Technical and Safety Support

Report

Hinkley Point B Power Station

Annual Report for the Hinkley Point Site Stakeholder Group on Radioactive Discharges and Environmental Monitoring at Hinkley Point B Power Station During 2017

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Report Summary

Report title: Annual Report for the Hinkley Point Site Stakeholder Group on Radioactive Discharges and Environmental Monitoring at Hinkley Point B Power Station During 2017

Report Reference: HINB/R/TET/1036

Summary

This report by EDF Energy Nuclear Generation Limited (EDF NGL) is presented to the Hinkley Point Site Stakeholder Group (SSG) and provides data covering radioactive discharges, solid radioactive waste disposals and environmental monitoring at Hinkley Point B (HPB) power station for 2017. Historic data is available from previous annual reports and graphical trending data presented in this report covers the previous five years.

All radioactive discharges are made under the terms of the permit granted by the Environment Agency. The disposal of radioactive waste from nuclear sites is regulated under the Environmental Permitting (England and Wales) Regulations 2016 (EPR). The permit limits are set after considering the actual quantities of radioactivity that both sites need to discharge but with consideration of the overall requirement to keep the levels as low as reasonably practicable and to keep doses to the public below the internationally recognised limits. During 2017, there were no variations to the permit for Hinkley Point B.

Throughout 2017, the levels of radioactivity in liquid and gaseous effluents discharged to sea and air, together with transfers of solid radioactive low-level waste to the Low Level Waste Repository (LLWR) and other locations, remained below the permit limits set by the Environment Agency. Although releases of radioactivity to the environment are controlled at source, a condition of the authorisations is that a programme of environmental monitoring is maintained. Such monitoring provides reassurance by demonstrating that the controls used to limit radioactive releases are satisfactory, and that there is no significant accumulation of radioactivity in the environment.

Conclusions

The monitoring programme showed that radiological discharges have minimal impact on the environment. There is no evidence of any long-term accumulation of radioactivity resulting from the operation of Hinkley Point B power station or from work to decommission the Hinkley Point A site. Radiation doses to members of the public from the discharges, and from direct radiation from both sites, were significantly less than the UK legal limit and within the 1 mSv per year dose level recommended by the International Commission on Radiological Protection (ICRP). In 2016, the total dose to members of the public from the all pathways of exposure was 0.013 mSv (RIFE 22, 2016), which is <2 % of the dose limit and well within the public dose constraint value of 0.3 mSv per year from a ‘single site’, recommended by Public Health England.

Recommendations

There are no specific recommendations arising from the report.

Report issue/amendment

Date	Author	Revision	Amendment
May 2018	H Dyer	000	First issue

Glossary

Word, Phrase or Acronym	Description
AETP	Active Effluent Treatment Plant
AGR	Advanced Gas Cooled Reactor
CO_2	Carbon Dioxide
CW	Cooling Water
EA	Environment Agency
EDF NGL	EDF Energy Nuclear Generation Limited
EPR	Environmental Permitting Regulations
EPR	Environmental Permitting Regulations
FMDTs	Final Monitoring Delay Tanks
HPA	Hinkley Point A Power Station
HPB	Hinkley Point B Power Station
ICRP	International Commission on Radiological Protection
IRR	Ionising Radiations Regulations
LLW	Low Level Waste
LLWR	Low Level Waste Repository
MDA	Minimum Detectable Activity
NGL	Nuclear Generation Limited
PHE	Public Health England
QNL	Quarterly Notification Level
RACW	Reactor Ancillary Cooling Water
RIFE	Radioactivity in Food and the Environment
SSG	Site Stakeholder Group
TLD	Thermoluminescent Dose Meter
TWST	Tritiated Water Storage Tanks
WAL	Weekly Advisory Level

Verification Certificate

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1 Introduction

In its simplest form, nuclear power stations use heat generated from the fission process to generate steam. The steam then passes over a number of turbines which spin and generate electricity (Figure 1). Hinkley Point B Power Station operated by EDF Energy Nuclear Generation Limited is an advanced gas cooled reactor (AGR) type which uses gaseous carbon dioxide (CO_2) as the heat transfer coolant.

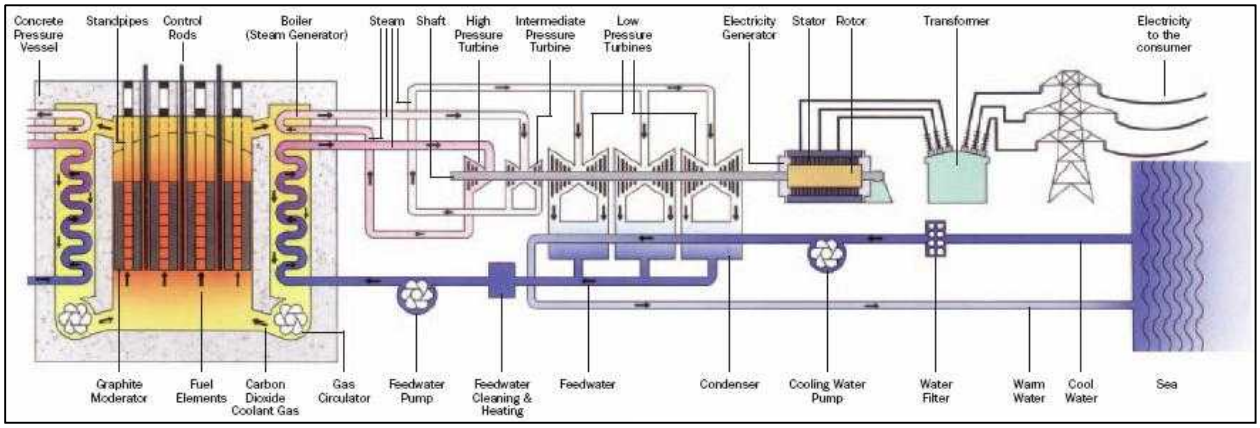

Figure 1 Schematic of electricity generation from nuclear power.

In an AGR, the reactor contains uranium fuel assemblies which are located inside a graphite core. The uranium provides the energy to power the reactor via the fission process. The graphite acts as a moderator to slow down neutrons emitted during the fission process, facilitating a chain reaction and provides structural integrity of the core. Power is controlled by raising and lowering control rods into the graphite core. The control rods absorb neutrons and control the fission process. Inserting the rods causes more neutrons to be absorbed, so less fission occurs and less heat is produced. Fully inserting the rods stops the fission process altogether.

Serpentine boilers have thousands of steel tubes running through them acting as heat exchangers so that as the CO_2 coolant is pumped around the reactor by the gas circulators, heat from the fuel is transferred into the gas and then into the feed water contained within the boiler tubes. The core and boilers are encapsulated by a concrete pressure vessel which allows the gas coolant to be pressurised and also provides shielding from radiation.

Feed water is pumped through the boilers at approximately 500 litres per second. As the feed water travels up the boilers it is transferred into steam and this provides the kinetic energy required to spin the turbines. The turbine setup is one high, one intermediate and three low pressure turbines which have increasing blade size as the steam pressure decreases. This maximises the efficiency of energy transfer from the steam to the turbine. Seawater is passed through condenser tubes and as the steam passes over these tubes, is cooled and condenses back into water that is reused in the feed water cycle.

The generator consists of a magnet attached to the turbine shaft (rotor) which spins inside the stationary coils of wire (stator) to generate electricity. The transformers convert 23kV to 400kV for transmission to the National Grid.

1.1 Environmental Benefits of Nuclear Power

All forms of electricity generation impact upon the environment. These effects range from simple visual impacts through to discharges to air and water as well as disposals to land. Nuclear fission produces roughly a million times more energy per unit than fossil fuels making it the most affordable large-scale, low carbon energy source currently available. EDF Energy recognises that it has a duty of care to protect the environment and to minimise the effects of its operations on both the environment and the public. EDF Energy fulfils this duty by the implementation of Environmental Policies and by the adoption of Environmental Management System Standards. The continued compliance with these standards results in enhanced environmental performance independently verified by auditors at least every 12 months.

The UK Government considers nuclear power stations to be low-carbon electricity generators due to the production of very low levels of carbon dioxide (CO_2) during operation and over their life cycle. The carbon footprint of a nuclear power station is about 16 grams of carbon dioxide-equivalent for each kilowatt-hour of electricity it generates (g CO2 e/kWh). This is the average level of greenhouse gas emissions a nuclear power station is responsible for over its lifetime from construction to decommissioning. Uranium extraction accounts for about 40% of emissions from nuclear power, decommissioning for about 35% and less than 1% comes from operation. By comparison, gas-fired power stations have a carbon footprint of 487g CO2 e/kWh, coal-fired power stations 870g CO2 e/kWh and oil-fired power stations have a carbon footprint of around 650g CO2 e/kWh.

Increasing concentrations of CO_2 is one of the main contributors to climate change. Sulphur dioxide (SO_2) and nitrogen oxides (NO_x) are associated by-products of fossil fuel generation and are known contributors to acid rain and photochemical smog. The process involved with generating nuclear power results in much lower amounts of CO_2 and significantly less SO_2 and NO_x than conventional power stations burning fossil fuels.

1.2 ISO 14001:2004

ISO 14001:2004 is an International Standard that provides the elements for an effective Environmental Management System. This system enables us to work and act responsibly towards the environment and it applies to all of the environmental aspects which an organisation has control or influence over. The Standard is integrated with other management requirements to help the stations achieve their environmental goals.

Three significant benefits are gained by adopting this standard:

- A formal mechanism to apply Company Environmental Policy at site level
- A formal requirement for continual environmental improvement
- Independent verification of Company environmental protection standards

Both Hinkley Point B operate under an ISO 14001:2015 certification. Regular reviews and audits are carried out to ensure that the requirements of the standard are being met. ISO14001:2015 is a fleet wide certification for EDF Energy, therefore any non-conformities identified at any site must be addressed at all other sites. This more vigorous approach will continue to improve the stations environmental performance.

1.3 Environmental Permitting Regulations 2016

Hinkley Point B holds permits under the Environmental Permitting (England & Wales) Regulations 2016 (EPR 2016) which covers the following activities –

- Disposals to air
- Disposals to water
- Radioactive waste management
- Combustion plant
- Sewage treatment plant
- Greenhouse gas emissions

1.4 EDF Energy Environmental Policy

EDF Energy is the UK's largest producer of low carbon electricity operating a diverse portfolio of generating assets alongside a customer facing power supply business. The Environmental Policy sets out our approach to achieve our ambition to lead the decarbonisation of the electricity sector and achieve net zero environmental impact. This means staying within our permitted limits for operations, using best available techniques to tackle our environmental impacts, prioritising our efforts where we can make the most difference in reducing our contribution to climate change and to protect a cleaner, healthier and more resilient environment that benefits society and our economy.

The key principles for achieving this are that -

- We will ensure every job will be done safely to protect the environment, employees, contractors and the communities.

- We will promote a positive and engaged culture throughout the business and integrate environmental safety into everyday activities and decisions.

- We will assess the environmental impact of each facility we propose to construct or acquire and will design, build, engineer, operate and maintain all our facilities and equipment so they are safe, secure, acceptable to local communities and protect the environment.

- We will be prepared for emergencies and will provide leadership to assist our local communities to improve their emergency preparedness.

- We will identify and comply with relevant environmental legislation, our policies, procedures and objectives.

- We will identify our significant environmental impacts associated with the lifecycle of our operations and take action to manage these, including in abnormal and emergency situations, to prevent pollution or environmental damage.

- We will consider environmental performance when selecting our contractors and suppliers.

- We will work with our contractors and other partners to ensure the products and services they supply comply with this policy, meet best environmental practice and demonstrate continuous improvement.

- We will seek to minimise the environmental impacts of goods and services, using innovation to use less resources, and to use them well to deliver more, whilst focussing on the things which are affordable and make the biggest difference.

- We will work with interested parties on environmental issues to ensure their concerns and expectations are considered in a robust and transparent decision-making processes.

- We will actively monitor our performance and compliance and take action to ensure we prevent harm to the environment and continuously improve our environmental management and performance by setting challenging objectives and targets for ourselves and our contractors.

- We will openly report our performance on our Better Energy Plan to our key stakeholders.

- We will embed these environmental principles within an effective management system and provide environmental training and information to ensure a competent workforce.

1.5 Hinkley Point B Environmental Events and Policy Compliance

Any environmental 'events' or 'near misses' are recorded as part of the company's corrective action programme and classified as per the Bird's Triangle shown in Figure 2. The open reporting of 'minor events' and 'near misses' remains encouraging and continues to demonstrate a greater awareness of environmental impacts amongst staff and contract partners. This highlights that staff are not willing to tolerate practices that may have the potential for environmental damage and allows the station to rectify potential problem areas before the environment is put at risk. The site also receives requests for information, largely for student projects and less frequently complaints. These are also formally recorded as part of the Environmental Management System.

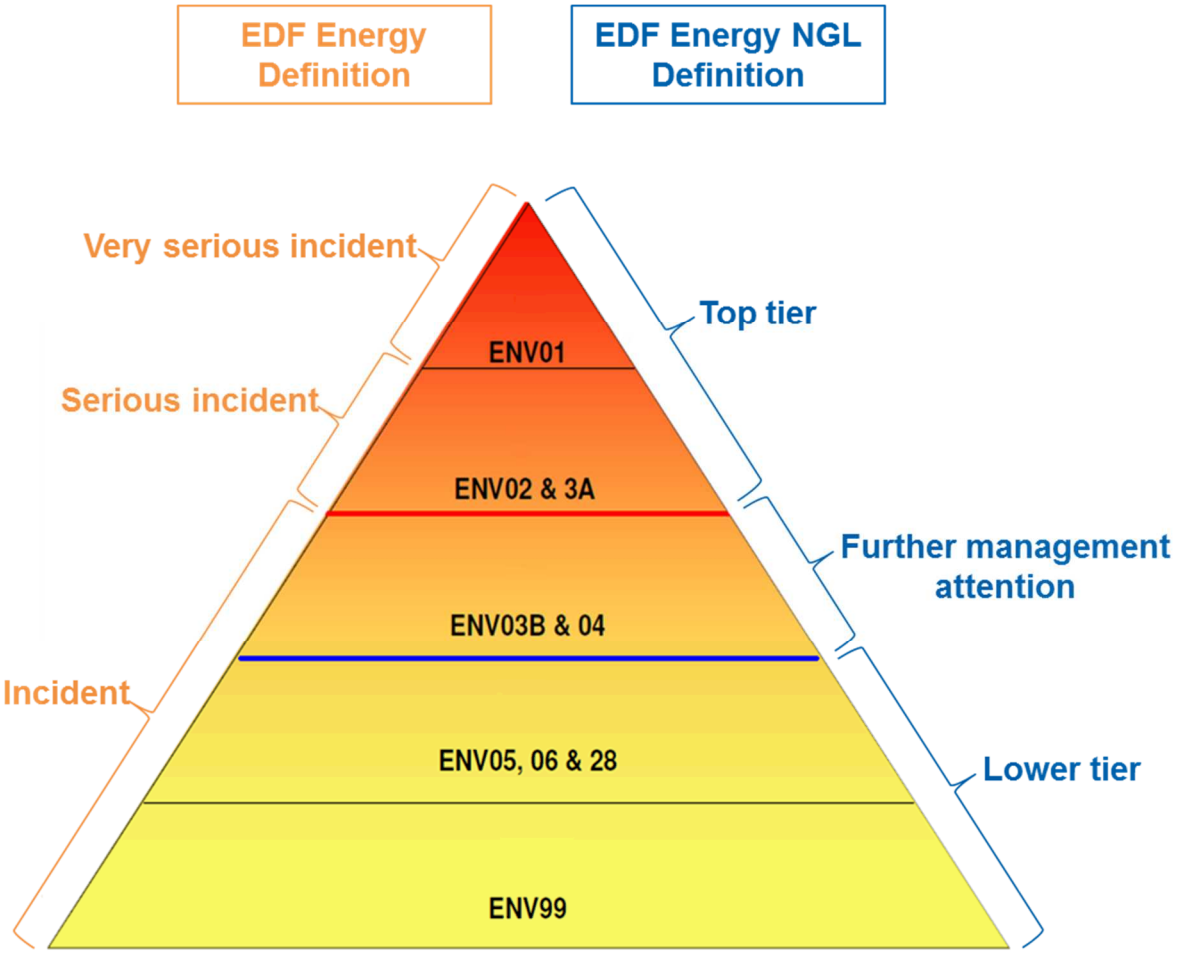

Figure 2 Environmental event classification.

An explanation of each category and the number of events occurring in 2017 that specifically affected compliance with environmental legislation and the station permit are detailed in Table 1.

Table 1 Event category definitions and results for 2017.

Event	Description	2017
ENV01	The station has caused a pollution incident which has had a physical environmental impact.	0
ENV02	A discharge limit has been exceeded or there has been an unauthorised discharge.	0
ENV03A	The station failed to comply with a requirement of environmental legislation or obtain a permit. This has resulted in an environmental impact.	0
ENV03B	As above, but there has been no environmental impact.	0
ENV04	The station failed to meet a requirement of an environmental permit but there has been no environmental impact.	1
ENV05	A notification level has been exceeded; there has been an unusual discharge, or there has been a potential event on permitted plant.	4
ENV06	An event or 'near miss' occurred that could have led to a higher category.	16
ENV28	There has been an unplanned entry into an ECO condition.	29
ENV99	Something of environmental interest that merits recording.	282
Total environmental events		**332**

Environmental events that require reporting to a regulatory body form one of the key performance indicators for EDF Energy NGL and events are taken very seriously at all levels of the organisation.

During 2017, there were three ENV05 events that required reporting to the regulator, these being statistically significant (4 sigma) results for sulphur-35 in herbage samples. The first two events were from results at Farm 20 and 23 in Q1 2017. The external analytical laboratory where the samples were analysed had a problem with their chemical preparation which led to an anomalous result. A second analysis proved unsuccessful due to the time passed since the sample was taken so the original result was used. The third event was a true deviation as the sampling location nearest the Hinkley Point B site saw elevated sulphur-35 following a large number of planned blowdowns during a reactor outage in the summer. The subsequent analysis from that sampling location showed that results had returned to normal levels.

Good progress continues to be made against the objectives set down in the EDF NGL Environmental Policy statement and monitoring against specific performance targets is used to support this. The environmental key performance indicators (KPI) set by Hinkley Point B are detailed in Table 2

Table 2 KPI data for 2017.

KPI #	Objective	Information	Status
1	To have zero environmental events with reporting categories of ENV01, ENV02 and ENV03A	ENV01, ENV02 and ENV03A are of the highest significance and associated with some environmental impact. These events are reportable due to their significance. During 2017, there were no events in these categories.	0
2	To have no more than two environmental occurrences with reporting categories of ENV03B or ENV04.	ENV03B and ENV04 record breaches of permits or legislation which have no physical environmental impact. During 2017 there was one ENV04 event. An FDT tank was discharged outside of the process when the cobalt-60 assessment was not performed prior to the discharge.	1
3	Send less than 1% of non-radioactive waste generated to landfill	In 2017 we moved to a new waste contractor for dry mixed recyclable waste which we hope will improve our future recycling rates.	1.3%
4	Have no more than 27 unplanned ESPEC entries.	There was a significant number of unplanned ESPEC entries due to issues with tank level gauges. These were investigated and rectified.	29
5	Have more than 250 environmental occurrences with reporting categories of ENV99 or ENV06.		298
6	Have an RWFI score > 97	The programme for consigning solid radioactive waste	100
7	Implement solid radioactive waste segregation at source.	The trial was completed in the gas circulator workshop in June and the process has been adapted for other areas.	Trial complete. On target for implementation.
8	Environmental project: HPA sea discharge line clean and seal.	One pit cleaned in 2017 and all activity not removed.	Strategy being reviewed in 2018.
9	Environmental project: Computer hardware at Combwich laboratory.	Improved bandwidth at Combwich and new software completed. New PC's and specialist software outstanding.	Complex project with many inter-dependencies.
10	Environmental project: Gas circulator settling tank trench pipework upgrade.	Preparatory works and installation of secondary containment pipework completed in 2017.	Connection to be completed in 2018.

2 Hinkley Point B Liquid Effluent Discharges

The HPB environmental permit authorises tritium, sulphur-35, cobalt-60, caesium-137 and other radionuclides to be disposed via specific outlets as liquid effluent discharges. Table 3 shows the annual and monthly discharges of each permitted radionuclide with the respective permit discharge limits.

Table 3 Total liquid discharges in 2017.

Month	Tritium Activity (TBq)	Sulphur-35 Activity (TBq)	Cobalt-60 Activity (GBq)	Caesium-137 Activity (GBq)	Other Activity (GBq)
January	19.3	0.027	0.003	0.11	0.32
February	20.9	0.024	0.014	0.10	0.44
March	6.9	0.008	0.003	0.08	0.11
April	23.3	0.023	0.011	0.14	0.32
May	19.0	0.018	0.010	0.25	0.27
June	30.4	0.028	0.005	0.13	0.30
July	16.8	0.021	0.006	0.08	0.20
August	24.4	0.027	0.005	0.08	0.28
September	24.4	0.024	0.006	0.07	0.29
October	15.9	0.013	0.006	0.06	0.21
November	30.5	0.033	0.005	0.04	0.41
December	22.8	0.022	0.005	0.02	0.28
Annual Total (2017)	254.6	0.268	0.079	1.14	3.43
Annual Total (2016)	239.1	0.260	0.233	1.07	3.70
Annual Authorisation Limit	**650**	**2**	**10**	**100**	**80**

2.1 Liquid Tritium (H-3)

Tritium has a half-life of 12.3 years and the annual discharge limit for liquid tritium discharges at HPB is 650 TBq.

Tritium occurs naturally in the environment. In AGR power stations, it is produced in the reactor core by the neutron irradiation of small quantities of lithium present in the graphite and via the fission process. The main source of tritium discharged is from water extracted from the gas coolant by the gas bypass plant dryers. The quantity discharged depends on the burn-up of the lithium in the core, the reactor power, operating time and the gas chemistry requirements.

Liquid tritium discharges over the previous five years are illustrated in Figure 3.

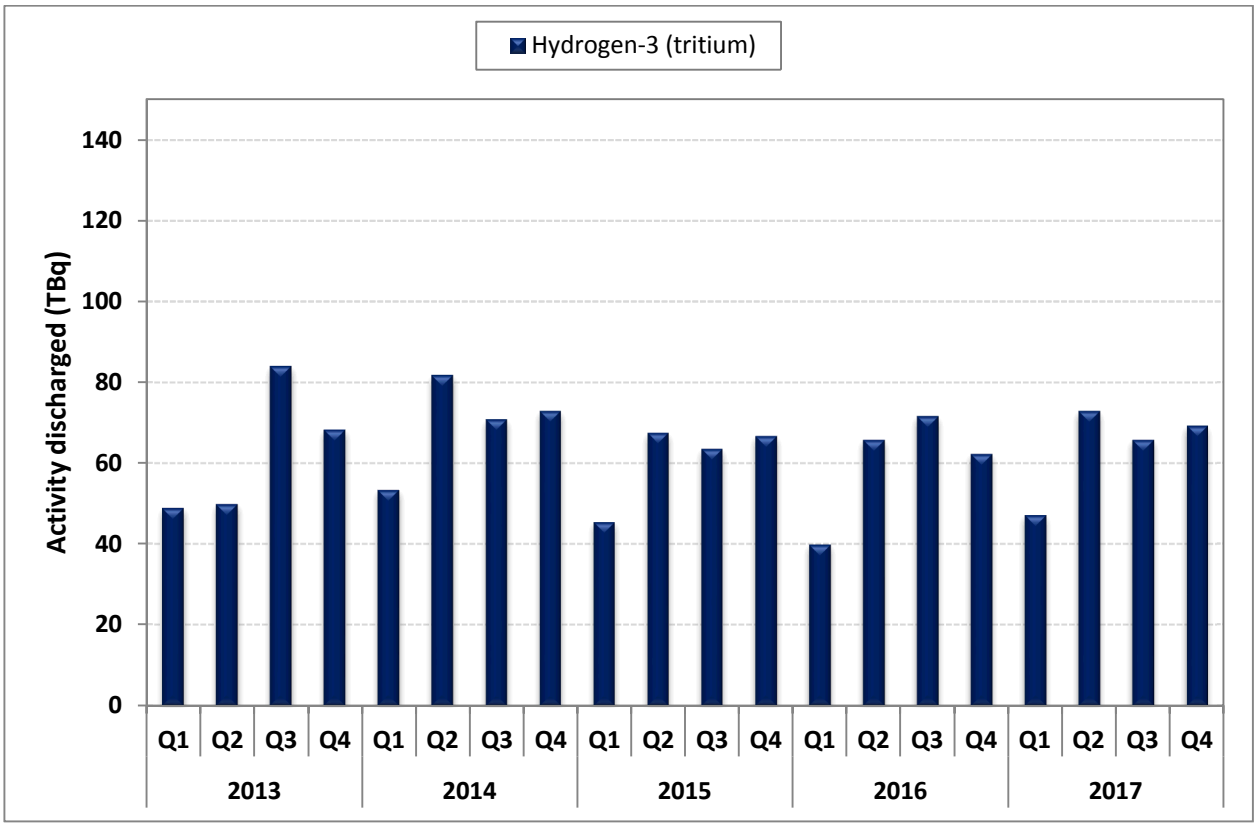

Figure 3 Liquid tritium discharges 2013-2017.

The tritium discharges show no adverse trends during the period and tend to follow normal plant operations.

2.2 Liquid Sulphur (S-35)

Sulphur-35 has a half-life of 87 days and the annual discharge limit for liquid sulphur-35 discharges at HPB is 2 TBq.

In AGR power stations, sulphur-35 is produced as a result of the irradiation of stable chlorine or sulphur that exists as impurities within the graphite or from oil deposits in the reactor and the gas circuits. The principle source of sulphur-35 in the reactor originates from small quantities of chlorine impurities present in the graphite core and in the sleeve of the fuel elements. The sulphur then combines with carbon dioxide and carbon monoxide to produce gaseous carbonyl sulphide. This is removed by the gas bypass plant dryers and condensed into a dischargeable liquid effluent.

Liquid sulphur-35 discharges over the previous five years are illustrated in Figure 4.

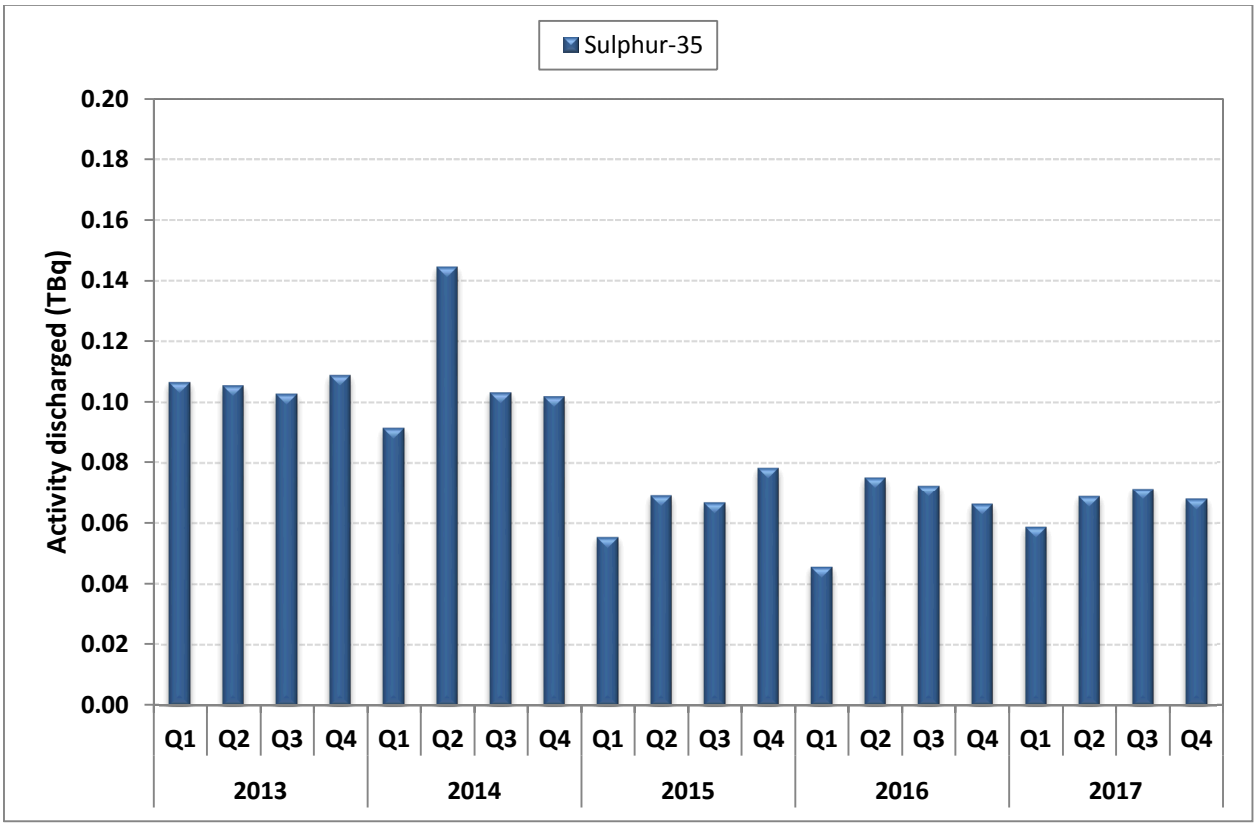

Figure 4 Liquid sulphur-35 discharges 2013-2017.

There were higher than average sulphur-35 discharges during the second quarter of 2014 which was due to a tritiated water discharge tank (TWST) discharge being above the action level. The gas bypass plant had been isolated for maintenance causing fluctuations in gas flows. This caused adsorbed sulphur-35 to become mobile in the gaseous circuit and be removed by the gas bypass plant dryers, elevating the specific activity of the extracted liquid. The slight decrease in the average sulphur-35 from 2015 onwards aligns with changes to operational procedures to minimise sulphur being desorbed into the gas circuit.

2.3 Liquid Cobalt (Co-60)

Cobalt-60 has a half-life of just over 5 years and the annual discharge limit for liquid cobalt-60 discharges at HPB is 10 GBq.

Cobalt-60 arises predominantly from the active effluent treatment plant (AETP) where it has originated from surface contamination on fuel elements.

Liquid cobalt-60 discharges over the previous five years are illustrated in Figure 5.

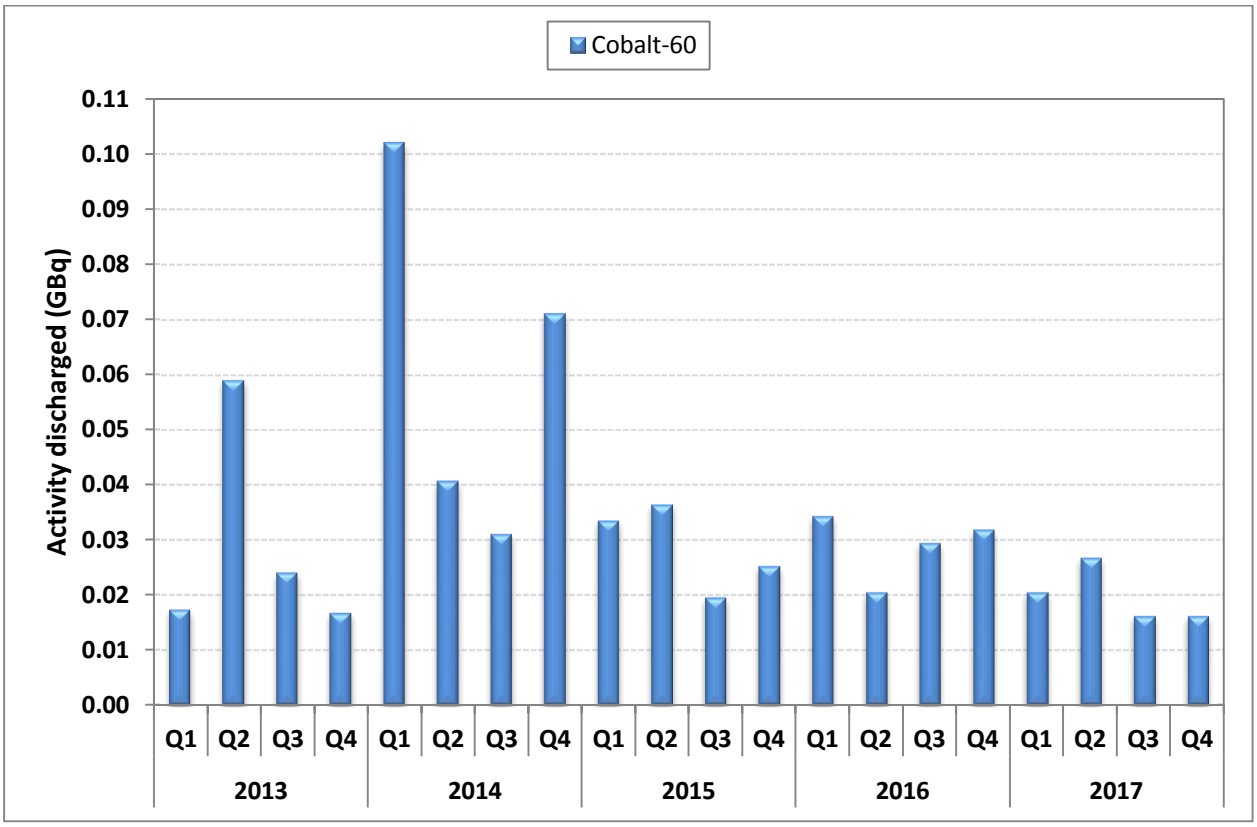

Figure 5 Liquid cobalt-60 discharges 2013-2017.

The general cobalt-60 peaks are associated with the transfer of supernatant effluent to the final delay tanks and backwashing of funda filters which are part of the entrapment process of particulate in the AETP. The elevated reading in quarter 1 2014 was due to pond water leaking into the backwash tank after the funda filter had been cleaned. Additionally, there was a supernatant tank discharged that month, increasing the amount of aqueous cobalt-60 discharged.

2.4 Liquid Caesium (Cs-137)

Caesium-137 has a half-life of 30.1 years and the annual discharge limit for liquid caesium-137 discharges at HPB is 100 GBq.

Caesium-137 is a fission product and the majority of caesium-137 discharges are associated with routine pond water treatment plant operations.

Liquid caesium-137 discharges over the previous five years are illustrated in Figure 6.

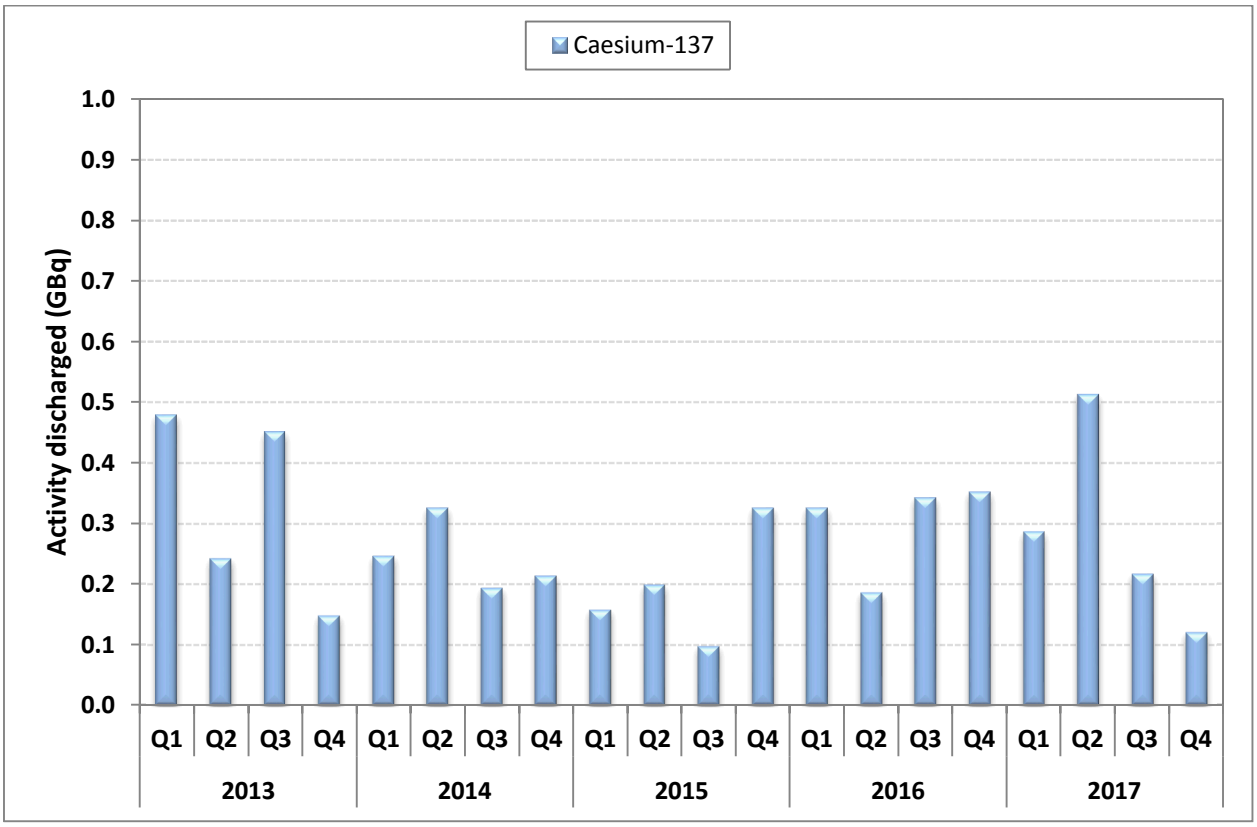

Figure 6 Liquid caesium-137 discharges 2013-2017.

The general trend follows operational activities. The slight elevation as in Q2 2017 followed two reactor outages that required an increased number of discharges in that period.

2.5 Liquid Other Activity (excluding H-3, S-35, Co-60 & Cs-137)

The 'other activity' present in liquid discharges is defined as a gross measurement of radioactivity present in the effluent that has not already been accounted for within the measurements for the named nuclides tritium, sulphur-35, cobalt-60 and caesium-137. The annual limit for liquid other activity discharges at HPB is 80 GBq.

Liquid other activity discharges over the previous five years are illustrated in Figure 7.

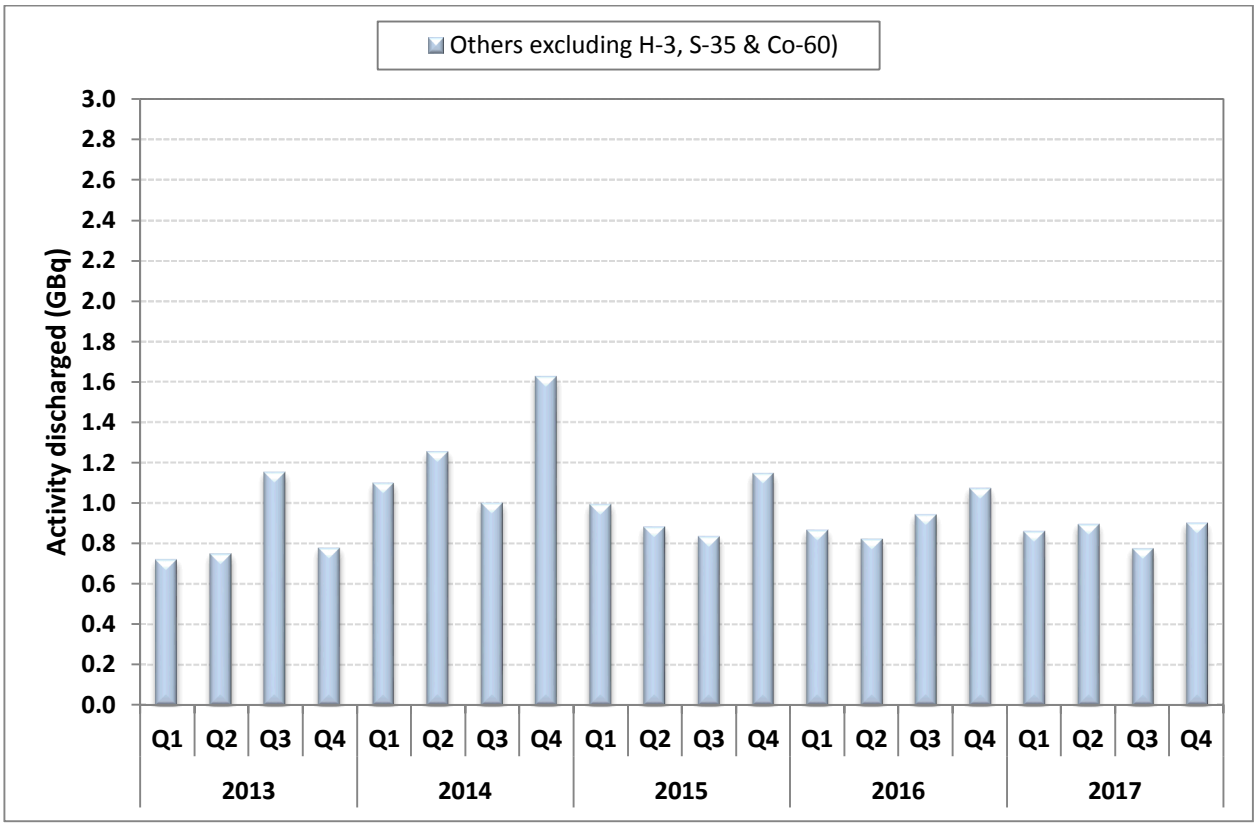

Figure 7 Liquid other activity discharges 2013-2017.

The general background trend follows operational activities. Slight elevations such as in Q4 2014 are attributed to periods where larger volumes of discharges were being made.

3 Hinkley Point B Gaseous Effluent Discharges

The HPB environmental permit authorises tritium, carbon-14, sulphur-35, argon-41, iodine-131 and cobalt-60 (associated with particulate matter) to be disposed via specific outlets as gaseous effluent discharges. Table 4 shows the annual and monthly discharges of each permitted radionuclide with the respective permit discharge limits.

Table 4 Total gaseous discharges in 2017.

Month	Tritium Activity (TBq)	Carbon-14 Activity (TBq)	Sulphur-35 Activity (GBq)	Argon-41 Activity (TBq)	Iodine-131 Activity (GBq)	Cobalt-60 Particulate Activity (MBq)
January	0.08	0.12	7.3	0.9	0.00035	0.65
February	0.10	0.29	8.4	1.1	0.00042	0.57
March	0.08	0.16	5.1	0.6	0.00044	0.76
April	0.10	0.06	4.9	0.9	0.00033	0.61
May	0.13	0.26	6.7	0.9	0.00039	0.74
June	0.13	0.07	6.1	1.1	0.00036	0.63
July	0.13	0.10	7.1	1.6	0.00037	0.64
August	0.15	0.28	17.4	2.0	0.00037	0.69
September	0.11	0.06	5.0	1.0	0.00034	0.64
October	0.10	0.09	6.2	0.9	0.00038	0.65
November	0.10	0.14	5.0	1.4	0.00035	0.67
December	0.10	0.09	6.4	0.9	0.00044	0.77
Annual Total (2017)	1.31	1.70	85.7	13.2	0.0045	8.01
Annual Total (2016)	1.34	1.39	71	11.9	0.0048	8.49
Annual Authorisation Limit	**12**	**3.7**	**350**	**100**	**1.5**	**100**

3.1 Gaseous Tritium (H-3)

Tritium has a half-life of 12.3 years and the annual discharge limit for gaseous tritium discharges at HPB is 12 TBq.

Tritium is one of the most abundant radionuclides present in the reactor coolant gas. It arises mainly from the ternary fission processes inside the fuel followed by diffusion through the fuel pin cladding into the coolant gas. The production rate for tritium therefore mainly depends on reactor power. As more than 99% of the tritium in the reactor gas is removed as water via the gas bypass plant, gaseous discharges of tritium are far smaller. Liquid discharges are less radiologically significant than gaseous discharges, and therefore a better environmental option.

The main chemical form of tritium is water vapour and it is therefore a gas that will not be trapped by filtration systems. The quantity of tritium that exists in coolant gas at any one time is dependent on coolant chemistry requirements at particular operational states. The chemistry is controlled by the ratio of moisture, methane and carbon monoxide in the coolant gas which balances the rate of graphite core oxidation against excessive carbon deposition on the boilers.

Gaseous tritium discharges over the previous five years are illustrated in Figure 8.

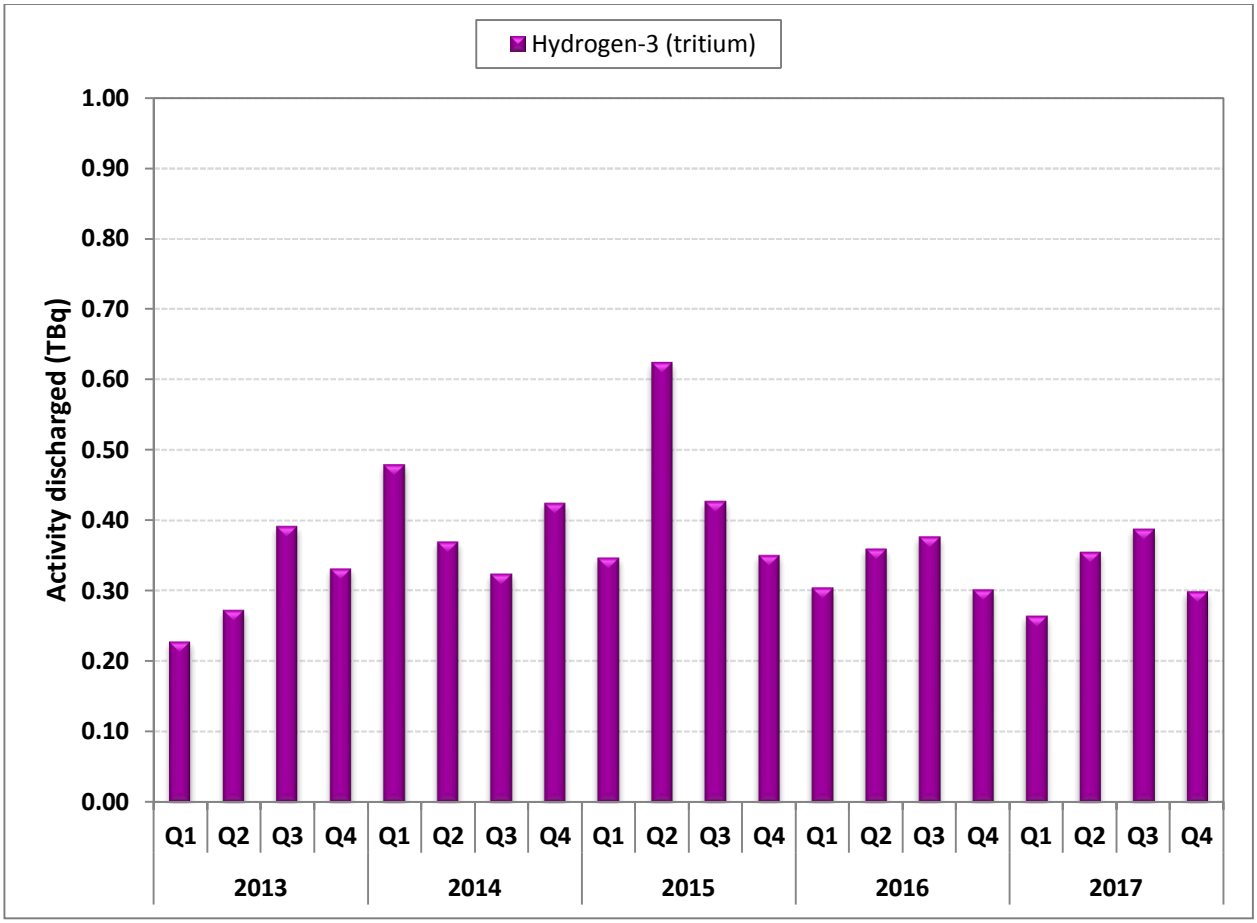

Figure 8 Gaseous tritium discharges 2013-2017.

The tritium discharge levels fluctuate around an average dependent on operational activities such as the peak in Q2 2015 where a gas bypass plant fault required additional moisture to be removed from the coolant gas leading to an elevated discharge.

3.2 Gaseous Carbon (C-14)

Carbon-14 has a half-life of 5730 years and the annual discharge limit for gaseous carbon-14 discharges at HPB is 3.7 TBq.

Carbon-14 is either produced via the neutron activation of carbon, nitrogen and oxygen in the coolant gas or via the neutron activation of carbon and nitrogen in the graphite core. Once within the coolant gas, activation of nitrogen impurities is potentially the major contributor to carbon-14 production. Furthermore, due to the continued operation, the proportion of carbon-14 in the core increases due to ongoing neutron activation. All carbon-14 discharged to atmosphere is associated with the loss of reactor coolant gas and is discharged as carbon dioxide containing carbon-14.

Gaseous carbon-14 discharges over the previous five years are illustrated in Figure 9.

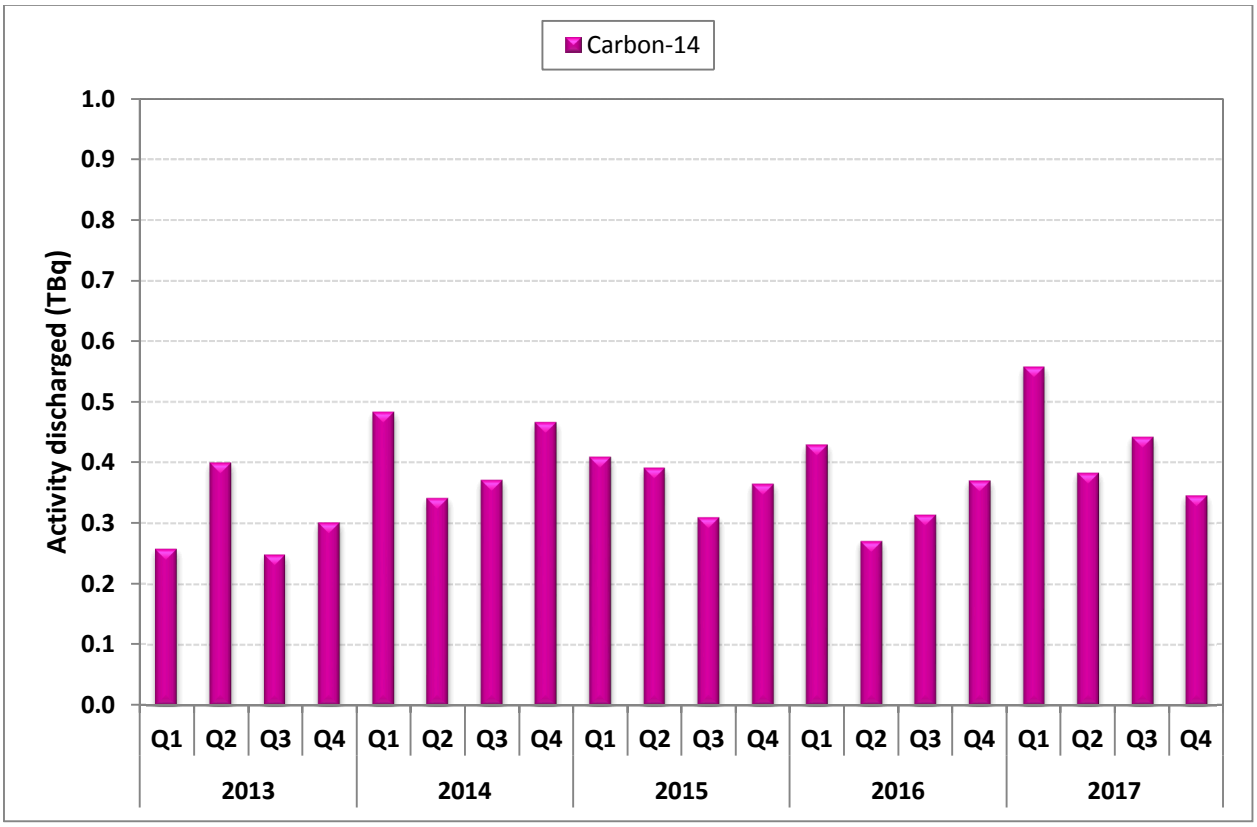

Figure 9 Gaseous carbon-14 discharges 2013-2017.

The general fluctuations in the discharges follow outage and operational blowdowns of the two reactors such as in Q1 2014 and Q1 2017.

3.3 Gaseous Sulphur (S-35)

Sulphur-35 has a half-life of 87 years and the annual discharge limit for gaseous sulphur-35 discharges at HPB is 350 GBq.

In AGR power stations, sulphur-35 is produced as a result of the irradiation of stable chlorine or sulphur that exists as impurities within the graphite or from oil deposits in the reactor and the gas circuits. The principle source of sulphur-35 in the reactor originates from small quantities of chlorine impurities present in the graphite core and in the sleeve of the fuel elements. The sulphur then combines with carbon dioxide and carbon monoxide to produce gaseous carbonyl sulphide which can be released from the reactor during normal operational activities and planned blowdowns.

Gaseous sulphur-35 discharges over the previous five years are illustrated in Figure 10.

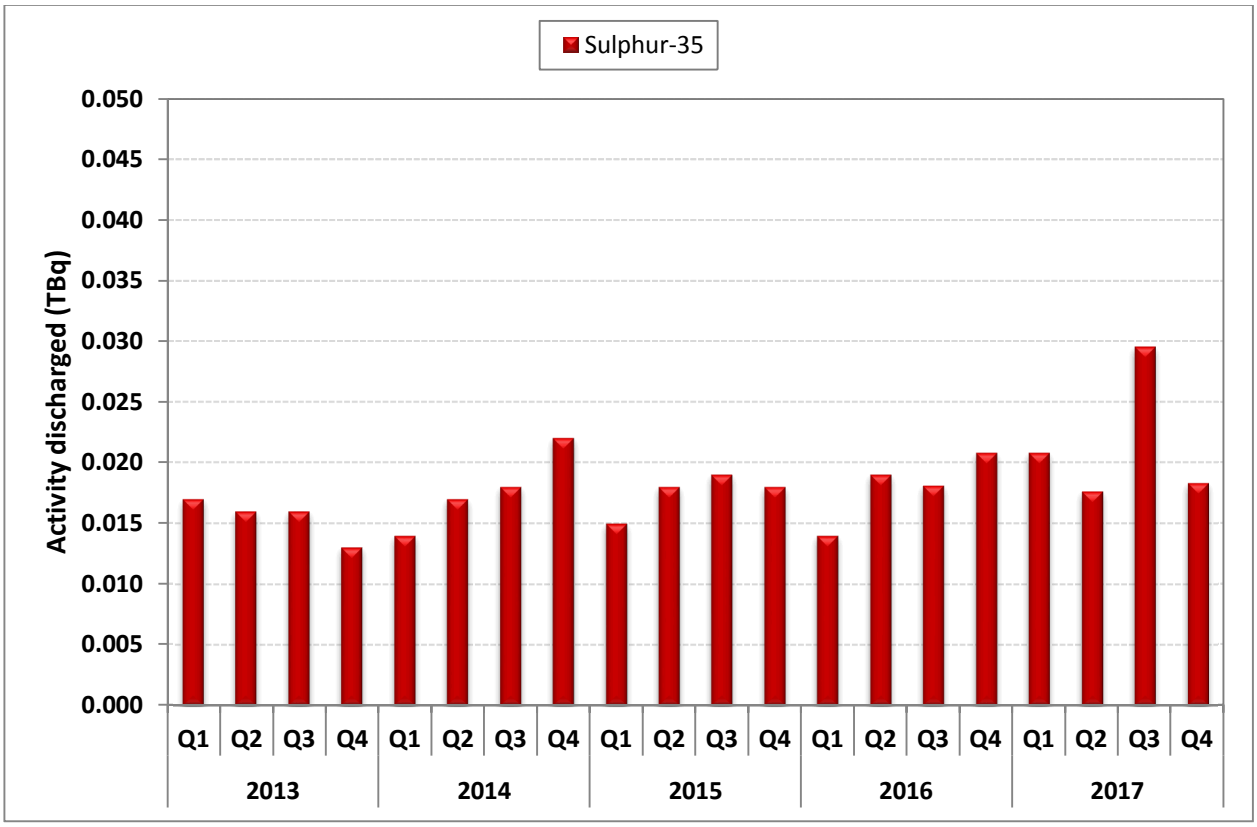

Figure 10 Gaseous sulphur-35 discharges 2013-2017.

The general baseline fluctuations can be matched to operational activities and planned reactor blowdowns during outage periods. The peak in Q3 2017 was due to an extended reactor shutdown which required a number of blowdowns of the reactor in a short period.

3.4 Gaseous Argon (Ar-41)

Argon-41 has a half-life of 110 minutes and the annual discharge limit for gaseous argon-41 discharges at HPB is 100 TBq.

Argon-41 is produced in the reactor by neutron activation of naturally occurring non-radioactive argon-40 that is present in the coolant gas as a contaminant from residual air and other bulk gases. Care is taken to exclude argon impurities in the coolant gas which will therefore minimise potential discharges. Due to its short half-life, argon-41 discharges are directly proportional to reactor power and the quantity of coolant gas being discharged.

Gaseous argon-41 discharges over the previous five years are illustrated in Figure 11.

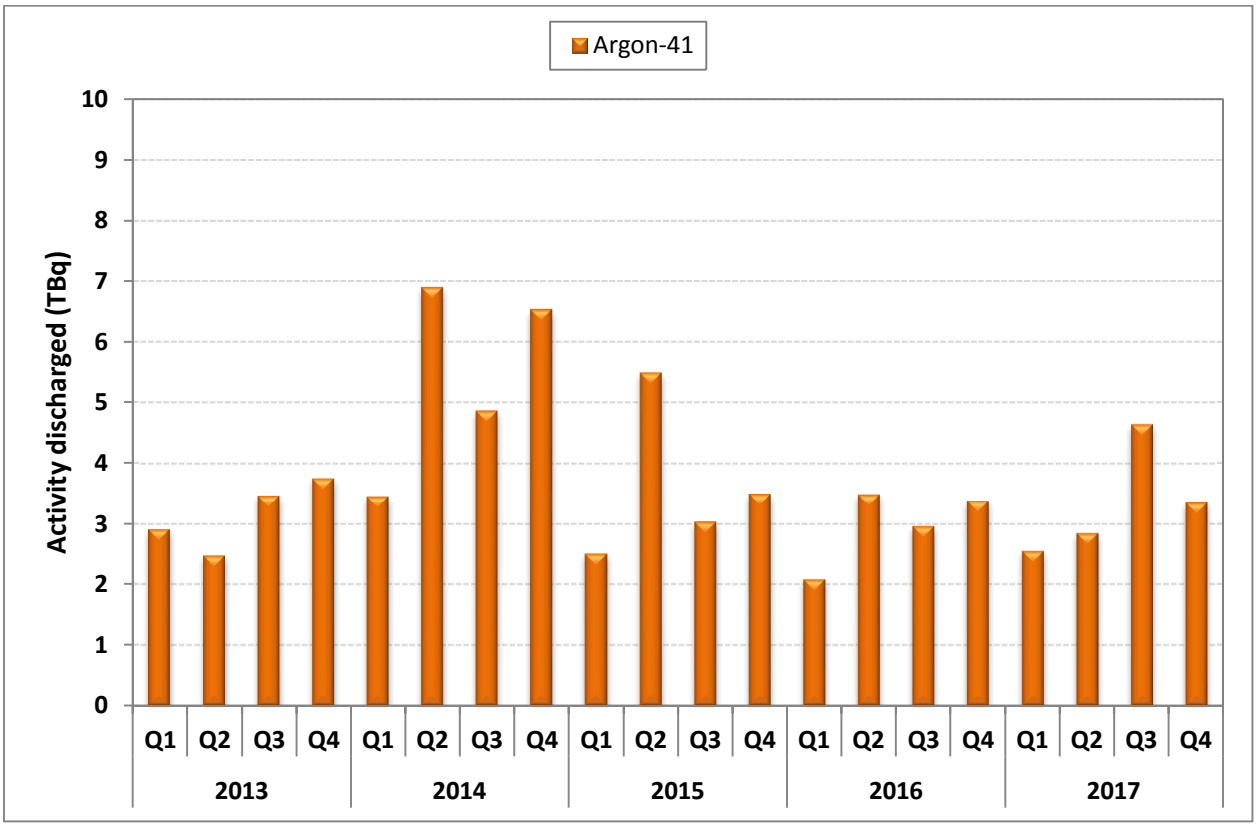

Figure 11 Gaseous argon-41 discharges 2013-2017.

The argon-41 discharges tend to follow operational activities. The slightly above average results in 2014, Q2 2015 and Q3 2017 were due to a reactor interim outage, gas bypass plant fault and a forced outage respectively.

3.5 Gaseous Iodine (I-131)

Iodine-131 has a half-life of just over 8 days and the annual discharge limit for gaseous iodine-131 discharges at HPB is 1.5 GBq.

Iodine-131 is a fission product that remains inside the fuel unless there is a failure in the fuel cladding. If the cladding were to be breached, it would be detected by reactor instrumentation and reactor gas sampling, enabling measures to be put in place to minimise gaseous discharges. In addition, discharges of reactor coolant gas are routinely passed over iodine adsorption beds containing activated charcoal which are tested to ensure they meet the required efficiency, minimising discharges to the atmosphere.

Gaseous iodine-131 discharges over the previous five years are illustrated in Figure 12.

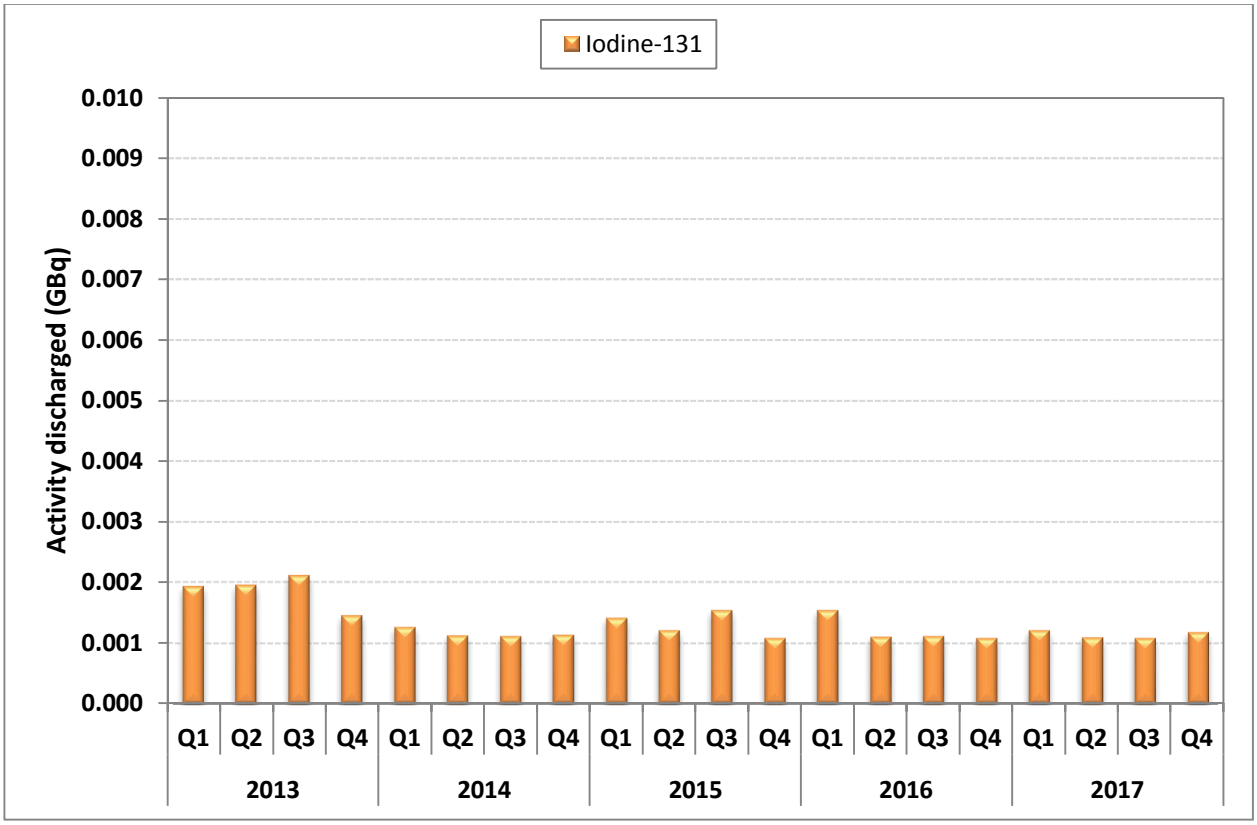

Figure 12 Gaseous iodine-131 discharges 2013-2017.

Discharges are reasonably constant as most results are at the Minimum Detectable Activity (MDA).

3.6 Gaseous Particulate Activity (Co-60)

Cobalt-60 has a half-life of just over 5 years and the annual discharge limit for gaseous cobalt-60 discharges associated with particulate matter at HPB is 100 MBq.

Cobalt-60 is produced by neutron activation of cobalt-59 within steel components. Whilst most cobalt-60 remains immobile within these steel components, it can become mobile by mechanisms such as corrosion and erosion and be released into the reactor coolant gas. Corrosion is minimised by strict reactor coolant chemistry. Discharges of cobalt-60 associated with particulate matter are further minimised by filtration systems on routes subject to reactor gas and contaminated ventilation air with the main discharge points being:

- Contaminated ventilation systems which discharge ventilation air from many places around each reactor and from the central block. This route is also used for minor carbon dioxide discharges from the reactors to adjust reactor pressures or purity of the gas coolant.

- The reactor blowdown stack used for major discharges of carbon dioxide by reactor depressurisation.

Gaseous iodine-131 discharges over the previous five years are illustrated in Figure 13.

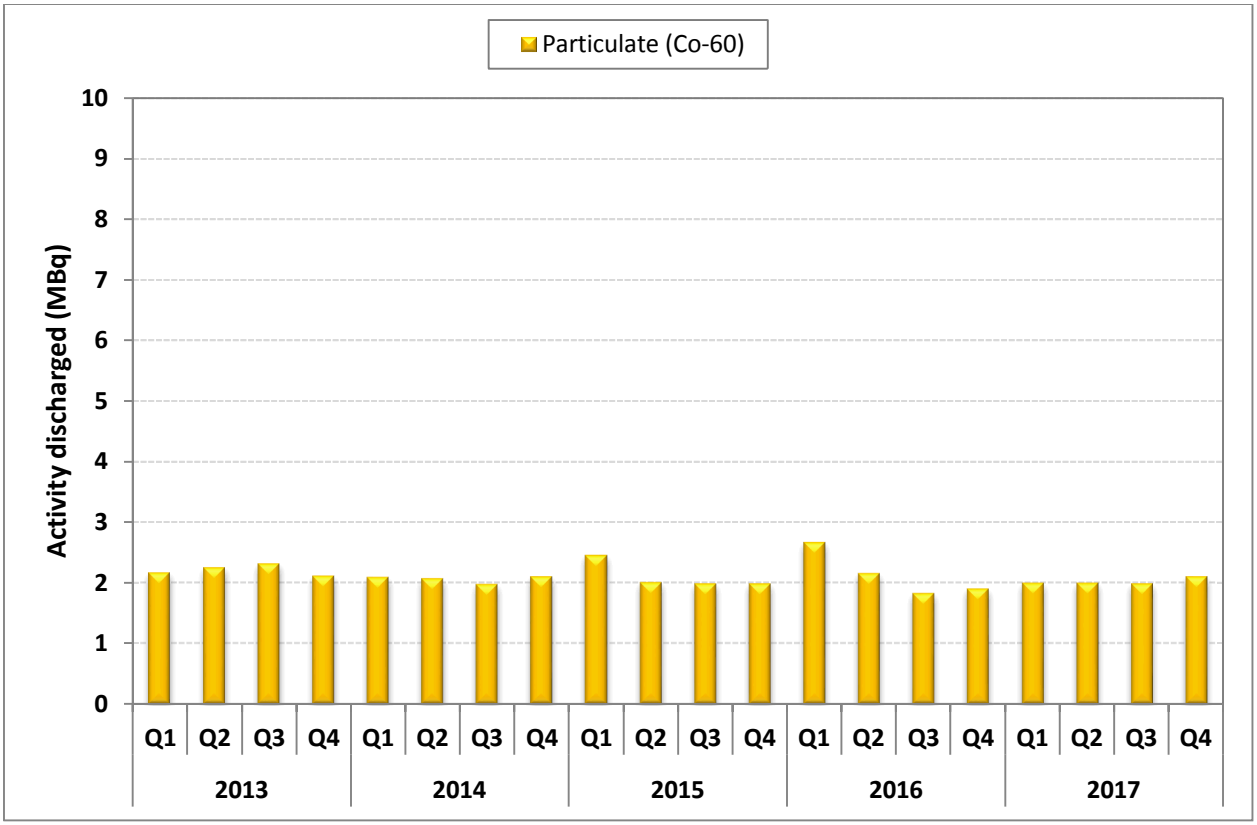

Figure 13 Gaseous cobalt-60 discharges (particulate) 2013-2017.

The levels of activity are normally very small and vary little under normal operating conditions.

4 District Survey Monitoring

A substantial number of samples are taken from various reference points around the areas surrounding Hinkley Point B. The analysis ensures that any impact that the operation of the power station may have on the environment is adequately monitored according to the company procedures and the environmental permit. The district survey monitoring data, along with habit surveys of the local area are used to create a company dose model for the critical population. It is also utilised by the Centre for Environment, Fisheries and Aquaculture Science for their annual report on radioactive doses to members of the public.

4.1 Beach Dose Rates

The presence of radionuclides in sediments and soils can make a significant contribution to the total exposure to members of the public. For this reason, the estimation of 'external dose' is assessed by measuring gamma dose rates at specific locations.

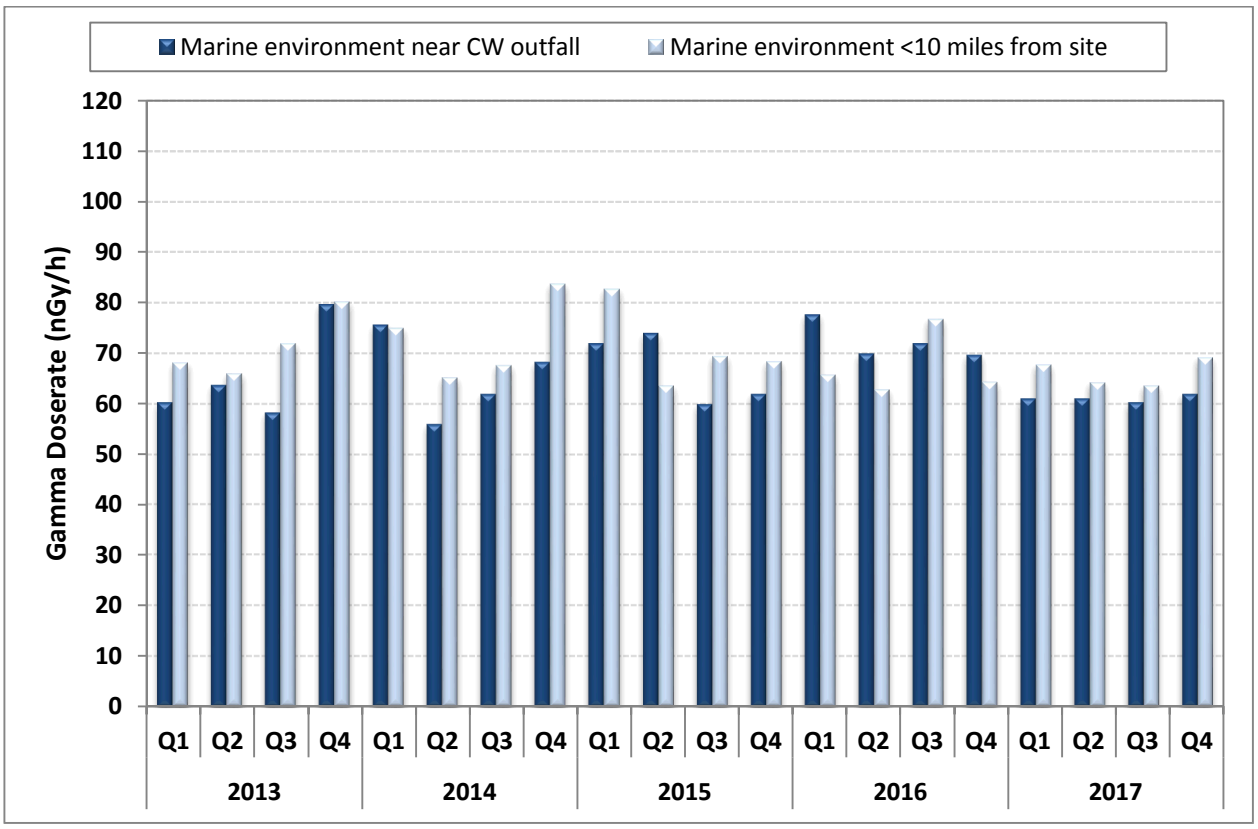

Figure 14 Gamma radiation monitoring on the beach.

The results in Figure 14 show the gamma dose rate in the vicinity of the cooling water (CW) outfall at HPB. The dose rate has remained fairly stable over the past 5 years with an average dose rate of approximately 65nGy/h. The major contribution to the observed gamma dose rate is from natural sources rather than radioactive discharges from HPB. This includes cosmic rays and naturally occurring radionuclides in the sediment and rocks. A better indication of the impact of liquid discharges on beach sediment can be seen from the caesium-137 activity concentrations shown in Figure 19.

Figure 14 also shows dose rates within a 10 mile radius from site. These results are a mean of ten separate measurements taken at a range of different sites. Although the dose rates vary

slightly between individual sites depending on the geology there is no significant difference between the average dose rate at these points and those that are near to the outfall.

The average beach gamma dose rates for 2017 are shown in Table 5. The average dose rate measured close to the outfall is similar to the ambient background due to the reduction in direct radiation since the shutdown of the reactors at the Hinkley Point A site. More specifically, the contribution from caesium-137 (assuming a typical activity concentration of 40 Bq/kg) is just 4.5nGy/hr or less than 10% of the observed dose rates. This illustrates that the majority of the gamma dose rate is due to background cosmic radiation combined with the presence of natural series radionuclides in the sediment.

Table 5 Average beach gamma dose rates for 2017.

Site		Number of Observations	Mean Gamma Dose Rate (nGy/h)
Near	47	4	64
	49	4	53
	50	4	67
<10 miles	51	4	57
	52	4	77
	53	4	59
	54	4	61
	56	4	78
	58	4	63
	59	4	71

4.2 Marine Sampling

Fish, shrimp, seaweed and sediment are all collected from a number of locations around the locality and analysed under the marine district survey programme each quarter. The results of gross beta and caesium-137 activity concentrations for each of the sampling locations are shown in Table 6.

Table 6 Average activity concentrations in marine samples during 2017.

Sample	Sampling Location	Units	Gross Beta	Caesium-137
Bottom Feeding Fish	51	Bq/kg wet	105	0.43
Free Swimming Fish	51	Bq/kg wet	79	0.41
Shrimp	51	Bq/kg wet	70	0.33
Sediment	47	Bq/kg dry	650	9.5
Sediment	49	Bq/kg dry	842	16.2
Sediment	50	Bq/kg dry	785	11.6
Sediment	51	Bq/kg dry	713	11.8
Sediment	52	Bq/kg dry	844	14.6
Sediment	53	Bq/kg dry	685	11.1
Sediment	54	Bq/kg dry	856	10.0
Sediment	55	Bq/kg dry	743	12.7
Sediment	56	Bq/kg dry	868	15.0
Sediment	58	Bq/kg dry	978	20.8
Sediment	59	Bq/kg dry	927	15.3
Seaweed	47	Bq/kg wet	204	0.38
Seaweed	49	Bq/kg wet	205	0.38
Seaweed	50	Bq/kg wet	208	0.36
Seaweed	51	Bq/kg wet	189	0.39
Seaweed	52	Bq/kg wet	212	0.29
Seaweed	54	Bq/kg wet	254	0.29
Seaweed	55	Bq/kg wet	215	0.38

Demersal (bottom feeding) and pelagic (free swimming) fish that are caught close to Hinkley Point by a local fisherman are analysed for the activity concentration of the single gamma emitting radionuclide caesium-137. Results for caesium-137 in both types of fish are shown in Figure 15. In some samples, the results were below the MDA and therefore the values used in this report represent maximum estimates. The activity concentration is shown to be stable over the past 5 years with small decreases in activity corresponding to a reduction in the amount of caesium-137 discharged from the Hinkley Point A site.

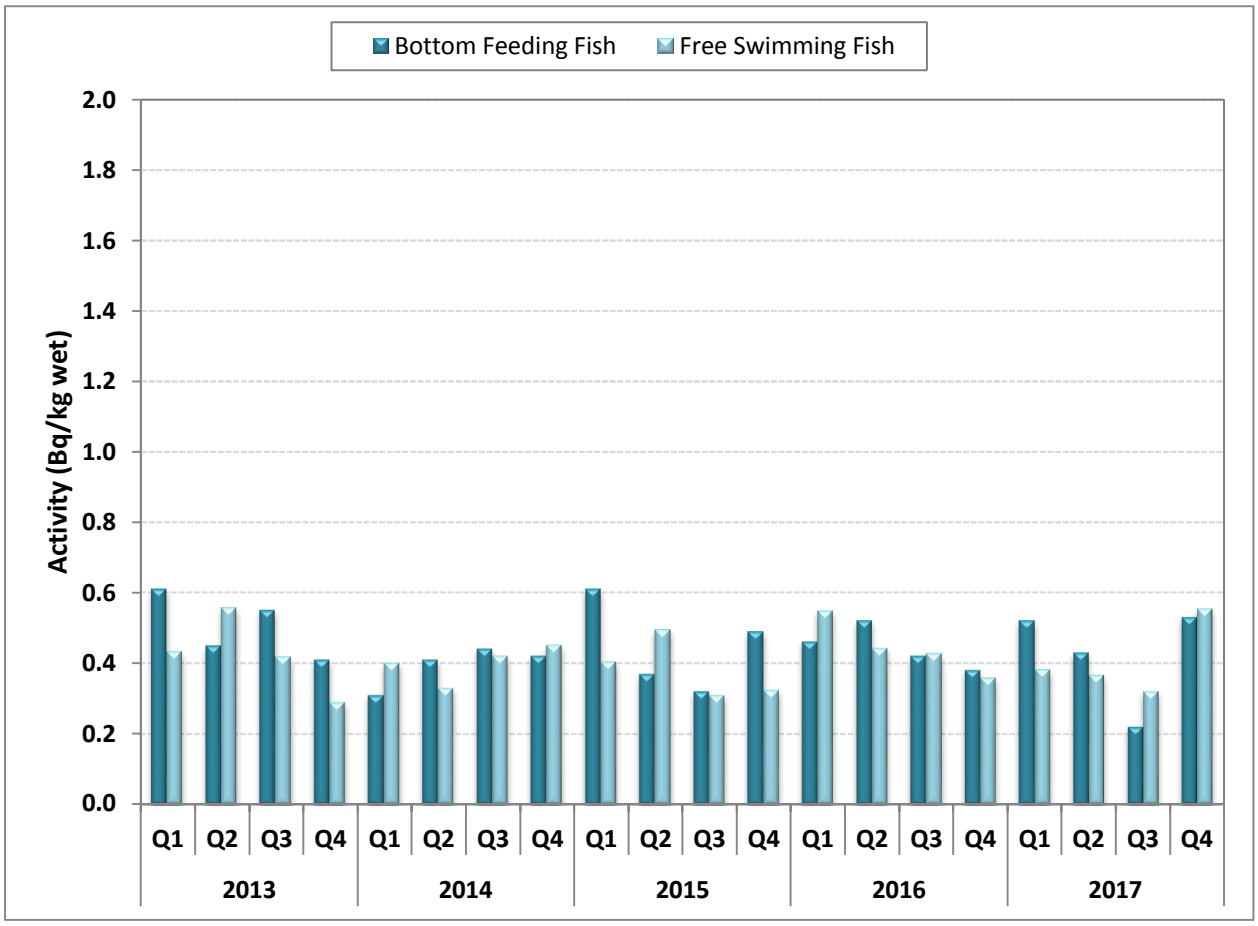

Figure 15 Ceasium-137 activity in bottom feeding and free swimming fish.

Measurements are also carried out to assess total beta activity in fish for reassurance purposes. The predominant contribution to the total beta activity is provided by the naturally occurring radionuclide potassium-40. In 2017, values for gross beta activity of demersal and pelagic fish were in the range ~53 to 121 Bq/kg wet weigh, considerably greater than those for caesium 137.

The sole gamma emitting artificial radionuclide that was positively detected in shrimps caught close to Hinkley Point was caesium-137. The data shown in Figure 16 indicates that caesium-137 activity concentrations in shrimp are similar to those observed in fish samples (Figure 15). Measurements of gross beta activity are also carried out on shrimp and were in the range of 46 to 86 Bq/kg (wet weight). Similarly to the fish data, the major contribution to gross beta activity was due to the presence of the naturally occurring potassium-40 radionuclide, with levels considerably greater than those for caesium-137.

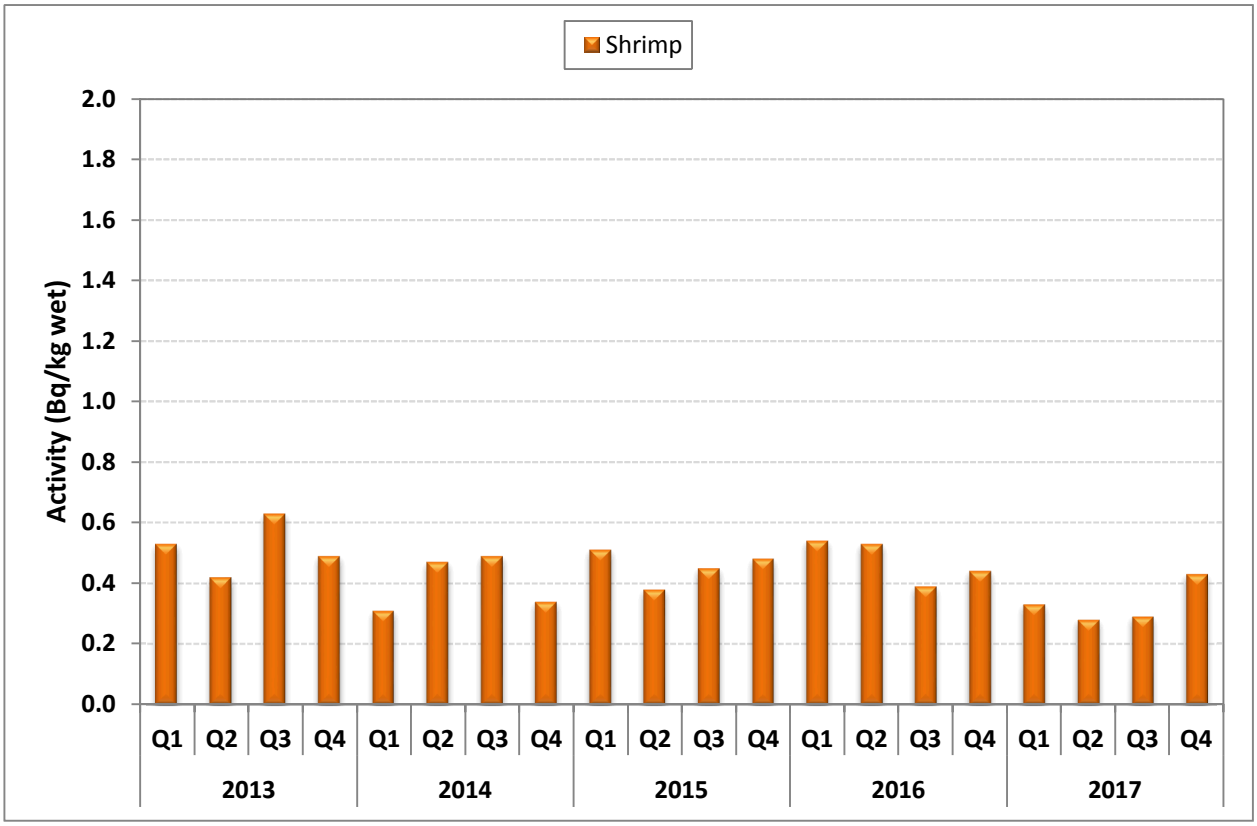

Figure 16 Ceasium-137 activity in shrimp.

Seaweed is collected from 3 locations near the HPB cooling water outfall and from beaches within 10 miles from the site. A particular variety of seaweed, Bladderwrack (*Fucus Vesiculosis)* shown in Figure 17 is collected. In addition to occasional use in foods and as fertilisers, seaweeds are useful as indicator materials in an environmental monitoring programme because they effectively concentrate radionuclides.

Figure 17 Bladderwrack seaweed.

The sole gamma emitting artificial radionuclide that was positively detected in seaweed was caesium-137. Measurements of gross beta activity were once again assessed for reassurance purposes. The gross beta activity in seaweed close to the HPB cooling water outfall in 2017 was in the range of 144 to 234 Bq/kg (wet weight). The predominant contribution was due to the presence of the naturally occurring potassium-40 radionuclide, with levels considerably greater than those for caesium-137. The data from seaweed analysis over the previous 5 years is shown in Figure 18.

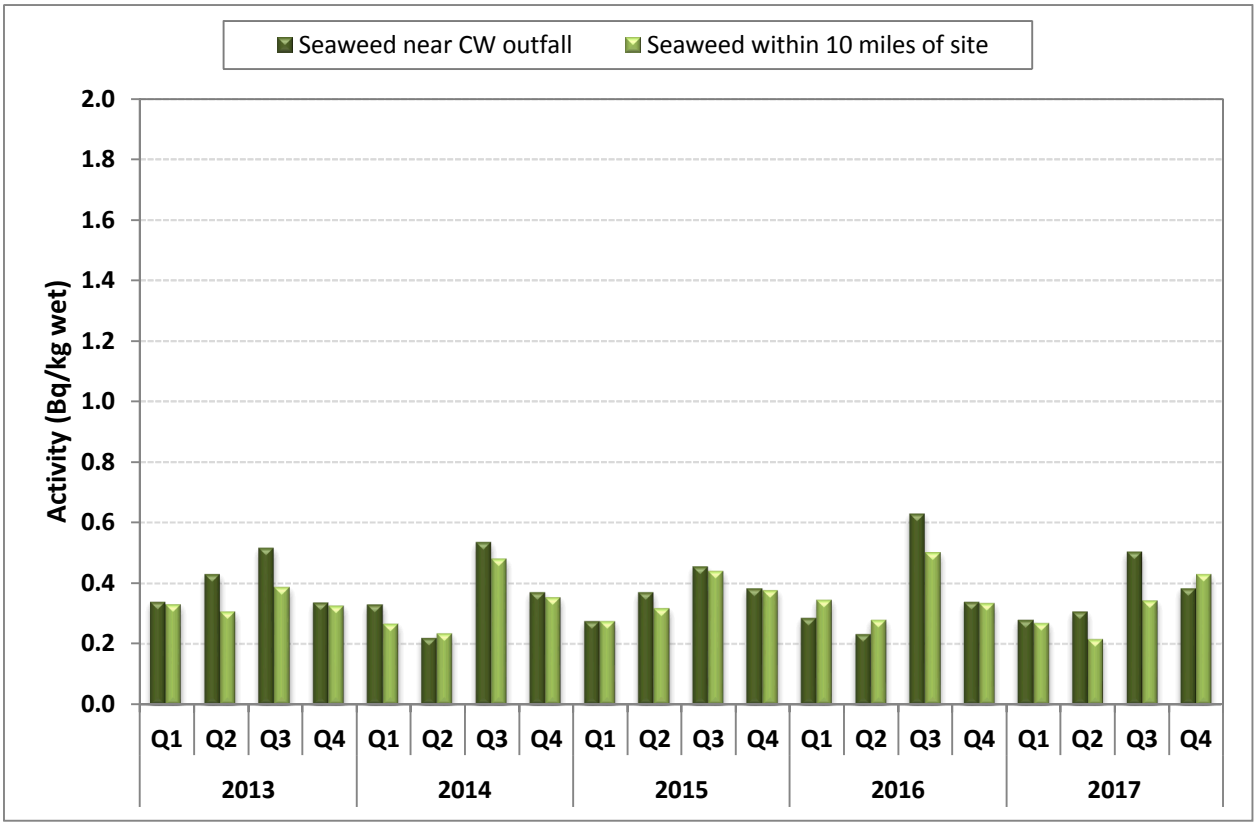

Figure 18 Ceasium-137 activity in seaweed

The caesium-137 activity concentration appears broadly stable over the period considered here albeit that, due to the low levels, there is some scatter in the data. Although maximum activity concentrations have been observed in samples obtained closest to the outfall, there is no consistent trend apparent within the inevitable scatter inherent in a series of low level data. It is therefore considered that both sets of results are similar.

Like seaweed, sediment is a useful indicator material in an environmental monitoring programme because it effectively concentrates radionuclides. The presence of radionuclides in sediment can make a significant contribution to the total exposure of members of the public, via the external exposure pathway. The sole gamma emitting artificial radionuclide that was positively detected in sediment in the vicinity of Hinkley Point was caesium-137.

Samples of sediment are collected from 3 locations near the HPB cooling water outfall and from beaches within 10 miles of the site. Data in Figure 19 shows the average caesium-137 concentration in sediment. The range of activity concentrations is broadly similar for both sets of samples, although as expected, the actual activity in the samples within 10 miles of site is generally less than the activities present at the HPB cooling water outfall.

Measurements of gross beta activity are also undertaken and values for sediment close to the cooling water outfall in 2017 were in the range of 608 to 833 Bq/kg (dry weight). The predominant contribution was due to the presence of natural radionuclides including potassium-40 and beta emitters in the uranium-238 and thorium-232 series.

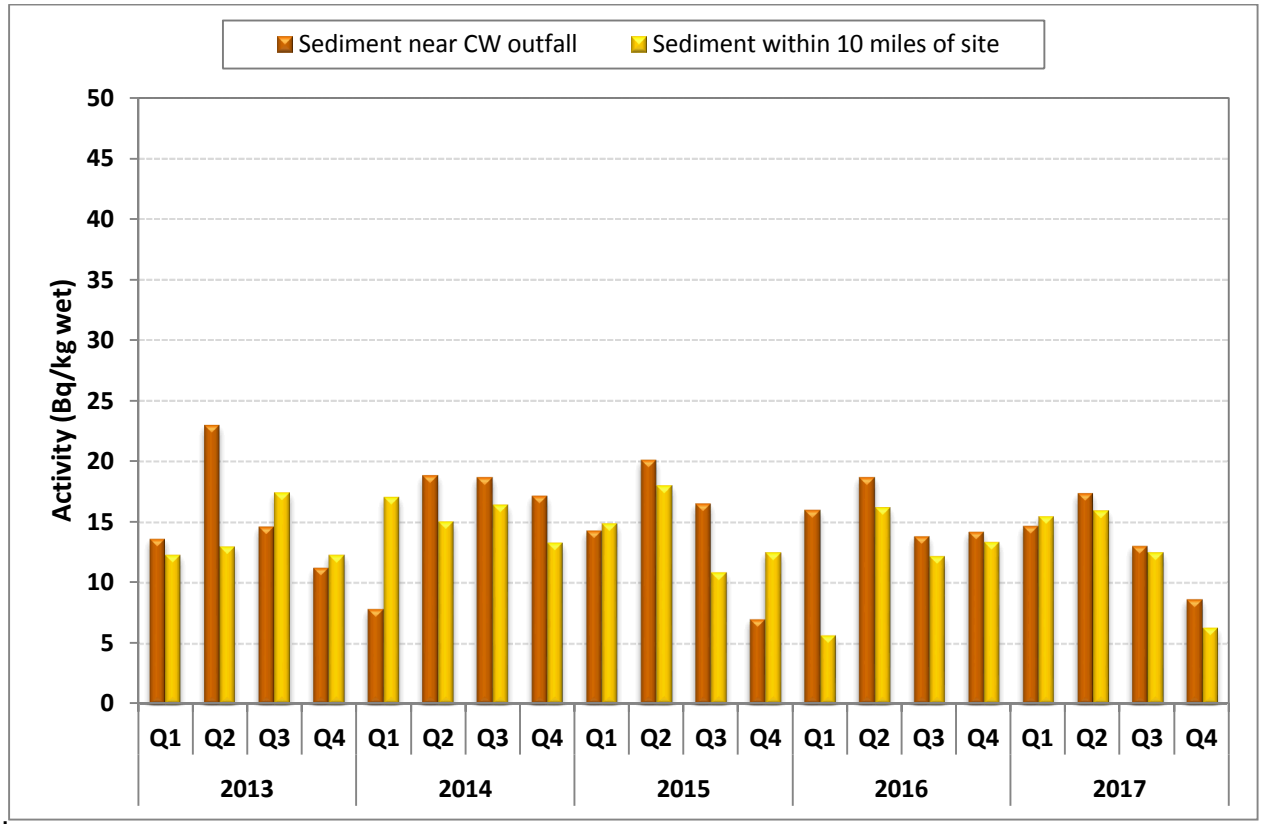

Figure 19 Ceasium-137 activity in sediment.

There is some variation in the data in Figure 19 with one reason being that activity concentrations are typically greater in silt than sand. It is sometimes very difficult to find silt at the sampling positions, and hence the radioactivity levels in sediment are variable since they depend on the relative proportions of sand to silt in each sample.

4.3 Terrestrial Dose Rates and Radioactivity

Terrestrial (land) dose rates are measured quarterly within 1 mile from Hinkley Point and between 1 and 5 miles from HPB. The radiation dose rates shown in Figure 20 represent the average from the 14 analysis sites (7 < 1mile and 7 between 1 and 5 miles from HPB).

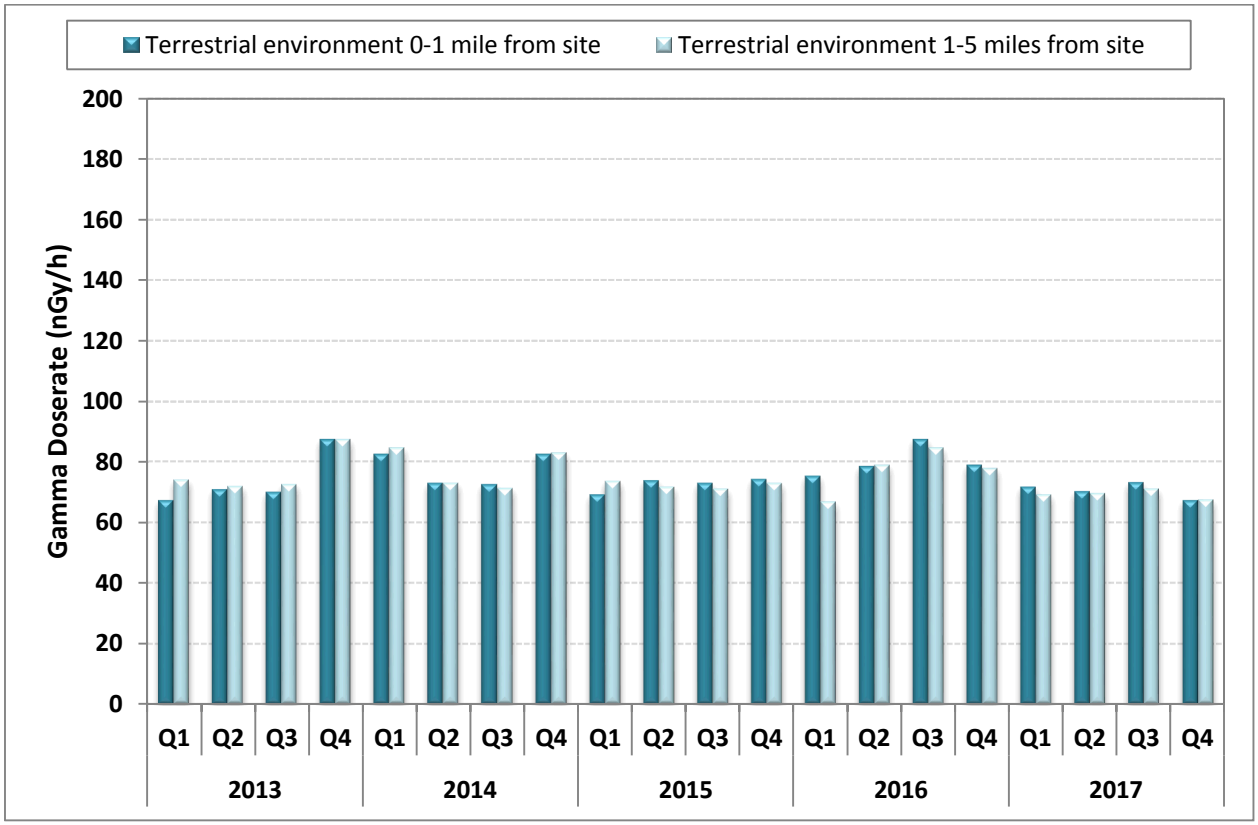

Figure 20 Terrestrial environmental gamma dose rate up to 5 miles from HPB.

Dose rates have remained broadly stable over this 5 year period and there is no significant difference between the average dose rate at up to 5 miles away, and those that are close to Hinkley Point.

An inevitable variation between readings at individual sites is due to the gamma dose rate above soil depending on in part on the water content of the soil. High water content reduces gamma background resulting in a consequent reduction in dose rate. Conversely during a period of abnormally low rainfall it is to be expected that a corresponding increase in the outdoor environmental gamma-ray dose rate would be observed. Additionally, during periods of heavy rainfall after a dry spell, dose rates can show a transient increase as a result of the washout of radon daughter products from the air. Consequently, variations in individual readings are to be expected as a result of variable weather conditions.

The results in Figure 21show the average gamma dose rate at terrestrial sites furthermost from Hinkley Point (i.e. more than 5 miles away). Each value shown represents the mean of readings from up to 32 separate sites. Measurements are recorded at least once a year, but for the majority of years there have been 2 sets of measurements.

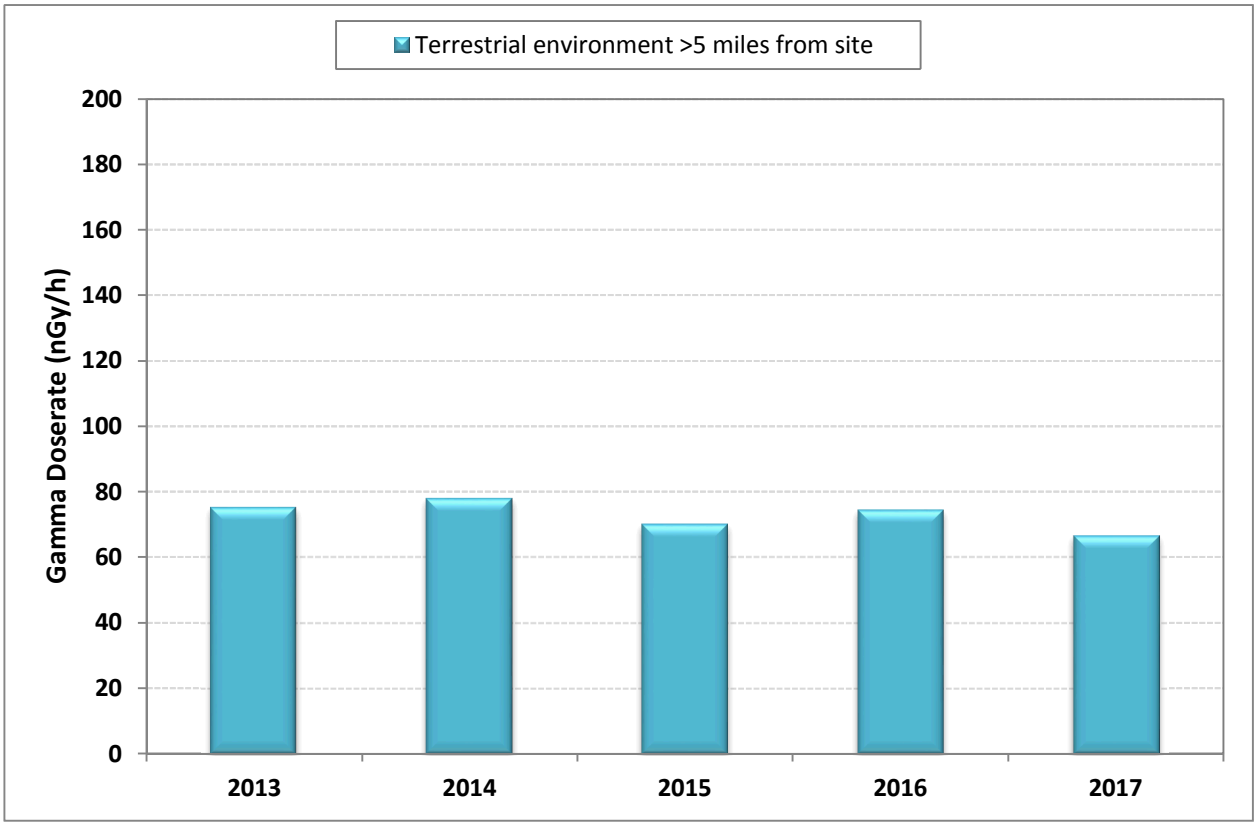

Figure 21 Terrestrial environmental gamma dose rate greater than 5 miles from HPB.

Once again, although the dose rates vary slightly between individual sites, depending on the underlying geology, there is no significant difference between the average dose rate at these points and those that are close to Hinkley Point. During 2017, measurements were taken at all 32 sites.

All the data collected for terrestrial gamma dose rates during 2017 are shown in Table 7.

Table 7 Average terrestrial gamma dose rates for 2017.

Zone	Number of Observations	Mean Gamma Dose Rate (nGy/h)
Inner (0-1 mile)	28	70
Outer (1-5 miles)	28	69
Ring Roads (>5 miles)	32	66

Exposure figures are measured at the HPB site on a quarterly basis using a number of thermoluminescent dose meters (TLD). For 2017, the average annual accumulated gamma dose at positions on the inner site security fence was 766 uS/y. This compares favourably with the annual accumulated gamma dose measured by TLDs positioned some distance from HPB.

Radioactivity is measured using tacky shades positioned at 9 sites around the locality. A range of radionuclides are analysed for on a monthly basis as shown in Table 8. The values reported in Table 8 are maximum figures from the 12 month period. They are all MDA and are therefore maximum estimates.

Table 8 Radioactivity in tacky shade collectors during 2017.

Radionuclide	Typical MDA (Bq/shade)
Cobalt-60	<0.16
Niobium-95	<0.19
Zirconium-95	<0.29
Ruthenium-106	<0.91
Antimony-125	<0.25
Caesium-134	<0.11
Caesium-137	<0.11
Cerium-144	<0.72
Europium-154	<0.24
Europium-155	<0.37

4.4 Terrestrial Sampling

Milk and herbage samples are taken from farms within 5 miles of HPB once a quarter and involve both on site analysis and some that is conducted by an external analytical laboratory. Annual soil core samples at various depths are also taken from the farm nearest to site.

Milk samples are analysed for sulphur-35, iodine-131, caesium-134 and caesium-137. Second quarter samples are additionally analysed for carbon-14 and strontium-90. The maximum results from the milk samples for each quarter are shown in Table 9.

Table 9 Maximum results for milk <5 miles from HPB during 2017.

Quarter	C-14 (Bq/kg carbon)	S-35 (Bq/m^3)	Sr-90 (Bq/m^3)	I-131 (Bq/l)	Cs-134 (Bq/l)	Cs-137 (Bq/l)
1	Not analysed	834	Not analysed	<0.16	<0.11	<0.10
2	376	<378	<19.4	<0.15	<0.10	<0.11
3	Not analysed	<892	Not analysed	<0.15	<0.15	<0.11
4	Not analysed	<459	Not analysed	<0.21	<0.11	<0.11

The natural background levels of carbon-14 in the environment are approximately 250 Bq/kg of carbon. The pathway for carbon-14 into milk is via deposition on herbage from gaseous discharges. The results in Table 9 imply that members of the public who consume above average quantities of milk (all produced locally) would have received doses of less than 5 µSv.

The most likely source of any strontium-90 and radio-caesium is fall-out from weapons testing and the Chernobyl incident. The results for strontium-90, together with those for radio-caesium and iodine-131, are all below the threshold of detection for the respective analysis techniques.

For herbage, usually grass, the sulphur-35 content is measured each quarter with an additional carbon-14 measurement being made in the second quarter. Site 5 is the closest location to the station where grass can be sampled, but there are no edible crops grown there. The other four farm locations where grass is sampled are further away from HPB and are not all milk producing farms. The data from 2017 for herbage analysis is shown in Table 10.

Table 10 Radioactivity in herbage samples during 2017.

Sampling Location	Sulphur-35 (Bq/kg)				C-14 (Bq/kg carbon)
	Q1	Q2	Q3	Q4	Q2
Site 5 (nearest)	15.3	15.3	42.1	12.9	716
Inner Farm 20	6.7	3.4	60.2	3.89	357
Inner Farm 23	4.4	2.0	2.35	1.29	421
Inner Farm 24	2.4	<0.9	2.21	3.22	336
Inner Farm 29	2.3	2.1	0.95	0.89	295

The results in Table 10 show elevated readings of both sulphur-35 and carbon-14 at the nearest sampling location (Site 5). This is due to the close proximity of the sampling location to the power station and the prevailing winds. The carbon-14 levels do however decrease at sampling locations further away from HPB and are only slightly above the natural background level of 250 Bq/kg of carbon-14 in the environment. Elevated readings of sulphur-35 seen in the third quarter correspond to a reactor gas blowdown during a shutdown period. Gamma spectroscopy of herbage is also undertaken, and traces of caesium-137 are detected, consistent with national background measurements resulting from known historic events.

Annual soil core samples are taken on a rotational basis so that each site is sampled at least once every five years. In 2016, Inner Farm 23 was the sampling location and for 2017, Inner Farm 20 was used. The results for 2017 at Inner Farm 20 are shown in Table 11.

Table 11 Reactivity in soil core samples for 2017.

Sampling Location	Total Beta (Bq/kg dry)	Caesium-134 (Bq/kg dry)	Caesium-137 (Bq/kg dry)
Inner Farm 20 (5 cm depth)	1005	<0.95	9.04
Inner Farm 20 (30 cm depth)	1025	<1.26	2.25

The results show no evidence of build-up of contamination from site emissions and instead are likely to represent the legacy of fallout from atmospheric testing of atomic weapons in the 1950's and 1960's.

5 Dose Summary

An annual report entitled Radioactivity in Food and the Environment (RIFE) is compiled by the Centre for Environment, Fisheries and Aquaculture Science on behalf of the Environment Agency, Food Standards Agency, Food Standards Scotland, Natural Resource Wales, Northern Ireland Environment Agency and the Scottish Environment Protection Agency (Ref 1). The report uses data from monitoring programmes conducted by these agencies and by nuclear site operators to assess the radioactive dose received by members of the public in the vicinity of nuclear licensed sites and industrial and landfill sites.

The estimated annual dose to members of several local groups of the general public in 2016 is summarised in Table 12.

Full dose assessment figures for 2017 are not yet available and will be documented in the next annual report.

Table 12 Summary of doses taken from the annual 2016 report (RIFE 22).

Radiation Exposure Pathway	Exposure (mSv per year)		
	2014	2015	2016
Total dose to the public from all pathways and sources of radiation	0.022	0.016	0.013
Fish and shellfish consumption, and exposure to external radiation over intertidal areas	0.032	0.021	0.018
Terrestrial foods, external exposure and inhalation near site	0.015	0.005	0.011

Discharges of radioactivity from Hinkley Point B and results of the environmental monitoring measurements have shown no significant change in 2016. The population group affected is small and it is unlikely that annual doses to members of the public will vary from the figures listed in Table 12.

The total dose from all pathways and sources of radiation was 0.0013 mSv in 2016. This equates to 1.3 % of the effective dose limit (1 mSv) to members of the public as defined in the Ionising Radiations Regulations 2017 (IRR17). For comparison, the average annual radiation dose to the public in the UK from natural radioactivity is over 2 mSv as shown in the Public Health England (PHE) information in Figure 1. The representative person in this case was adults who spent a large amount of time over sediments. The trend for decrease in total dose is attributed to relatively low gamma dose rates over local beaches.

A source specific assessment for a high rate consumer of locally grown food was undertaken and the exposure was found to be 0.011 mSv. The increase in dose since 2015 was mostly due to higher carbon-14 concentrations in milk.

The dose to a local fisherman who consumed a large amount of seafood and was exposed to external radiation over intertidal areas was 0.018 mSv, less than 2 percent of the dose limit for members of the public. The reason for the apparent decrease in dose since 2015 is the same as

that contributing to the maximum total dose. The dose estimate also includes the effects of historical discharges of tritium and carbon-14 from the GE Healthcare Limited plant at Cardiff.

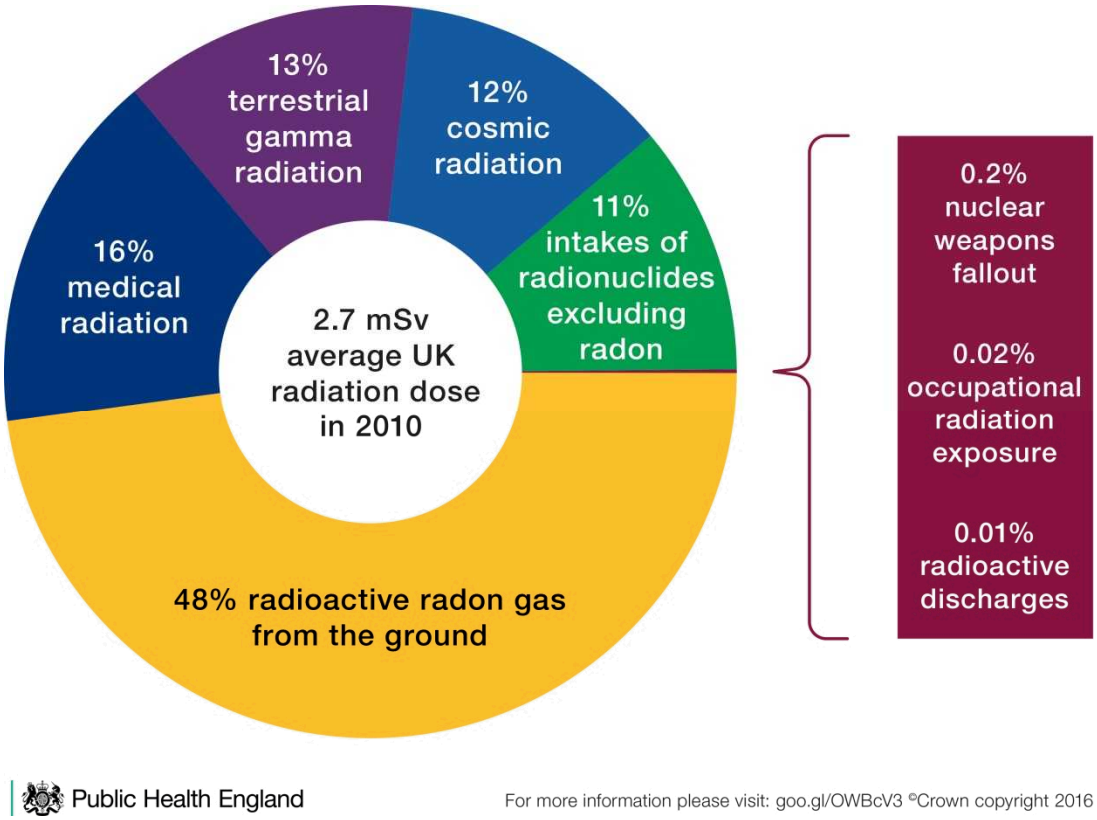

Figure 22 PHE Comparison of radiation doses.

6 Solid and Non-Aqueous Liquid Waste Disposal

Good progress in waste minimisation and management was made in 2017. A self-imposed rolling target of holding less than 50 m^3 of radioactive waste on site was achieved. Due to this, Hinkley Point B achieved best in fleet status across EDF Energy for radioactive waste management. During 2017, one shipment of solid low level waste was transferred to Tradebe for offsite waste processing, the activities of which are detailed in Table 13.

Solid low level radioactive waste (LLW) is transferred to the Low Level Waste Repository (LLWR) in Cumbria for disposal, either directly or via treatment facilities. Solid LLW metal is also transferred to treatment operators for decontamination by melting or direct methods such as grit blasting. No metal waste was sent offsite during 2017 due to the low volume created. Combustible solid LLW and non-aqueous liquid radioactive waste is also transferred to incinerator operator at Hythe in Hampshire.

Table 13 Activity of total waste transferred for offsite processing during 2017.

Radionuclides	Total Activity (MBq)
Uranium	33.2
Radium-226 plus thorium-232	0.06
Other alpha emitters	44.1
Carbon-14	387
Iodine-129	2.3×10^{-4}
Tritium	3.0×10^{3}
Cobalt-60	4.6×10^{3}
Others	4.1×10^{3}
Total volume of waste including primary containment	**8.2 m^3**

Three consignments of solid low level and non-aqueous liquid radioactive waste were transferred to the operator of the incinerator at the Hythe facility. The total volume of the waste including primary containment was 38.8 m^3 with the total activity for this waste being detailed in Table 14.

Table 14 Activity of total waste transferred to the Hythe incinerator during 2017.

Radionuclides	Total Activity (MBq)
Tritium + carbon-14	105
Alpha emitters	3.6
Others	699
Total volume of waste including primary containment	**38.8 m^3**

7 Conclusion

During 2017 the levels of radioactivity in liquid and gaseous effluents, and solid radioactive low level waste transferred for off-site processing, remained well below the permit limits set by the Environment Agency for Hinkley Point B power station.

The environmental monitoring programme has confirmed that there is no evidence of any long term accumulation of radioactivity resulting from the operation of the power station. Radiation doses to members of the public from the discharges and direct radiation from the power station site is well below the UK legal limit of 1 mSv per year. Furthermore, environmental management initiatives suggest that the environment surrounding Hinkley Point is in a good state.

The total dose to members of the public from the all pathways exposure for 2016 is 0.013 mSv (Ref. 1). This is similar to previously assessed doses which are well within the public dose constraint value of 0.3 mSv per year from a ‘single site’, recommended by Public Health England.

8 References

Ref.	Document Identifier	Document Title
1.	RIFE 22 - 2016	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/665561/Radioactivity_in_Food_and_the_Environment_2016__RIFE_22_.pdf

9 Distribution List

Name	Position / Location	User ID
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Anna England	Environment Regulation and Oversight / COR	HPB0487
Laurence Austin	Environmental and Nuclear Liabilities / COR	AA02118

Appendix A Glossary of Terms

A.1. Radioactivity

Radioactive decay or radioactive disintegration is a process whereby an unstable atomic nucleus loses energy by emitting radiation.

The becquerel (Bq) is a unit of radioactivity.

1 Bq = 1 radioactive disintegration per second.

1,000,000 Bq	= 10^6 becquerels	= 1 MBq (mega becquerel)
1,000,000,000 Bq	= 10^9 becquerels	= 1 GBq
1,000,000,000,000 Bq	= 10^{12} becquerels	= 1 TBq

A.2. Absorbed Dose

The absorbed dose is the amount of energy from ionising radiation that is deposited in any physical matter that it passes through.

The gray (Gy) is a unit of absorbed dose.

1 Gy = 1 joule of radiation energy being absorbed per 1 kilogram of physical matter.

$\frac{1}{1,000,000,000}$ Gy	= 10^{-9} gray	= 1 nGy (nano gray)

A.3. Equivalent and Effective Dose

The equivalent dose is specific for individual organs. It is based on the absorbed dose to an organ that is then adjusted to account for the sensitivity of that particular body tissue to the particular type of radiation it is exposed to.

The effective dose is calculated for the whole body. It is the total of the equivalent doses to all organs and tissues.

The sievert (Sv) is a unit of equivalent and effective dose.

1 Sv = 1 joule of radiation energy being absorbed per 1 kilogram of biological matter

Appendix B Local Environmental Monitoring Site Maps

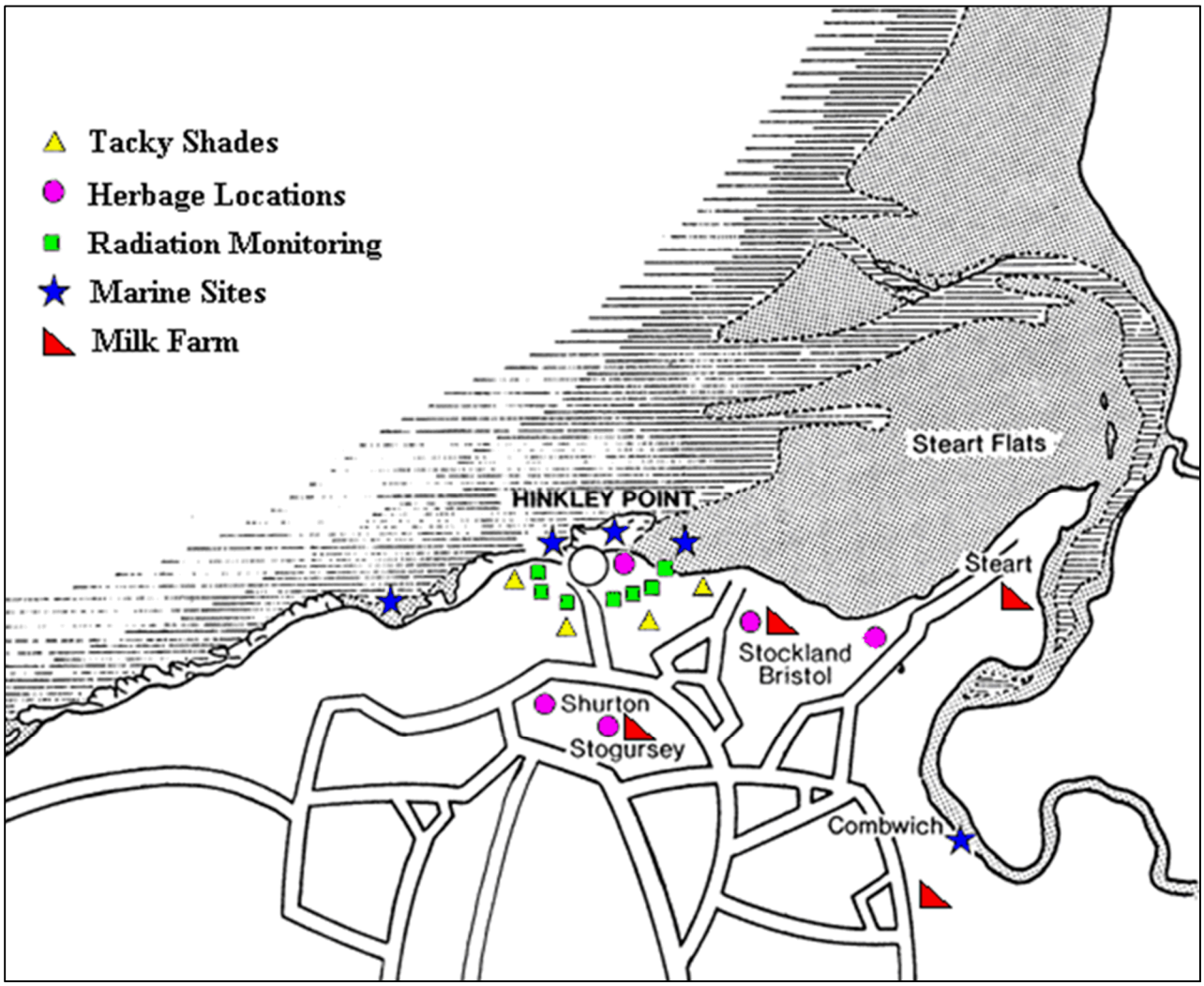

Figure 23 Local environmental monitoring map (< 4 miles from HPB).

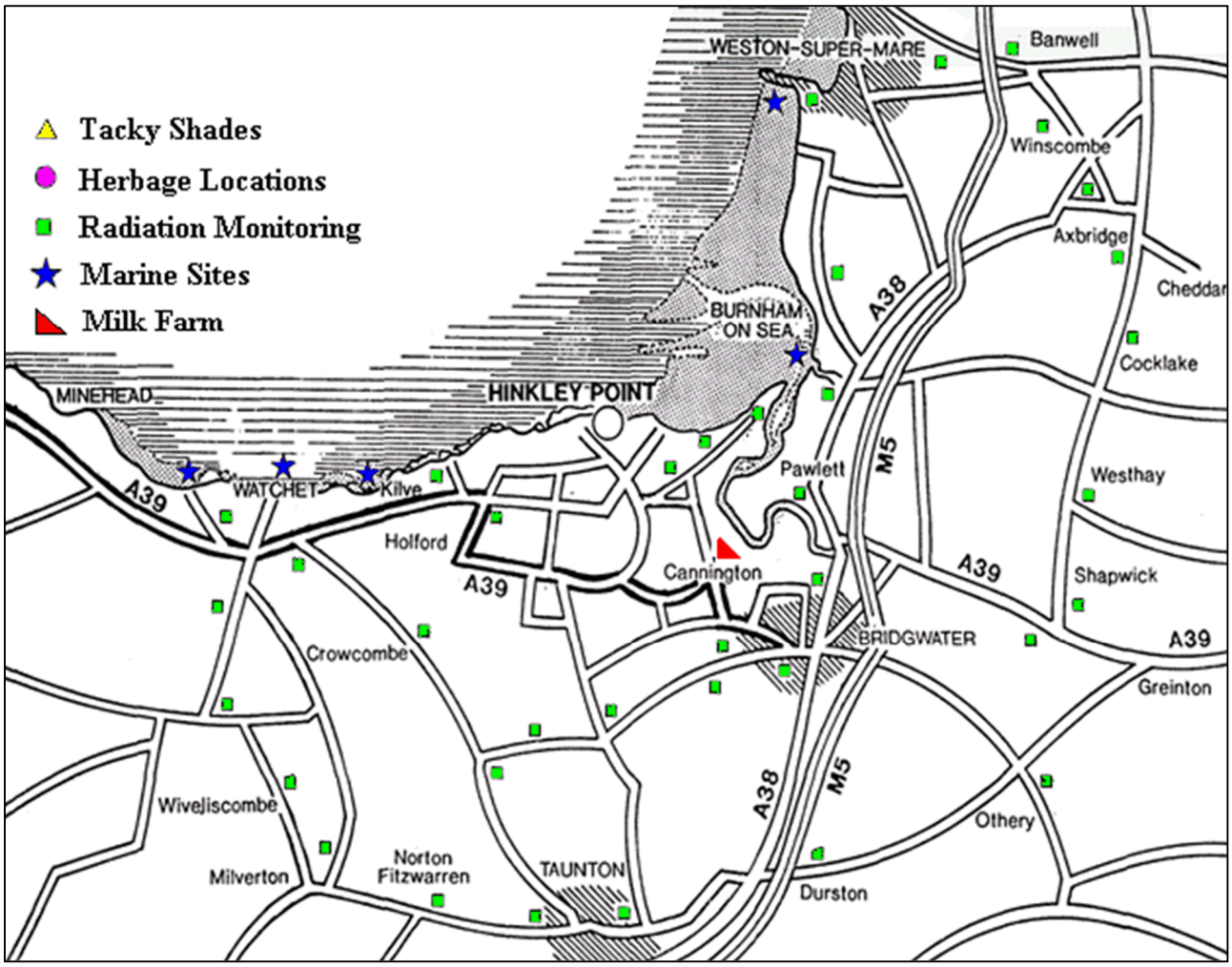

Figure 24 Local environmental monitoring map (> 4 miles from HPB).