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# Environmental Monitoring for Radioactivity around Devonport Royal Dockyard

## Annual Report

## Jan-Dec 2023

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## DOCUMENT RESPONSIBILITY

The Director Assurance is responsible for alterations to this document.

**Executive Summary**

This report presents the findings of Devonport Royal Dockyard Limited's (DRDL's) environmental radioactivity monitoring programme during 2023. DRDL is the name of the operator/licensee under ONR regulations and the parent company is Babcock International. DRDL is contracted by the Ministry of Defence (MOD) to refit, repair and maintain nuclear powered submarines at Devonport Royal Dockyard (DRD). DRDL is permitted under the Environmental Permitting (England and Wales) Regulations 2016 to dispose of the radioactive waste generated at DRD.

Under Condition 3.2.1(b) of its radioactive waste disposal Permit (Reference 1), DRDL is required to "define, document and carry out an environmental monitoring programme". DRDL's programme consists of sediment, biota and river water sampling and radiation monitoring surveys at numerous locations in the area around DRD (e.g. Tamar Estuary, Rivers Plym, Tavy and Lynher) and High Volume Air Sampling within DRD.

DRD's environmental monitoring programme is carried out quarterly. This report specifies the programmes for both marine and airborne radioactivity monitoring/sampling, presents and discusses the results of the monitoring/sampling and makes conclusions, comparing the results with independent monitoring programmes, regulatory dose limits, constraints and levels and with natural background radiation doses within the United Kingdom (UK).

Cobalt-60 (the radionuclide of most radiological significance in discharges from DRD) was not detected in any of the samples taken during 2023. The calculated annual effective radiation dose from DRDL's discharges of radioactive waste from DRD was less than 3 μSv per annum which equates to below 0.3% of the UK legal and International Commission for Radiological Protection (ICRP) dose limit of 1,000 μSv per annum for members of the public. The results of DRDL's environmental radioactivity monitoring programme are also comparable with the findings of the independent monitoring programmes reported in the Radioactivity in Food and the Environment (RIFE) reports, which state that the dose to members of the public from DRDL's radioactive discharges is less than 5 μSv. For comparison, the annual average background radiation dose in the UK is 2,300 μSv.

Based on the results in this report, it is concluded that DRD continues to be a site of low radiological significance.

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## *1.0 INTRODUCTION*

1.1 Devonport Royal Dockyard Limited (DRDL) is contracted by the Ministry of Defence (MOD) to refit, repair and maintain nuclear powered submarines at Devonport Royal Dockyard (DRD). DRDL is part of Babcock International Group plc. DRDL is Licensed by the Office for Nuclear Regulation (ONR) and Authorised by the Defence Nuclear Safety Regulator (DNSR) to operate DRD and is permitted by the Environment Agency under the Environmental Permitting (England and Wales) Regulations 2016 (EPR2016) to dispose of solid, liquid and gaseous radioactive waste generated at DRD.

1.2 DRDL's Permit (Reference 1) imposes limits and conditions relating to the methods by which liquid radioactive waste is disposed, the quantities of radioactivity permitted to be discharged, the samples to be taken and the records to be kept. Condition 3.2.1(b) of DRDL's Permit requires DRDL to "define, document and carry out an environmental radioactivity monitoring programme". Requirements for compliance with this permit condition are detailed in DRDL's management arrangements, which specifies that the results of DRDL's environmental radioactivity monitoring programme shall be reported quarterly and annually to the Environment Agency.

1.3 The purpose of DRDL's environmental radioactivity monitoring programme is to determine the radiation exposure of members of the public as a result of discharges of liquid radioactive waste from DRD. This report covers the results of monitoring/sampling carried out and, from the results, assesses the potential exposure of the most exposed members of the public. It does not address radiation exposure of Company employees as this is covered by occupational monitoring programmes within DRD.

1.4 This annual report covers the environmental radioactivity monitoring programme and results for the period from 01 January to 31 December 2023.

1.5 Defence Science and Technology Laboratory (Dstl) Chemical, Biological and Radiological Division (referred to in this Report as 'Dstl') publishes an annual report detailing its marine environmental radioactivity monitoring surveys at nuclear submarine berths (Reference 2). This report also includes the results of the quarterly monitoring surveys carried out by DRDL.

1.6 Independent radiological monitoring of food and the environment is also carried out around the dockyard through programmes sponsored by the Environment Agency and the Food Standards Agency. These monitoring programmes provide an independent check on the effects of discharges made by users of radioactive materials in the UK and ensure that any radioactivity present in food and the environment does not compromise public health or the environment.

1.7 The results of monitoring around all major nuclear sites in the United Kingdom, including those from monitoring carried out around DRD, are published in the series of annual reports titled 'Radioactivity in Food and the Environment (RIFE)', the most recent of which is Reference 3. The RIFE Report contains results of radiological monitoring carried out by the UK environment agencies and Food Standards Agency.

1.8 Although some differences between the results can be expected because of the variability associated with biological systems and the uncertainties which are inherent in the measurement of radioactivity at the low levels present in the environment, the results presented in RIFE are generally consistent with those measurements made by DRDL (see Section 4).

## 2.0 *MONITORING PHILOSOPHY*

2.1 DRDL's radioactive waste stream contains primarily Cobalt-60, Tritium and Carbon-14, with other radionuclides of lower radiological significance. Table 1 details the activity limits permitted for discharge to the Hamoaze and the activities discharged during 2023.

2.2 DRDL's monitoring philosophy is focused on the detection of Cobalt-60, since in radiological terms Cobalt-60 is recognised as being the most significant radionuclide in discharges from DRD. This is due to its relative abundance in DRD waste streams and physical characteristics, such as its relatively long half-life (i.e. 5.3 years), its emission of high energy gamma radiation and its tendency to adsorb onto marine sediments.

2.3 Further monitoring is carried out for Tritium and Carbon-14. Although the greatest quantity of activity discharged is Tritium, this radionuclide, which also occurs naturally in the environment, is of less radiological significance than Cobalt-60 primarily because it emits low energy beta particles, is readily dispersed and diluted in the environment and, if an intake were to occur, is relatively quickly excreted from the body.

2.4 Carbon-14 is present in discharges from the dockyard and also occurs naturally in the environment. It has a long half-life and decays through emission of a low energy beta particle.

## 3.0 *THE MARINE ENVIRONMENTAL MONITORING PROGRAMME*

3.1 In order to monitor the effect of liquid radioactive waste discharges on the marine environment, a radiation monitoring and sampling survey is undertaken each calendar quarter. The survey programme, which is detailed in Attachment 1, is carried out by DRDL in conjunction with Dstl. The monitoring programme has been agreed with the Environment Agency, MOD and Dstl.

3.2 Attachment 1 provides a description of DRDL's marine environmental monitoring programme. The following types of measurement are made at up to thirteen points centred around the Tamar estuary (measurements are also taken in the rivers Plym, Tavy and Lynher):

- Gamma radiation dose rates at 1 metre above the ground. (A measurement of the gamma radiation in air resulting from natural sources and from any contamination present in the sediment.)

- Gamma radiation dose rates in contact with the strand-line. (Measurements of contact dose rate along the high tide mark where there is a visible accumulation of items deposited on the shoreline.)

- High resolution gamma spectrometry analysis of samples of sediment, seaweed, shellfish, fish and river water. (Identifies and assesses concentrations of gamma emitting radionuclides present in the sample).

- Liquid scintillation analysis of shellfish and fish to identify the beta emitting radionuclides Tritium and Carbon-14. Samples are analysed for total Tritium to ensure that any tritiated water present in each sample is included in the result, in addition to any organically bound Tritium.

## 4.0 *MARINE ENVIRONMENTAL MONITORING RESULTS*

4.1 The measurements made during 2023 are summarised in Tables 2 to 8. Where 'ND' is used in the tables, this means 'not detected' (i.e. the activity level within each such sample was below the limit of detection (LoD) for the analysis of that sample). The generic limit of detection used by DRDL/Dstl for Cobalt-60 in samples is 1.0 becquerel per kilogram ($Bqkg^{-1}$). Limits of detection for Carbon-14 and Tritium in biota samples are 50 $Bqkg^{-1}$ and 20 $Bqkg^{-1}$ respectively.

## *5.0 DISCUSSION OF MARINE RESULTS*

5.1 Whilst the DRDL marine environmental radioactivity monitoring programme focuses on the detection and measurement of Cobalt-60, the gamma spectrometry analyses of the sediment, seaweed, shellfish, fish and river water routinely search for the presence of other significant gamma emitting radionuclides. The only gamma emitting radionuclides detected in 2023 are those which occur naturally and trace levels of Iodine-131 and Caesium-137. Iodine-131 is used in nuclear medicine. Caesium-137 is a fission product mainly attributable to atmospheric weapons testing and the Chernobyl accident in 1986.

5.2 The average environmental gamma dose rate measured at a height of 1 metre around the inter-tidal area during 2023 was 0.087 microgray per hour ($\mu Gyh^{-1}$), with individual results ranging from 0.064 to 0.112 $\mu Gyh^{-1}$, (see Table 2 and Table 11). These gamma radiation dose rates give no environmental radiological concern and are comparable with published figures of radiation dose rates measured independently around Devonport (Reference 3), which are in the region of 0.082 to 0.11 $\mu Gyh^{-1}$.

5.3 No Cobalt-60 was detected in any of the marine samples collected by DRDL during 2023. A low level of Carbon-14 was measured in 13 biota samples and a low level of Tritium was measured in 5 biota samples.

5.4 The results are comparable with results for these radionuclides in biota detected at other UK sites (Reference 3) and are of low radiological significance.

5.5 Published data on natural radioactivity concentrations is summarised in Table 10 for comparison with the results obtained at Devonport. The average environmental monitoring results for Devonport in 2023 are presented in Table 11.

## *6.0 LIQUID RADIOACTIVE WASTE DISCHARGES*

6.1 All discharges to the Hamoaze during the reporting period were below DRDL's permitted activity limits, which are provided in Table 1. Graphs 1 and 2 show the levels of radioactivity discharged to the Hamoaze via the dedicated pipeline since 1987.

6.2 The volume of discharges to the river also varies depending on the work packages being undertaken. There was a decrease in the volume of discharges to the Hamoaze during the reporting period, from 335.3 $m^3$ in 2022 to 240.8 $m^3$ in 2023.

## *7.0 ENVIRONMENTAL MONITORING FOR AIRBORNE RADIOACTIVITY*

7.1 DRDL's airborne environmental monitoring programme includes High Volume Air Sampling (HVAS) and rainwater sampling and analysis (see Attachment 2). However, the HVAS and rainwater sampling does not form part of the statutory monitoring programme, having been removed in January 2018 following discussion with the Environment Agency.

7.2 The results from the airborne monitoring programme are summarised in Table 9. The HVAS ceased to operate mid Quarter 4 2022 and is beyond economical repair so only rainwater sample analysis is presented. A replacement HVAS is on order, awaiting delivery. This unit will operate in the same location, with the same flow rate using the same filter papers.

7.3 No Tritium or Cobalt-60 was detected in any of the rainwater samples. Where ND is used in the Tables, this means 'not detected' (i.e. the activity levels were below the limit of detection).

7.4 In accordance with the approach taken by the Environment Agency and Food Standards Agency (Reference 3) the levels of radionuclides detected in the airborne radioactivity samples are so low that radiological assessment of internal exposure from airborne radioactivity is not considered necessary.

## *8.0 CALCULATION OF RADIATION EXPOSURE*

8.1 In order to interpret the results of the marine environmental radioactivity monitoring programme in terms of radiation dose to members of the public, it is necessary to identify the most significant pathway, or combination of pathways, for radiation exposure and the group of people who are most likely to be exposed to the radiation from this (these) exposure pathway(s) (i.e. the 'representative individual'). A Radiological Habits Survey was carried out by Cefas in 2017 on behalf of the Environment Agency, Food Standards Agency and the ONR (Reference 5). Habits Surveys identify the occupancy levels, activities and eating patterns (including types of food, consumption rates, etc.) of the local population. This information is then used by the regulators to review the adequacy of the environmental monitoring programmes for the area.

8.2 Around Devonport, the representative individual for exposure from the marine pathways includes a member of the local community who resides or works on the mud flats and who eats locally caught seafood.

8.3 The quantity of interest in terms of the radiological effect is the effective dose to the representative individual. The unit of effective dose is the sievert (Sv). Since environmental gamma dose rates measured at a height of one metre are generally indistinguishable from the natural background levels (Reference 4) it is not possible to use these values directly to calculate the radiation doses resulting from liquid effluent discharges.

8.4 Consequently, an alternative method is used to determine the external dose. Models defined in Reference 6 enable the environmental dose rate resulting from a particular concentration of radionuclide and type of sediment to be calculated. Using information provided in Reference 6, the effective dose rate above sediment uniformly contaminated with Cobalt-60 is calculated to be 0.7 nanosievert per hour (nSvh$^{-1}$) per Bqkg$^{-1}$. As no Cobalt-60 was detected in the sediment samples, it is conservatively assumed that the activity is present, but just at the limit of detection, and the average LoD value (1.1 Bqkg$^{-1}$) is assigned. The maximum annual effective dose to the representative individual from external exposure over intertidal areas, for occupancy of 2100 hours per year over mud, is therefore calculated to be 1.4 $\mu$Svy$^{-1}$.

8.5 The internal dose to members of the local community who consume locally caught fish and shellfish (the main contributors to the total internal dose) is assessed using an average of results obtained from the sampling programme. The dose contribution from a radionuclide in each food type was calculated using the average concentration for that radionuclide (the average is calculated by pessimistically assigning the LoD to samples where no activity was detected, along with any positive results). This average specific activity, together with data on the consumption rates and dose per unit intake from ingestion of seafood as provided in References 5 and 7 was used to calculate the internal dose. The dose to the representative individual from internal exposure to Cobalt-60, Tritium and Carbon-14 is calculated to be less than 1 $\mu$Svy$^{-1}$.

8.6 The annual effective dose to the most exposed members of the local community from external and internal exposure as a result of radioactive liquid discharges from DRD is therefore assessed to be less than 3 $\mu$Svy$^{-1}$.

## *9.0 CONCLUSION*

9.1 The results of DRDL's environmental radioactivity monitoring programme show that Devonport continues to be a site of low radiological significance.

9.2 The annual effective dose of less than 3 $\mu Svy^{-1}$ is:

- less than 0.3% of the current International Commission on Radiological Protection (ICRP) principal limit of exposure for members of the public of 1 $mSvy^{-1}$ (Reference 8);
- less than 1% of the dose constraint of 500 $\mu Svy^{-1}$ for discharges from a single site (Reference 9);
- less than 2% of the dose constraint of 300 $\mu Svy^{-1}$ for discharges from a single source (Reference 9);
- well below the 'threshold of optimisation level' of 20 $\mu Svy^{-1}$ referred to in Command 2919 (Reference 10).

9.3 Exposure to background radiation within the UK averages some 2300 μSv per person per annum with annual variations of several thousand μSv in different parts of the UK, notably Devon and Cornwall (Reference 11). This can help to put the magnitude of the dose to the representative individual for Devonport (less than 3 $\mu Svy^{-1}$) into perspective (see Figure 1).

## *10.0 REFERENCES*

1 DRDL Permit for the Receipt and Disposal of Radioactive Waste, Number EPR/BB3098DX

2 Dstl Report, "Marine Environmental Radioactivity Surveys at Nuclear Submarine Berths 2022".

3 "Radioactivity in Food and the Environment, 2022 (RIFE-28)", Food Standards Agency, Scottish Environment Protection Agency, Environment Agency and the Northern Ireland Environment Agency.

4 Aquatic Environment Monitoring Report No 45, "Radioactivity in Surface and Coastal Waters of the British Isles 1994" by W C Camplin, MAFF Directorate of Fisheries Research, (now Cefas), Lowestoft (1995).

5 Cefas Radiological Habits Survey: Devonport, 2017. K. J. Moore, F. J. Clyne, B. J. Greenhill and K. Clarke (2018).

6 Simple models for Prediction of External Radiation Exposure from Aquatic Pathways" by G J Hunt; Radiation Protection Dosimetry Vol. 8 No. 4 p 215-224 (1984).

7 International Commission on Radiological Protection, Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5, Compilation of Ingestion and Inhalation Dose Coefficients, ICRP Publication 119, 2012.

8 International Commission on Radiological Protection (ICRP); ICRP Publication 103; "2007 Recommendations of the International Commission on Radiological Protection". Annals of the ICRP Vol. 37 no. 2-4 (2007).

9 The Environmental Permitting (England and Wales) Regulations 2016, Schedule 23, Part 4.

10 "Review of Radioactive Waste Management Policy - Final Conclusions". Cmnd. 2919 (1995).

11 PHE-CRCE-026: Ionising Radiation Exposure of the UK Population: 2010 review. W Oatway et al. April 2016

## *11.0 GLOSSARY OF TERMS AND ABBREVIATIONS*

| | |
|---|---|
| Activity | Attribute of an amount of radionuclide. Describes the rate at which transformations occur in it – each transformation being associated with the emission of radiation. Unit becquerel, symbol Bq (see below). 1Bq = 1 transformation per second. |
| Beta Particle | An energetic electron emitted by some radionuclides. |
| Bq | The unit of radioactivity is the becquerel (Bq). In this report, Cobalt-60 concentrations are expressed in terms of becquerels per kilogram of sample material ($Bqkg^{-1}$). |
| CEFAS | Centre for Environment, Fisheries and Aquaculture Science. |
| DRD | Devonport Royal Dockyard. (Note: The overall site at Devonport consists of two parts; the Naval Base and Devonport Royal Dockyard.) |
| DRDL | Devonport Royal Dockyard Limited. |
| Dose rate | The rate at which radiation dose is received. |
| Dstl | Defence Science and Technology Laboratory (Chemical, Biological and Radiological Division). |
| Effective dose | An indicator of the effects of radiation on the body as a whole when different body tissues are exposed to different amounts and types of radiation (measured in Sievert (see below)). |
| Electron | A negatively charged sub-atomic particle. |
| EPR 2016 | Environmental Permitting (England and Wales) Regulations 2016. |
| Gamma Radiation | Electromagnetic radiation, without mass or charge, emitted by some radionuclides. |
| G | giga ($10^9$) |
| Gray (Gy) | Quantity of energy imparted by ionising radiation to unit mass of matter such as tissue. This quantity is the absorbed dose and the standard international (SI) unit for absorbed dose is the Gray. 1 Gy = 1 joule per kilogram. |
| ICRP | International Commission on Radiological Protection. |
| Limit of Detection (LoD) | The limit at which it may be stated with a certain degree of statistical confidence (dependent upon the confidence limit, 95% or 99%) that activity has been detected. |
| MOD | Ministry of Defence. |
| M | mega ($10^6$) |
| m | milli ($10^{-3}$) |

| | |
|---|---|
| μ | micro ($10^{-6}$) |
| n | nano ($10^{-9}$) |
| ND | Not Detected. |
| PHE (RPD) | Public Health England (Radiation Protection Division). Formerly National Radiological Protection Board, then Health Protection Agency. |
| Representative Individual | A hypothetical individual receiving a dose that is representative of the most exposed individuals in the population (formerly the 'Critical Group'). |
| Sievert (Sv) | The unit of Effective Dose (see above) obtained by multiplying the absorbed dose (see gray) by a factor to allow for the relative biological effectiveness of the various ionising radiations (for gamma, beta and X-rays the factor is 1). |

## Attachment 1

## Marine environmental monitoring programme

### *1.1 Gamma Dose Rate*

Gamma dose rate measurements made quarterly 1 metre above inter-tidal sediment at:

| | | |
|---|---|---|
| Royal Albert Bridge (east) | Royal Albert Bridge (west) | Bull Point |
| Wearde Quay | Thankes Park (Torpoint) | Slipway (Tamar St) |
| Stonehouse | Torpoint (south) | |

and annually at:

| | | |
|---|---|---|
| Calstock | St Germans Quay | Mount Gould |
| Mount Jessop | Bovisand Bay | |

Contact dose rate measurements are made bi-annually along strand lines at:

Bull Point Wearde Quay

### *1.2 Sediment*

Samples of inter-tidal surface sediment (scraped from the top few mm) are collected quarterly at:

Bull Point Wearde Quay Stonehouse Torpoint (south)

and annually at:

Calstock St Germans Quay Mount Jessop Bovisand Bay Mount Gould

### *1.3 Seaweed*

Samples of Fucus seaweeds (usually *'Fucus vesiculosus'*) are collected bi-annually at:

Bull Point Wearde Quay Stonehouse Torpoint (south)

and annually at:

Mount Jessop St Germans Quay Mount Gould Bovisand Bay

The top 5 cm (i.e. recent growth) of samples, rinsed free of sediment, is analysed.

### *1.4 Fish and Shellfish*

Fish caught in Plymouth Sound (within the Breakwater) were obtained from local suppliers during quarter 3.

Samples of mussels *'Mytilus edulis'* of the largest size available are collected quarterly at Royal Albert Bridge (East) and Wearde Quay when available in sufficient numbers.

Mussels are prepared and the flesh extracted as if for eating. Only the mussel flesh is analysed.

### *1.5 River Water*

1 litre samples of river water are collected quarterly from the River Tamar at:

Royal Albert Bridge (East)  Torpoint (South)

All intertidal survey points are shown in Map 1.

**Map 1 – Marine environmental monitoring programme – intertidal survey locations**

## Attachment 2

### Environmental monitoring programme for airborne radioactivity

| | Description | Frequency of Analysis | Analysis |
|---|---|---|---|
| **High Volume Air Sampler (HVAS)*** | A HVAS is located within DRD. It operates at a flow rate of 1000 litres per minute. The filter papers are changed periodically and bulked together for analysis. | Quarterly | Gamma spectrometry and gas flow proportional counting. |
| **Rainwater Sampler** | Rainwater is collected at the dockyard. Once every quarter a one litre sample is taken from the rainwater collected and sent away for analysis. | Quarterly | Gamma spectrometry and liquid scintillation for Tritium. |

*Asset failed during Quarter 4 and is beyond economical repair. Replacement HVAS being procured.

**The High Volume Air Sampler at the Dockyard**

**Table 1**

**Discharges of radioactive liquid waste to the Hamoaze during 2023**

| Radionuclide | Discharge Limit (GBq) | Discharges (GBq) | % of limit |
|---|---|---|---|
| Cobalt 60 | 0.80 | 0.001 | 0.1 |
| Tritium | 700 | 2.90 | 0.4 |
| Carbon-14 | 1.70 | 0.006 | 0.3 |
| Other Radionuclides[1] | 0.30 | 0.001 | 0.3 |

Notes:
1. Total activity of all other radionuclides.
2. The volume of effluent discharged to the Hamoaze during 2023 was 240.8 $m^3$.

**Marine environmental monitoring results for 2023**

**Table 2**
**Gamma radiation dose rates at 1 metre above inter-tidal sediment (µGyh$^{-1}$)**

| Location [Point Number] | 2023 Doserates (µGy/h) | | | |
|---|---|---|---|---|
| | January | April | July | October |
| Royal Albert Bridge (East) [1] | 0.088 | 0.091 | 0.104 | 0.090 |
| Thankes Park (Torpoint) [4] | 0.089 | 0.098 | 0.097 | 0.097 |
| Wearde Quay (Saltash) [5] | 0.087 | 0.085 | 0.094 | 0.083 |
| Slipway (Tamar Street) [6] | 0.071 | 0.070 | 0.079 | 0.069 |
| Royal Albert Bridge (West) [8] | 0.095 | 0.087 | 0.092 | 0.086 |
| Torpoint (South) [10] | 0.102 | 0.097 | 0.101 | 0.098 |
| Stonehouse [14] | 0.073 | 0.067 | 0.064 | 0.065 |
| Mount Gould [22] | | | 0.100 | |
| Mount Jessop [26] | | | 0.106 | |
| St Germans Quay [29] | | | 0.093 | |
| Bovisand Bay [30] | | | 0.078 | |
| Calstock [32] | | | 0.112 | |
| Bull Point [40] | 0.086 | 0.081 | 0.080 | 0.071 |

Notes: (1) Measurements were made using a RadEye GX with geiger-müller probe on a 1m tripod stand.

(2) Points 22, 26, 29, 30 and 32 are only surveyed once a year.

**Table 3**
**Gamma radiation dose rates in contact with the strand line (μGyh$^{-1}$)**

| Location | 2023 Contact Dose rates (μGyh$^{-1}$) | | | |
|---|---|---|---|---|
| | January | | July | |
| | Maximum | Average | Maximum | Average |
| Wearde Quay (Saltash) | 0.123 | 0.115 | 0.117 | 0.116 |
| Bull Point | 0.123 | 0.114 | 0.120 | 0.112 |

Notes: (1) Measurements were made using a RadEye GX with the geiger-müller probe placed in contact with the strandline.

**Table 4**
**Cobalt-60 in sediment samples (Bqkg$^{-1}$) (dry weight)**

| Location | 2023 Cobalt-60 Activity (Bqkg$^{-1}$) | | | |
|---|---|---|---|---|
| | January | April | July | October |
| Wearde Quay (Saltash) | ND[1] | ND[2] | ND[3] | ND[3] |
| Torpoint (South) | ND[1] | ND[2] | ND[1] | ND[3] |
| Stonehouse | ND[1] | ND[2] | ND[1] | ND[3] |
| Mount Gould | | | ND[1] | |
| Mount Jessop | | | ND[1] | |
| St Germans Quay | | | ND[1] | |
| Bovisand Bay | | | ND[3] | |
| Calstock | | | ND[1] | |
| Bull Point | ND[1] | ND[2] | ND[1] | ND[3] |

Note:
Sediment samples were of the type (1) mud
(2) sand/silt
(3) silt
'ND' = Not Detected. Generalised limit of detection for sediment samples was 1 Bqkg$^{-1}$.
Mount Gould to Calstock points are only surveyed once a year.

**Table 5 - Cobalt-60 in seaweed samples (Bqkg$^{-1}$) (wet weight)**

| Location | 2023 Cobalt-60 Activity (Bqkg$^{-1}$) | | |
|---|---|---|---|
| | January | April | July |
| Wearde Quay (Saltash) | ND | | ND |
| Torpoint (South) | ND | ND | ND |
| Stonehouse | ND | ND | ND |
| Mount Gould | | | ND |
| Mount Jessop | | | ND |
| St Germans Quay | | | ND |
| Bovisand Bay | | | ND |
| Bull Point | ND | | ND |

Note: (1) All seaweeds were *fucus sp*.
(2) 'ND' = Not Detected. Generalised limit of detection for all samples was 1 Bqkg$^{-1}$.
(3) Trace positive I-131 was found in two seaweed samples in January. Repeat seaweed samples, in addition to the standard bi-annual samples, were taken from these locations in April and no I-131 was found. I-131 was not detected in any discharges from DRDL; I-131 is used in nuclear medicine.

**Table 6 - Cobalt-60, Carbon-14 and Tritium in shellfish (M.edulis) samples (Bqkg$^{-1}$ Wet Weight) (2023)**

| Location | Radionuclide | January | April | July | October | Limit of Detection[2] |
|---|---|---|---|---|---|---|
| Royal Albert Bridge (East) | Cobalt-60 | NA[5] | NA | NA | ND | 1 |
| | Carbon-14 | 15(9) | NA | NA | 14(7) | 50 |
| | Tritium[1] | ND | NA | NA | ND | 20 |
| Wearde Quay | Cobalt-60 | ND | ND | NA | ND | 1 |
| | Carbon-14 | 20(10) | 14.6 (8.2) | NA | 13(7) | 50 |
| | Tritium[1] | ND | ND | NA | ND | 20 |

Note: (1) Total Tritium.
(2) Actual limits of detection vary between samples. This can give rise to positive results which are less than the standard limits of detection required by the monitoring programme.
(3) Uncertainties of two standard deviations are shown in brackets.
(4) ND = Not Detected; NA = Not Available for collection.
(5) Insufficient sample collected January location 1 to perform Gamma Spectrometry analysis.

**Table 7**
**Cobalt-60, Carbon-14 and Tritium in fish samples (2023)**
**($Bqkg^{-1}$ wet weight)**

| Fish Species | Cobalt-60 | Carbon-14 | Tritium |
|---|---|---|---|
| Limit of Detection[1] ($Bqkg^{-1}$) | 1 | 50 | 20 |
| Sea Bream | ND | 15(9) | 31(14) |
| Sea Bream | ND | 26(11) | 34(15) |
| Sea Bass | ND | 17(9) | 13(13) |
| Sea Bass | ND | 30(11) | 16(13) |
| Wrasse | ND | 14(9) | 10(12) |
| Wrasse | ND | 25(10) | ND |
| Mackerel | ND | 25(10) | ND |
| Mackerel | ND | 33(12) | ND |

Notes:

(1) Actual limits of detection vary between samples. This can give rise to positive results which are less than the standard limits of detection required by the monitoring programme.
(2) Uncertainties shown in brackets include all analytical uncertainties in accordance with ISO 17025 and provide a 95% confidence level that the value is within this range.
(3) ND = not detected
(4) Fish analysis results are presented as an average $Bqkg^{-1}$ per fish species.

**Table 8**
**Cobalt-60 and Tritium in river water samples (2023) ($Bql^{-1}$)**

| Location | Radionuclide | Jan | Apr | Sep | Oct | Generic Limit of Detection |
|---|---|---|---|---|---|---|
| Royal Albert Bridge (East) | Cobalt-60<br>Tritium | ND<br>ND | ND<br>ND | ND<br>ND | ND<br>ND | 1<br>10 |
| Torpoint (South) | Cobalt-60<br>Tritium | ND<br>ND | ND<br>ND | ND<br>ND | ND<br>ND | 1<br>10 |

## Airborne environmental monitoring results for 2023

### Table 9 Cobalt-60 and Tritium rainwater results

| Measurement Period | Radioactivity Concentration ($Bql^{-1}$) | |
|---|---|---|
| | Tritium | Cobalt-60 |
| Generic Limit of Detection | 10 | 1 |
| Quarter 1 | ND | ND |
| Quarter 2 | ND | ND |
| Quarter 3 | ND | ND |
| Quarter 4 | ND | ND |

'ND' – not detected.

**Table 10**

**A Summary of the average concentrations of natural radioactivity found within the inter-tidal region in the UK.(1)**

| Material | Total Beta Radioactivity Concentration (wet weight)(2) | |
|---|---|---|
| | $Bqkg^{-1}$ | Comments |
| Sand | 200-400 | K-40 and decay products of U and Th |
| Mud | 700-1000 | K-40 and decay products of U and Th |
| Seaweed | 200-600 | Mostly K-40 |
| Shellfish | 40-100 | Mostly K-40 |
| Fish | 40-100 | Mostly K-40 |

Notes:
(1) The information presented is taken from Reference 4.
(2) Except sediments for which dry weight concentrations apply.
(3) K-40 is naturally occurring potassium-40.

**Table 11**
**Average marine environmental monitoring results for 2023**

| | | Mean Radioactivity Concentrations (Bq/kg) (Bq/l for water) | | | | |
|---|---|---|---|---|---|---|
| **Sample Type** | **No. of Samples** | **Co-60** | **Cs-137** | **K-40** | **H-3** | **C-14** |
| Sediment | 21 | [1.1] | 1.9 | 665 | N/A | N/A |
| Seaweed | 14 | [1] | [1] | 234 | N/A | N/A |
| Mussels | 5 | [1] | [1] | 45 | [16.6] | 15.3 |
| Fish | 8 | [1] | [1] | 111 | 20.5 | 23.1 |
| River Water | 8 | [1] | [1] | [20] | [6.9] | N/A |

| | |
|---|---|
| **Mean Gamma Dose rate in air at 1m** | 0.087 $\mu Gyh^{-1}$ |
| **Mean Contact Gamma Dose rate along the strandline** | 0.114 $\mu Gyh^{-1}$ |

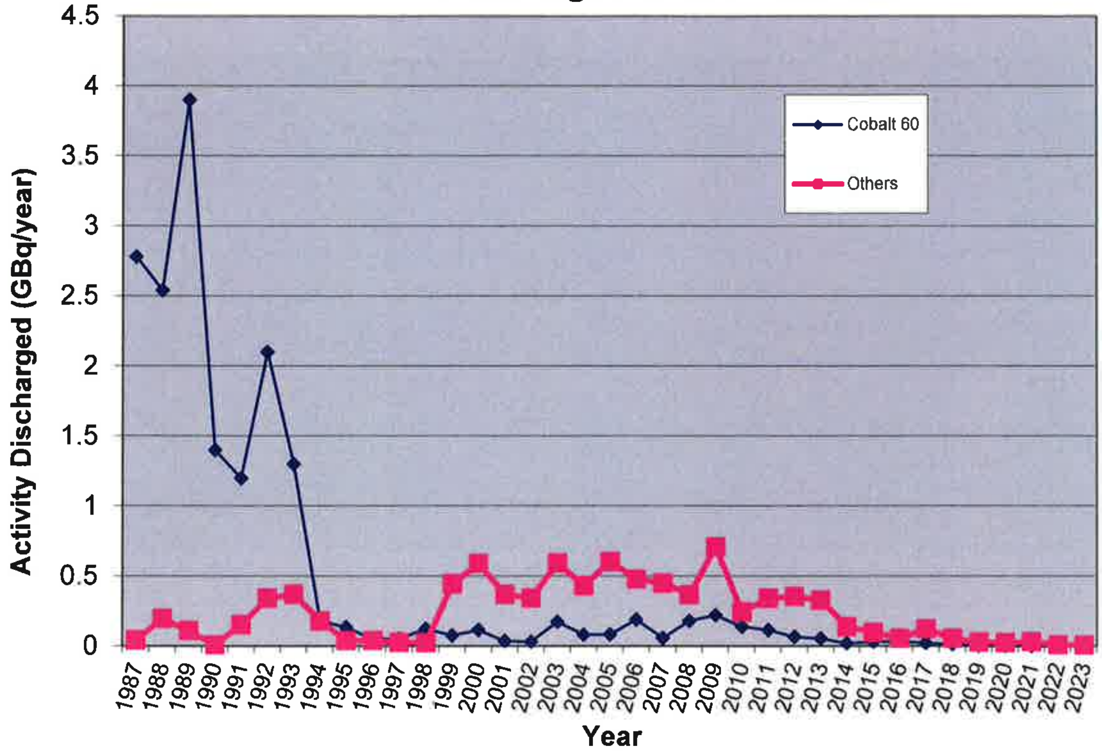
Notes: (1) Values shown in square brackets indicate that there were no positive results in those samples. The figure given is the limit of detection. The respective LoD value for each radionuclide is assigned to all samples in which no activity is detected (ND), thus a pessimistic mean concentration is calculated. The LoD achieved by the laboratory for Co-60 for a small number of sediment samples in Quarter 3 was 2 Bq/kg rather than the usual 1 Bq/kg because there was insufficient sample; this resulted in a slightly elevated average LoD of 1.1 Bq/kg.

(2) The samples of sediment, seaweed, river water, shellfish and fish contained some natural radioactivity predominately in the form of potassium-40 (K-40), which is present in all living, or once living, organisms and vegetation. Samples of sediment and seaweed also contained decay products of naturally occurring thorium and uranium.

(3) Very small quantities of caesium-137 (Cs-137) were detected in some environmental samples. This is attributed to atomic weapons test fall-out, discharges from other nuclear establishments and the Chernobyl accident.

(4) Results for sediment samples are dry weight concentrations, and results for biota are wet weight concentrations.

**Graph 1 - Cobalt-60 and Other Activity (excluding Tritium) Discharged to the Hamoaze**




Notes:

(1) The discharge of effluent for 1987 was recorded from June 1987 to December 1987 (i.e. after DRDL's first Radioactive Substances Act Authorisation was issued).

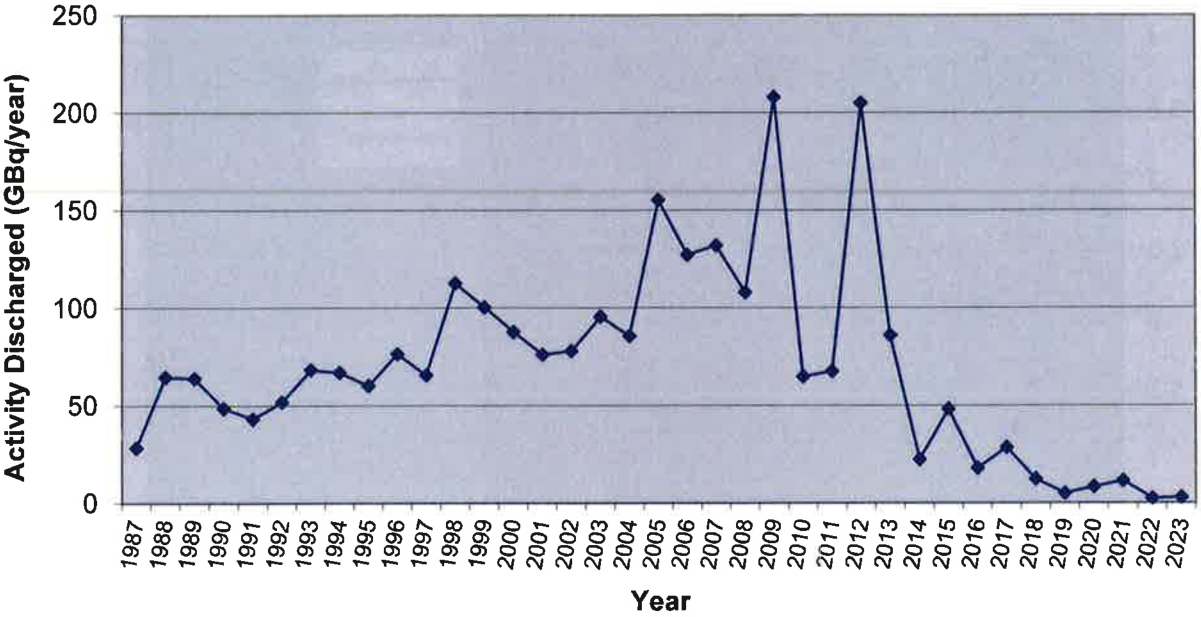
(2) Prior to 1992 only gamma emitting radionuclides were included in 'Other Radionuclides'. From 1992 onwards this group includes both gamma and beta emitting radionuclides.

(3) Carbon-14 was not included in the activity measurements for 'Other Radionuclides' until 1999.

(4) Discharges of Tritium are presented in Graph 2.

(5) Annual discharge limits are given in Table 1.

**Graph 2 - Tritium Activity Discharged per year into the Hamoaze**




Note: (1) The discharge of effluent for 1987 was recorded from June 1987 to December 1987 (i.e. after DRDL's first Radioactive Substances Act authorisation was issued).

(2) Graph 2 shows the elevated discharges of Tritium to the Hamoaze since 2002, which are associated primarily with the discharge of certain submarine effluents, arising from discrete operations during their Deep Maintenance Period. The graph illustrates the intermittent nature of discharges from DRD to the Hamoaze, which vary depending on the work packages being undertaken on nuclear powered submarines at DRD.

(3) Annual discharge limits are given in Table 1.

**Figure 1 – Comparison of radiation doses**