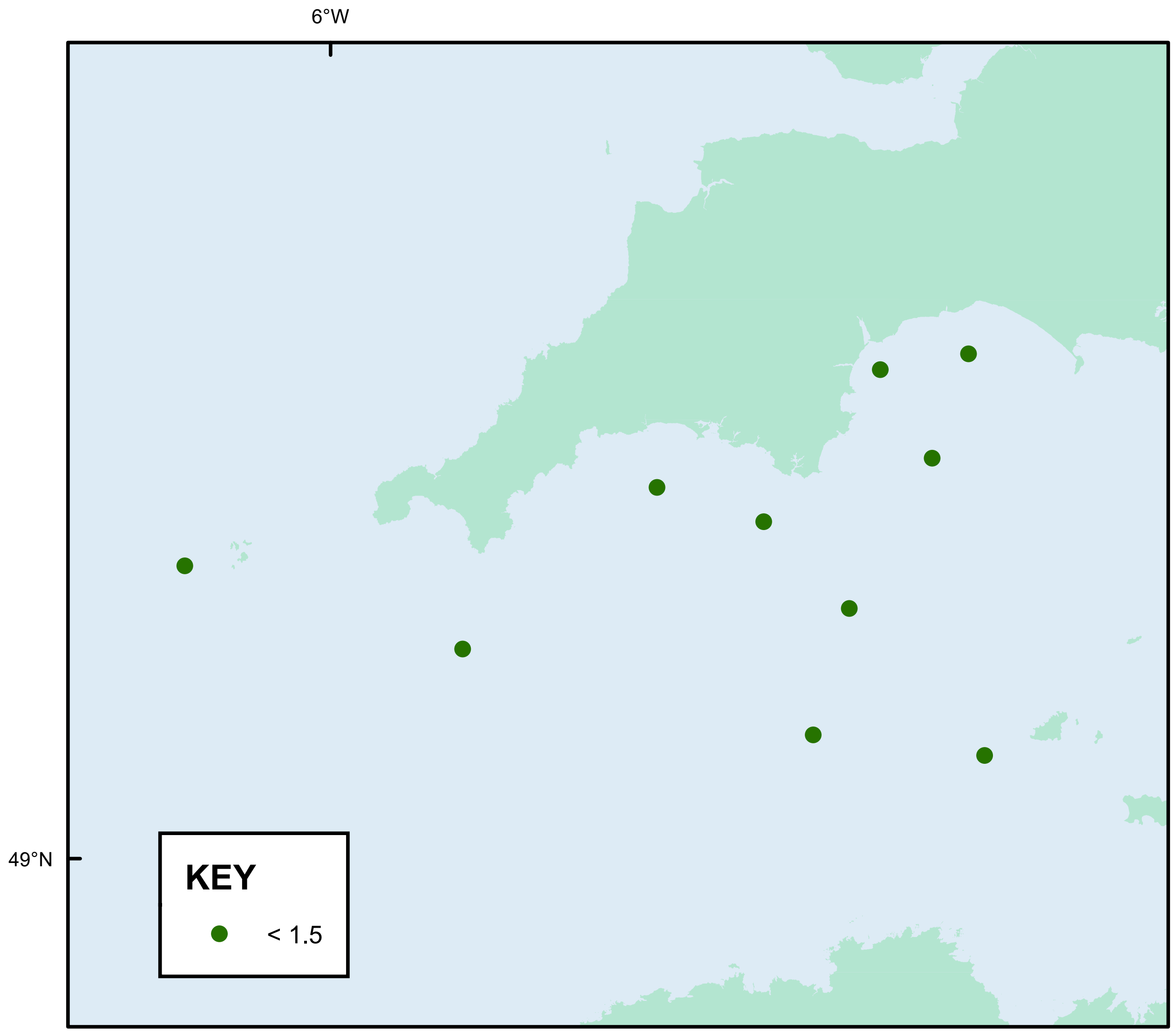


Figure 8.8 Concentrations (Bq l^{-1}) of tritium in surface water from the English Channel, March 2022

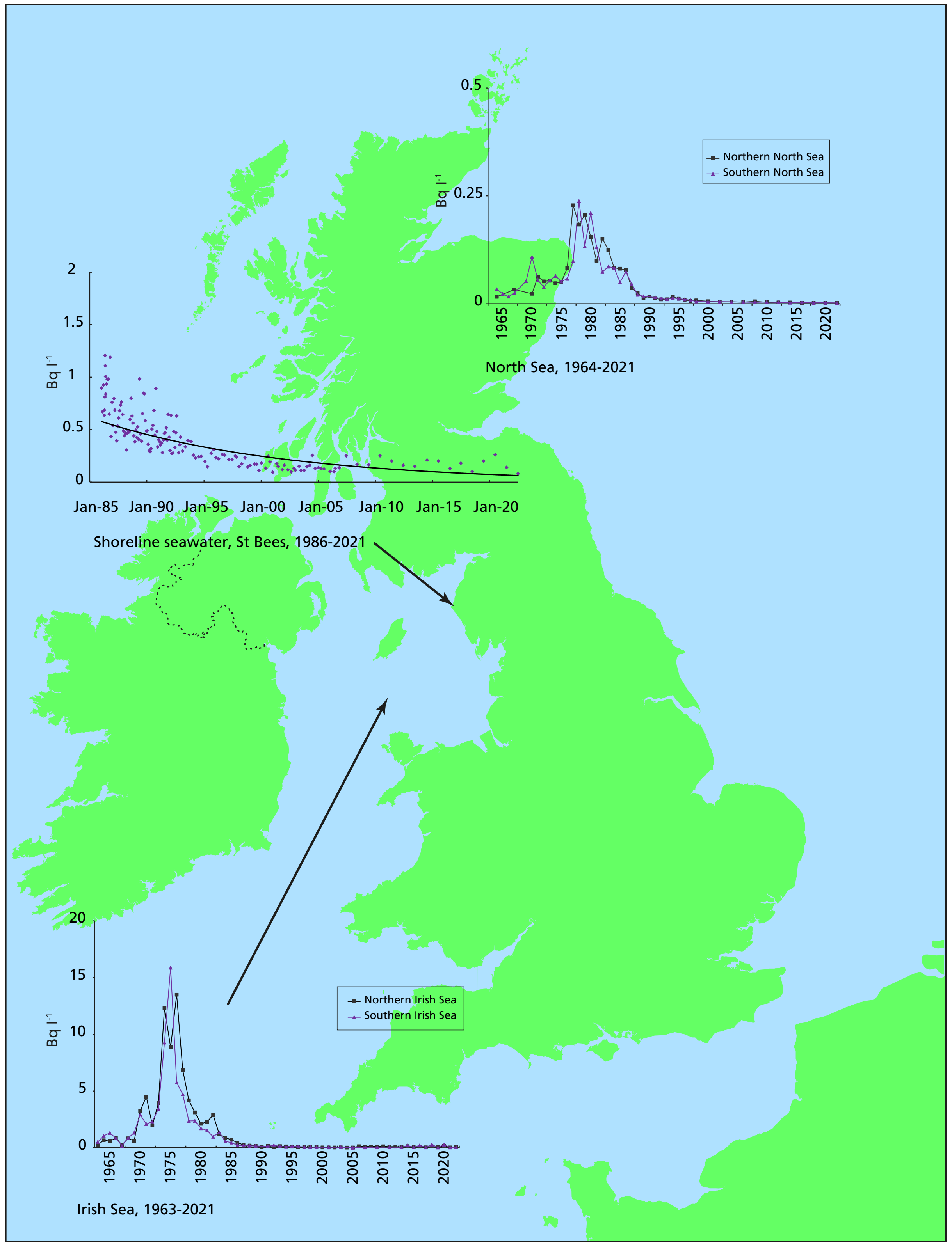


A seawater survey of the North Sea was carried out in 2022. Caesium-137 concentrations are given in Figure 8.4 and show that concentrations were very low (up to 0.004Bq l^{-1}) throughout the survey area. The few positively detected values were only slightly above those observed for global fallout levels in surface seawaters (0.0001 to 0.0028Bq l^{-1}, [234]). The overall distribution in the North Sea is characteristic of that observed in previous surveys over the last decade, with generally positively detected values near the coast, due to the long-distance transfer, possibly from Sellafield- or Chernobyl-derived activity. In 2022, there was no significant evidence of input of Chernobyl-derived caesium-137 from the Baltic (via the Skaggerak) close to the Norwegian Coast. Recently, trends and observations of caesium-137 concentrations in the waters of the North Sea (and Irish Sea), over the period 1995 to 2015, have been published [235].

Over several 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 [236]. Caesium-137 concentrations in the North Sea have 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 concentrations of caesium-137 of up to 0.5Bq l^{-1} 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 was considered to be the dominant source of water contamination for most of the North Sea [237].

Caesium-137 concentrations in the Irish Sea are only a very small percentage of those prevailing in the late 1970s (typically up to 30Bq l^{-1}, [238]), when discharges were substantially higher. The 2021 seawater survey recorded concentrations of up to 0.04Bq l^{-1} in the eastern Irish Sea and 0.08Bq l^{-1} of the west coast of Wales. Elsewhere concentrations were generally below 0.02Bq l^{-1}. The predominant source of caesium-137 to the Irish Sea is considered to be remobilisation into the water column from activity associated with seabed sediment [239]. 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 decrease in caesium-137 concentrations in shoreline seawater at St Bees (Figure 8.9). In more recent years, the rate of decline of caesium-137 concentrations over time has been decreasing at St Bees. Longer time series showing peak concentrations in the Irish Sea, and, with an associated time-lag, the North Sea are also shown in Figure 8.9.

Figure 8.9 Concentration of caesium-137 in the Irish Sea, North Sea and in shoreline seawater close to Sellafield at St. Bees (Note different scales used for activity concentrations)



In 2022, caesium-137 concentrations were reported as less than values (or close to the less than value) in the western English Channel (including those near the Channel Islands) and were not distinguishable from the background of fallout from nuclear weapons testing (Figure 8.5).

A full assessment of historic long-term trends of caesium-137 in surface waters of Northern European seas is provided elsewhere [236].

Tritium concentrations in North Sea seawater in 2022 are shown in Figure 8.6 and were generally lower than those observed in 2020 [66] due to the influence of discharges from Sellafield and other nuclear licensed sites. As in previous North Sea surveys, tritium concentrations were positively detected in a few water samples taken from the most southerly sampling locations of the North Sea and measured just above the less than value in 2022. The most probable source is most likely to be from the authorised discharges of tritium from nuclear power plants located in the vicinity (including those on the English Channel coast).

Tritium concentrations in Irish Sea seawater in 2022 are shown in Figure 8.7. As expected, these are generally higher (by small amounts) than those observed in the North Sea in 2022 (Figure 8.6) due to the influence of discharges from Sellafield and other nuclear licensed sites. As in previous Irish Sea surveys, tritium concentrations to the south and west of the Isle of Man, including along the coastline of Ireland, were mostly reported as below (or close to) a less than value.

In the Bristol Channel, the combined effect of historical tritium discharges from the former GE Healthcare Limited facility at Cardiff, and those from Berkeley, Oldbury, and Hinkley Point, is shown in Figure 8.7. Tritium concentrations in the Bristol Channel were very low in 2022. Most results are reported as less than values (or close to the less than value) in the vicinity of the Welsh coast. Overall, tritium concentrations were lower in the inner region of the Bristol Channel, in comparison to recent years. There is no evidence of tritium entering the Irish Sea from the combined effect of discharges from the former GE Healthcare Limited facility at Cardiff, Berkeley, Oldbury, and Hinkley Point. Tritium concentrations in the western English Channel were all reported as below the less than value (or close to the less than value) (Figure 8.8).

Technetium-99 concentrations in seawater have decreased following the substantial reduction in discharges resulting from Environment Agency requirements for discharge abatement. This followed substantial increases observed from 1994 to their most recent peak in 2003. The results of research cruises to study this radionuclide have been published [237,240–243] and an estimate of the total inventory residing in the sub-tidal sediments of the Irish Sea has also been published [244]. Trends in plutonium and americium concentrations in seawater of the Irish Sea have also been published [245].

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 [110,246–248]. The Fifth Periodic Evaluation covers both radioactive discharges from the nuclear and non-nuclear sectors and environmental concentrations and demonstrated that Contracting Parties successfully fulfilled the RSS objectives for the nuclear and non-nuclear sectors [4].

Shoreline sampling was also carried out around the UK, as part of routine site and regional monitoring programmes. Much of the shoreline sampling was directed at establishing whether the impacts of discharges from individual sites are detectable. Where appropriate, these are reported in the relevant sections of this report, and the results are collated in Table 8.10. Most radionuclides are reported as less than values. Tritium and caesium-137 concentrations remote from site discharge points are consistent with those in Figure 8.4 to Figure 8.8.

Collection and analysis of marine sediment and seawater samples from across Scotland was not performed in 2022. Results up to 2019 are included in earlier RIFE reports (for example, [23]).

Table 8.1 Concentrations of radionuclides in seafood and the environment near the Channel Islands, 2022

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}							
			Organic							
			^{3}H	^{3}H	^{14}C	^{60}C	^{90}Sr	^{99}Tc	^{106}Ru	^{137}Cs
Guernsey										
	Crabs	1				<0.05			<0.47	<0.05
	Lobsters	1				<0.07			<0.60	<0.07
	Limpets	1				<0.04			<0.43	<0.04
	Oysters	1				<0.07			<0.64	<0.06
	Scallops	1				<0.03			<0.30	<0.03
St. Sampson's Harbour	Mud	1				<0.13			<1.2	0.70
	Seawater	2								<0.0013
Jersey										
	Crabs	1				<0.04			<0.39	<0.04
	Spiny spider crabs	1				<0.04			<0.40	<0.04
	Lobsters	1				<0.05		<0.19	<0.42	<0.09
La Rocque	Oysters	1				<0.02			<0.18	<0.02
Plemont Bay	Fucus ceranoides	2				<0.05			<0.44	<0.06
La Rozel	Fucus vesiculosus	4				<0.06	<0.033	1.5	<0.50	<0.07
La Rozel	Ascophyllum nodosum	4				<0.07			<0.57	<0.08

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh)[a], Bq kg^{-1}						
			^{155}Eu	^{238}Pu	^{239}Pu+ ^{240}Pu	^{241}Am	^{242}Cm	^{243}Cm+ ^{244}Cm	Gross beta
Guernsey									
	Crabs	1	<0.15	0.00030	0.00091	0.0023	0.000054	0.00030	80
	Lobsters	1	<0.15			<0.15			86
	Limpets	1	<0.13			<0.17			58
	Oysters	1	<0.12			<0.08			21
	Scallops	1	<0.09	0.00074	0.0025	0.0020	*	0.00015	71
St. Sampson's Harbour	Mud	1	<0.59	0.038	0.17	0.23	0.00089	0.011	440
	Seawater	2							
Jersey									
	Crabs	1	<0.13	0.00008	0.00027	0.0017	*	0.00013	76
	Spiny spider crabs	1	<0.13			<0.17			90
	Lobsters	1	<0.10	0.00016	0.00026	0.0042	*	0.00026	97
La Rocque	Oysters	1	<0.06	0.00081	0.0024	0.0033	*	0.00024	52
Plemont Bay	Fucus ceranoides	2	<0.13			<0.18			138
La Rozel	Fucus vesiculosus	4	<0.15	0.005	0.014	0.0064	0.000042	0.00042	170
La Rozel	Ascophyllum nodosum	4	<0.17			<0.27			150

* Not detected by the method used

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

Table 8.2(a) Concentrations of radionuclides in seafood and the environment in Northern Ireland, 2022[a]

Location	Material	No. of sampling observations	Mean radioactivity concentration (fresh)[b], Bq kg^{-1}					
			^{14}C	^{60}Co	^{99}Tc	^{125}Sb	^{134}Cs	^{137}Cs
Cod	Kilkeel	3	29	<0.04		<0.10	<0.05	0.31
Plaice	Kilkeel	2		<0.04		<0.10	<0.04	0.20
Haddock	Kilkeel	3		<0.06		<0.13	<0.06	0.31
Herring	Ardglass	2		<0.07		<0.19	<0.09	0.19
Lesser spotted dogfish	North coast	3		<0.11		<0.25	<0.09	0.98
Skates / rays	Kilkeel	2		<0.10		<0.19	<0.08	0.67
Skate / dogfish	Kilkeel	1		<0.12		<0.29	<0.21	0.42
Crabs	Kilkeel	3		<0.05		<0.13	<0.06	<0.08
Lobsters	Ballycastle	1		<0.08	6.3	<0.12	<0.05	0.13
Lobsters	Kilkeel	3		<0.07	7.4	<0.13	<0.06	0.12
Nephrops	Kilkeel	3		<0.08	1.4	<0.15	<0.09	0.31
Limpets	Minerstown	2		<0.06		<0.15	<0.08	0.14
Winkles	Minerstown	1		<0.04		<0.09	<0.05	0.15
Mussels	Carlingford Lough	2		<0.10	3.1	<0.25	<0.12	0.39
Scallops	County Down	2		<0.05		<0.11	<0.05	<0.05
Toothed winkles	Minerstown	1		<0.09		<0.20	<0.09	0.16
Fucus spiralis	Carlingford Lough	2		<0.06	9.2	<0.08	<0.04	0.16
Fucus species	Portrush	2		<0.05		<0.10	<0.03	<0.04
Fucus serratus	Portrush	2		<0.04		<0.10	<0.03	<0.05
Fucus spiralis	Ardglass	2		<0.04	5.8	<0.08	<0.03	0.20
Fucus vesiculosus	Ardglass	1		<0.04		<0.12	<0.05	0.67
Rhodymenia species	Strangford Lough - Island Hill	4		<0.05	0.15	<0.12	<0.07	0.40
Mud	Carlingford Lough	2		<0.25		<0.67	<0.35	30
Mud	Ballymacormick	1		<0.14		<0.41	<0.27	12
Sandy mud	Ballymacormick	1		<0.15		<0.43	<0.26	7.8
Clay	Dundrum Bay	1		<0.17		<0.48	<0.35	3.4
Mud	Dundrum Bay	1		<0.20		<0.48	<0.15	4.7
Mud	Strangford Lough - Nicky's Point	2		<0.24		<0.62	<0.34	12
Sandy mud	Oldmill Bay	2		<0.15		<0.39	<0.17	5.8
Sand	Portrush	2		<0.11		<0.33	<0.16	0.39
Mud	Carrichue	1		<0.15		<0.44	<0.12	1.5
Sandy mud	Carrichue	1		<0.14		<0.39	<0.16	2.5
Seawater	North of Larne	3			0.00077		*	0.0029

Table 8.2(a) continued

Location	Material	No. of sampling observations	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	3	<0.11			<0.09		
Plaice	Kilkeel	2	<0.13			<0.17		
Haddock	Kilkeel	3	<0.14			<0.16		
Herring	Ardglass	2	<0.22			<0.28		
Lesser spotted dogfish	North coast	3	<0.28			<0.40		
Skates / rays	Kilkeel	2	<0.18			<0.14		
Skate / dogfish	Kilkeel	1	<0.31			<0.39		
Crabs	Kilkeel	3	<0.14			<0.15		
Lobsters	Ballycastle	1	<0.13			0.32		
Lobsters	Kilkeel	3	<0.16			<0.24		
Nephrops	Kilkeel	3	<0.13	0.0014	0.0090	0.024	*	*
Limpets	Minerstown	2	<0.16			<0.22		
Winkles	Minerstown	1	<0.10	0.030	0.19	0.13	*	*
Mussels	Carlingford Lough	2	<0.28			<0.43		
Scallops	County Down	2	<0.12			<0.14		
Toothed winkles	Minerstown	1	<0.22			<0.47		
Fucus spiralis	Carlingford Lough	2	<0.16			<0.19		
Fucus species	Portrush	2	<0.11			<0.10		
Fucus serratus	Portrush	2	<0.11			<0.17		
Fucus spiralis	Ardglass	2	<0.09			<0.16		
Fucus vesiculosus	Ardglass	1	<0.15			0.34		
Rhodymenia species	Strangford Lough - Island Hill	4	<0.13	0.076	0.48	1.10	*	*
Mud	Carlingford Lough	2	<1.4	1.4	9.8	8.0	*	*
Mud	Ballymacormick	1	<0.57			14		
Sandy mud	Ballymacormick	1	<1.1			8.9		
Clay	Dundrum Bay	1	<1.6			2.0		
Mud	Dundrum Bay	1	<1.1			2.7		
Mud	Strangford Lough - Nicky's Point	2	<1.2			7.6		
Sandy mud	Oldmill Bay	2	<0.71			6.1		
Sand	Portrush	2	<0.81			<1.4		
Mud	Carrichue	1	<1.4	0.059	0.36	0.66	*	*
Sandy mud	Carrichue	1	<1.4			<2.1		
Seawater	North of Larne	3						

* 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 8.2(b) Monitoring of radiation dose rates in Northern Ireland, 2022[a]

Location	Ground type	No. of sampling observations	Mean gamma dose rate in air at 1m, μGy h^{-1}
Lisahally	Mud	1	0.058
Donnybrewer	Shingle	1	0.052
Carrichue	Mud	1	0.069
Bellerena	Mud	1	0.056
Benone	Sand	1	0.054
Castlerock	Sand	1	0.055
Portstewart	Sand	1	0.055
Portrush, Blue Pool	Sand	1	0.055
Portrush, White Rocks	Sand	1	0.055
Portballintrae	Sand	1	0.055
Giant`s Causeway	Sand	1	0.051
Ballycastle	Sand	1	0.052
Cushendun	Sand	1	0.055
Cushendall	Sand and stones	1	0.057
Red Bay	Sand	1	0.057
Carnlough	Sand	1	0.055
Glenarm	Sand	1	0.055
Half Way House	Sand	1	0.056
Ballygally	Sand	1	0.072
Drains Bay	Sand	1	0.057
Larne	Sand	1	0.057
Whitehead	Sand	1	0.061
Carrickfergus	Sand	1	0.057
Jordanstown	Sand	1	0.057
Helen`s Bay	Sand	1	0.058
Groomsport	Sand	1	0.061
Millisle	Sand	1	0.070
Ballywalter	Sand	1	0.072
Ballyhalbert	Sand	1	0.065
Cloghy	Sand	1	0.061
Portaferry	Shingle and stones	1	0.078
Kircubbin	Sand	1	0.069
Greyabbey	Sand	1	0.085
Ards Maltings	Mud	1	0.072
Island Hill	Mud	1	0.079
Nicky`s Point	Mud	1	0.076
Strangford	Shingle & Stone	1	0.097
Kilclief	Sand	1	0.067
Ardglass	Mud	1	0.076
Killough	Mud	1	0.080
Ringmore Point	Sand	1	0.071
Tyrella	Sand	1	0.069
Dundrum	Sand	1	0.097
Newcastle	Sand	1	0.097
Annalong	Sand	1	0.10
Cranfield Bay	Sand	1	0.082
Mill Bay	Sand	1	0.082
Greencastle	Sand	1	0.082
Rostrevor	Sand	1	0.10
Narrow Water	Mud	1	0.088

a. All measurements are made on behalf of the Northern Ireland Environment Agency

Table 8.3 Concentrations of radionuclides in diet, 2022[a]

Region	Number of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
Canteen meals					
England	7		91	<0.023	<0.07
Northern Ireland	5		98	<0.027	<0.06
Scotland	12	36	87	<0.030	<0.02
Wales	5		83	<0.049	<0.07

Region	Number of sampling observations	Mean radioactivity concentration (fresh), Bq kg^{-1}			
		^{14}C	^{40}K	^{90}Sr	^{137}Cs
Mixed diet in Scotland					
Dumfriesshire					
Dumfries	4		86	<0.10	<0.05
East Lothian					
North Berwick	4		72	<0.10	<0.05
Renfrewshire					
Paisley	4		86	<0.10	<0.05
Ross-shire					
Dingwall	4		77	<0.12	<0.05

a. Results are available for other artificial nuclides detected by gamma spectrometry
All such results were less than the limit of detection

Table 8.4 Concentrations of radionuclides in milk remote from nuclear sites, 2022

Location	Selection[a]	No. of farms / daries[b]	Mean radioactivity concentration, ^{14}C			
			^{3}H	^{14}C	^{90}Sr	^{137}Cs
Milk						
Co. Antrim		2		19	<0.020	<0.06
	max					<0.08
Buckinghamshire		1		11	<0.022	<0.04
Ceredigion		1			0.030	<0.04
Clywd		1		43	<0.023	<0.03
Cornwall		1		13	<0.018	<0.04
Devon		1		20	<0.021	<0.04
Dorset		1		22	<0.020	<0.04
Co. Down		1			<0.022	<0.04
Dumfriesshire		1	<5.0	<16	<0.10	<0.06
Co. Fermanagh		1			<0.022	<0.04
Gloucestershire		1		15	<0.022	<0.04
Gwynedd		1		16	0.029	<0.04
Humberside		1		19	<0.022	<0.04
Kent		1		22	<0.019	<0.03
Lanarkshire		1	<5.0	<15	<0.012	<0.02
Lancashire		1		19	<0.022	<0.04
Leicestershire		1		15	<0.019	<0.04
Londonderry		1			<0.024	<0.04
Middlesex		1		13	<0.021	<0.04
Midlothian		1	<5.0	<15	<0.10	<0.05
Nairnshire		1	<5.0	<16	<0.10	<0.05
Norfolk		1		19	<0.019	<0.03
North Yorkshire		1		21	<0.019	<0.03
Renfrewshire		1	<5.0	<15	<0.10	<0.05
Shropshire		1		20	<0.022	<0.03
Suffolk		1		14	0.023	<0.04
Co. Tyrone		2		25	<0.019	<0.05
	max				<0.020	<0.06
Mean Values						
England				18	<0.021	<0.04
Northern Ireland				22	<0.021	<0.05
Wales				30	<0.027	<0.03
Scotland			<5.0	<15	<0.082	<0.05
United Kingdom			<5.0	<18	<0.033	<0.04

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

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

Table 8.5 Concentrations of radionuclides in rainwater and air, 2022

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a]				
				^{3}H	^{7}Be	$^{7}Be^{d}$	^{90}Sr	^{137}Cs
Ceredigion								
	Aberporth	Rainwater	4	<1.6	1.2			<0.012
		Air	4		0.0037			$<7.4\ 10^{-7}$
Co. Down								
	Conlig	Rainwater	4		0.77			<0.012
		Air	4		0.0027			$<7.3\ 10^{-7}$
Dumfries and Galloway								
	Eskdalemuir	Rainwater	12	<1.0	0.62		<0.0051	<0.010
		Air	12		0.0027			$<1.0\ 10^{-5}$
	Newton Stewart	Air	11		0.0024			$<1.0\ 10^{-5}$
City of Edinburgh								
	Edinburgh Silvan	Air	1		0.0033			$<1.0\ 10^{-5}$
North Lanarkshire								
	Holytown	Rainwater	12	<1.0	<0.43		<0.0060	<0.025
		Air	12		0.0016			$<1.0\ 10^{-5}$
North Yorkshire								
	Dishforth/Leeming	Rainwater	4		1.1			<0.013
		Air	4		0.0025			$<6.6\ 10^{-7}$
Oxfordshire								
	Chilton	Rainwater	4		0.85	0.65	0.00031	<0.029
		Air	12		0.0033			$<3.9\ 10^{-7}$
Shetland								
	Lerwick	Rainwater	12	<1.0	1.6		<0.0061	<0.010
		Air	12		0.0024			$<1.0\ 10^{-5}$
Suffolk								
	Orfordness	Rainwater	4	<1.6	1.1			<0.017
		Air	4		0.0038			$<4.8\ 10^{-7}$

Regional monitoring

Table 8.5 continued

Location		Sample	Number of sampling observations	Mean radioactivity concentration[a] ^{3}H	^{7}Be	^{7}Be[d]	^{90}Sr	^{137}Cs	Gross
Ceredigion									
	Aberporth	Rainwater	4		$<6.4\ 10^{-6}$	$7.4\ 10^{-6}$	$5.8\ 10^{-6}$		
		Air	4		$<1.8\ 10^{-9}$	$9.0\ 10^{-10}$	$<1.0\ 10^{-10}$		
Co. Down									
	Conlig	Rainwater	4						
		Air	4						
Dumfries and Galloway									
	Eskdalemuir	Rainwater	12						
		Air	12						<0.00026
	Newton Stewart	Air	11						<0.00020
City of Edinburgh									
	Edinburgh Silvan	Air	1						<0.00024
North Lanarkshire									
	Holytown	Rainwater	12						
		Air	12						<0.00022
North Yorkshire									
	Dishforth/Leeming	Rainwater	4						
		Air	4						
Oxfordshire									
	Chilton	Rainwater	4	<0.00057				0.024	0.18[d]
		Air	12						
Shetland									
	Lerwick	Rainwater	12						
		Air	12						<0.00022
Suffolk									
	Orfordness	Rainwater	4						
		Air	4						

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 8.6 Concentrations of radionuclides in sources of drinking water in Scotland, 2022

Area	Location or selection	Number of sampling observations	Mean radioactivity concentration, Bq l^{-1} ^{3}H	^{90}Sr	^{137}Cs	Gross alpha	Gross beta
Annual Samples							
Angus	Loch Lee	4	<1.0	<0.0050	<0.010	<0.010	0.028
Argyll and Bute	Auchengaich	2	<1.0		<0.010	<0.010	0.016
Argyll and Bute	Helensburgh Reservoir	2	<1.0		<0.010	<0.010	0.082
Argyll and Bute	Loch Ascog	1	<1.1		<0.010	<0.010	0.072
Argyll and Bute	Loch Eck	2	<1.1		<0.010	<0.010	0.021
Argyll and Bute	Lochan Ghlas Laoigh	2	<1.0		<0.010	<0.010	0.040
Argyll and Bute	Loch Finlas	2	<1.0		<0.010	<0.010	0.047
Clackmannanshire	Gartmorn Dam	2	<1.0		<0.010	<0.010	0.013
Dumfries and Galloway	Black Esk	1	1.1		<0.010	<0.010	0.37
Dumfries and Galloway	Gullielands Burn	1	21		<0.010	0.019	0.20
Dumfries and Galloway	Purdomstone	1	<1.0		<0.010	<0.010	0.043
Dumfries and Galloway	Winterhope	1	<1.0		<0.010	<0.010	0.027
East Lothian	Hopes Reservoir	1	1.4		<0.010	0.013	0.016
East Lothian	Thorters Reservoir	1	<1.0		<0.010	<0.010	0.044
East Lothian	Whiteadder	1	<1.0		<0.010	<0.010	0.029
East Lothian	Thornton Loch Burn	1	<1.0		<0.010	0.014	0.10
Fife	Holl Reservoir	2	1.1		<0.010	<0.010	0.039
Highland	Loch Baligill	1	<1.0		<0.010	<0.010	0.043
Highland	Loch Calder	1	<1.0		<0.010	<0.010	0.053
Highland	Loch Glass	4	<1.0	<0.0050	<0.010	<0.010	0.033
Highland	Loch Shurrerey	1	<1.0		<0.010	0.013	0.044
North Ayrshire	Camphill	1	<1.0		<0.010	<0.010	0.036
North Ayrshire	Knockendon Reservoir	1	1.1		0.018	<0.010	0.064
North Ayrshire	Outerwards	1	<1.0		<0.010	<0.010	0.019
North Ayrshire	Busbie Muir	1	<1.0		<0.010	<0.010	0.040
Orkney Islands	Heldale Water	1	<1.0		<0.010	<0.010	0.046
Perth and Kinross	Castlehill Reservoir	2	<1.0		<0.010	<0.010	0.016
Scottish Borders	Knowesdean	4	<1.0	<0.0050	<0.010	<0.010	0.035
Stirling	Loch Katrine	12	<1.0	0.0016	<0.0012	<0.0071	0.028
West Dunbartonshire	Loch Lomond (Ross Priory)	2	<1.0		<0.010	0.011	0.15
West Lothian	Morton No 2 Reservoir	2	<1.0		<0.010	<0.010	0.037

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

Table 8.7 Concentrations of radionuclides in sources of drinking water in England and Wales, 2022

Location	Sample source	No. of sampling observations	Mean radioactivity concentration , Bq l^{-1}			
			^{3}H	^{40}K	^{90}Sr	^{125}I
England						
Buckinghamshire	Bourne End, Groundwater	4	<3.8	0.029	<0.00069	
Cambridgeshire	Grafham Water	4	<3.8	0.32	<0.00070	
Cheshire	River Dee	4	<3.7	0.071	<0.00072	<0.00084
Cornwall	River Fowey	4	<3.7	0.051	<0.00082	<0.00076
County Durham	Honey Hill Water Treatment Works, Consett	4	<3.6	0.030	<0.00072	
County Durham	River Tees, Darlington	4	<3.6	<0.022	<0.00077	<0.00071
Cumbria	Ennerdale Lake	4	<3.8	<0.016	<0.0011	
Cumbria	Haweswater Reservoir	4	<3.8	<0.017	<0.00080	
Derbyshire	Arnfield Water Treatment Plant	4	<3.7	<0.019	<0.00092	
Derbyshire	Matlock, Groundwatera	4	<3.8	0.031	<0.00069	
Devon	River Exe, Exeter	4	<3.8	0.099	<0.00081	<0.00076
Devon	Roadford Reservoir, Broadwoodwidger	4	<3.6	0.061	<0.00079	
Gloucestershire	River Severn, Tewkesbury	`4	<3.8	0.19	<0.00078	<0.00087
Greater London	River Lee, Walthamstow	4	<3.7	0.28	<0.00086	<0.0012
Hampshire	River Avon, Christchurch	4	<3.7	0.086	<0.00069	<0.00089
Humberside	Littlecoates, Groundwater	4	<3.6	0.092	<0.00075	
Kent	Sittingbourne, Deep Groundwater	3	<3.5	0.034	<0.00067	
Kent	Denge, Shallow Groundwater	4	<3.7	0.11	<0.00083	
Lancashire	Worsthorne, Groundwater	4	<3.5	<0.017	<0.00077	
Norfolk	River Drove, Stoke Ferry	4	<3.7	0.11	<0.00090	<0.00083
Northumberland	Kielder Reservoir	4	<3.6	<0.016	<0.00074	
Oxfordshire	River Thames, Oxford	4	<3.8	0.20	<0.00081	<0.00096
Somerset	Ashford Reservoir, Bridgwater	4	<3.7	0.075	<0.00072	
Somerset	Chew Valley Lake Reservoir, Bristol	4	<3.6	0.12	<0.00075	
Surrey	River Thames, Chertsey	4	<3.7	0.25	<0.00072	<0.0010
Surrey	River Thames, Walton	4	<3.7	0.26	<0.00075	<0.0010
Yorkshire	Chellow Heights, Bradford	4	<3.6	<0.019	<0.00081	
Yorkshire	Washburn Valley Reservoirs, Leeds	4	<3.6	0.056	<0.00083	
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	<3.7	<0.019	<0.0015	
Mid-Glamorgan	Llwyn-on Reservoir	4	<3.7	<0.017	<0.00080	
Powys	Elan Valley Reservoir	3	<3.6	<0.066	<0.00096	

Table 8.7 continued

Location	Sample source	No. of sampling observations	^{137}Cs	Gross alpha	Gross beta[1]	Gross beta[2]
England						
Buckinghamshire	Bourne End, Groundwater	4	<0.00078	<0.030	0.046	0.038
Cambridgeshire	Grafham Water	4	<0.00085	0.039	0.41	0.35
Cheshire	River Dee	4	<0.00083	0.024	0.10	0.082
Cornwall	River Fowey	4	<0.00078	0.026	0.078	0.064
County Durham	Honey Hill Water Treatment Works, Consett	4	<0.00099	0.012	0.046	0.037
County Durham	River Tees, Darlington	4	<0.00085	0.015	0.056	0.045
Cumbria	Ennerdale Lake	4	<0.00079	0.028	0.046	0.037
Cumbria	Haweswater Reservoir	4	<0.00079	<0.0071	0.018	0.015
Derbyshire	Arnfield Water Treatment Plant	4	<0.00083	0.011	0.032	0.025
Derbyshire	Matlock, Groundwatera	4	<0.00084	0.12	0.10	0.081
Devon	River Exe, Exeter	4	<0.00084	0.013	0.12	0.095
Devon	Roadford Reservoir, Broadwood-widger	4	<0.00078	<0.0061	0.078	0.063
Gloucestershire	River Severn, Tewkesbury	`4	<0.00084	0.042	0.22	0.18
Greater London	River Lee, Walthamstow	4	<0.00082	<0.045	0.38	0.31
Hampshire	River Avon, Christchurch	4	<0.00082	<0.030	0.098	0.081
Humberside	Littlecoates, Groundwater	4	<0.00080	<0.033	0.12	0.098
Kent	Sittingbourne, Deep Groundwater	3	<0.00081	<0.024	0.051	0.042
Kent	Denge, Shallow Groundwater	4	<0.00084	<0.018	0.13	0.11
Lancashire	Worsthorne, Groundwater	4	<0.00079	<0.013	0.029	0.023
Norfolk	River Drove, Stoke Ferry	4	<0.00078	<0.033	0.16	0.13
Northumberland	Kielder Reservoir	4	<0.00085	0.016	0.032	0.026
Oxfordshire	River Thames, Oxford	4	<0.00074	0.039	0.23	0.19
Somerset	Ashford Reservoir, Bridgwater	4	<0.00080	0.022	0.10	0.082
Somerset	Chew Valley Lake Reservoir, Bristol	4	<0.00081	0.034	0.15	0.13
Surrey	River Thames, Chertsey	4	<0.00080	<0.041	0.29	0.24
Surrey	River Thames, Walton	4	<0.00077	<0.037	0.30	0.24
Yorkshire	Chellow Heights, Bradford	4	<0.00076	0.024	0.045	0.036
Yorkshire	Washburn Valley Reservoirs, Leeds	4	<0.00081	0.014	0.081	0.066
Wales						
Gwynedd	Cwm Ystradllyn Treatment Works	4	<0.00080	<0.0078	0.019	0.016
Mid-Glamorgan	Llwyn-on Reservoir	4	<0.00079	0.0078	0.026	0.021
Powys	Elan Valley Reservoir	3	<0.00087	0.0079	0.020	0.016

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 <0.0097, 0.021, 0.043, <0.0012 and 0.022 Bq l^{-1} respectively

Table 8.8 Concentrations of radionuclides in sources of drinking water in Northern Ireland, 2022

Area	Location	No. of sampling observa-tions	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	<7.0	<0.0028	<0.0021	0.0040	<0.06	0.0050	<0.0010	0.0030	<0.04	<0.25
Co. Antrim	Lough Neagh	4	<7.0	<0.0017	<0.0038	0.0030	<0.08	0.0030	<0.0010	0.0020	<0.04	0.55
Co. Down	Silent Valley	4	<7.0	< 0.0016	<0.0027	0.0050	<0.05	0.010	0.0030	0.0060	<0.04	<0.24

Table 8.9 Doses from radionuclides in drinking water, 2022[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	0.030	0.010	Matlock, Groundwater, Derbyshire	0.030
Wales[d]	<0.001			Cwm Ystradllyn Treatment Works Gwynedd	<0.001[d]
Northern Ireland	<0.001	0.026	0.026	Lough Neagh, County Antrim	0.027
Scotland[d]	<0.001			Gullielands Burn, Dumfries and Galloway	<0.001[d]
UK	<0.001	0.030	0.021	Matlock, Groundwater, Derbyshire	0.030

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 8.10 Concentrations of radionuclides in seawater, 2022

Location	No. of sampling observations	Mean radioactivity concentration, Bq l⁻¹							
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{129}I
Dounreay (Sandside Bay)	2[S]	<1.0		<0.10			<0.20	<0.10	
Dounreay (Brims Ness)	2[S]	<1.0		<0.10			<0.19	<0.10	
Rosyth	2[S]	<1.0		<0.10			<0.19	<0.10	
Torness[a]	2[S]	13		<0.10			<0.32	<0.10	
Hartlepool (North Gare)[b]	2	<4.6		<0.42			<2.9	<0.51	
Sizewell	2	<3.7	<7.4	<0.23			<2.0	<0.28	
Bradwell (Beach pipeline)	2	<3.8		<0.34			<2.6	<0.44	
Dungeness south	2	<3.9		<0.27			<2.3	<0.34	
Winfrith (Lulworth Cove)	1			<0.43			<3.0	<0.53	
Jersey	1[C]	4.5							
Guernsey	2[C]								
Devonport (Millbrook Lake)	1	<3.8	<2.8	<0.40					
Devonport (Tor Point South)	1	<3.7	<3.4	<0.45					
Hinkley	1	<3.7		<0.29	<0.060		<2.5	<0.44	
Berkeley and Oldbury	2	<3.7		<0.27			<2.1	<0.33	
Holyhead	1[B]	<1.5							
Wylfa (Cemaes Bay)	2	<3.4		<0.25			<1.9	<0.30	
Llandudno	1[B]								
Prestatyn	1[B]								

Location	No. of sampling observations	Mean radioactivity concentration, Bq l⁻¹						
		^{134}Cs	^{137}Cs	^{144}Ce	^{237}Np	^{241}Am	Gross alpha	Gross beta
Dounreay (Sandside Bay)	2[S]	<0.10	<0.10	<0.11		<0.10		
Dounreay (Brims Ness)	2[S]	<0.10	<0.10	<0.10		<0.10		
Rosyth	2[S]	<0.10	<0.10	<0.12		<0.10		
Torness[a]	2[S]	<0.10	<0.10	<0.18		<0.10		
Hartlepool (North Gare)[b]	2	<0.43	<0.34	<1.1		<0.35	<3.7	14
Sizewell	2	<0.26	<0.20	<1.2		<0.59	<6.2	12
Bradwell (Beach pipeline)	2	<0.37	<0.29	<1.1		<0.33	<3.5	12
Dungeness south	2	<0.30	<0.26	<1.2		<0.41	<2.9	13
Winfrith (Lulworth Cove)	1	<0.39	<0.34	<1.2		<0.36	<5.5	16
Jersey	1[C]	*	<0.0013					
Guernsey	2[C]	*	<0.0013					
Devonport (Millbrook Lake)	1							
Devonport (Tor Point South)	1							
Hinkley	1	<0.36	<0.25	<1.6		<0.48	<3.4	14
Berkeley and Oldbury	2	<0.31	<0.25	<1.1		<0.38	<2.8	8.2
Holyhead	1[B]	*	0.0029					
Wylfa (Cemaes Bay)	2	<0.27	<0.21	<0.99		<0.50	<4.3	13
Llandudno	1B	*	0.0078					
Prestatyn	1B	*	0.013					

Table 8.10 continued

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}							
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{129}I
New Brighton	1[B]								
Rossall	1[B]								
Heysham[c]	2	11		<0.33			<2.3	<0.37	
Half Moon Bay	1[B]								
Silecroft	1[B]								
Seascale (Particulate)[d]	2			<0.02	<0.019		<0.16	<0.02	<0.020
Seascale (Filtrate)	2	<4.0	<13	<0.07	<0.078	<0.031	<0.67	<0.12	<1.5
St. Bees (Particulate)[e]	2			<0.02	<0.021		<0.19	<0.03	<0.019
St. Bees (Filtrate)	2	<3.8	<14	<0.09	<0.088	<0.030	<0.90	<0.15	<1.5
Whitehaven	1[B]								
Maryport	1[B]								
Silloth	1[B]								
Seafield (near Chapelcross)	2[S]	<1.4		<0.10			<0.24	<0.10	
Southerness	2[S]	1.4		<0.10			<0.23	<0.10	
Auchencairn	2[S]	1.5		<0.10			<0.35	<0.10	
Ross Bay	1B								
Isle of Whithorn	1[B]								

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}						
		^{134}Cs	^{137}Cs	^{144}Ce	^{237}Np	^{241}Am	Gross alpha	Gross beta
New Brighton	1B	*	0.0089					
Rossall	1B	*	0.014					
Heyshamc	2	<0.32	<0.27	<1.1		<0.50	<4.9	14
Half Moon Bay	1B	*	0.021					
Silecroft	1B	*	0.027					
Seascale (Particulate)d	2	<0.02	<0.02	<0.08	<0.0040	<0.022	0.035	0.020
Seascale (Filtrate)	2	<0.08	<0.06	<0.50	<0.32	<0.26	<3.0	11
St. Bees (Particulate)e	2	<0.02	<0.02	<0.08	<0.0040	<0.021	0.035	0.021
St. Bees (Filtrate)	2	<0.10	<0.08	<0.55	<0.32	<0.21	<3.4	15
Whitehaven	1B	*	0.015					
Maryport	1B	*	0.0093					
Silloth	1B	*	0.026					
Seafield (near Chapelcross)	2S	<0.10	<0.10	<0.15		<0.10		
Southerness	2S	<0.10	<0.13	<0.14		<0.10		
Auchencairn	2S	<0.10	<0.10	<0.19		<0.10		
Ross Bay	1B	*	0.015					
Isle of Whithorn	1B	*	0.015					

Table 8.10 continued

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}							
		^{3}H	^{14}C	^{60}Co	^{90}Sr	^{99}Tc	^{106}Ru	^{110m}Ag	^{129}I
Drummore	1[B]								
Port Patrick	2[S]	<1.0		<0.10			<0.31	<0.10	
Knock Bay	1[B]	<1.5							
Hunterston[f]	2[S]	<1.0		<0.10			<0.18	<0.10	
North of Larne	3[N]					0.00077			
Faslane (Carnban)	2[S]	<1.0		<0.10			<0.27	<0.10	

Location	No. of sampling observations	Mean radioactivity concentration, Bq l^{-1}						
		^{134}Cs	^{137}Cs	^{144}Ce	^{237}Np	^{241}Am	Gross alpha	Gross beta
Drummore	1B	*	0.0099					
Port Patrick	2S	<0.10	<0.10	<0.20		<0.10		
Knock Bay	1B	*	0.0095					
Hunterston[f]	2S	<0.10	<0.10	<0.11		<0.10		
North of Larne	3N	*	<0.0029					
Faslane (Carnban)	2S	<0.10	<0.10	<0.15		<0.10		

* Not detected by the method used
a. The concentration of ^{35}S was <0.50 Bq l^{-1}
b. The concentration of ^{35}S was <0.23 Bq l^{-1}
c. The concentration of ^{35}S was <0.19 Bq l^{-1}
d. The concentrations of ^{238}Pu, $^{239/40}Pu$ and ^{241}Pu were <0.00070, <0.0059 and <0.11 Bq l^{-1} respectively
e. The concentrations of ^{238}Pu, $^{239/40}Pu$ and ^{241}Pu were <0.00076, <0.0052 and <0.097 Bq l^{-1} respectively
f. The concentration of ^{35}S was <1.1 Bq l^{-1}

Results are made on behalf of the Environment Agency unless indicated otherwise
B Measurements labelled "B" are made on behalf of the Department of Business, Energy and Industrial Strategy (BEIS)
C Measurements labelled "C" are made on behalf of the Channel Islands States
N Measurements labelled "N" are made on behalf of the Northern Ireland Environment Agency
S Measurements labelled "S" are made on behalf of the Scottish Environment Protection Agency

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Appendix 1 Disposals of radioactive waste

Table A1.1 Principal discharges of gaseous radioactive wastes from nuclear establishments in the United Kingdom, 2022

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Nuclear fuel production and reprocessing				
Capenhurst	Uranium	1.00E+07	Nil	Nil
(Urenco Nuclear Stewardship Ltd)	Alpha	1.00E+07	Nil	Nil
	Beta	5.00E+07	Nil	Nil
Capenhurst				
(Urenco UK Ltd)	Uranium	7.50E+06	2.76E+05	3.7
	Other alpha	2.40E+06	Nil	Nil
	Technetium-99	1.00E+08	Nil	Nil
	Others	2.25E+09	Nil	Nil
Capenhurst				
(UCP)	Uranium	7.50E+06	1.54E+05	2.1
	Other Alpha	2.40E+06	Nil	Nil
	Technetium-99	1.00E+08	Nil	Nil
	Other radionuclides	7.50E+06	Nil	Nil
Sellafield[d]	Alpha[1]	6.60E+08	6.98E+07	11
	Beta[1]	3.20E+10	9.04E+08	2.8
	Tritium[2]	3.70E+14	1.55E+13	4.2
	Carbon-14[2]	2.30E+12	8.63E+10	3.8
	Krypton-85[2]	7.00E+16	2.46E+15	3.5
	Strontium-90[1]	5.00E+08	3.26E+06	<1
	Ruthenium-106	2.80E+09	6.07E+08	22
	Antimony-125[2]	3.00E+10	4.11E+08	1.4
	Iodine-129[2]	4.20E+10	1.83E+09	4.4
	Caesium-137[1]	4.80E+09	3.55E+07	<1
	Plutonium alpha[1]	1.30E+08	6.12E+06	4.7
	Americium-241 and curium-242[1]	8.40E+07	8.62E+06	10
Springfields	Uranium	5.30E+09	3.26E+06	<1
Springfields	Tritium	1.00E+08	7.40E+05	<1
(National Nuclear Laboratory)	Carbon-14	1.00E+07	1.76E+03	<1
	Krypton-85	7.20E+11	Nil	Nil
	Other alpha radionuclides	1.00E+06	Nil	Nil
	Other beta radionuclides	1.00E+07	1.45E+03	<1
Research establishments				
Dounreay[e]				
	Alpha[f]	3.1E+07	6.4E+04	<1
	Non-alpha[g]	1.7E+09	9.9E+05	<1
	Tritium	1.72E+13	2.4E+10	<1
	Krypton-85[h]	5.69E+14	4.6E+07	<1

Table A1.1 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
	Iodine-129	1.08E+08	1.6E+07	15
Harwell				
(Magnox)	Alpha	8.00E+05	2.20E+04	2.8
	Beta	2.00E+07	6.50E+05	3.3
	Tritium	1.50E+13	9.00E+10	<1
	Krypton-85	2.00E+12	Nil	Nil
	Radon-220	1.00E+14	4.80E+12	4.8
	Radon-222	3.00E+12	2.40E+11	8.0
	Iodines	1.00E+10	Nil	Nil
	Other radionuclides	1.00E+11	3.20E+06	<1
Winfrith				
(Inutec)	Alpha	1.00E+05	1.26E+02	<1
	Tritium	1.95E+13	1.02E+12	5.2
	Carbon-14	3.00E+10	2.04E+02	<1
	Other	1.00E+05	4.80E+02	<1
Winfrith				
(Magnox)	Alpha	2.00E+06	1.22E+03	<1
	Tritium	4.95E+13	6.50E+09	<1
	Carbon-14	5.90E+09	1.34E+08	2.3
	Other	5.00E+06	1.26E+04	<1
Nuclear power stations				
Berkeley[i]	Beta	2.00E+07	3.61E+05	1.8
	Tritium[3]	1.00E+12	6.65E+09	<1
	Carbon-14	5.00E+09	6.22E+08	12
Bradwell	Beta	2.00E+07	1.70E+05	<1
	Tritium	6.00E+11	6.10E+09	1.0
	Carbon-14	4.00E+10	4.20E+08	1.1
Chapelcross	Tritium	7.50E+14	2.62E+12	<1
	All other nuclides	2.50E+09	1.68E+09	67
Dungeness				
A Station	Beta[j]	5.00E+08	7.85E+05	<1
	Tritium	2.60E+12	5.03E+10	1.9
	Carbon-14	5.00E+12	3.99E+08	<1
Dungeness				
B Station	Tritium	1.20E+13	6.28E+10	<1
	Carbon-14	3.70E+12	6.32E+09	<1
	Sulphur-35	3.00E+11	5.08E+08	<1
	Argon-41	7.50E+13	Nil	Nil
	Cobalt-60[j]	1.00E+08	2.49E+06	2.5
	Iodine-131	1.50E+09	2.30E+07	1.5
Hartlepool	Tritium	1.00E+13	5.16E+11	5.2
	Carbon-14	4.50E+12	9.85E+11	22
	Sulphur-35	2.30E+11	1.48E+10	6.4
	Argon-41	1.50E+14	3.87E+12	2.6
	Cobalt-60[j]	1.00E+08	1.96E+07	20

Table A1.1 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
	Iodine-131	1.50E+09	1.29E+08	8.6
Heysham				
Station 1	Tritium	1.00E+13	1.33E+12	13
	Carbon-14	4.50E+12	1.67E+12	37
	Sulphur-35	2.00E+11	1.83E+10	9.2
	Argon-41	1.50E+14	7.43E+12	5.0
	Cobalt-60[j]	1.00E+08	7.28E+06	7.3
	Iodine-131	1.50E+09	6.07E+07	4.0
Heysham				
Station 2	Tritium	1.00E+13	1.23E+12	12
	Carbon-14	3.70E+12	1.54E+12	42
	Sulphur-35	2.30E+11	1.42E+10	6.2
	Argon-41	7.50E+13	9.87E+12	13
	Cobalt-60[j]	1.00E+08	9.87E+06	9.9
	Iodine-131	1.50E+09	7.84E+07	5.2
Hinkley Point				
A Station	Beta	5.00E+07	1.92E+05	<1
	Tritium	7.50E+11	1.54E+10	2.1
	Carbon-14	5.00E+10	5.36E+08	1.1
Hinkley Point				
B Station	Tritium	1.20E+13	8.16E+11	6.8
	Carbon-14	3.70E+12	1.21E+12	33
	Sulphur-35	3.50E+11	3.69E+10	11
	Argon-41	1.00E+14	4.89E+12	4.9
	Cobalt-60[j]	1.00E+08	9.57E+06	9.6
	Iodine-131	1.50E+09	3.58E+06	<1
Hunterston				
A Station	Tritium	2.00E+10	4.35E+08	2.2
	Carbon-14	2.00E+09	5.15E+07	2.6
	All other radionuclides	3.00E+06	4.41E+05	15
Hunterston				
B Station[e]	Particulate beta	5.00E+08	4.46E+07	8.9
	Tritium	1.50E+13	7.34E+11	4.9
	Carbon-14	4.50E+12	2.41E+11	5.4
	Sulphur-35	5.00E+11	6.92E+09	1.4
	Argon-41	1.50E+14	8.10E+11	<1
	Iodine-131	2.00E+09	Nil	Nil
Oldbury	Beta	1.00E+08	1.44E+05	<1
	Tritium	9.00E+12	2.10E+10	<1
	Carbon-14	4.00E+12	1.44E+09	<1
Sizewell				
A Station	Beta	8.50E+08	2.92E+04	<1
	Tritium	3.50E+12	1.88E+10	<1
	Carbon-14	1.00E+11	6.53E+08	<1

Table A1.1 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Sizewell				
B Station	Noble gases	3.00E+13	2.62E+12	8.7
	Particulate Beta	1.00E+08	3.00E+06	3.0
	Tritium	3.00E+12	6.95E+11	23
	Carbon-14[4]	6.00E+11	4.48E+11	75
	Iodine-131	5.00E+08	7.00E+06	1.4
Torness	Particulate beta	4.00E+08	1.45E+07	3.6
	Tritium	1.10E+13	1.69E+12	15
	Carbon-14	4.50E+12	1.08E+12	24
	Sulphur-35	3.00E+11	4.44E+10	15
	Argon-41	7.50E+13	1.39E+12	1.9
	Iodine-131	2.00E+09	3.05E+06	<1
Trawsfynydd	Particulate Beta	5.00E+07	1.64E+05	<1
	Tritium	3.75E+11	1.72E+10	4.6
	Carbon-14	1.00E+10	1.13E+09	11
Wylfa	Particulate Beta	7.00E+08	1.76E+06	<1
	Tritium	1.80E+13	5.70E+10	<1
	Carbon-14	2.30E+12	8.64E+08	<1
Defence establishments				
Aldermaston[k]	Alpha	1.65E+05	1.93E+04	12
	Particulate Beta	6.00E+05	8.96E+03	1.5
	Tritium	3.90E+13	3.27E+12	8.4
	Carbon-14	6.00E+06	Nil	Nil
	Activation products[l]	BAT	4.50E+07	NA
	Volatile beta	1.00E+08	8.00E-01	<1
Barrow[m]	Tritium	3.20E+06	Nil	Nil
	Argon-41	4.80E+10	Nil	Nil
Burghfield[k]	Tritium	9.00E+09	Nil	Nil
	Alpha	5.00E+03	1.78E+03	36
Coulport	Tritium	5.00E+10	3.47E+09	6.9
Derby[j, n]	Alpha[o]	3.00E+06	1.07E+06	36
	Alpha[p,q]	2.40E+04	7.00E+00	<1
	Beta[p, q]	1.80E+06	3.22E+04	1.8
Devonport[r]	Beta[j]	3.00E+05	1.55E+04	5.2
	Tritium	4.00E+09	8.00E+07	2.0
	Carbon-14	6.60E+10	1.40E+08	<1
	Argon-41	1.50E+10	Nil	Nil
Dounreay[e]	All other radionuclides	5.10E+06	8.90E+05	17
(Vulcan)	Noble gases	5.00E+09	Nil	Nil
Rosyth[e, s]	Tritium	1.00E+07	1.64E+05	1.6
	Carbon-14	5.00E+07	2.24E+05	<1
	Other radionuclides	1.00E+05	4.43E+04	44

Table A1.1 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Radiochemical production				
Amersham (GE Healthcare)	Other alpha-emitting radionuclides	2.25E+06	2.35E+04	1.0
	Radionuclides T1/2<2hr[t]	7.50E+11	Nil	Nil
	Tritium	2.00E+12	1.48E+11	7.4
	Radon-222	1.00E+13	2.34E+12	23
	All other radionuclides	1.60E+10	2.68E+08	1.7
Industrial and landfill sites				
LLWR	Alpha	BAT	1.02E+03	NA
	Beta	BAT	1.04E+04	NA
Lillyhall (Cyclife UK Limited)	Alpha (particulate)	5.00E+05	4.03E+03	<1
	Beta (particulate)	5.00E+05	1.60E+04	3.2

* As reported to SEPA and the Environment Agency
a. These are the limits in force at end of the calendar year, unless otherwise stated. There may be changes in limits during the year (see notes for each nuclear site). In some cases permits/authorisations specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites.
b. Data quoted to 3 significant figures, except where fewer significant figures are provided in source documents
c. Data quoted to 2 significant figures except where values are <1%. Where permit/authorisation limits have changed during the year, this will not necessarily reflect the compliance position
d. Revised discharge permit limits came into force with effect 1 October 2020. The new permit allows for upper limits to be in force for completion of Magnox reprocessing;
e. until completion of active commissioning of HEPA filtration in the Magnox Swarf Storage Silo stack; and specific remediation activities, subject to a best available techniques case. See EPR/KP3690SX/V011 for more details. Lower limits are in effect unless otherwise specified. Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection
f. All alpha emitting nuclides taken together
g. All non-alpha emitting radionuclides, not specifically listed, taken together
h. Krypton-85 discharges are calculated
i. Combined data for Berkeley Power Station and Berkeley Centre
j. Particulate activity
k. Discharges were made by AWE plc
l. Argon-41 is reported under the Activation products total and the limit is the demonstration of Best Available Technique
m. 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
n. Discharges were made by Rolls Royce Submarines Ltd
o. Discharge limit is for the Nuclear Fuel Production Plant Site
p. Annual limits on beta and alpha derived from monthly and weekly notification levels
q. Discharge limit is for the Neptune Reactor Raynesway Site
r. Discharges were made by Devonport Royal Dockyard Ltd
s. Discharges were made by Rosyth Royal Dockyard Ltd
t. Denotes radionuclides with a half-life on less than 2 hours
1. Upper limit in force until completion of the active commisioning of HEPA filters in the MSSS stack. See Section 2.3 for further details
2. Upper limit in force during Magnox reprocessing operations. See Section 2.3 for further details
3. Discharge permit revised with effect 1 May 2021
4. Discharge permit revised with effect 1 September 2021
NA Not applicable under permit
BAT Best available technology

Table A1.2 Principal discharges of liquid radioactive waste from nuclear establishments in the United Kingdom, 2022

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Nuclear fuel production and reprocessing				
Capenhurst				
(Urenco UK Ltd)	Uranium	7.50E+08	1.58E+06	<1
	Uranium daughters	1.36E+09	3.47E+06	<1
	Non-uranic alpha	2.20E+08	7.78E+06	3.5
	Technetium-99	1.00E+09	2.24E+06	<1
Sellafield[d]	Alpha	3.40E+11	7.98E+10	23
	Beta	6.30E+13	6.53E+12	10
	Tritium[1]	3.00E+15	1.34E+14	4.5
	Carbon-14[1]	1.30E+13	8.51E+11	6.5
	Cobalt-60	2.50E+12	1.26E+10	<1
	Strontium-90	1.40E+13	1.84E+12	13
	Technetium-99[1]	7.50E+12	3.54E+11	4.7
	Ruthenium-106	3.10E+12	1.59E+11	5.1
	Iodine-129	3.20E+11	1.67E+10	5.2
	Caesium-137	1.70E+13	1.34E+12	7.9
	Uranium alpha	2.00E+10	3.77E+09	19
	Plutonium alpha	2.90E+11	6.71E+10	23
	Plutonium-241	6.00E+12	7.26E+11	12
	Americium-241	1.40E+11	1.01E+10	7.2
Springfields	Alpha	1.00E+11	6.12E+09	6.1
	Beta	2.00E+13	1.33E+10	<1
	Technetium-99	6.00E+11	7.72E+08	<1
	Thorium-230	2.00E+10	3.40E+07	<1
	Thorium-232[e]	1.50E+10	6.00E+06	<1
	Neptunium-237	4.00E+10	1.50E+07	<1
	Other transuranic radionuclides	2.00E+10	6.10E+07	<1
	Uranium	4.00E+10	5.99E+09	15
Research establishments				
Dounreay[e]	Alpha[f]	3.40E+09	1.70E+08	5.0
	Non-alpha[g]	4.80E+10	7.70E+09	16
	Tritium	6.90E+12	1.50E+10	<1
	Strontium-90	1.77E+11	4.60E+10	26
	Caesium-137	6.29E+11	2.70E+09	<1
Harwell (Lydebank Brook)	Alpha	3.00E+07	3.99E+06	13
	Beta	3.00E+08	7.41E+06	2.5
	Tritium	2.00E+10	1.80E+08	<1
Harwell (sewer)	Alpha	1.00E+07	1.40E+04	<1
	Beta	6.00E+08	7.50E+04	<1
	Tritium	1.00E+11	3.09E+08	<1
	Cobalt-60	5.00E+06	2.24E+05	4.5
	Caesium-137	2.00E+08	1.25E+05	<1
Winfrith (inner pipeline)[h]	Alpha	1.40E+10	3.90E+05	<1
	Tritium	4.00E+13	6.50E+08	<1
	Caesium-137	1.98E+12	5.03E+07	<1
	Other radionuclides	9.80E+11	7.92E+06	<1

Table A1.2 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Winfrith (outer pipeline)	Alpha	2.00E+09	6.78E+05	<1
	Tritium	1.50E+11	6.96E+07	<1
	Other radionuclides	1.00E+09	1.52E+06	<1
Nuclear power stations				
Berkeley	Tritium	1.00E+12	1.10E+08	<1
	Caesium-137	2.00E+11	1.40E+08	<1
	Other radionuclides	2.00E+11	8.00E+07	<1
Bradwell	Tritium	7.00E+10	1.20E+09	1.7
	Caesium-137	7.00E+09	4.50E+07	<1
	Other radionuclides	7.00E+09	1.70E+08	2.4
Chapelcross	Alpha	1.00E+09	1.05E+06	<1
	Non-alpha[i]	1.00E+12	9.69E+08	<1
	Tritium	6.50E+12	6.28E+08	<1
Dungeness A Station	Tritium	8.00E+12	2.07E+09	<1
	Caesium-137	1.10E+12	6.44E+09	<1
	Other radionuclides	8.00E+11	9.86E+09	1.2
Dungeness B Station	Tritium	6.50E+14	2.21E+09	<1
	Sulphur-35	2.00E+12	1.21E+07	<1
	Cobalt-60	1.00E+10	6.50E+07	<1
	Caesium-137	1.00E+11	3.63E+08	<1
	Other radionuclides	8.00E+10	3.20E+08	<1
Hartlepool	Tritium	6.50E+14	3.59E+14	55
	Sulphur-35	3.60E+12	6.53E+11	18
	Cobalt-60	1.00E+10	1.89E+08	1.9
	Caesium-137	1.00E+11	1.35E+09	1.4
	Other radionuclides	8.00E+10	3.08E+09	3.9
Heysham Station 1	Tritium	6.50E+14	3.00E+14	46
	Sulphur-35	2.00E+12	4.03E+11	20
	Cobalt-60	1.00E+10	1.49E+08	1.5
	Caesium-137	1.00E+11	2.36E+08	<1
	Other radionuclides	8.00E+10	4.10E+09	5.1
Heysham Station 2	Tritium	6.50E+14	2.91E+14	45
	Sulphur-35	2.00E+12	1.40E+11	7.0
	Cobalt-60	1.00E+10	1.35E+08	1.4
	Caesium-137	1.00E+11	5.79E+08	<1
	Other radionuclides	8.00E+10	9.40E+09	12
Hinkley Point A Station	Tritium	1.00E+12	8.32E+08	<1
	Caesium-137	1.00E+12	3.80E+07	<1
	Other radionuclides	7.00E+11	7.90E+07	<1

Table A1.2 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Hinkley Point B Station	Tritium	6.50E+14	1.48E+14	23
	Sulphur-35	2.00E+12	1.68E+11	8.4
	Cobalt-60	1.00E+10	4.08E+07	<1
	Caesium-137	1.00E+11	6.52E+08	<1
	Other radionuclides	8.00E+10	1.90E+09	2.4
Hunterston A Station	Alpha	2.00E+09	3.00E+06	<1
	All other non-alpha[j]	6.00E+10	3.90E+07	<1
	Tritium	3.00E+10	7.00E+06	<1
	Caesium-137	1.60E+11	4.80E+07	<1
	Plutonium-241	2.00E+09	1.00E+06	<1
Hunterston B Station	Alpha	1.00E+09	3.09E+07	3.1
	All other non-alpha	1.50E+11	2.59E+09	1.7
	Tritium	7.00E+14	2.30E+13	3.3
	Sulphur-35	6.00E+12	1.52E+10	<1
	Cobalt-60	1.00E+10	2.24E+08	2.2
Oldbury	Tritium	1.00E+12	2.43E+08	<1
	Caesium-137	7.00E+11	2.63E+08	<1
	Other radionuclides	7.00E+11	1.13E+09	<1
Sizewell A Station	Tritium	5.00E+12	4.90E+08	<1
	Caesium-137	1.00E+12	2.29E+09	<1
	Other radionuclides	7.00E+11	2.71E+09	<1
Sizewell B Station	Tritium	8.00E+13	2.17E+13	27
	Caesium-137	2.00E+10	1.00E+08	<1
	Other radionuclides	1.30E+11	4.30E+09	3.3
Torness	Alpha	5.00E+08	1.85E+07	3.7
	All other non-alpha	1.50E+11	4.92E+09	3.3
	Tritium	7.00E+14	2.56E+14	37
	Sulphur-35	3.00E+12	1.20E+11	4.0
	Cobalt-60	1.00E+10	3.29E+08	3.3
Trawsfynydd	Tritium	3.00E+11	2.16E+09	<1
	Caesium-137	1.50E+10	1.83E+08	1.2
	Other radionuclides[k]	3.00E+10	6.46E+08	2.2
Wylfa	Tritium	1.50E+13	8.00E+07	<1
	Other radionuclides	1.10E+11	6.00E+07	<1

Table A1.2 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Defence establishments				
Aldermaston (Silchester)[l]	Alpha	1.00E+07	1.67E+06	17
	Other beta emitting radio-nuclides	2.00E+07	7.90E+06	40
	Tritium	2.50E+10	1.00E+08	<1
Aldermaston (to Stream)[l, m]	Tritium	NA	1.60E+08	NA
Barrow[n]	Tritium	1.20E+10	1.93E+05	<1
	Carbon-14	2.95E+08	2.67E+05	<1
	Cobalt-60	1.34E+07	1.94E+03	<1
	Other beta-gamma emitting radionuclides	3.50E+06	1.75E+03	<1
Burghfield (Sewer)	Alpha[o]	NA	8.66E+02	NA
Derby[p]	Alpha[q]	2.00E+09	3.62E+07	1.8
	Alpha[r]	3.00E+05	1.44E+04	4.8
	Beta[r]	3.00E+08	6.44E+05	<1
Devonport (sewer)[s]	Tritium	2.00E+09	5.99E+06	<1
	Cobalt-60	3.50E+08	1.07E+06	<1
	Other radionuclides	6.50E+08	1.22E+07	1.9
Devonport (estuary)[s]	Tritium	7.00E+11	2.39E+09	<1
	Carbon-14	1.70E+09	7.55E+06	<1
	Cobalt-60	8.00E+08	1.41E+06	<1
	Other radionuclides	3.00E+08	1.35E+06	<1
Faslane	Alpha	2.00E+08	1.40E+04	<1
	Beta[i,t]	5.00E+08	1.40E+05	<1
	Tritium	1.00E+12	1.58E+09	<1
	Cobalt-60	5.00E+08	7.00E+04	<1
Rosyth[e, u]	Tritium	3.00E+08	5.68E+07	19
	Cobalt-60	1.00E+08	7.70E+05	<1
	Other radionuclides	1.00E+08	2.67E+06	2.7
Radiochemical production				
Amersham (GE Healthcare)[t]	Alpha	3.00E+08	1.91E+06	<1
	Tritium	1.41E+11	7.00E+05	<1
	Other radionuclides	6.50E+10	4.12E+07	<1

Table A1.2 continued

Establishment	Radioactivity	Discharge limit (annual equivalent)[a] Bq[b]	Discharges during 2022 Bq[b]	% of annual limit[c]
Industrial and landfill sites				
LLWR	Alpha	BAT	2.14E+07	NA
	Beta	BAT	3.94E+08	NA
	Tritium	BAT	1.74E+10	NA
Lillyhall (Cyclife UK limited)				
	Alpha	5.00E+05	5.70E+02	<1
	Other radionuclides	5.00E+05	1.49E+04	3.0

a. These are the limits in force at end of the calendar year, unless otherwise stated. There may be changes in limits during the year (see notes for each nuclear site). In some cases permits/authorisations specify limits in greater detail than can be summarised in a single table; in particular, periods shorter than one year are specified at some sites.
b. Data quoted to 3 significant figures, except where fewer significant figures are provided in source documents
c. Data quoted to 2 significant figures except where values are <1%. Where permit/authorisation limits have changed during the year, this will not necessarily reflect the compliance position
d. Includes discharges made via the sea pipelines, factory sewer and Calder interceptor sewer. Revised discharge permit limits came into force with effect 1 October 2020. The new permit allows for upper limits to be in force for completion of Magnox reprocessing; and specific remediation activities, subject to a best available techniques case. See EPR/KP3690SX/V011 for more details. Lower limits are in effect unless otherwise specified
e. Some discharges are upper estimates because they include 'less than' data derived from analyses of effluents at limits of detection. Data quoted to 2 decimal places
f. All alpha emitting radionuclides taken together
g. All non-alpha emitting radionuclides, not specifically listed, taken together
h. Discharges reported include those from Inutec Limited. There was no overall change in the 2018 discharge limits at the Winfrith site due to the Magnox and Inutec discharge permits
i. Excluding tritium
j. Excluding Tritium, caesium-137 and plutonium-241
k. Including strontium
l. Discharges were made by AWE plc
m. The discharge limit has been replaced by an activity notification level of 30 Bq l^{-1}
n. Discharges from Barrow are included with those from MOD sites because they are related to submarine activities. Discharges were made by BAE Systems Marine Ltd
o. Quarterly notification level of 5.00E+03 Bq is in effect
p. Discharges were made by Rolls Royce Submarines Ltd
q. Discharge limit is for Nuclear Fuel Production Plant
r. Discharge limit is for Neptune Reactor Raynesway Site
s. Discharges were made by Devonport Royal Dockyard Ltd
t. Excluding cobalt-60
u. Discharges were made by Rosyth Royal Dockyard Ltd
1. Upper limit in force during Magnox reprocessing operations. See Section 3.3 for further details
NA Not applicable under permit
BAT Best available technology

Table A1.3 Disposals and receipt with the intention of disposal of solid radioactive waste at nuclear establishments in the United Kingdom, Financial Year 2022/23

Radionuclide or group of radionuclides	Total vault disposed[a] waste FY22/23 (Bq)	Cumulative total vault disposed[a, b] waste (Bq)
Tritium	1.16E+11	2.80E+13
Carbon-14	4.52E+10	5.56E+11
Chlorine-36	4.76E+08	7.16E+11
Calcium-41	Nil	1.20E+10
Selenium-79	6.59E+03	7.08E+03
Molybdenum-93	1.46E+02	1.40E+06
Zirconium-93	Nil	3.83E+10
Niobium-94	1.10E+07	6.95E+09
Technetium-99	Nil	3.04E+12
Silver-108m	2.14E+09	1.55E+10
Iodine-129	5.76E+07	3.42E+09
Caesium-135	1.42E+04	5.25E+08
Radium-226	3.03E+08	7.41E+10
Thorium-229	Nil	5.38E+05
Thorium-230	2.50E+08	7.30E+09
Thorium-232	1.84E+06	3.57E+10
Protactinium-231	Nil	2.44E+09
Uranium-233	2.13E+07	5.69E+10
Uranium-234	4.36E+09	4.72E+11
Uranium-235	1.54E+08	3.21E+10
Uranium-236	2.95E+08	2.83E+10
Uranium-238	5.23E+09	5.34E+11
Neptunium-237	1.36E+09	4.44E+10
Plutonium-238	3.91E+09	2.33E+11
Plutonium-239	1.34E+10	5.33E+11
Plutonium-240	8.68E+09	3.45E+11
Plutonium-241	1.02E+11	1.00E+13
Plutonium-242	1.13E+07	1.02E+09
Americium-241	2.87E+10	1.45E+12
Americium-242m	7.69E+04	5.87E+10
Americium-243	4.86E+07	6.65E+08
Curium-243	1.24E+07	3.38E+09
Curium-244	3.10E+08	2.10E+10
Curium-245	2.01E+05	5.93E+06
Curium-246	1.91E+04	2.08E+06
Curium-248	Nil	4.98E+07
OTHRT**	9.63E+08	2.16E+09
PUALD**	Nil	1.01E+11
UALD**	Nil	1.13E+10
URRM**	Nil	2.38E+10
Others*	2.95E+12	6.89E+13

a. In this context, ‘disposed’ includes waste already disposed in Vault 8 and wastes accepted with the intention to dispose and currently in storage in Vault 8 & 9, pending disposal
b. the quoted radioactivity’s exclude any Waste Consignment Information (WCI) form resubmissions made by consignors as part of ongoing investigations. Refer to Section 5 of the 2018/19 Environmental Safety Case Annual Review for specific consignment details (report ref; LLWR/ESC/R(19)10103).
* ‘Others’ includes all radionuclides not listed above and radionuclides with ‘no value’ listed above, but excludes radionuclides of less than three months half-life.
** ‘OTHRT’ is the sum of activity from radium and thorium isotopes other than Ra-226 and Th-232; ‘PUALD’, ‘UALD’ and ‘URRM’ represent plutonium and uranium, respectively, arising from defence-related activities.

Table A1.3 continued

Year	Actual receipt data[a, b]		Projected data[c]	
	Total vault disposed waste for financial year (m³)	Cumulative (to financial year end) total vault disposed waste (m³)	Total vault disposed waste for financial year (m³)	Cumulative (to financial year end) total vault disposed waste (m³)
2015/16	3.32E+03	2.44E+05	1.94E+04	3.68E+05
2016/17	3.35E+03	2.47E+05	2.00E+04	3.88E+05
2017/18	1.81E+03	2.49E+05	2.00E+04	4.31E+05
2018/19	1.72E+03	2.51E+05	2.31E+04	4.54E+05
2019/20	6.93E+02	2.51E+05	2.39E+04	4.78E+05
2020/21	4.36E+02	2.52E+05	2.78E+04	5.06E+05
2021/22	5.33E+02	2.53E+05	2.53E+04	5.31E+05
2022/23	1.04E+03	2.54E+05	3.19E+04	5.63E+05

a. In this context, ‘disposed’ includes waste already disposed in Vault 8 and wastes accepted with the intention to dispose and currently in storage in Vault 8 & 9, pending disposal
b. ‘disposed waste’ volumes refer to the gross package volume of each container or cumulative gross package volume of all containers received at LLWR site
c. ‘projected data’ volumes quoted within this report are different to those quoted for the same period in previous RIFE reports. Refer to LLWR Learning Report reference LR004845, raised on the 23rd July 2019.

Table A1.4 Solid waste transfers from nuclear establishments in Scotland, 2022*

Establishment Transfer from	Volume m³	Total Activity Bq	Alpha Bq	Beta/Gamma Bq
Research establishments				
Dounreay	1.90E+02		2.01E+09	2.03E+10
Nuclear Power Stations				
Chapelcross[a]	2.25E+02	5.08E+09		
Hunterston A	5.28E+01	7.53E+08		
Hunterston B	4.96E+01		9.77E+05	4.60E+08
Torness	6.28E+01		7.50E+05	1.41E+12
Defence establishments				
Coulport	Nil	Nil	Nil	Nil
Dounreay (Vulcan)	Nil	Nil	Nil	Nil
Faslane	Nil		Nil	Nil
Rosyth	3.00E+01	2.28E+07	Nil	Nil

* As reported by site operators to SEPA
a. Reported as total activity only

Table A1.5 Summary of unintended leakages, spillages, emissions or unusual findings of radioactive substances from nuclear licensed sites in the UK in 2022

Site	Month/ Year	Summary of incident	Consequences and action taken
Sellafield	June 2021	The Environment Agency were notified of a potential leakage of radioactive condensate through perforations in ventilation ductwork at the HALES facility.	The Environment Agency determined that there were breaches of the permit in allowing a potential disposal of radioactive waste from an unpermitted disposal route and for not maintaining the ventilation ductwork in good repair. The Environment Agency issued a warning letter to Sellafield Limited for breaches of permit conditions and placed an action to ensure that Sellafield Limited return to compliance. Sellafield Limited has provided a programme of work that will ensure disposals of radioactive waste are only by the permitted disposal routes. The environmental impact of this event was considered to be minor.
Dounreay	April 2022	In April 2022, DSRL notified SEPA of an incident at a sodium storage facility associated with the Prototype Fast Reactor (PFR) facility. It was established that, during an operation to destroy sodium, there was a very small release of caustic liquid and a release of tritium from an unauthorised and unmonitored route following a tank drainage failure.	In September 2022 SEPA issued an Information Notice to DSRL requiring reports detailing a review of the tank drainage and liquid monitoring arrangements. Based on the estimate of the tritium release provided by DSRL, SEPA consider the risk to the public or the environment to be extremely low. SEPA's investigation of the circumstances concluded that DSRL had contravened conditions of its EASR radioactive substances authorisation. In January 2023, SEPA issued a Final Warning Letter to DSRL.
Chapelcross	June 2022	In June 2022 Magnox Ltd contacted SEPA to inform them that the annual activity limit for gaseous 'all radionuclides other than tritium' associated with the Advanced Vacuum Drying System (AVDS) had been exceeded in May 2022. The AVDS serves to condition packaged ILW that has been removed from the pond facility prior to storage in the site's ISF.	Following an investigation conducted by SEPA, it was concluded that the exceedance constituted a small fraction of the site's relevant Site Limit and that the exceedance did not result in harm to the public or the environment.
Dounreay	August 2022	In August 2022, DSRL notified SEPA that a filter, which is part of the air supply ventilation system for a laundry facility, was not installed. The filter contributes to minimising particulate entering the facility and being entrained with the radioactive discharges.	Although there was no harm to the environment as a result of the failure to install the filter, SEPA's investigation of the circumstances concluded that DSRL had contravened conditions of its EASR radioactive substances authorisation and issues a Warning Letter to DSRL.
Wylfa	October 2022	Magnox Ltd. at Wylfa discovered an error in the calculation of discharges of tritium (H-3) and Sulphur-35 (S-35) to air. This resulted in an underestimate of some H-3 and S-35 discharges by up to 23.3 % from 2002 to 2022. Some beta particulate discharges to air may also have been calculated incorrectly, however this would have resulted in a slight over-estimation of the discharges.	NRW determined that there were two breaches of permit conditions because of the failure to calculate and report accurate discharge data. The NRW enforcement response was to provide a warning to Magnox Ltd. NRW also required that Magnox Ltd. complete corrective actions in response to the event; and review their change control procedures for techniques to ensure compliance with the permit. Despite the calculation errors, there would not have been any exceedences of permitted discharge limits. As a consequence, the potential environmental impact of the errors was assessed as being minor. Magnox Limited were not required to re-submit corrected discharge data for the period over which the error persisted as this would involve extensive work for little environmental benefit.
Dounreay	November 2022	In November 2022, SEPA was notified by DSRL of a potential unplanned release of tritium from an unauthorised and unmonitored route. The source of the potential release was a drum containing sodium with an associated tritium inventory, stored at the Prototype Fast Reactor (PFR) facility.	Based on the estimate of the tritium release provided by DSRL, SEPA consider the risk to the public or the environment to be extremely low. SEPA's investigation concluded that DSRL had contravened conditions of its EASR radioactive substances authorisation. In May 2023, SEPA issued a Warning Letter to DSRL.

Appendix 2 Abbreviations and glossary

ABL	AWE plc, Babcock and Lockheed Martin UK
AGIR	Advisory Group on Ionising Radiation
AGR	Advanced Gas-cooled Reactor
AWE	Atomic Weapons Establishment
BAT	Best Available Techniques
BEIS	Department of Business, Energy and Industrial Strategy
BIP	Border Inspection Post
BNFL	British Nuclear Fuels plc
BPM	Best Practicable Means
BSS	Basic Safety Standards
BSSD 13	Basic Safety Standards 2013
CCFE	Culham Centre for Fusion Energy
CEDA	Consultative Exercise on Dose Assessments
Cefas	Centre for Environment, Fisheries & Aquaculture Science
COMARE	Committee on Medical Aspects of Radiation in the Environment
CoRWM	Committee on Radioactive Waste Management
DAERA	Department of Agriculture Environment and Rural Affairs
Defra	Department for Environment, Food and Rural Affairs
DESNZ	Department for Energy Security & Net Zero
DPE	Designated Point of Entry
DPAG	Dounreay Particles Advisory Group
DSRL	Dounreay Site Restoration Limited
Euratom	European Atomic Energy Community
EASR18	Environmental Authorisations (Scotland) Regulations 2018
EARP	Enhanced Actinide Removal Plant
EC	European Commission
EIA	Environmental Impact Assessment
ENRMF	East Northants Resource Management Facility
EPR	Environmental Permitting Regulations

EPR 16	Environmental Permitting (England and Wales) Regulations 2016
EPR 18	Environmental Permitting (England and Wales) Regulations 2018
EPR 19	Environmental Permitting (England and Wales) Regulations 2019
EPR™	European Pressurised Reactor™
EU	European Union
FEPA	Food and Environment Protection Act
FSA	Food Standards Agency
FSS	Food Standards Scotland
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GES	Good Environmental Status
GOCO	Government Owned Contractor Operator
GRR	Guidance on Requirements for Release of Nuclear Sites from Radioactive Substances Regulation
HAW	Higher Activity Radioactive Waste
HEPA	High-Efficiency Particulate Filters
HMIP	His Majesty's Inspectorate of Pollution
HMNB	His Majesty's Naval Base
HPA	Health Protection Agency
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ID	Indicative Dose
IRPA	International Radiation Protection Association
IRR 17	Ionising Radiations Regulations 2017
ISO	International Standards Organisation
JET	Joint European Torus
JWMP	Joint Waste Management Plan
LLLETP	Low Level Liquid Effluent Treatment Plant
LLW	Low-Level Waste
LLWF	Low Level Radioactive Waste Facility
LLWR	Low Level Waste Repository

LoA	Letter of Agreement
LoD	Limit of Detection
MAFF	Ministry of Agriculture, Fisheries & Food
MAST	Mega Amp Spherical Tokamak
MMO	Marine Management Organisation
MOD	Ministry of Defence
MRF	Metals Recycling Facility
MRL	Minimum Reporting Level
MSSS	Magnox Swarf Storage Silo
ND	Not Detected
NDA	Nuclear Decommissioning Authority
NDAWG	National Dose Assessment Working Group
NEAES	North-East Atlantic Environment Strategy
NIEA	Northern Ireland Environment Agency
NNB GenCo	NNB Generation Company Limited
NORM	Naturally Occurring Radioactive Material
NRPB	National Radiological Protection Board
NRW	Natural Resources Wales
NRTE	Naval Reactor Test Establishment
NWS	Nuclear Waste Services
OBT	Organically Bound Tritium
ONR	Office for Nuclear Regulation
OSPAR	Oslo and Paris Convention for the Protection of the marine environment of the North-East Atlantic
PARCOM	Paris Commission
PBO	Parent Body Organisation
PRAG(D)	Particles Retrieval Advisory Group (Dounreay)
PHE	Public Health England
PWR	Pressurised Water Reactor
RAPs	Reference Animals and Plants
RIFE	Radioactivity in Food and the Environment
RRDL	Rosyth Royal Dockyard Limited

RNAS	Royal Naval Air Station
RRSL	Rolls-Royce Submarines Limited
RSA 93	Radioactive Substances Act 1993
RSR	Radioactive Substances Regulation
RSR 18	Radioactive Substances (Modification of Enactments) Regulations (Northern Ireland) 2018
RSRL	Research Sites Restoration Limited
RSS	Radioactive Substances Strategy
RWM	Radioactive Waste Management Ltd
SEPA	Scottish Environment Protection Agency
SFL	Springfields Fuels Limited
SIXEP	Site Ion Exchange Effluent Plant
STW	Sewage Treatment Works
THORP	Thermal Oxide Reprocessing Plant
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
TRAMP	Terrestrial Radioactivity Monitoring Programme
UCP	Urenco ChemPlants Limited
UKAEA	United Kingdom Atomic Energy Authority
UKAS	UK Accreditation Service
UKHSA	UK Health Security Agency (formerly PHE and HPA)
UKNWM	UK Nuclear Waste Management Limited
UOC	Uranium Ore Concentrate
UNS	Urenco Nuclear Stewardship Limited
UUK	Urenco UK Limited
VLLW	Very Low-Level Waste

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}.
Artificial radionuclides	These are radioactive isotopes that are not found readily in nature. They are generally produced during nuclear power generation, nuclear fuel reprocessing, from nuclear weapons testing or in specialist devices by neutron bombardment.
Authorised Premises	These are 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 radiation	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 1mSv 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.
Ionising radiation	Radiation composed of particles that individually carry enough kinetic energy to liberate an electron from an atom or molecule, ionising it. Ionising radiation is generated through nuclear reactions, either artificial or natural, by very high temperature (for example, plasma discharge or the corona of the Sun), via production of high energy particles in particle accelerators, or due to acceleration of charged particles by the electromagnetic fields produced by natural processes, from lightning to supernova explosions.
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.
Nuclear Sites	Shortened form of 'Nuclear Licensed sites'.
Orphan source	Is a radioactive source which is neither exempted nor under regulatory control. For example, this could be because it has never been under regulatory control or abandoned, lost misplaced, stolen or otherwise transferred without proper approval.
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 of the type and quality of the radiation. Example radiation weighting factors: alpha particles = 20; beta particles = 1; photons = 1.
Radioactivity	The emission of alpha particles, beta particles, neutrons and gamma or x-radiation from the transformation of an atomic nucleus.
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Representative person	Representative person is an approach used in the assessment of radiation exposures ('total doses') to the public. Direct measurement of doses to the public is not possible under most normal conditions. Instead, doses to the public are estimated using environmental radionuclide concentrations, dose rates and habits data. The estimated doses are compared with dose criteria. In this report, the dose criteria are legal limits for the public.

Source specific dose	An assessment of dose that focuses on specific sources on sites (for example, liquid or gaseous discharges) and their associated pathways (for example, external exposure over shoreline areas). See Section 2, and Appendix 4 for more information on these dose calculations. In some cases, assessments may include the impacts from multiple sites. For example, the source specific assessment of the Dumfries and Galloway coast includes the impacts of discharges from Chapelcross and Sellafield.
TENORM	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 take 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 3 Modelling of concentrations of radionuclides in foodstuffs, air, and sewage systems

A3.1 Foodstuffs

At Sellafield and the LLWR near Drigg, a simple food chain model has been used to provide concentrations of activity in milk and livestock for selected radionuclides to supplement data obtained by direct measurements. This is done where relatively high limits of detection exist or where no measurements were made.

Activities in milk, meat and offal were calculated for technetium-99, ruthenium-106, cerium-144, and plutonium-241 using the equations:

$Cm = Fm\ Ca\ Qf$ and
$Cf = Ff\ Ca\ Qf$ where

Cm is the concentration in milk (Bq l^{-1}),
Cf is the concentration in meat or offal (Bq kg^{-1} (fresh)),
Fm is the fraction of the animal's daily intake by ingestion transferred to milk (d l^{-1})
Ff is the fraction of the animal's daily intake by ingestion transferred to meat or offal (d kg^{-1} (fresh)),
Ca is the concentration in fodder (Bq kg^{-1} (dry)),
Qf is the amount of fodder eaten per day (kg (dry) d^{-1})

No direct account is taken of radionuclide decay or the intake by the animal of soil associated activity. The concentration in fodder is assumed to be the same as the maximum observed concentration in grass or, in the absence of such data, in leafy green vegetables. The food chain data for the calculations are given in Table A3.1 [249,250] and the estimated concentrations in milk, meat and offal are presented in Table A3.2.

A3.2 Air

For some sites, discharges to air may lead to significant doses. Doses may arise from radionuclides transferred from the plume to food crops and animal products, inhalation of radionuclides in the plume itself and external doses from radionuclides in the plume.

Average annual concentrations of radionuclides in the air at nearest habitations were calculated using a Gaussian plume model, PC CREAM 08 [251], and the reported discharges of radionuclides to air. Each site assessment uses generic meteorological data based on the Pasquill stability category shown in Table A3.3. The core modelling assumptions (such as the effective discharge/ stack height and distance to habitation) are also shown in Table A3.3. The discharge stack is assumed to be at the centre of the site. For multi-station sites (for example, Sizewell A and B), the gaseous discharges are summed together and assumed to be discharged via a common discharge point (at the centre of both sites).

External radiation doses from radionuclides in the plume and from deposited activity were calculated taking into account occupancy levels indoors and outdoors and location factors to allow for building shielding. During the time people are assumed to be indoors, the standard assumption that the dose from gamma-emitting radionuclides in the plume will be reduced by 80% has been made. Internal radiation doses from inhalation of discharged radionuclides were assessed using breathing rates. Doses were initially assessed for three age groups: adults, children (10-year-old), and infants (1-year-old). All ages are assumed to have year-round occupancy at the nearest habitation. The assumptions of the inhalation and occupancy rates assessment are shown in Table A3.4. The dose to the prenatal children age group was taken to be the same as that for an adult.

A3.3 Sewage systems

The facilities at Aldermaston and Amersham discharge liquid radioactive waste to local sewers. Wastes are processed at local sewage treatment works (STW). The prolonged proximity to raw sewage and sludge experienced by sewage treatment workers could lead to an increase in the dose received, via a combination of external irradiation from the raw sewage and sludge and the inadvertent ingestion and inhalation of resuspended radionuclides.

An assessment of the dose received by workers at the Maple Lodge STW, near Amersham and the Silchester STW, near Aldermaston has been conducted using the methodology and data given by the Environment Agency [252,253]. The flow rate through the sewage works is used to calculate a mean concentration in raw sewage and sludge of each nuclide discharged. These mean concentrations are combined with habits data concerning the workers' occupancy near raw sewage and sludge, external and internal dosimetric data, and physical data such as inhalation rates to provide dose estimates. Workers are assumed to spend 75% of a working year in proximity to the raw sewage, and the other 25% in proximity to the sewage sludge. Where liquid discharges are not nuclide-specific, a composition has been assumed based on advice from the operators and concentrations calculated accordingly.

The model parameters and habits data used to assess the dose to sewage treatment workers are given in Table A3.5 and the amounts of radioactivity discharged from each site can be found in Appendix 1 of this report.

Table A3.1 Data for food chain model

Parameter	Nuclide	Food				
		Milk	Beef	Beef offal	Sheep	Sheep offal
Q_f		13	13	13	1.5	1.5
F_m or F_f	^{99}Tc	10^{-2}	10^{-2}	$4\ 10^{-2}$	10^{-1}	$4\ 10^{-1}$
	^{106}Ru	10^{-6}	10^{-3}	10^{-3}	10^{-2}	10^{-2}
	^{241}Pu	10^{-6}	10^{-4}	$2\ 10^{-2}$	$4\ 10^{-4}$	$3\ 10^{-2}$

Table A3.2 Predicted concentrations of radionuclides from food chain model used in assessments of exposures

Foodstuff	Location	Radioactivity concentration (fresh weight), Bq kg^{-1}		
		^{99}Tc	^{106}Ru	^{241}Pu
Milk	Sellafield	[b]	$3.7\ 10^{-5}$	$6.4\ 10^{-5}$
	LLWR near Driggc	[a]	$3.9\ 10^{-4}$	$1.2\ 10^{-4}$
Beef	Sellafield	b	$3.7\ 10^{-2}$	$6.4\ 10^{-3}$
	LLWR near Drigg[c]	$1.2\ 10^{-1}$	$3.9\ 10^{-1}$	$1.2\ 10^{-2}$
Sheep	Sellafield	[b]	$4.2\ 10^{-2}$	$2.9\ 10^{-3}$
	LLWR near Drigg[c]	$1.4\ 10^{-1}$	[a]	$5.4\ 10^{-3}$
Beef offal	Sellafield	[b]	$3.7\ 10^{-2}$	a
	LLWR near Drigg[c]	$4.7\ 10^{-1}$	$3.9\ 10^{-1}$	$2.3\ 10^{0}$
Sheep offal	Sellafield	[b]	$4.2\ 10^{-2}$	$2.2\ 10^{-1}$
	LLWR near Drigg[c]	[a]	[a]	$4.1\ 10^{-1}$

a. Positive result used, or LoD result used because modelling result greater than LoD
b. No grass or leafy green vegetable data available
c. 2022 data for LLWR near Drigg based on oats sample (no grass or leafy green samples available)

Table A3.3 Air concentrations modelling assumptions

Nuclear site	Stack height, m	Estimated site diameter, km	Estimated distance from stack to nearest habitation, km	Frequency of Pasquill stability catergory D
Aldermaston	15	2	0.3	60
Amersham	20	0.4	0.3	55
Berkeley	20	1.6	0.4	55
Bradwell	14	0.4	0.3	65
Burghfield	15	0.6	0.3	60
Capenhurst	15	1.1	0.3	65
Chapelcross	30	1.2	0.7	60
Derby	50	0.5	0.5	55
Devonport	15	1	0.3	65
Dounreay	15	1	1	75
Dungeness	17	1	0.3	70
Hartlepool	23	0.6	2	70
Harwell	20	1	0.2	55
Heysham	21	1	0.5	70
Hinkley	21	0.8	1	55
Hunterston	15	0.4	0.4	60
Oldbury	20	0.8	0.7	55
Sellafield	93	2	0.5	65
Sizewell	18	0.4	1	70
Springfields	27	1	0.3	70
Torness	72	0.5	0.6	70
Trawsfynydd	18	0.6	0.6	70
Winfrith	15	1.6	0.4	60
Wylfa	17	1	0.4	70

Table A3.4 Inhalation and occupancy data for dose assessment of discharges to air

Age group	Inhalation rates, m^3 h^{-1}	Fraction of time indoors
1-year-old	0.22	0.9
10-year-old	0.64	0.8
Adults	0.92	0.7

Table A3.5 Sewage workers dose assessment modelling assumptions and occupancy data

Flow rate, m^3 d^{-1}	Aldermaston (Silchester STW) Amersham (Maple Lodge STW)	[a]$6.7\ 10^3$ [b]$1.5\ 10^5$
Occupancy - sewage, h y^{-1}		1380
Occupancy - sludge, h y^{-1}		[c]460
Inadvertent ingestion rate, kg h^{-1}		[d]$5\ 10^{-6}$
Inhalation rate, m^3 h^{-1}		[d]1.2
Airborne concentration of sewage or sludge, kg m^{-3}		[d]$1\ 10^{-7}$
Density of raw sewage and treated sludge, kg l^{-1}		[d]1

a. Based on average flow rate of 0.078 m3 s^{-1} [254]
b. Based on average flow rate of 1.8 m3 s^{-1} [255]
c. A working year is assumed to be 40 hours per week and 48 weeks per year
d. Parameter values used in Environment Agency methodology (see text for reference)

Appendix 4 Consumption, inhalation, handling and occupancy rates

This appendix gives the consumption, handling and occupancy rate data used in the source specific assessment of exposures from terrestrial consumption and aquatic pathways. Consumption rates for terrestrial foods are based on [134] and are given in Table A4.1. These are derived from national statistics and are taken to apply at each site. Site-specific data for aquatic pathways based on local surveys are given in Table A4.2. These site-specific data have been supplemented with referenceable generic information [171,256] where appropriate. Occupancy over intertidal areas and rates of handling from local surveys has been reassessed to take account of a change in the factor used to determine the range of rates typical of those most exposed. For using the ‘cut-off’ method to define those most exposed [257,258] a factor of 3.0 is used to describe the ratio of the maximum to the minimum rate within the group. Data used for routine assessments of external and inhalation pathways from gaseous discharges are given in Appendix 3.

Consumption rates refer to the mass of a foodstuff as prepared for consumption (with, for example, stalks or shells removed) and are consistent with the mass quantity used for presentation of concentration data in this report. The term “fresh weight” is used in the data tables of concentrations. For shellfish, the consumption rates and concentrations are for cooked weights. For other foodstuffs, uncooked weights are used.

Table A4.1 Consumption rates for terrestrial foods

Food Group	Consumption rates (kg y^{-1})#					
	Average			Above average consumption rate*		
	Adult	10-year-old	Infant	Adult	10-year-old	Infant
Beef	15	15	3	45	30	10
Cereals	50	45	15	100	75	30
Eggs	8.5	6.5	5	25	20	15
Fruit	20	15	9	75	50	35
Game	6	4	0.8	15	7.5	2.1
Green vegetables	15	6	3.5	45	20	10
Honey	2.5	2	2	9.5	7.5	7.5
Legumes	20	8	3	50	25	10
Milk	95	110	130	240	240	320
Mushrooms	3	1.5	0.6	10	4.5	1.5
Nuts	3	1.5	1	10	7	2
Offal	5.5	3	1	20	10	5.5
Pig	15	8.5	1.5	40	25	5.5
Potatoes	50	45	10	120	85	35
Poultry	10	5.5	2	30	15	5.5
Root crops	10	6	5	40	20	15
Sheep	8	4	0.8	25	10	3
Wild fruit	7	3	1	25	10	2

Except for milk where units are l y^{-1}
* These rates are the 97.5th percentile of the distribution across all consumers

Table A4.2 Consumption, inhalation, handling and occupancy rates for aquatic pathways

Site (Year of Last Survey)	Representative person[a]	Rates
Aldermaston (2022)		1 kg y^{-1} pike
		1600 h y^{-1} over riverbank
Amersham (2016)		1 kg y^{-1} pike
		1 kg y^{-1} crayfish
		530 h y^{-1} over riverbank
Barrow (2012)	A	27 kg y^{-1} fish
		12 kg y^{-1} crabs and lobsters
		5.9 kg y^{-1} molluscs
		760 h y^{-1} over mud and sand
	B (houseboat)	2600 h y^{-1} over mud and sand
Berkeley and Oldbury (2014)	A	10 kg y^{-1} fish
		0.3 kg y^{-1} crabs and lobsters
		310 h y^{-1} over mud, stones and saltmarsh
	B (houseboat)	3700 h y^{-1} over mud
Bradwell (2015)		21 kg y^{-1} fish
		1.0 kg y^{-1} lobsters
		5.0 kg y^{-1} Pacific and European oysters
		2600 h y^{-1} over mud
Capenhurst (2021)	10 year old children	500 h y^{-1} over sediment
		5 10^{-3} kg y^{-1} sediment by inadvertent ingestion
		20 l y^{-1} water by inadvertent ingestion
Channel Islands (1997)		62 kg y^{-1} fish
		30 kg y^{-1} crabs, spider crabs and lobsters
		30 kg y^{-1} scallops and whelks
		1400 h y^{-1} over mud and sand
Chapelcross (2022)	A	5 kg y^{-1} salmonids
		130 kg y^{-1} wildfowl
		790 h y^{-1} over mud and salt marsh
	C	180 h y^{-1} handling nets
Clyde (small users) (NA)		20 kg y^{-1} molluscs
Culham (NA)		600 l y^{-1} water
Derby (2021)		600 l y^{-1} water
		1 kg y^{-1} freshwater fish
		1 kg y^{-1} freshwater crustaceans
		600 h y^{-1} over riverbank
Devonport (2017)	A	38 kg y^{-1} fish
		3.4 kg y^{-1} Crustaceans

Table A4.2 continued

Site (Year of Last Survey)	Representative person[a]	Rates
		1.2 kg y^{-1} Molluscs
		580 h y^{-1} over mud, sand and stones
	B	2100 h y^{-1} over mud
Dounreay (2018)	A	1800 h y^{-1} handling fishing gear
	B	48 kg y^{-1} fish
		21 kg y^{-1} crab and lobster
		21 kg y^{-1} Molluscs
		750 h y^{-1} over sand
	C (2013)	6 h y^{-1} in a Geo
Drinking water (NA)	Adults	600 l y^{-1}
	10 y	350 l y^{-1}
	1 y	260 l y^{-1}
Dungeness (2019)		49 kg y^{-1} fish
		34 kg y^{-1} crustaceans
		18 kg y^{-1} molluscs
		770 h y^{-1} over sand
Faslane (2016)		201 kg y^{-1} fish
		13 kg y^{-1} crustaceans
		1.2 kg y^{-1} winkles
		800 h y^{-1} sand
Hartlepool (2014)		42 kg y^{-1} fish
		26 kg y^{-1} crab and lobster
		11 kg y^{-1} winkles and whelks
		1100 h y^{-1} over sand
Harwell (2015)		1.0 kg y^{-1} fish
		1.0 kg y^{-1} crayfish
		520 h y^{-1} over riverbank
Heysham (2016)	A	24 kg y^{-1} fish
		10 kg y^{-1} shrimps
		4.5 kg y^{-1} mussels
		750 h y^{-1} over sand
	B	560 h y^{-1} over salt marsh
Hinkley Point (2017)	A	45 kg y^{-1} fish
		12 kg y^{-1} shrimps
		0.7 kg y^{-1} whelks
		910 h y^{-1} over mud
	B	1500 h y^{-1} over mud
Holy Loch (1989)		730 h y^{-1} over mud

Table A4.2 continued

Site (Year of Last Survey)	Representative person[a]	Rates
Hunterston (2017)	A	66 kg y^{-1} fish
		18 kg y^{-1} crustaceans
		24 kg y^{-1} Mussels and scallops
		590 h y^{-1} over sand
	B	48 kg y^{-1} wildfowl
		560 h y^{-1} over sand and stones
	C	1800 h y^{-1} handling fishing gear
		460 h y^{-1} handling sediment
Landfill (NA)		2.5 l y^{-1} water
LLWR near Drigg	NA	35 l y^{-1} water
	2012	Marine pathways as Sellafield
Rosyth (2022)		31 kg y^{-1} fish
		28 kg y^{-1} crabs and lobsters
		820 h y^{-1} over mud and sand
Sellafield	A (Sellafield fishing	41kg y^{-1} cod (15%) and other fish (85%)
	community) (2022)	20kg y^{-1} crab (35%), lobster (55%) and other crustaceans (10%)
		670 h y^{-1} over mud and sand
	B (Fishermen's nets and	1400 h y^{-1} handling nets and pots
	pots) (2018)	
	C (Bait digging and	510 h y^{-1} handling sediment
	mollusc collecting) (2018)	
	D (Whitehaven commercial)	40 kg y^{-1} plaice and cod
	(1998)	9.7 kg y^{-1} Nephrops
		15 kg y^{-1} whelks
	E (Morecambe Bay)	see Heysham
	F (Fleetwood) (1995)	93 kg y^{-1} plaice and cod
		29 kg y^{-1} shrimps
		23 kg y^{-1} whelks
	G (Dumfries and Galloway) (2017)	33 kg y^{-1} fish
		60 kg y^{-1} crabs and other crustaceans
		14 kg y^{-1} winkles and other molluscs
		30 kg y^{-1} wildfowl
		720 h y^{-1} over mud and salt marsh
	H (Laverbread) (1972)	47 kg y^{-1} laverbread
	I (Typical fish consumer) (NA)	15 kg y^{-1} cod and plaice
	J (Isle of Man) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
	K (Northern Ireland) (2000)	99 kg y^{-1} haddock and other fish
		34 kg y^{-1} Nephrops and crabs
		7.7 kg y^{-1} mussels and other molluscs
		1100 h y^{-1} over mud and sand

Table A4.2 continued

Site (Year of Last Survey)	Representative person[a]	Rates
	L (North Wales) (NA)	100 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		20 kg y^{-1} molluscs
		300 h y^{-1} over mud and sand
	M (Sellafield fishing community	12 kg y^{-1} cod
	2018-2022) (NA)	28 kg y^{-1} other fish
		9.2 kg y^{-1} crabs
		15 kg y^{-1} lobsters
		5.5 kg y^{-1} other crustaceans
		4.6 kg y^{-1} winkles
		4.8 kg y^{-1} other molluscs
		680 h y^{-1} over mud and sand
	N (Typical recreational use over beaches,	300 h y^{-1} over intertidal substrates
	muddy areas or salt marsh) (NA)	
	O (Typical beach user e.g. tourist) (NA)	1 kg y^{-1} fish
		0.2 kg y^{-1} crustaceans
		0.2 kg y^{-1} molluscs
		30 h y^{-1} over sand
	P (Ravenglass marsh users) (2022)	550 h y^{-1} over salt marsh
		5.0 10^{-6} kg h^{-1} mud by inadvertent ingestion
		9.2 10^{-8} kg h^{-1} mud by resuspension and inhalation
	Q (Sellafield fishing community mollusc	3.4 kg y^{-1} Other molluscs (70% winkles and 30% other molluscs)
	consumption) (2022)	
Sizewell (2015)	A	23 kg y^{-1} fish
		10 kg y^{-1} crab and lobster
		3.2 kg y^{-1} whelks
		710 h y^{-1} over mud
	B (houseboats)	420 hy^{-1} over mud
Springfields	A (2022)	29 kg y^{-1} fish
		4.0 kg y^{-1} crustaceans
		44 kg y^{-1} wildfowl
		420 h y^{-1} over mud and sand
	B (2022)	550 h y^{-1} handling nets
	C (10 year old children) (NA)	30 h y^{-1} over mud
		1.0 10^{-5} kg h^{-1} mud by inadvertent ingestion
		6.3 10^{-8} kg h^{-1} mud by resuspension and inhalation
	D (Farmers) (2022)	330 h y^{-1} over salt marsh

Table A4.2 continued

Site (Year of Last Survey)	Representative person[a]	Rates
Torness (2016)	A	102 kg y^{-1} fish
		29 kg y^{-1} crab and lobster
		35 kg y^{-1} molluscs
		940 h y^{-1} over sand
	B	116 kg y^{-1} wildfowl
		280 h y^{-1} over mud
	C	1500 h y^{-1} handling fishing gear
Trawsfynydd (2018)		12 kg y^{-1} brown trout
		50 kg y^{-1} rainbow trout
		470 h y^{-1} over lake shore
Upland lake (NA)		37 kg y^{-1} fish
Whitehaven (phosphate processing) (2012)		Marine pathways as Sellafield
Winfrith (2019)		21 kg y^{-1} fish
		20 kg y^{-1} crustaceans
		14 kg y^{-1} molluscs
		560 h y^{-1} over sand and stones
Wylfa (2013)		33 kg y^{-1} fish
		7.9 kg y^{-1} crabs, lobsters and prawns
		1.8 kg y^{-1} mussels
		420 h y^{-1} over mud and sand

[a] Where more than one group exists at a site the groups are denoted A, B etc. Year of habits survey is given where appropriate
NA Not appropriate

Appendix 5 Dosimetric data

The dose coefficients used in assessments in this report are provided in Table A5.1 for ease of reference. For adults and postnatal children, they are based on generic data contained in ICRP Publication 119 [137]. Dose coefficients for prenatal children have been obtained primarily from ICRP 88 [138] and NRPB [139]. For a few radionuclides where prenatal dose coefficients are unavailable the relevant adult dose coefficient has been used.

In the case of tritium, polonium, plutonium and americium radionuclides, dose coefficients have been adjusted according to specific research work of relevance to assessments in this report.

A5.1 Polonium

The current ICRP advice is that a gut uptake factor of 0.5 is appropriate for dietary intakes of polonium by adults [259]. A study involving the consumption of crab meat containing natural concentrations of polonium-210 has suggested that the factor could be as high as 0.8 [260]. More recently, similar experiments with mussels, cockles and crabs suggested a factor in the range 0.15 to 0.65, close to the ICRP value of 0.5 [261–263]. Previous assessments have considered the effects of a factor of 0.8 for considering monitoring results in RIFE. In view of the most recent review [263], a value of 0.5 has been adopted for all food, consistent with ICRP advice.

A5.2 Plutonium and americium

Studies using adult human volunteers have suggested a gut uptake factor of 0.0002 is appropriate for the consumption of plutonium and americium in winkles from near Sellafield [264,265]. For these and other actinides in food in general, a factor of 0.0005 is considered as a reasonable best estimate [266]. These values are to be used if data are not available for the specific circumstances under consideration. In this report, a gut uptake factor of 0.0002 is used for plutonium and americium, for estimating doses to consumers of winkles from Cumbria and this is consistent with UKHSA advice. For other foods and for winkles outside Cumbria, the factor of 0.0005 is used for these radionuclides. This choice is supported by studies of cockle consumption [267].

A5.3 Technetium-99

Volunteer studies have been extended to consider the transfer of technetium-99 in lobsters across the human gut [268]. Although values of the gut uptake factor found in this study were lower than the ICRP value of 0.5, dose coefficients are relatively insensitive to changes in the gut uptake factor. This is because the effective dose is dominated by 'first pass' dose to the gut [269]. In this report, we have therefore retained use of the standard ICRP factor and dose coefficient for technetium-99.

A5.4 Tritium

In 2002, UKHSA reviewed the use of dose coefficients for tritium associated with organic material [270]. Subsequently, UKHSA published a study of the uptake and retention of organically bound tritium (OBT) in rats fed with fish from Cardiff Bay ([271]. These experiments suggested that the dose coefficient for OBT in fish from the Severn Estuary near Cardiff should be 6.0 x 10-11 Sv Bq^{-1}, higher than the standard ICRP value for OBT ingestion. The higher value is used for adults in the assessment of seafood collected near the Cardiff site in this report, and the standard ICRP value for other assessments. This approach is consistent with advice [272] which takes account of the conclusions reached by the Independent Advisory Group on Ionising Radiation (AGIR) concerning relative biological effectiveness and radiation weighting [273]. Thereafter, results of uptake experiments involving adult volunteers, who ate samples of sole from Cardiff Bay, provided further evidence that this approach is indeed cautious [274].

Table A5.1 Dosimetric data

Radionuclide	Half life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology (Sv Bq^{-1})			
				Adults	10 yr.	1 yr.	Foetus
H-3	1.24E+01	5.68E-03	0.00E+00	1.8E-11	2.3E-11	4.8E-11	3.1E-11
H-3 (f)				4.2E-11	5.7E-11	1.2E-10	6.3E-11
H-3 (h)				6.0E-11	8.0E-11	2.0E-10	9.0E-11
C-14	5.73E+03	4.95E-02	0.00E+00	5.8E-10	8.0E-10	1.6E-09	8.0E-10
P-32	3.91E-02	6.95E-01	0.00E+00	2.4E-09	5.3E-09	1.9E-08	2.5E-08
S-35 (g)	2.39E-01	4.88E-02	0.00E+00	7.7E-10	1.6E-09	5.4E-09	1.6E-09
Ca-45	4.46E-01	7.72E-02	0.00E+00	7.1E-10	1.8E-09	4.9E-09	8.7E-09
Cr-51	7.59E-02	0.00E+00	3.20E-01	3.8E-11	7.8E-11	2.3E-10	3.8E-11
Mn-54	8.56E-01	4.22E-03	8.36E-01	7.1E-10	1.3E-09	3.1E-09	7.1E-10
Fe-55	2.70E+00	4.20E-03	1.69E-03	3.3E-10	1.1E-09	2.4E-09	8.1E-11
Co-57	7.42E-01	1.86E-02	1.25E-01	2.1E-10	5.8E-10	1.6E-09	1.1E-10
Co-58	1.94E-01	3.41E-02	9.98E-01	7.4E-10	1.7E-09	4.4E-09	5.8E-10
Co-60	5.27E+00	9.66E-02	2.50E+00	3.4E-09	1.1E-08	2.7E-08	1.9E-09
Zn-65	6.67E-01	6.87E-03	5.85E-01	3.9E-09	6.4E-09	1.6E-08	4.1E-09
Se-75	3.28E-01	1.45E-02	3.95E-01	2.6E-09	6.0E-09	1.3E-08	2.7E-09
Sr-90†	2.91E+01	1.13E+00	3.16E-03	3.1E-08	6.6E-08	9.3E-08	4.6E-08
Zr-95†	1.75E-01	1.61E-01	1.51E+00	1.5E-09	3.0E-09	8.8E-09	7.6E-10
Nb-95	9.62E-02	4.44E-02	7.66E-01	5.8E-10	1.1E-09	3.2E-09	3.7E-10
Tc-99	2.13E+05	1.01E-01	0.00E+00	6.4E-10	1.3E-09	4.8E-09	4.6E-10
Ru-103†	1.07E-01	7.48E-02	4.69E-01	7.3E-10	1.5E-09	4.6E-09	2.7E-10
Ru-106†	1.01E+00	1.42E+00	2.05E-01	7.0E-09	1.5E-08	4.9E-08	3.8E-10
Ag-110m†	6.84E-01	8.70E-02	2.74E+00	2.8E-09	5.2E-09	1.4E-08	2.1E-09
Sb-124	1.65E-01	1.94E-01	1.69E+00	2.5E-09	5.2E-09	1.6E-08	1.0E-09
Sb-125	2.77E+00	1.01E-01	4.31E-01	1.1E-09	2.1E-09	6.1E-09	4.7E-10
Te-125m	1.60E-01	1.09E-01	3.55E-02	8.7E-10	1.9E-09	6.3E-09	8.7E-10
I-125	1.65E-01	1.94E-02	4.21E-02	1.5E-08	3.1E-08	5.7E-08	9.1E-09
I-129	1.57E+07	6.38E-02	2.46E-02	1.1E-07	1.9E-07	2.2E-07	4.4E-08
I-131†	2.20E-02	1.94E-01	3.81E-01	2.2E-08	5.2E-08	1.8E-07	2.3E-08
Cs-134	2.06E+00	1.63E-01	1.55E+00	1.9E-08	1.4E-08	1.6E-08	8.7E-09
Cs-137†	3.00E+01	2.49E-01	5.65E-01	1.3E-08	1.0E-08	1.2E-08	5.7E-09
Ba-140†	3.49E-02	8.49E-01	2.50E+00	4.6E-09	1.0E-08	3.1E-08	3.5E-09
Ce-144†	7.78E-01	1.28E+00	5.28E-02	5.2E-09	1.1E-08	3.9E-08	3.1E-11
Pm-147	2.62E+00	6.20E-02	4.37E-06	2.6E-10	5.7E-10	1.9E-09	2.6E-10
Eu-154	8.80E+00	2.92E-01	1.24E+00	2.0E-09	4.1E-09	1.2E-08	2.0E-09
Eu-155	4.96E+00	6.34E-02	6.06E-02	3.2E-10	6.8E-10	2.2E-09	3.2E-10
Pb-210†	2.23E+01	4.28E-01	4.81E-03	6.9E-07	1.9E-06	3.6E-06	1.4E-07
Bi-210	1.37E-02	3.89E-01	0.00E+00	1.3E-09	2.9E-09	9.7E-09	6.6E-12
Po-210(c)	3.79E-01	0.00E+00	0.00E+00	1.2E-06	2.6E-06	8.8E-06	1.3E-07
Po-210(d)				1.9E-06	4.2E-06	1.4E-05	2.1E-07
Ra-226†	1.60E+03	9.56E-01	1.77E+00	2.8E-07	8.0E-07	9.6E-07	3.2E-07
Th-228†	1.91E+00	9.13E-01	1.57E+00	1.4E-07	4.3E-07	1.1E-06	2.4E-07
Th-230	7.70E+04	1.46E-02	1.55E-03	2.1E-07	2.4E-07	4.1E-07	8.6E-09
Th-232	1.41E+10	1.25E-02	1.33E-03	2.3E-07	2.9E-07	4.5E-07	9.4E-09
Th-234†	6.60E-02	8.82E-01	2.10E-02	3.4E-09	7.4E-09	2.5E-08	1.5E-11
U-234	2.44E+05	1.32E-02	1.73E-03	4.9E-08	7.4E-08	1.3E-07	1.5E-08
U-235†	7.04E+08	2.15E-01	1.82E-01	4.7E-08	7.1E-08	1.3E-07	1.4E-08
U-238†	4.47E+09	8.92E-01	2.24E-02	4.8E-08	7.5E-08	1.5E-07	1.3E-08

Table A5.1 continued

Radionuclide	Half life (years)	Mean β energy (MeV per disintegration)	Mean γ energy (MeV per disintegration)	Dose per unit intake by ingestion using ICRP-60 methodology (Sv Bq^{-1})			
				Adults	10 yr.	1 yr.	Foetus
Np-237†	2.14E+06	2.67E-01	2.38E-01	1.1E-07	1.1E-07	2.1E-07	3.6E-09
Pu-238(a)	8.77E+01	1.06E-02	1.81E-03	2.3E-07	2.4E-07	4.0E-07	9.0E-09
Pu-238(b)				9.2E-08	9.6E-08	1.6E-07	3.6E-09
Pu-239(a)	2.41E+04	6.74E-03	8.07E-04	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-239(b)				1.0E-07	1.1E-07	1.7E-07	3.8E-09
Pu-α(e)	2.41E+04	6.74E-03	8.07E-04	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-240(a)	6.54E+03	1.06E-02	1.73E-03	2.5E-07	2.7E-07	4.2E-07	9.5E-09
Pu-240(b)				1.0E-07	1.1E-07	1.7E-07	3.8E-09
Pu-241(a)	1.44E+01	5.25E-03	2.55E-06	4.8E-09	5.1E-09	5.7E-09	1.1E-10
Pu-241(b)				1.9E-09	2.0E-09	2.3E-09	4.4E-11
Am-241(a)	4.32E+02	5.21E-02	3.25E-02	2.0E-07	2.2E-07	3.7E-07	2.7E-09
Am-241(b)				8.0E-08	8.8E-08	1.5E-07	1.1E-09
Cm-242	4.46E-01	9.59E-03	1.83E-03	1.2E-08	2.4E-08	7.6E-08	4.7E-10
Cm-243	2.85E+01	1.38E-01	1.35E-01	1.5E-07	1.6E-07	3.3E-07	1.5E-07
Cm-244	1.81E+01	8.59E-03	1.70E-03	1.2E-07	1.4E-07	2.9E-07	2.2E-09

Radionuclide	Dose per unit intake by inhalation using ICRP-60 methodology (Sv Bq^{-1})			
	Adults	10 yr.	1 yr.	Foetus
H-3	4.5E-11	8.2E-11	2.7E-10	2.6E-12
H-3(f)	4.1E-11	5.5E-11	1.1E-10	6.3E-11
C-14	2.0E-09	2.8E-09	6.6E-09	6.6E-11
P-32	3.4E-09	5.3E-09	1.5E-08	6.5E-09
S-35(g)	1.4E-09	2.0E-09	4.5E-09	1.5E-11
Ca-45	2.7E-09	3.9E-09	8.8E-09	1.7E-09
Cr-51	3.7E-11	6.6E-11	2.1E-10	3.7E-11
Mn-54	1.5E-09	2.4E-09	6.2E-09	1.5E-09
Fe-55	3.8E-10	6.2E-10	1.4E-09	6.6E-11
Co-57	5.5E-10	8.5E-10	2.2E-09	6.1E-11
Co-58	1.6E-09	2.4E-09	6.5E-09	2.5E-10
Co-60	1.0E-08	1.5E-08	3.4E-08	1.2E-09
Zn-65	1.6E-09	2.4E-09	6.5E-09	7.4E-10
Se-75	1.0E-09	2.5E-09	6.0E-09	1.1E-09
Sr-90†	3.8E-08	5.4E-08	1.2E-07	1.0E-08
Zr-95†	6.3E-09	9.0E-09	2.1E-08	4.6E-10
Nb-95	1.5E-09	2.2E-09	5.2E-09	1.6E-10
Tc-99	4.0E-09	5.7E-09	1.3E-08	8.3E-11
Ru-103†	2.4E-09	3.5E-09	8.4E-09	1.1E-10
Ru-106†	2.8E-08	4.1E-08	1.1E-07	4.1E-10
Ag-110m†	7.6E-09	1.2E-08	2.8E-08	1.5E-09
Sb-124	6.4E-09	9.6E-09	2.4E-08	4.4E-10

Table A5.1 continued

Radionuclide	Dose per unit intake by inhalation using ICRP-60 methodology (Sv Bq^{-1})			
	Adults	10 yr.	1 yr.	Foetus
Sb-125	4.8E-09	6.8E-09	1.6E-08	2.6E-10
Te-125m	3.4E-09	4.8E-09	1.1E-08	3.4E-09
I-125	5.1E-09	1.1E-08	2.3E-08	3.1E-09
I-129	3.6E-08	6.7E-08	8.6E-08	1.5E-08
I-131†	7.4E-09	1.9E-08	7.2E-08	8.1E-09
Cs-134	6.6E-09	5.3E-09	7.3E-09	3.0E-09
Cs-137†	4.6E-09	3.7E-09	5.4E-09	2.0E-09
Ba-140†	6.2E-09	9.6E-09	2.6E-08	1.4E-09
Ce-144†	3.6E-08	5.5E-08	1.6E-07	4.2E-10
Pm-147	5.0E-09	7.0E-09	1.8E-08	5.0E-09
Eu-154	5.3E-08	6.5E-08	1.5E-07	5.3E-08
Eu-155	6.9E-09	9.2E-09	2.3E-08	6.9E-09
Pb-210†	1.2E-06	1.6E-06	4.0E-06	6.1E-08
Bi-210	9.3E-08	1.3E-07	3.0E-07	9.1E-12
Po-210	3.3E-06	4.6E-06	1.1E-05	1.9E-08
Ra-226†	3.5E-06	4.9E-06	1.1E-05	9.9E-08
Th-228†	4.3E-05	5.9E-05	1.4E-04	2.5E-07
Th-230	1.4E-05	1.6E-05	3.5E-05	2.6E-08
Th-232	2.5E-05	2.6E-05	5.0E-05	2.8E-08
Th-234†	7.7E-09	1.1E-08	3.1E-08	6.7E-12
U-234	3.5E-06	4.8E-06	1.1E-05	4.9E-08
U-235†	3.1E-06	4.3E-06	1.0E-05	4.5E-08
U-238†	2.9E-06	4.0E-06	9.4E-06	4.4E-08
Np-237†	2.3E-05	2.2E-05	4.0E-05	4.3E-07
Pu-238	4.6E-05	4.4E-05	7.4E-05	1.1E-06
Pu-239	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-α(e)	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-240	5.0E-05	4.8E-05	7.7E-05	1.2E-06
Pu-241	9.0E-07	8.3E-07	9.7E-07	1.4E-08
Am-241	4.2E-05	4.0E-05	6.9E-05	3.2E-07
Cm-242	5.2E-06	7.3E-06	1.8E-05	5.1E-08
Cm-243	3.1E-05	3.1E-05	6.1E-05	3.1E-05
Cm-244	2.7E-05	2.7E-05	5.7E-05	2.6E-07

† Energy and dose per unit intake data include the effects of radiations of short-lived daughter products

[a] Gut transfer factor 5.00E-4 for consumption of all foodstuffs except Cumbrian winkles
[b] Gut transfer factor 2.00E-4 for consumption of Cumbrian winkles
[c] Gut transfer factor 0.5
[d] Gut transfer factor 0.8
[e] Pu-239 data used
[f] Organically bound tritium
[g] Organically bound sulphur
[h] Organically bound tritium for seafood near the Cardiff site

Appendix 6 Estimates of concentrations of natural radionuclides

A6.1 Aquatic foodstuffs

Table A6.1gives estimated values of concentrations of radionuclides due to natural sources in aquatic foodstuffs. The values are based on sampling and analysis conducted by Cefas [275,276]. Data for lead-210 and polonium-210 are quoted as medians with minimum and maximum values given in brackets. Dose assessments for aquatic foodstuffs are based on concentrations of these radionuclides net of natural background.

The carbon-14 concentrations are adjusted to take account of the dilution of natural atmospheric carbon-14 by the emission of carbon dioxide from fossil fuel burning. A dilution of 0.28% for each part per million of carbon dioxide added due to fossil fuel burning is used [277]. Values for the carbon dioxide additions are taken each year from: https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_mlo.txt.

The initial specific activity of carbon-14 was 256Bq kg^{-1} [115]. In 2022, the adjusted value used as the basis for Table A6.1 was 213Bq kg^{-1}.

A6.2 Terrestrial foodstuffs

The values of carbon-14 in terrestrial foodstuffs due to natural sources that are used in dose assessments are given in Table A6.2 and based on earlier data [115]. The value for the specific activity of carbon-14 in 2022 (given in Section A6.1) was used to derive these estimates.

Table A6.1 Concentrations of radionuclides in seafood due to natural sources

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (fresh))[a]					
	Fish	Cod	Plaice	Crustaceans	Crabs	Lobsters
Carbon-14	20			23		
Lead-210	0.042 (0.0030-0.55)			0.20 (0.013-2.4)	0.24 (0.043-0.76)	0.080 (0.020-0.79)
Polonium-210	0.82 (0.18-4.4)	0.38 (0.18-1.1)	2.5 (0.88-4.4)	9.1 (1.1-35)	19 (4.1-35)	5.3 (1.9-10)
Radium-226	0.04			0.03	0.03	0.06
Thorium-228	0.0054			0.0096	0.04	0.0096
Thorium-230	0.00081			0.0026	0.008	0.0026
Thorium-232	0.00097			0.0014	0.01	0.0014
Uranium-234	0.0045			0.040	0.055	0.040
Uranium-238	0.0039			0.035	0.046	0.035

Radionuclide	Concentration of radioactivity (Bq kg^{-1} (fresh))[a]					
	Molluscs	Winkles	Mussels	Cockles	Whelks	Limpets
Carbon-14	20					
Lead-210	1.2 (0.18-6.8)	1.5 (0.69-2.6)	1.6 (0.68-6.8)	0.94 (0.59-1.3)	0.39 (0.18-0.61)	1.5 (0.68-4.9)
Polonium-210	17 (1.2-69)	13 (6.1-25)	42 (19-69)	18 (11-36)	6.5 (1.2-11)	8.4 (5.9-15)
Radium-226	0.08	0.08				
Thorium-228	0.37	0.46		0.37		
Thorium-230	0.19	0.26		0.19		
Thorium-232	0.28	0.33		0.28		
Uranium-234	0.99	0.99				
Uranium-238	0.89	0.89				

[a] Values are quoted as medians with minimum and maximum values given in brackets

Table A6.2 Carbon-14 in terrestrial foodstuffs due to natural sources

Food category	% Carbon content (fresh)	Concentration of carbon-14 (Bq kg^{-1} (fresh))
Milk	7	15
Beef meat	17	37
Sheep meat	21	45
Pig meat	21	45
Poultry	28	60
Game	15	32
Offal	12	26
Eggs	15	32
Green vegetables	3	7
Root vegetables	3	7
Legumes / other domestic vegetables	8	17
Dry beans	20	42
Potato	9	19
Cereals	41	87
Cultivated fruit	4	8
Wild fruit	4	8
Mushrooms	2	4
Honey	31	66
Nuts	58	123

Appendix 7 Research in support of the monitoring programmes

The environment agencies, FSA and FSS 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 habits and agricultural practice data, to ensure that dose assessment calculations reflect the real-world situation
- 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.

Information on ongoing and recently completed extramural research is presented in Table A7.1. Those sponsored by the Environment Agency and FSA are also listed on their websites: https://www.gov.uk/government/organisations/environment-agency, and https://www.food.gov.uk, respectively. Copies of the final reports for each of the projects funded by the FSA are available from Clive House, 70 Petty France, London, SW1H 9EX. Further information on studies funded by SEPA and the Scotland and Northern Ireland Forum for Environmental Research is available from Edinburgh Centre for Carbon Innovation, High School Yards, Infirmary Street, Edinburgh, EH1 1LZ. Environment Agency reports are available from https://www.gov.uk/government/organisations/environment-agency. A charge may be made to cover costs.

Table A7.1 Extramural Projects

Topic	Reference	Further details	Target completion date
Soil and herbage survey	UKRSR01 and SCO00027	E, S	Q4, 2023
Offshore Dose Assessment Model	N/A	S	Q3 2023
Thorium Transfer Work	N/A	S	In press[1]
NORM Biota Project	N/A	S	In press[1]
McGuire, C. (2023). Radiological Protection of the Public from Radioactive Particles (PhD Thesis). University of Stirling	N/A	S	Q1 2023[2]
Clyde Estuary Assessment	N/A	S	Q2 2023
Soil and herbage follow-up	N/A	S	Q1 2023
Coastal Monitoring	N/A	S	Q1 2023
Shetland Background Sampling		S	Q4 2023
SW Scotland Background Sampling		S	Q4 2023
Investigation of the fate and behaviour of lutetium-177 in the environment	N/A	E	Q2 2024

Notes

[E] Environment Agency
[S] Scotland and Northern Ireland Forum for Environmental Research or SEPA

[1] The work is complete and the intent is to publish on the SEPA website, however the cyber attack has delayed publication

[2] The official completion date is 25th January 2023. It will however be embargoed until 25th January 2025, when available in the University of Stirling repository. https://www.storre.stir.ac.uk/handle/1893/35173

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