Generic design assessment of new nuclear power plants

Gaseous and liquid discharges of radioactive waste for the UK HPR1000 design - AR04

Detailed assessment – final report

10 January 2022

Version 1

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Executive summary

This report covers our detailed assessment of the Requesting Party's (RP) submission on gaseous and liquid discharges of radioactive waste supporting the development of the United Kingdom Hualong One Pressurised Reactor design (UK HPR1000). Our requirements and expectations regarding these arrangements are set out in Table 1, Item 5 of our Process and Information Document (P&ID) (Environment Agency, 2016).

Our assessment has considered the RP's submission in relation to relevant UK policy, legislation and guidance, including the Environment Agency's Radioactive Substances Regulation (RSR) Environmental Principles (REPs) (Environment Agency, 2010).

Our conclusions are that:

- the RP has provided us with information on estimated gaseous and liquid discharges and proposed limits. It is clear how it has derived these discharge estimates and the estimates are supported by suitable evidence
- the proposed annual gaseous and liquid discharge limits for the UK HPR1000 are clearly derived, taking into account our limit setting guidance (Environment Agency, 2012)
- we consider that the RP has demonstrated that the UK HPR1000 discharges and limits are generally comparable with international OPEX and previous GDAs. Where there are differences, we are satisfied that the RP has provided reasonable explanations
- the gaseous and liquid discharges from the UK HPR1000 would be capable of complying with the limits set out below (Tables 1 and 2)

Table 1: Proposed gaseous emission limits for a single unit of the UKHPR1000

Radionuclide	Proposed annual limit (Bq)
Hydrogen-3	5.23E+12
Carbon-14	1.69E+12
Noble gases (including xenon-133 & xenon-135)	1.56E+13
Xenon-133	1.16E+13
Xenon-135	3.45E+12

Radionuclide	Proposed annual limit (Bq)
Halogens	2.21E+08
Other radionuclides	1.12E+07

Table 2: Proposed liquid emission limits for a single unit of the UK HPR1000

Radionuclide	Proposed annual limit (Bq)
Hydrogen-3	1.04E+14
Carbon-14	5.90E+10
Other radionuclides	1.04E+09

During our assessment, we raised one Regulatory Observation (RO) and 6 Regulatory Queries (RQs) related to gaseous and liquid radioactive discharges and proposed limits (see also Appendix 2).

We have not identified any GDA Issues.

In order to ensure that headroom (that is, the difference between actual discharges and permitted limits) is minimised, we consider the following Assessment Finding to be appropriate:

Assessment Finding 16: A future operator shall keep the headroom factors derived during GDA under review. Operational data generated by the UK HPR1000 should be used to periodically revise the headroom factors to ensure that they are the minimum necessary to permit normal operation.

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1. Introduction

This report provides our detailed assessment of the Requesting Party's (RP) submission in relation to gaseous and liquid discharges of radioactive waste in the UK HPR1000 design for GDA purposes.

This report is based on the latest generic design assessment (GDA) submissions, consideration of all relevant consultation responses and submissions to General Nuclear System Limited's (GNSL) comments process up to 17 September 2021.

We use a 2-stage process to carry out GDA: initial assessment, followed by detailed assessment. The findings from our initial assessment are set out in the Initial assessment: Statement of findings published in November 2018.

This detailed assessment has built on that initial assessment and is based on additional submissions and technical engagement with the Requesting Party (RP) throughout the GDA process. We held a public consultation on our preliminary detailed assessment findings for 12 weeks between 11 January 2021 and 4 April 2021. Our assessment method, findings, responses to relevant public consultation comments and final conclusions are presented in this final detailed assessment report.

This assessment considers the predicted levels of radioactivity in gaseous and liquid radioactive waste discharged to the environment. We have assessed the submissions relating to gaseous and liquid discharges and proposed limits that the RP provided for its UK HPR1000 design. The assessment aims to establish whether the design could be operated in England in line with UK statute, policy and guidance on radioactive waste. It also aims to identify the important issues that should be taken forward into any environmental permit that may be issued with relevant limitations and conditions.

We require new nuclear power plants to use best available techniques (BAT) to prevent and, where that is not practicable, minimise the creation of radioactive waste, and to minimise the impact of discharges of radioactive waste on the environment. We have considered the application of BAT for the UK HPR1000 design in another assessment report (Environment Agency, 2022b).

Our consideration as to the acceptability of proposed discharges has been carried forward into our radiological impact assessment both in terms of impact on members of the public and on wildlife (Environment Agency, 2022d). This allows us to compare the design with the legislative dose limits and dose constraints prescribed for England.

We have also assessed the non-radioactive discharges from the UK HPR1000; details of this assessment can be found in a separate assessment report (Environment Agency, 2022e).

There are a number of documents in the RP's submission that we assessed (see Appendix 1).

In this report 'liquid radioactive wastes' refers to aqueous liquid radioactive wastes only, which excludes non-aqueous liquid wastes such as oils. Although liquid and gaseous wastes are subject to filtration, discharges may include small amounts of particulate material.

In order to help the reader, a summary of the gaseous and liquid discharge routes is provided before the discussion of our assessment.

2. Summary of the gaseous and liquid discharge routes

The gaseous and liquid discharge routes for the UK HPR1000 are complex and are outlined in the main submission for this assessment area 'Pre-Construction Environmental Report (PCER) Chapter 6 - Quantification of Discharges and Limits v2' (GNSL, 2021a). Greater detail on the gaseous and liquid waste management systems can be found in other chapters of the RP's submission such as PCER Chapter 3 - Demonstration of BAT, PCER Chapter 4 - Radioactive Waste Management Arrangements and PCER Chapter 8 - Conventional Impact Assessment. Our understanding of the gaseous and liquid waste management systems has been developed by using all 4 documents. The systems can be summarised as follows.

2.1. Gaseous effluent discharge routes

There are 3 main systems that handle gaseous radioactive waste:

- gaseous waste treatment system (GWTS)
- heating ventilation and air-conditioning (HVAC) system - this is made up of a number of sub-systems, most notably the 'nuclear auxiliary building ventilation system' (NABVS)
- condenser vacuum system (CVS)

All 3 systems combine in the HVAC system for discharge to air through a single site main stack. The RP has summarised the gaseous effluent discharge routes in the following diagram:

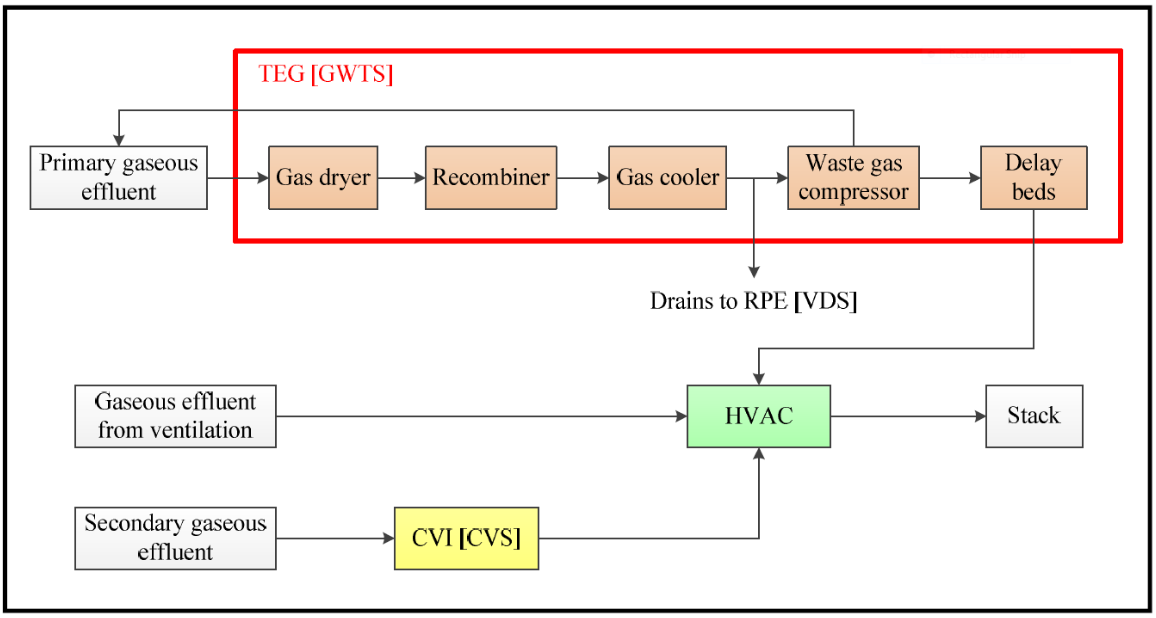


Figure 1: Radioactive gaseous effluent streams (GNSL, 2021a, Section 6.4)

The diagram shows how the 3 systems link together to treat and manage the 3 categories of gaseous effluents; primary effluent, gaseous effluent from ventilation and secondary effluent.

Primary gaseous effluent comes from the degassing and headspaces of primary coolant or primary effluent vessels. Under normal operation, the GWTS operates as an almost closed-loop system, with only a small amount of gas going to the delay beds (which allows decay of noble gases). During start-up and shutdown and some maintenance scenarios the system becomes open loop where the gaseous effluents flow to the delay beds rather than being recirculated within the system. After the delay beds, the gas stream discharges into the HVAC system where it is treated by high efficiency particulate air (HEPA) filters before being discharged via the main site stack. There is also the option to use iodine adsorbers (referred to as iodine traps in the RP's documentation) if deemed necessary.

The gaseous effluents from ventilation arise from the possible leakage from radioactive components inside buildings or from evaporation from the spent fuel pool. This gas stream goes directly to the HVAC system for HEPA filtration.

Secondary gaseous effluent is normally a non-radioactive waste stream. There is, however, a possibility of leakage from the primary to the secondary circuit which would need treatment. This waste stream is, therefore, classed as being a radioactive waste stream and is directed to the HVAC system for HEPA filtration and, if necessary, iodine adsorbers.

The main site stack is the single emission point for gaseous radioactive waste. The waste stream is monitored continuously to collect data to demonstrate compliance with the discharge limits, which will be included in a future radioactive substances activity environmental permit. We assess sampling and monitoring in another assessment report (Environment Agency, 2022c).

2.2. Liquid effluent discharge routes

Liquid radioactive wastes go through a number of collection and treatment systems before being discharged into the environment. All of the liquid effluents described here flow to the 'seal pit' before being discharged through a single site outfall. The seal pit is a structure designed to prevent air getting back into the cooling water and effluent systems and is linked to the main site outfall into the environment.

The system can be summarised in the following diagram:

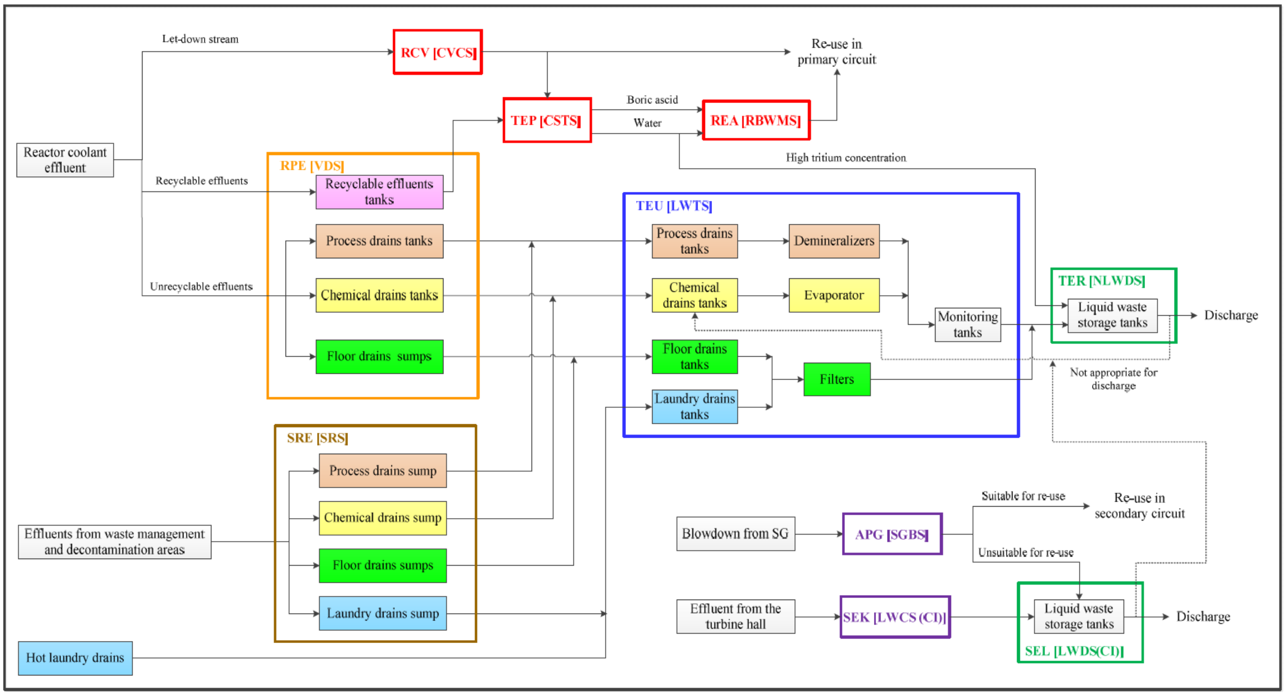


Figure 2: Radioactive liquid effluent streams (GNSL, 2021a, Section 6.4)

The liquid waste streams can be divided into 3 categories:

- reactor coolant effluent
- effluents from waste management and decontamination areas
- secondary circuit effluent (steam generator blow-down and turbine hall effluent)

The source of the reactor coolant effluent is from let-down of primary coolant (routed to the 'chemical and volume control system' (CVCS) and drainage and leakage (routed to the 'nuclear island vent and drain system' (VDS)). Some of the reactor coolant effluent is recyclable within the system and this can go back into the primary circuit (unless the treated effluent is unsuitable for re-use, where it is then routed to the 'nuclear island liquid waste discharge system' (NLWDS)). The non-recyclable reactor coolant effluent stream is collected in process, chemical or floor drains (in VDS) and directed to the liquid waste treatment system (LWTS).

Effluents from waste management and decontamination areas, including laundry drains, are collected in process, chemical, floor or laundry drains in the 'sewage recovery system' (SRS) and then treated appropriately in the 'liquid waste treatment system' (LWTS).

The treatment options used in the LWTS are filtration, demineralisation and evaporation. These liquid treatment techniques are consistent with those widely used in similar nuclear power plants. The treatment facilities have been assessed in one of our other assessment reports on the best available techniques for minimising production and disposal of radioactive waste (Environment Agency, 2022b).

The liquid effluent streams described above all flow to the NLWDS where they are tested before being released to the seal pit then discharged into the environment. If, when tested, the effluent quality is found not to be suitable for discharge, it can be sent back into the LWTS for additional treatment.

The secondary circuit effluent (steam generator blow-down and turbine hall effluent) is expected to be non-radioactive for the majority of the time but may, on occasion, become contaminated by small leakages of radioactivity from the primary to the secondary circuit. Any radioactivity would be picked up by the monitoring carried out on the effluent, and this would inform the decision to discharge directly to the seal pit and then into the environment (if no detectable radioactive contamination or acceptable levels of chemical contamination are present) or to the LWTS for treatment.

The sampling and monitoring of liquid effluent before it is discharged into the environment is covered in a separate assessment report (Environment Agency, 2022c).

3. Assessment

3.1. Assessment method and process

The basis of our assessment was to:

- consider the submissions the RP made that make up the 'quantification of discharges and limits' topic area
- hold technical meetings with the RP to clarify our understanding of the information presented and explain any concerns we had with that information
- raise Regulatory Queries (RQs) to clarify our understanding of the information presented
- raise Regulatory Issues (RIs) or Regulatory Observations (ROs) where we believed the RP did not provide enough information
- consider the proposed discharges and limits in relation to legislation and guidance applicable in England
- compare them to similar operating plants around the world
- decide if there are any GDA Issues to be resolved at the end of detailed assessment and identify any Assessment Findings to carry forward from the GDA process to a site-specific stage.

3.2. Assessment objectives

Important areas of the RP's submission for the UK HPR1000 design that we have considered are:

- Are all the sources of gaseous and liquid radioactive waste identified?
- Are all the significant radionuclides relating to gaseous and liquid radioactive waste identified and quantified?
- Are all the assumptions in the submission relating to gaseous and liquid radioactive waste appropriate?
- Have all discharge routes for gaseous and liquid aqueous radioactive waste been identified?
- Have the annual limits the RP has proposed:
    - been clearly derived?

    - been given acceptable headroom in relation to the discharge estimates they have been derived from?
    - taken account of our limit setting guidance?

- Do the proposed discharges from the UK HPR1000 exceed those of comparable stations around the world?

3.3. Assessment limitations and scope

This assessment considers gaseous and liquid radioactive waste generated from all aspects of 'normal operation', which includes start-up, at power, shutdown, outage and discharges resulting from any other reasonably foreseeable events expected to occur during the lifetime of the reactors ('expected events') (Environment Agency, 2012).

Any increase in discharges caused by an event outside the above definition (for example, a nuclear accident) is not covered by this assessment. We assess gaseous and liquid discharges from 'normal operations' only, while ONR assesses the radiological consequences of accidents and regulates arrangements for the control and mitigation of radiological consequences following a significant release of radioactivity in an accident scenario.

This assessment report does not cover gaseous or liquid radioactive waste arising from commissioning or decommissioning at the end of the reactor life cycle. These phases of the plant life cycle have been agreed to be out of scope of GDA (GNSL, 2019a). Also out of scope are discharges from the spent fuel interim storage facility, intermediate level waste (ILW) interim storage facility and the low level waste (LLW) buffer store (GNSL, 2019a) because these stores are only at conceptual design stage in GDA. The aspects of the design that are out of scope of GDA will need to be fully assessed at the site-specific stage.

Our GDA is based on a single reactor design. At GDA stage it is not known how many reactors a future operator may want to deploy at any given site. This approach ensures the GDA is applicable for any future deployment model.

The assessment presented in this report links to 2 other aspects of our overall GDA. Our assessment of the processes and systems that result in liquid and gaseous discharges to the environment have been assessed in our report 'Best available techniques for minimising production and disposal of radioactive waste' (Environment Agency, 2022b). The estimated discharges and proposed limits produced by this report are the inputs into our radiological impact assessment, the outputs of which were then compared against UK dose constraints and legal dose limits (see our assessment report on the impact of radioactive discharges (Environment Agency, 2022d)).

The main legislative areas that have been taken into account are all now encompassed within the:

- Environmental Permitting Regulations (EPR 16). These Regulations set the regulatory framework for controlling radioactive substances, including waste, in England and Wales (UK Parliament, 2016)

- statutory guidance to the Environment Agency concerning the Regulation of Radioactive Discharges into the Environment (DECC, 2009)

The requirements of the legislative framework are considered at GDA via our P&ID requirements (Environment Agency, 2016) and our Radioactive Substances Regulation Environmental Principles (REPs) (Environment Agency, 2010).

We published our REPs in 2010 (Environment Agency, 2010). The REP that is most relevant to assessing gaseous and liquid discharges is:

- RSMDP12 – Limits and levels on discharges: Limits and levels should be established on the quantities of radioactivity that can be discharged into the environment where these are necessary to secure proper protection of human health and the environment

3.4. Our assessment

In November 2018, we published our initial assessment findings on the UK HPR1000 design (Environment Agency, 2018) (https://www.gov.uk/government/publications/new-nuclear-power-stations-initial-assessment-of-general-nuclear-systems-uk-hpr1000-design). After our initial assessment of this topic area, we concluded that in order to carry out our detailed assessment we required the following:

- evidence on the basis for the annual and monthly discharge estimates

- evidence of expected events likely to occur over the lifetime of the plant and clearly show how they have been included in the limit calculations

- a clear method for how the proposed discharge limits are derived

- a comparison of discharges with comparable plants worldwide

In the period between our initial assessment and the time of writing this report, we held regular technical meetings with the RP, and issued a number of Regulatory Queries (RQs) and one Regulatory Observation (RO). These are summarised in Appendix 2 and will be discussed in the appropriate sections below.

3.4.1. Regulatory context

In its submission, the RP demonstrated a good understanding of the main legislation and guidance that set out our regulatory expectations relating to the quantification of discharges and limits.

3.4.2. Discussion of Regulatory Queries and Regulatory Observation

Very early in the assessment process (April 2018), we raised RQ-UKHPR1000-0076 (see Appendix 2). In this RQ, we asked the RP to outline the method that it would present for the quantification of discharges and limits. The response the RP provided was discussed in an Environment Agency/Requesting Party workshop in April 2018. The RP outlined the differences between the Chinese and UK approach and confirmed that a method based on operating experience (OPEX) would be developed for GDA. This would be based on real data from predecessor designs. It also outlined the RP's proposed approach to calculating correction and headroom factors. The OPEX units are selected because of their similarity to the UK HPR1000 but there may be some differences that could affect the discharge estimates. Correction factors are applied to convert OPEX data to match the UK HPR1000 characteristics.

Based on the information we had at the time, we were satisfied with the response, and the RP proceeded to develop the first version of its PCER chapter 6 on 'quantification of discharges and limits', which it submitted in November 2018 (GNSL, 2018).

During our assessment of the first version of the Pre-Construction Environmental Report (PCER), we had access to all the relevant supporting documents, but also needed to review one of the underpinning references (the methodology for the identification of expected events (GNSL, 2019d)) in order to carry out a full assessment. We raised RQ-UKHPR1000-0193 in February 2019 to obtain it (see Appendix 2).

After our first full assessment of the PCER and the full set of supporting documents, we identified a number of shortfalls and considered a Regulatory Observation (RO) to be the appropriate way of resolving them. We issued RO-UKHPR1000-0010 in April 2019 and it identified 3 potential concerns relating to OPEX, calculation methodology and data presentation. During the course of the RO resolution, we held regular meetings with the RP, initially to agree the resolution plan and then to assess progress against the agreed plan. The RO was closed in June 2020. The issues raised in the RO and their resolution is summarised as follows.

RO Action 1 - OPEX used for deriving discharge estimates

In our assessment, we noted that the OPEX used was based on the Chinese fleet of predecessor reactor designs. Ten of the 14 reactors chosen had been in operation for less than 5 years and the maximum period of operation was 22 years. Our environmental principle for radioactive substances regulation, RSDMP12 states that "the process to determine discharge estimates and limits is to be based on a set of data of suitable quality and breadth". The proposed operational life of the UK HPR1000 is 60 years, so we considered the OPEX used initially not to be sufficiently representative. While we considered the total number of years of OPEX that the RP had used (52 years) to be a good level of data, our view was that it did not represent the full operational lifetime of a UK HPR1000. We considered it important that the underpinning data for the discharge estimates is justified as being wholly appropriate for the full operational life as the derived proposed limits are used as input data for the radiological assessment. This is then compared against UK dose constraints and legal dose limits (see our assessment report on dose Environment Agency, 2022d).

In its response, the RP acknowledged that the OPEX initially presented was based on the relatively young Chinese fleet, so representative international plants were selected to improve the data set. Additional OPEX was drawn from the UK, France and Germany. The improved data set was then subjected to long-term trend analysis over a whole plant life time.

A trend analysis of discharges representative of the full 60-year life of a UK HPR1000 based on a wider set of OPEX was presented in a document that was created specifically in response to this RO (GNSL, 2019c).

We assessed the trend analysis document and found that the additional OPEX selected, and trend data presented were considered to sufficiently demonstrate how discharges are unlikely to vary throughout the 60-year life of a UK HPR1000. We agree with the document conclusion that, for the data set presented, there is no notable increase in radioactive discharges due to plant ageing and, therefore, the Chinese fleet OPEX presented originally can be demonstrated to be representative of the full operational lifetime of the plant.

RO Action 2 - Calculation method used for deriving discharge limits

We noted that the method used to calculate the discharge estimates did not fully align with our limit setting guidance (Environment Agency, 2012) in so far as it wasn't clear how expected events had been included in the calculations, and what proportion of the discharges was due to expected events. Expected events are those operational fluctuations that can be reasonably expected to occur during the operational life of the plant and are considered to be part of normal operation. We would expect a headroom factor to be applied to account for the operational variability and uncertainty in the underpinning data when deriving discharge limits. We asked the RP to revise its calculations to clearly show expected events being part of normal operation and to minimise the headroom factor applied so it only covered variability and uncertainty in the underpinning data.

In response to the RO Action, the RP revised an existing supporting document on the 'Estimation of Radioactive Gaseous Discharges and Limits for the UK HPR1000' (GNSL, 2021b). The RP applied a new approach and revised its calculations to present annual discharges, headroom and expected events as individual elements of the calculations. This is aligned with our limit setting guidance (Environment Agency, 2012) and the P&ID requirement (Environment Agency, 2016).

The revised document 'Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000' (GNSL, 2021b) was assessed, and we found that the presentation of the headroom factor and expected event calculations had been improved from the previous approach.

RO Action 3 - Data presentation in accordance with the P&ID requirements

Our P&ID information requirement is that each constituent of normal operation should be clearly stated. These are:

- routine operation
- start-up and shutdown
- maintenance and testing
- expected events

At the time of the RO, the average and maximum monthly discharges had been calculated, but we could not see how each of the above constituents had fed into the calculation. We also asked the RP to acknowledge the variation in discharges that occur during both operation and outage and ensure that they are defined separately in the calculations.

In its response, the RP agreed to adjust the way its discharge estimates are presented in the relevant documents.

The revised approach required the RP to revise 2 documents (GNSL, 2021b) and (GNSL, 2019b), which were submitted and assessed.

The revisions provided better clarity on the individual elements that constitute the discharge estimates. The calculations that ultimately produce the discharge estimates and limits could now be followed in enough detail to carry out a fuller assessment. The approach was considered sufficient for GDA.

When we had fully assessed the revised and newly created documents that described the quantification of discharge estimates and limits, we found it necessary to clarify a number of points and issued RQ-UKHPR1000-0679 in March 2020 (See Appendix 2).

In RQ-UKHPR1000-0679 (see Appendix 2), we asked whether the headroom factors would be reviewed using real data throughout the life of the plant to ensure that they are the minimum necessary to permit normal operation. In its response, the RP stated that it had demonstrated in its trend analysis document (GNSL, 2020d) that discharges are expected not to increase (and, in many cases, decrease) throughout the operational life of the UK HPR1000, so the headroom factors derived at GDA represent a bounding case. While we accept this conclusion for GDA, it is still important that a future operator ensures that the variability assumed at GDA is periodically updated using real data generated by a UK HPR1000 throughout the life of the plant.

In its supporting document on estimating discharges and limits, the RP used a split of 10 months' operation and 2 months' outage. In RQ-UKHPR1000-0679 (see Appendix 2), we also asked the RP to explain its rationale behind this approach. In its response, the RP confirmed that despite shutdown for refuelling taking place approximately every 18 months, it considers the 10 month/2 month split used in its estimates to be a realistic bounding case to ensure the peak in discharges, generated during an outage, are captured in annual discharge estimates and limits. The 2-month duration is based on OPEX and covers preparatory activities, maintenance and testing and refuelling.

In RQ-UKHPR1000-0679, we also asked the RP to clarify why the expected events had not been separated into those that can happen only during operation or outage. In its response, the RP confirmed that it was not considered appropriate to separate them because, apart from unplanned shutdown, all the identified expected events could occur during either operation or outage. The RP also considered them difficult to separate because there may be some delay between the event and any release to the environment due to transportation through the system and decay as it does so.

We consider the responses to the RO and the subsequent RQ to be satisfactory, and we formally closed out the RO in June 2020. Having successfully completed the work associated with the RO, we are now able to summarise the RP's method for quantifying discharges and limits and present our preliminary conclusions on each element.

3.4.3. Our assessment of the Requesting Party’s method for quantifying discharges and limits

The main elements of the RP's method for quantifying discharges and limits are as follows:

- defining operating conditions
- selecting relevant OPEX
- identifying significant radionuclides
- deriving correction factors
- deriving headroom factors
- deriving appropriate expected events

The method is outlined in ‘PCER Chapter 6 - Quantification of Discharges and Limits’ (GNSL, 2021a), but the RP has produced several supporting documents to provide the detail that underpins the content of the PCER Chapter 6 (see Appendix 1).

Definition of operating conditions

The RP defines the normal operating conditions used for quantifying discharges and limits as:

- routine operation
- start-up and shutdown
- maintenance and testing

- expected events

Selecting relevant OPEX

The RP's approach was to source its data from OPEX rather than theoretically deriving it from a source term calculation. This meant it was not possible to separate out each of the above aspects as required by the P&ID (Environment Agency, 2016). The RP's approach was to include routine operation, start-up and shutdown and maintenance and testing as one of two operational states, either power operation or shutdown. The RP has stated in 'Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000' (GNSL, 2021b) that power operation includes routine operation and maintenance and testing carried out when the plant is generating power. Shutdown includes shutdown, discharges during preparatory activities and refuelling, maintenance and testing carried out during outage and start-up. We understand (from the responses to RO-UKHPR1000-0010 and RQ-UKHPR1000-0679) the difficulties the RP would have separating out each individual element described above from the OPEX and we are satisfied that the main intent of the requirements of the P&ID have been captured in the data. We therefore accept the RP's approach as being acceptable for GDA.

Expected events are presented as a distinct element throughout the calculations (see 'Deriving appropriate expected events' below).

Identifying significant radionuclides

The RP has used our guidance on limit setting to help define a set of significant radionuclides for which we expect a discharge limit to be proposed. The approach defines significant radionuclides as those which:

- are significant in terms of radiological impact on people (the dose to the most exposed group at the proposed limit exceeds 1μSv/yr)
- are significant in terms of radiological impact on wildlife (the impact on reference organisms from the discharge of a single radionuclide at the proposed limit exceeds 10μGy/hr)
- are significant in terms of quantity of radioactivity discharged (the discharge of a radionuclide exceeds 1TBq/yr)
- may contribute significantly to the collective dose - where the collective dose (truncated at 500 years from the discharges of all radionuclides at the proposed limits) exceeds one man-sievert per year to any of the UK, European or world populations
- are constrained under national agreements or are of concern internationally
- are indicators of plant performance

- are not covered by the limits set in the above criteria, but which require a limit under a generic category (such as alpha particulate or beta/gamma particulate)

The RP applied the criteria and presented its findings in both the ‘Quantification of Discharges and Limits’ (GNSL, 2021a) and the ‘Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000’ (GNSL, 2021b) documents. The radionuclides or groups of radionuclides that the RP identified under each criterion are as follows:

Selection criterion - Dose to most exposed person (>1μSv/yr)

- Gaseous discharge – carbon-14
- Liquid discharge – carbon-14

Selection criterion - Discharged activity (greater than 1TBq)

- Gaseous discharge - hydrogen-3, carbon-14, xenon-133, xenon-135
- Liquid discharge – hydrogen-3

Selection criterion - Collective dose (greater than 1 man-sievert)

- Gaseous discharge – carbon-14

Selection criterion - Plant performance indicators

- Gaseous discharge - xenon-133, xenon-135 (fuel reliability indicators). Other beta/gamma emitters (performance of gaseous waste management system)
- Liquid discharge - Other gamma emitters (performance of liquid waste management system)

The RP’s decision to select xenon-133 and xenon-135 as significant radionuclides to indicate plant performance was based on international practice used in other pressurised water reactors (PWRs) in the UK, France and China. The radionuclides of xenon were found to be released from failed fuel more quickly than iodine-131 and therefore considered to be better indicators of fuel reliability.

It is worth noting that for dose to non-human species, 10μGy/hr has been used for GDA rather than 40μGy/hr as stated in our limit setting guidance. We advise the use of 40 μGy/hr for the impact on the receptor (that is, species or habitat) from all sources of radioactive discharges that have a pathway to that receptor. This level is appropriate where we know the location and any other radioactive discharges that may affect the receptor(s). For GDA, we advise a lower level of 10μGy/hr because GDA is based on a single unit at an unknown location, with the possibility that the location could be adjacent to other sources of radioactive discharges. The figure the RP used is therefore considered to be correct.

We consider the radionuclides selected as significant to be appropriate for the purposes of GDA.

Deriving correction factors

The RP has based the estimation of discharges and therefore proposed limits on OPEX. The selection of OPEX data is detailed in a supporting document 'OPEX Data Selected for Quantification of Discharges and Limits for UK HPR1000' (GNSL, 2019b) and summarised within the main 'Pre-Construction Environmental Report Document - Quantification of Discharges and Limits' (GNSL, 2021a). The RP selected OPEX data from plants similar in design to the UK HPR1000. However, there are some design differences that could affect the discharge estimates.

Correction factors were derived as a way of reducing the impact of any differences on the discharge estimates for the UK HPR1000. The RP considered the applicability of correction factors for all the significant radionuclides, and concluded that a correction factor was only appropriate for hydrogen-3 (tritium) and carbon-14 in both gaseous and liquid discharges.

Hydrogen-3 is affected by power differences between the UK HPR1000 and OPEX units. The discharge estimates are multiplied by a factor to represent the increased power output of the UK HPR1000. This ensures discharges are not underestimated.

Carbon-14 is also affected by power differences, but will also be higher in the UK HPR1000 than in OPEX plants. This is because the UK HPR1000 uses nitrogen as a cover and purge gas in the gaseous waste treatment system instead of hydrogen, which is used in the Chinese fleet. Hydrogen is a flammable gas and poses an explosion risk, so nitrogen has been selected as an alternative for the UK HPR1000 design (Environment Agency, 2022b). Nitrogen can dissolve in the coolant and nitrogen-14 can be activated to form carbon-14. Nitrogen-14 in the primary coolant contributes about 12% of the carbon-14 production from the UK HPR1000. This is assessed in more detail in our assessment report 'Best available techniques for minimising production and disposal of radioactive waste' (Environment Agency, 2022b).

We consider that the RP's conclusions and methods for calculating correction factors seem reasonable and will not underestimate expected discharges.

Deriving headroom factors

Headroom factors are important to take account of the uncertainty in the OPEX data used to derive the discharge limits. They allow a future operator to comply with the proposed limits without unduly affecting its ability to operate the plant. We acknowledge in our limit setting guidance that "…there may be considerable uncertainty about the data presented in the application….and hence limits for new plants will, in general, provide for greater headroom than operational plants where discharge data are available. We would review limits against operating data, when available."

To ensure that the bounding case derived for GDA is continually revised as the design of the plant advances and operation begins, and so that headroom is the minimum necessary to permit normal operation, we consider the following Assessment Finding to be appropriate:

Assessment Finding 16: A future operator shall keep the headroom factors derived during GDA under review. Operational data generated by the UK HPR1000 should be used to periodically revise the headroom factors to ensure that they are the minimum necessary to permit normal operation.

The RP carried out a statistical analysis of the OPEX data and adopted a conservative approach of a one-sided normal distribution to quantify headroom. This provided a 99.9% confidence level over the 60-year lifetime of the plant that proposed limits would not be exceeded. Headroom factors were calculated for all significant radionuclides.

We consider that the RP's conclusions on headroom factors for all significant radionuclides are appropriate for GDA. However, they would be periodically reviewed throughout the life of the plant (see Assessment Finding 16).

Deriving appropriate expected events

The RP carried out a process to identify expected events and then quantify their contribution to the discharge estimates (in terms of Bq). Expected events for the UK HPR1000 have been derived in 2 supporting documents 'Methodology for Expected Events Identification for UK HPR1000' (GNSL, 2019d) and 'Expected Event List for UK HPR1000' (GNSL, 2021c). We were kept up to date on progress with this process in our regular meetings with the RP.

The process involved determining a preliminary set of expected events for each radionuclide group. A number of experts in a range of design areas from China General Nuclear (CGN), GNSL, EDF, Sizewell B and Hinkley Point C were then consulted with the list. This consultation was carried out via workshops, meetings or written reviews until a consensus was reached on the final list. We considered this to be an important step to validate the outcomes of the theoretical assessment process with expert judgement. Once the final list was established, a bounding case was developed for each significant radionuclide, taking into account reasonable occurrences of the expected events. This resulted in a contribution (in Bq) that could be used in calculating the annual limits for each significant radionuclide (see estimated discharges and proposed limits below). The RP presents additional detail on the process and the final expected event list in its supporting document ‘Expected Event List for UK HPR1000’ (GNSL, 2021c). The final list of expected events for each radionuclide, or radionuclide group, is as follows:

Hydrogen-3

- Unplanned shutdown
- Increase of the open water evaporation due to temperature, air velocity or humidity changes

- Small leak of the radioactive systems

Carbon-14

- Increase of nitrogen concentration in primary coolant

Noble gases

- Fuel pin cladding defect
- Unplanned shutdown
- Small leak of the radioactive systems
- Small leak from the primary side to the secondary side

Halogens

- Fuel pin cladding defect
- Unplanned shutdown
- Failure or low efficiency of the iodine adsorbers of HVAC system
- Failure of the online monitoring of HVAC before the iodine adsorbers
- Failure of evaporation unit or demineralisation unit of the liquid waste treatment system
- Small leak of the radioactive systems
- Small leak from the primary side to the secondary side

Other radionuclides

- Fuel pin cladding defect
- Unplanned shutdown
- Failure of evaporation unit or demineralisation unit of the liquid waste treatment system
- Failure of pre-filters or HEPA filters of HVAC system
- Contamination of primary coolant
- Small leak of the radioactive systems
- Small leak from the primary side to the secondary side

Note - 'Noble gases' are radioactive isotopes of krypton, argon and xenon. 'Halogens' are radioactive isotopes of iodine and bromine. 'Other radionuclides' contain a range of radioactive isotopes, which include fission and corrosion products.

As part of our assessment of the expected event list, we reviewed the RP's document 'Secondary Coolant Source Terms Supporting Report' (GNSL, 2020c). We would have expected this document to have been linked to the discharge estimates document (GNSL, 2021b) because 2 of the expected events identified in the list above (small leak from the radioactive systems and small leak from the primary circuit to secondary circuit) are considered likely to affect the secondary circuit. We could not identify where the impact of such leaks had been incorporated into the discharge estimate and limit calculations. We also noted that carbon-14 was not mentioned in the secondary coolant source term document (GNSL, 2020c).

In order to answer these questions, we raised RQ-UKHPR1000-678. In its response, the RP confirmed that the secondary source term in this document was derived from the primary source term by calculation and does not use OPEX. The secondary source term presented in this document is for carrying out radiological protection calculations, which ONR assessed separately. The RP also confirmed that the 2 expected events (small leak from the radioactive systems and small leak from the primary side to secondary side) would be very small in terms of radioactivity and are likely to be included in the OPEX data. For these reasons, the RP considered it not appropriate to include it in the secondary source term. We agree with the conclusions the RP reached.

In response to the other query in RQ-UKHPR1000-0678 regarding the exclusion of carbon-14, the RP confirmed that, as the main purpose of the secondary source term document (GNSL, 2020c) is for shielding design, carbon-14 (a low energy beta emitter) does not need to be included because it does not affect the shielding design.

Summary of our assessment of the Requesting Party's method for quantifying discharges and limits

In summary, we consider the methods the RP used and the conclusions it reached in establishing operating conditions, OPEX, significant radionuclides, correction factors, headroom factors and contributing expected events to meet our expectations for GDA.

3.4.4. Estimated discharges and proposed limits

Once the various factors described in section 3.4.3 above had been established, the RP used them in a series of calculations, along with OPEX, to determine discharge estimates and proposed limits. The specific outputs of the calculations are as follows:

- estimated monthly discharges
- estimated annual discharges

These estimates were then used to calculate:

- annual discharge limits

Calculations are also presented to derive maximum monthly discharge estimates. These estimates provide an indication of possible variations in short-term discharges during normal operation which would remain within specific annual limits. These discharge variations may lead to short-term increases in discharges and can be caused by expected events, variation in plant parameters and standard operating practices. The maximum monthly discharges presented are used solely as an input to the radiological impact assessment of short duration releases, which is included in PCER Chapter 7 - Radiological Assessment. Our view on this assessment is presented in a separate assessment report (Environment Agency, 2022d).

The RP's calculation of annual discharge limits involved establishing the estimated monthly discharges for power operation and shutdown and then using these to calculate the estimated annual discharges. The headroom factor and contribution of expected events, along with the estimated annual discharges, were then used to calculate a proposed annual limit for each significant radionuclide (see Tables 3 and 4 below).

We have assessed the calculations used to derive discharge estimates and proposed limits presented in Chapter 6 of the 'Pre-Construction Environmental Safety Report' (GNSL, 2021a) and the supporting document 'Estimation of Radioactive Gaseous and Liquid Discharges and Limits for the UK HPR1000' (GNSL, 2021b). We are satisfied that the discharge estimates meet the expectations in our limit setting guidance and cover the requirements of the P&ID. The estimated discharges and proposed limits are shown in Tables 3 and 4 below.

Table 3: Gaseous - Estimated discharges and proposed limits

Radionuclide	Monthly discharges during power operation (Bq)	Monthly discharges during shutdown (Bq)	Annual discharge (Bq)	Proposed annual limit (Bq)
Hydrogen-3	4.71E+10	1.82E+11	8.34E+11	5.23E+12
Carbon-14	1.75E+10	9.91E+10	3.74E+11	1.69E+12
Noble gases (including xenon-133 & xenon-135)	6.69E+10	2.71E+11	1.21E+12	1.56E+13
Xenon-133	5.00E+10	2.02E+11	9.04E+11	1.16E+13
Xenon-135	1.48E+10	5.99E+10	2.68E+11	3.45E+12
Halogens	4.79E+05	6.33E+06	1.75E+07	2.21E+08

Radionuclide	Monthly discharges during power operation (Bq)	Monthly discharges during shutdown (Bq)	Annual discharge (Bq)	Proposed annual limit (Bq)
Other radionuclides	3.15E+05	3.58E+05	3.86E+06	1.12E+07

Table 4: Liquid - Estimated discharges and proposed limits

Radionuclide	Monthly discharges during power operation (Bq)	Monthly discharges during shutdown (Bq)	Annual discharge (Bq)	Proposed annual limit (Bq)
Hydrogen-3	1.63E+12	5.27E+12	2.69E+13	1.04E+14
Carbon-14	7.67E+08	3.71E+09	1.51E+10	5.90E+10
Other radionuclides	1.84E+07	7.49E+07	3.33E+08	1.04E+09

3.4.5. Comparison of UK HPR1000 discharges with other similar reactors around the world

As required by our P&ID, the RP has carried out a comparison of the UK HPR1000 discharge estimates and proposed limits derived above with other similar reactors worldwide. The comparison is presented in both the main 'Pre-Construction Environmental Report' Chapter 6 (GNSL, 2021a) and the supporting document on 'Estimation of Discharges and Limits' (GNSL, 2021b). The RP approached this by carrying out a comparison with previous pressurised water reactor (PWR) GDAs and then with other publicly available international OPEX from the UK, France, Germany and USA.

Important points to consider are:

- Comparisons with both previous GDAs and international OPEX involve using data normalised to 1,000MWe. This is an acceptable approach as it enables as meaningful a comparison as possible to be carried out. For example, discharges of hydrogen-3 and carbon-14 are both proportional to power output, so normalising the data to 1,000MWe enables these radionuclides to be compared.

- Comparison with international OPEX is comparing conservatively derived estimates for the UK HPR1000 with actual discharges.

Comparison with previous PWR GDAs

The RP reviewed the publicly available information on the previous GDAs for the UK EPR and the UK AP1000. Acknowledging the difference in methods for quantifying discharges and limits used by each RP, the UK HPR1000 RP carried out an indicative comparison of the data normalised to 1,000MWe. The RP produced graphs of the results (see Appendix 3).

The graphs show that for all radionuclides, except gaseous hydrogen-3, carbon-14 and liquid hydrogen-3, the UK HPR1000's discharges are the same or slightly lower than the other PWRs.

Where the UK HPR1000 discharges are slightly higher (gaseous hydrogen-3, carbon-14 and liquid hydrogen-3), the RP has explained that this is likely to be due to the varying assumptions made between the 3 GDAs. We considered that better justification was necessary and issued RQ-UKHPR1000-0843 to obtain more information. The RP's response went into further detail on the different methodologies used for the 3 GDAs being compared. The differences relate to the Environment Agency guidance available at the time of each GDA, the different approaches to calculating headroom, the contribution of expected events and the calculation of proposed limits. We consider the differences in approach that the RP clarified in response to the RQ (and subsequently written into the PCER and the supporting document 'Estimation of Radioactive Gaseous and Liquid Discharges and Limits') to be a satisfactory explanation of for the variations displayed in the graphs. We also note that the discharge estimates for all 3 GDAs are within the same order of magnitude, which suggests that the differences can also be attributed to the conservatism in the UK HPR1000 discharge estimates and not a difference in environmental performance between the 3 modern PWR designs.

Comparison with international OPEX

In order to make a meaningful comparison, the RP took the annual averages from the international OPEX and the annual discharge estimates from the UK HPR1000 and then normalised them to 1,000MWe. The RP produced graphs of the results and they are reproduced in Appendix 4.

The graphs in Appendix 4 show that the UK HPR1000 annual discharges are broadly similar to the international OPEX from similar plants around the world. The OPEX data selected is based on annual averages and is described in detail in the supporting document OPEX data selected for quantification of discharges and limits for UK HPR1000 (GNSL, 2019b). In both the main 'Pre-Construction Environmental Report' Chapter 6 and the supporting document on 'Estimation of Radioactive Gaseous and Liquid Discharges and Limits' the RP provided the following considerations and conclusions.

Requesting Party considerations:

- The RP has calculated its discharges based on 10 months of power operation and 2 months of outage to ensure both operational and outage phases are captured in the annual figures. When compared to actual OPEX, where most plants use an 18-month refuelling cycle, the UK HPR1000 annual discharges can be considered to be overestimated.

- Differences in reporting approaches in different countries could have resulted in the UK HPR1000 figures being overestimated by comparison with certain countries. The UK, France and China have an approach that involves reporting half of the detection limit when the result obtained is below the detection limit. The UK HPR1000 also uses this approach. In contrast, in the USA and Germany, measurements below detection limits are not reported.

- The UK HPR1000 uses nitrogen as a cover and purge gas. This has been driven by safety considerations to replace hydrogen gas (which poses a risk of explosion) with nitrogen gas. Gaseous carbon-14 is generated from the activation of nitrogen gas. This approach mirrors that adopted at the German plants and the UK EPR design at Hinkley Point C. The RP therefore expects actual discharges to be closer to the German plants but higher than those that use hydrogen as the cover and purge gas.

Requesting Party conclusions:

- Gaseous carbon-14 from the UK HPR1000 design is slightly higher than comparable plants that use hydrogen as the cover and purge gas.

- Liquid discharges of carbon-14 are not reported or monitored for UK, German or United States plants so comparison can only be made with the French fleet. The estimated levels of carbon-14 from the UK HPR1000 are similar to those from the French fleet.

- Gaseous annual discharges of hydrogen-3, noble gases, halogens and other radionuclides and liquid annual discharges of hydrogen-3 and other radionuclides are generally comparable (higher than some, lower than others) to other plants. The RP cites the likelihood that some UK HPR1000 figures could be overestimated (see 'Requesting Party considerations' above).

Our assessment highlighted a discrepancy between the text in the submissions and the graphs it was describing. This was highlighted in RQ-UKHPR1000-1558 (see Appendix 2) and prompted the RP to redraft the appropriate section of its submissions. The revised set of conclusions described above reflect the text revisions made in the RP's submissions as a result of the RQ.

We consider the information the RP provided in this section demonstrates that the UK HPR1000 discharges and limits are generally comparable with international OPEX and previous GDAs. Where there are differences, we are satisfied that the RP has provided reasonable explanations (see ‘Requesting Party considerations’ above).

3.5. Compliance with Environment Agency requirements for GDA

Compliance with Environment Agency requirements for GDA can be summarised as follows:

- P&ID Table 1, item 5 – the RP has provided estimates of aqueous radioactive waste disposals for normal operation and proposed limits for the disposal of aqueous radioactive waste.

- RSDMP12 – Limits and levels on discharges – the RP has proposed limits for the UK HPR1000 gaseous and liquid waste disposals.

4. Public comments

4.1. General Nuclear System Limited's public comments process

GNSL received no public comments up to 17 September 2021 concerned directly with quantifying discharges and limits.

4.2. Environment Agency public consultation

We held a public consultation on our preliminary GDA assessment findings (Environment Agency, 2021a & b), which ran for 12 weeks from 11 January 2021 to 4 April 2021. We received a number of consultation responses, which we have published (https://consult.environment-agency.gov.uk/nuclear/assessing-new-nuclear-power-station-ukhpr1000/). Our replies to each point are presented within our decision document (Environment Agency, 2022a). Any points raised that were in GDA scope and relevant to quantifying discharges and limits are also presented here.

We received comment UKHPR1000-007 on the discharge of alpha particles and comment UKHPR1000-014, which was a more general point about the issue of detectability of alpha activity.

During one of our consultation events, the question of alpha activity in discharges was raised. At the event, we responded to say that discharges of alpha activity from PWRs were so low that they could not be detected. The question was followed up with the event attendee referring to published data on particulates from PWRs published in the UNSCEAR 2000 Annex C as evidence that such activity was discharged to air. We ran out of time to respond to this verbally in the meeting, but provided a written response, which was published on our consultation website while the consultation was still open (26 March 2021), as follows:

Table 34 documents particulates released from reactors in airborne effluents in GBq, but no indication is given of detailed radionuclide composition or particle size distribution.

Paragraph 141 in the supporting document notes that the particulate composition has been looked at for each reactor type, of all the nuclides noted in the text, none are alpha emitters (see below for UNSCEAR text):

'The radionuclide composition of releases has been examined for the various reactor types. In general, the releases of noble gases from PWRs are dominated by 133Xe, with a half-life of 5.3 days, but short-lived radionuclides such as 135Xe (half-life = 9.2 h) are also present. For the BWRs the composition of the noble gas releases is more varied, with most krypton and xenon radionuclides included. The releases of particulates from BWRs are also variable and difficult to generalize from the limited data available. The radionuclides 88Rb (half-life = 17.8 min), 89Rb (half-life = 15.2 min), 138Cs (half-life = 33.4 min), and 139Ba (half-life = 83.1 min) were prominent in the large releases mentioned above from the Ringhals 1 reactor. The radionuclide compositions of liquid releases from

PWRs seem to vary from reactor to reactor; the cobalt isotopes (58Co, 60Co) as well as the caesium isotopes (134Cs, 137Cs) are usually present. In some cases, large relative proportions of 110mAg and 124Sb are reported. It may be that some differences are accentuated by the various measuring and reporting practices at reactor stations.'

Based on the above, we believe it would be incorrect to assume that the PWR particulate data in UNSCEAR 2000 - Annex C Table 34 indicates alpha discharges or can be considered as a proxy for alpha discharges.

We have assessed the theoretically calculated activity of the primary circuit cooling water calculations to check the relative abundance of the activity concentrations of radionuclides associated with particulates (corrosions products and alpha emitting actinides) in light of this comment. We again note that all the nuclides referred to in UNSCEAR 2000 Annex C paragraph 141 are corrosion products, which are beta/gamma emitting nuclides and not alpha emitting nuclides. Our assessment of the UK HPR1000 source term analysis indicated that alpha activity concentrations are approximately one millionth of the activity concentrations associated with the corrosion products. This supports our written response that alpha discharges are so low that they are unlikely to be detectable and are not a significant radionuclide in the UK HPR1000 discharges.

We received comment UKHPR1000-009 regarding the comparison of discharges with other power stations. The RP made this comparison and our assessment is covered in section 3.4.5 of this report 'Comparison of UK HPR1000 discharges with other similar reactors around the world'. The key point to highlight here is that all the discharge data used for the comparison in this GDA has been normalised to 1,000 MWe which enables as meaningful a comparison as possible.

We received comment UKHPR1000-009 regarding the comparison of UKHPR1000 estimated discharges with those of previous PWR GDAs. The comment raised concern that the estimated discharges are not lower than those estimated for other PWR designs that have been previously subjected to GDA. This point was raised by the Environment Agency during our assessment and the RP has provided sufficient explanation for the reasons behind the differences shown in the graphs comparing the 3 designs assessed under GDA. These reasons are outlined in section 3.4.5 of this report 'Comparison of UK HPR1000 discharges with other similar reactors around the world' under the sub-heading 'Comparison with previous PWR GDAs'.

We received a comment UKHPR1000-026 regarding the impact of accidents on discharges. We assess gaseous and liquid discharges from 'normal operations' only. ONR assesses the radiological consequences of accidents and regulates arrangements for the control and mitigation of radiological consequences following a significant release of radioactivity. This is explained, along with the full definition of normal operation in section 3.3 of this report (Assessment limitations and scope).

We received comment UKHPR1000-043, which expressed a view that the use of the becquerel, rather than a more understandable term, is unsatisfactory. The becquerel is the internationally accepted unit of radioactivity and equals one radioactive decay (or nuclear disintegration) per second. Therefore, we cannot carry out any calculations to determine proposed levels of radioactivity released to the environment without using the internationally accepted unit for radioactivity.

We received 2 comments (UKHPR1000-045 and UKHPR1000-047) raising concern about the use of discharge estimates for our decision-making during GDA. It is important to note that during GDA our expectation, as defined in our P&ID (Environment Agency, 2016), is for the RP to estimate discharges and propose limits. The approach the RP took for this GDA was to use operating experience (OPEX) from similar operational plants within the China General Nuclear (CGN) fleet. The source of OPEX used for GDA has been covered in some detail throughout the RP’s submission (see the PCER document (GNSL, 2021a)) and we consider this to be a reasonable basis for calculating estimates for GDA. We would expect to see the OPEX refined and improved over time as more data become available. We would use the latest information available when making decisions about limits when considering a site-specific application.

Comment UKHPR1000-047 also raised a question regarding the number of reactors the GDA covered. Our GDA relates to a single reactor and this is stated in section 3.3 of this report (Assessment limitations and scope).

We received comment UKHPR1000-050, which also raised concerns over the acceptability of discharge estimates and proposed limits and the impact from unexpected accidents. The discharge estimates the RP presented are part of a wider GDA submission where applying BAT to minimise the amount of radioactive waste that needs to be discharged has to be justified (see our assessment report on ‘Best available techniques’ (Environment Agency, 2022b)). The discharge estimates are compared with comparable plant worldwide in this report and the proposed limits are used as input parameters for a radiological impact assessment covered in our assessment report (Environment Agency, 2022d). Our conclusions in this report on the acceptability of the discharge estimates and proposed limits are made having regard to our wider assessment of the UK HPR1000 design. The concern raised in this comment regarding accidents is similar to that raised in UKHPR1000-026 and the Environment Agency’s response to that is provided above.

5. Conclusion

We have reviewed the assessment objectives and our conclusions are that:

- the RP has provided us with information on estimated gaseous and liquid discharges and proposed limits. It is clear how it has derived these discharge estimates and the estimates are supported by suitable evidence
- the proposed annual gaseous and liquid discharge limits for the UK HPR1000 are clearly derived, taking into account our limit setting guidance
- we consider that the RP has demonstrated that the UK HPR1000's discharges and limits are generally comparable with international OPEX and previous GDAs. Where there are differences, we are satisfied that the RP has provided reasonable explanations
- the gaseous and liquid discharges from the UK HPR1000 would be capable of complying with the limits set out below (Tables 5 and 6):

Table 5: Proposed gaseous and emission limits for the UK HPR1000

Radionuclide	Proposed annual limit (Bq)
Hydrogen-3	5.23E+12
Carbon-14	1.69E+12
Noble gases (including xenon-133 & xenon-135)	1.56E+13
Xenon-133	1.16E+13
Xenon-135	3.45E+12
Halogens	2.21E+08
Other radionuclides	1.12E+07

Table 6: Proposed liquid emission limits for the UK HPR1000

Radionuclide	Proposed annual limit (Bq)
Hydrogen-3	1.04E+14
Carbon-14	5.90E+10
Other radionuclides	1.04E+09

We considered the following Assessment Finding to be appropriate:

Assessment Finding 16: A future operator shall keep the headroom factors derived during GDA under review. Operational data generated by the UK HPR1000 should be used to periodically revise the headroom factors to ensure that they are the minimum necessary to permit normal operation.

References

DECC, 2009

Statutory Guidance to the Environment Agency concerning the regulation of radioactive discharges into the environment. Department of Energy and Climate Change and Welsh Assembly Government, 2009.

http://webarchive.nationalarchives.gov.uk/20121217150421/http:/decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/nuclear/radioactivity/dischargesofradioactivity/1_20091202160019_e_@@_guidanceearadioactivedischarges.pdf

Environment Agency, 2010

Regulatory Guidance Series, No RSR 1. Radioactive Substances Regulation – Environmental Principles. Environment Agency, 2010. https://www.gov.uk/government/publications/radioactive-substances-regulation-environmental-principles

Environment Agency, 2012

Criteria for setting limits on the discharge of radioactive waste from nuclear sites. Environment Agency 2012.

https://www.gov.uk/government/publications/discharge-of-radioactive-waste-from-nuclear-sites-setting-limits

Environment Agency, 2016

Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs. (Environment Agency, version 3, October 2016).

Environment Agency, 2018

Initial assessment of General Nuclear System's UK HPR1000 design: Statement of findings. Version 1, 2018.

https://www.gov.uk/government/publications/new-nuclear-power-stations-initial-assessment-of-general-nuclear-systems-uk-hpr1000-design

Environment Agency, 2021a

Preliminary detailed assessment of gaseous and liquid discharges of radioactive waste for General Nuclear System Limited's UK HPR1000 design – AR04. Version 1, January 2021.

Environment Agency, 2021b

Assessing new nuclear power station designs. Generic design assessment of General Nuclear System Limited's UK HPR1000. Consultation Document. Version 1, January 2021.

Environment Agency, 2022a

Assessing new nuclear power station designs. Generic design assessment of the UK HPR1000. Decision Document. Version 1, January 2022.

Environment Agency, 2022b

Generic design assessment of new nuclear power plants. Best available techniques for the UK HPR1000 - AR03. Detailed assessment – final report. Version 1, January 2022.

Environment Agency, 2022c

Generic design assessment of new nuclear power plants. Sampling and monitoring for the UK HPR1000 - AR06. Detailed assessment – final report. Version 1, January 2022.

Environment Agency, 2022d

Generic design assessment of new nuclear power plants. Generic site, doses to the public and dose rates to wildlife for the UK HPR1000 - AR07. Detailed assessment – final report. Version 1, January 2022.

Environment Agency, 2022e

Generic design assessment of new nuclear power plants. Other environmental regulations for the UK HPR1000 - AR08. Detailed assessment – final report. Version 1, January 2022.

GNSL, 2018

Pre-Construction Environmental Report Chapter 6 - Quantification of Discharges and Limits. HPR/GDA/PCER/0006, Rev. 000-1, November 2018 (V0).

GNSL, 2019a

Scope for UK HPR1000 GDA project. HPR-GDA-REPO-0007 Rev 001 July 2019.

GNSL, 2019b

OPEX Data Selected for Quantification of Discharges and Limits for UK HPR1000. GHX35000001DNFP03GN, Rev D, November 2019.

GNSL, 2019c

Trend Analysis of Radioactive Discharges of Nuclear Power Plant during whole life-time. GHX35000003DNFP02GN, Rev B, November 2019.

GNSL, 2019d

Methodology for Expected Events Identification for UK HPR1000. GHX00500001DNHX02GN, Rev B, March 2019.

GNSL, 2020c

Secondary Coolant Source Term Supporting Report. GHX90300004DNFP03GN, Rev D, June 2020.

GNSL, 2021a

Pre-Construction Environmental Report Chapter 6 – Quantification of Discharges and Limits. GHX00510006KPGB02GN Rev K October 2021 (V2).

GNSL, 2021b

Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000. GHX35000002DNFP03GN, Rev F, April 2021.

GNSL, 2021c

Expected Event List for UK HPR 1000. GHX00500001DNFP02GN, Rev E, April 2021.

UK Parliament, 2016

The Environmental Permitting (England and Wales) Regulations 2016. SI 2016 No. 1154, as amended.

https://www.legislation.gov.uk/uksi/2016/1154/contents/made

List of abbreviations

AF	Assessment Finding
ALARA	As low as reasonably achievable
BAT	Best available techniques
BWR	Boiling water reactor
CGN	China General Nuclear
EC	European Commission
EDF	Électricité De France
EPR	Environmental Permitting Regulations
HEPA	High efficiency particulate air (filter)
GDA	Generic design assessment
GNSL	General Nuclear System Limited
HVAC	Heating, ventilation and air conditioning
LLW	Low level waste
ILW	Intermediate level waste
iSoDA	Interim statement of design acceptability
OPEX	Operating experience
P&ID	Process and Information Document
PCER	Pre-Construction Environmental Report
PWR	Pressurised water reactor
REPS	Radioactive Substances Regulation - Environmental Principles
RO	Regulatory Observation
RP	Requesting Party
RQ	Regulatory Query
SoDA	Statement of design acceptability
UK	United Kingdom

Appendix 1: Requesting Party documentation

We referred to the following documents to produce this report:

– Pre-Construction Environmental Report, Chapter 6 - Quantification of Discharges and Limits v0 (HPR/GDA/PCER/0006, Rev. 000-1, November 2018)

– Pre-Construction Environmental Report, Chapter 6 - Quantification of Discharges and Limits v1 (HPR/GDA/PCER/0006, Rev. 001, January 2020)

– Pre-Construction Environmental Report, Chapter 6 - Quantification of Discharges and Limits v1.1 (HPR/GDA/PCER/0006 Rev.001-1 October 2020)

– Pre-Construction Environmental Report Chapter 6 – Quantification of Discharges and Limits v2 (HX00510006KPGB02GN Rev K – October 2021)

– Scope for UK HPR1000 GDA project v1(HPR-GDA-REPO-0007 Rev 001 July 2019)

– Estimation of Radioactive Gaseous and Liquid Discharges and Limits for UK HPR1000 (GHX35000002DNFP03GN, Rev F, April 2021)

– OPEX Data Selected for Quantification of Discharges and Limits for UK HPR1000 (GHX35000001DNFP03GN, Rev D, November 2019)

– Trend Analysis of Radioactive Discharges of Nuclear Power Plant during whole life-time (GHX35000003DNFP02GN, Rev B, November 2019)

– Secondary Coolant Source Term Supporting Report (GHX90300004DNFP03GN, Rev D, June 2020)

– Methodology for Expected Events Identification for UK HPR1000 (GHX00500001DNHX02GN, Rev B, March 2019)

– Expected Event List for UK HPR 1000 (GHX00500001DNFP02GN, Rev E, April 2021)

Appendix 2: Summary of Regulatory Queries and Observations relating to quantification of discharges and limits

RQs and ROs that are most relevant to the quantification of discharges and limits for the UK HPR1000 are shown below (There are no Regulatory Issues [RIs] relevant to this topic area).

Regulatory Queries

RQ-UKHPR1000-0076 (03-April-2018): Provenance and validity of discharge estimates. The RP was requested to provide further information on its proposed method for deriving discharge estimates.

RQ-UKHPR1000-0193 (04-Feb-2019): Reference request - expected event methodology. The RP was asked to provide information on its expected events method.

RQ-UKHPR1000-0678 (13-Mar-2020): Secondary coolant source term. The RP was requested to provide clarification on why leakage from the primary to secondary side was not clearly highlighted in the discharge estimate calculations and also why carbon-14 did not feature in the secondary source term report.

RQ-UKHPR1000-0679 (13-Mar-2020): RO-10 clarification. The RP was asked to clarify some points relating to its response to RO-UKHPR-1000-0010.

RQ-UKHPR1000-0843 (09-Jun-2020): Comparison of radioactive discharges with other nuclear power plants. The RP was asked to provide better justification for its conclusions on the comparison between UK HPR1000 and previous PWR GDAs.

RQ-UKHPR1000-1558 (24-Feb-2021): Comparison of radioactive discharges with other nuclear plants – liquid discharges of ‘other radionuclides’. The RP was asked to clarify an apparent discrepancy between the graphs for liquid discharges of other radionuclides and the supporting text.

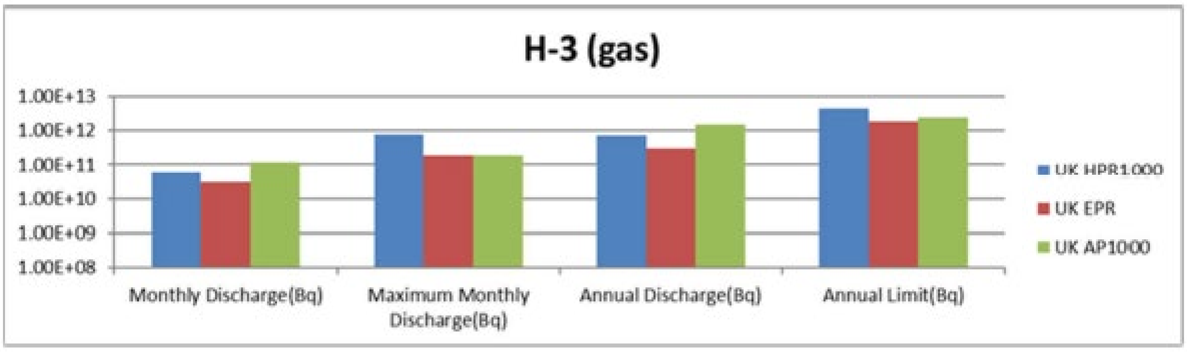
Regulatory Observation

RO-UKHPR1000-0010 (12-Apr-2019): Discharge estimates and limits. The RP was asked to carry out further work to:

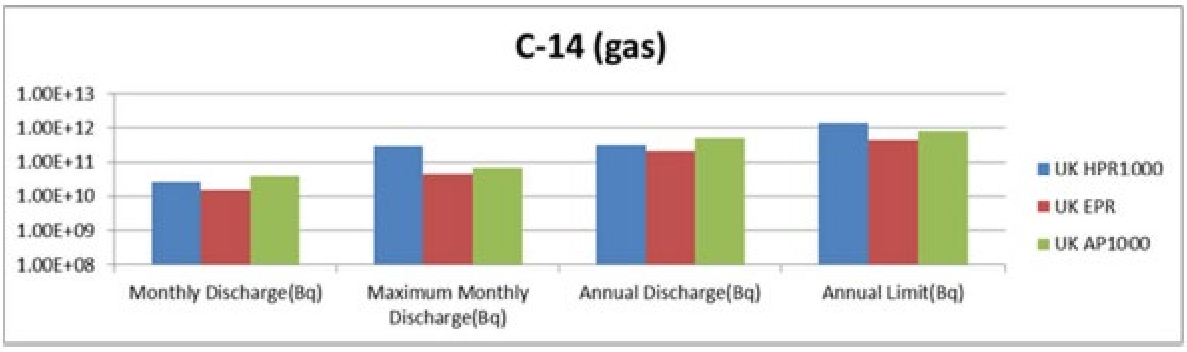
- demonstrate that OPEX used are representative of a full operational plant life
- demonstrate that the calculations are in line with Environment Agency guidance
- clearly show each constituent part of normal operations used to calculate the discharge estimates

Appendix 3 - Graphs showing comparison with previous pressurised water reactor (PWR) GDAs

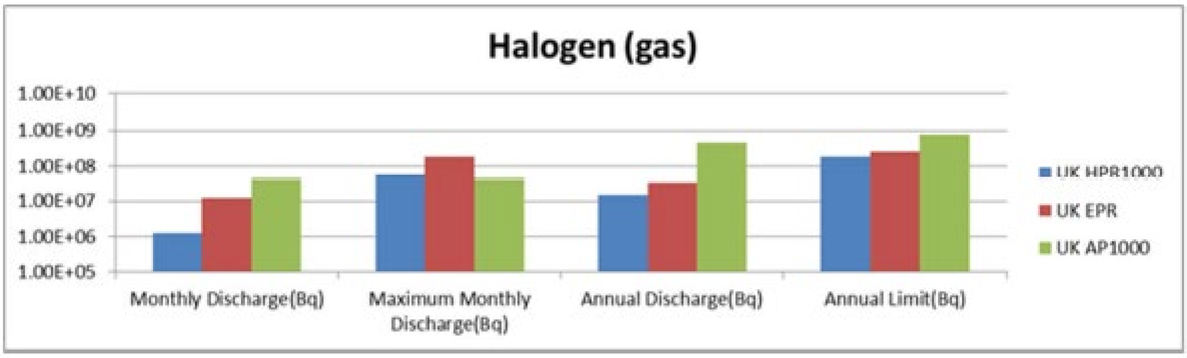
NOTE - all data used in the graphs are normalised to 1,000MWe to enable meaningful comparison (see section 3.4.5 above).



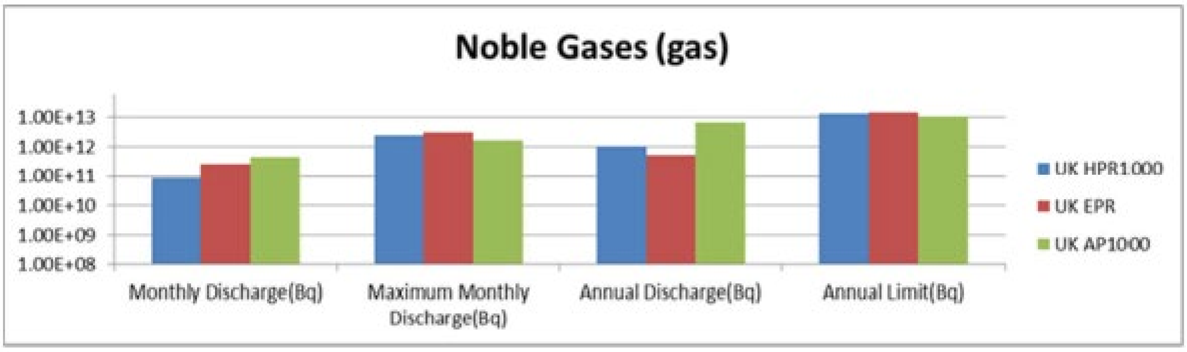
Gaseous - Hydrogen-3 - comparison of discharges and limits



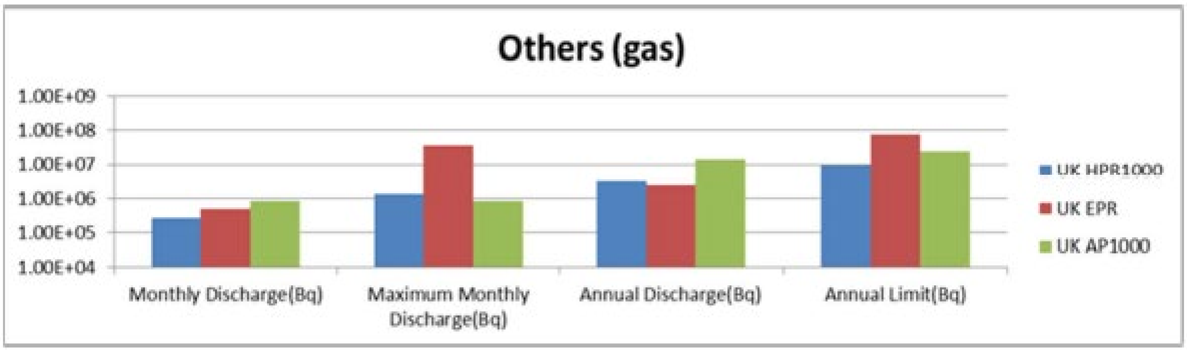
Gaseous - Carbon-14 - comparison of discharges and limits



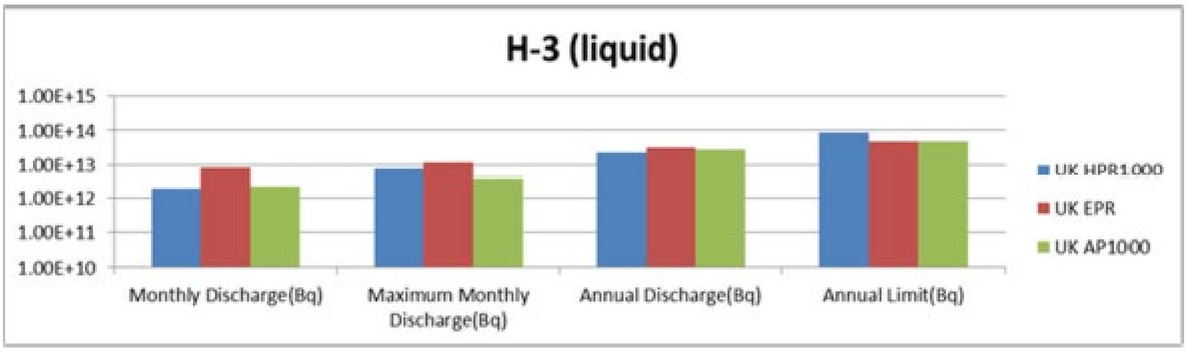
Gaseous - halogens - comparison of discharges and limits



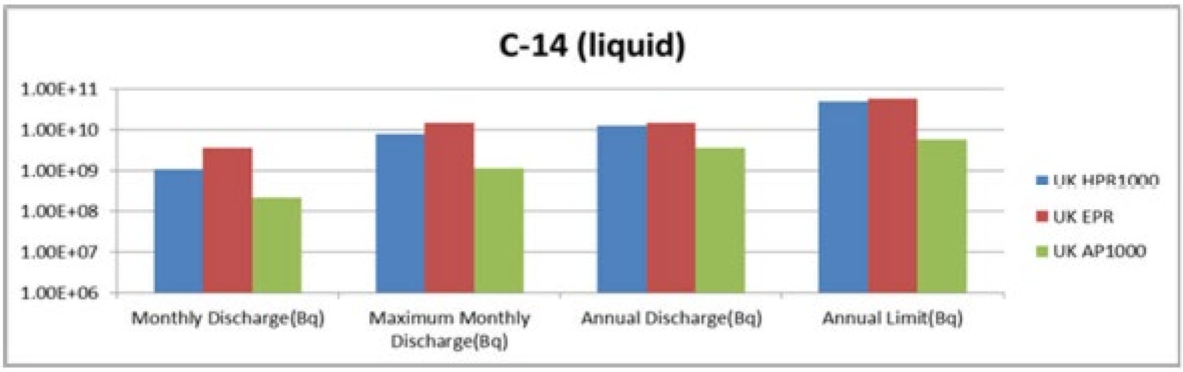
Gaseous - noble gases - comparison of discharges and limits



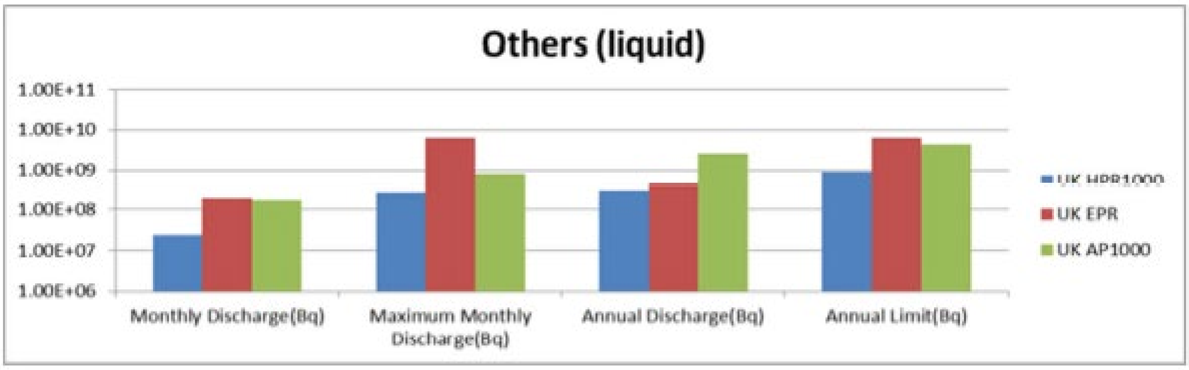
Gaseous - other radionuclides - comparison of discharges and limits



Liquid - Hydrogen-3 - comparison of discharges and limits



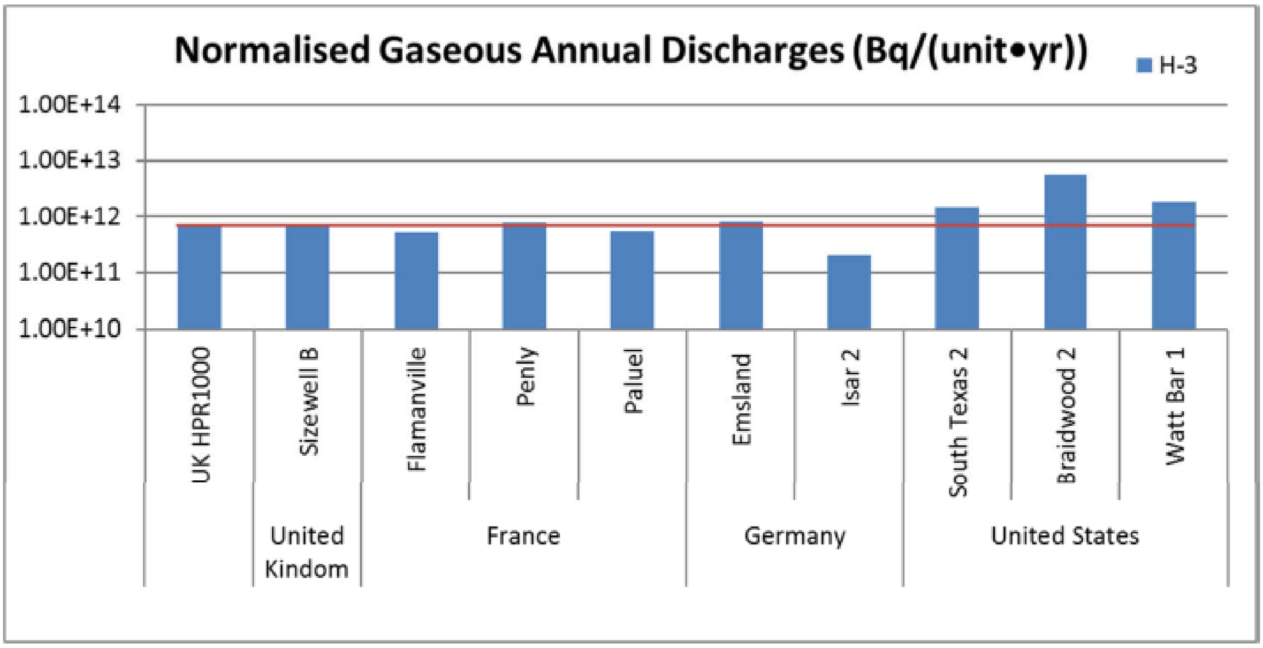
Liquid - Carbon-14 - comparison of discharges and limits



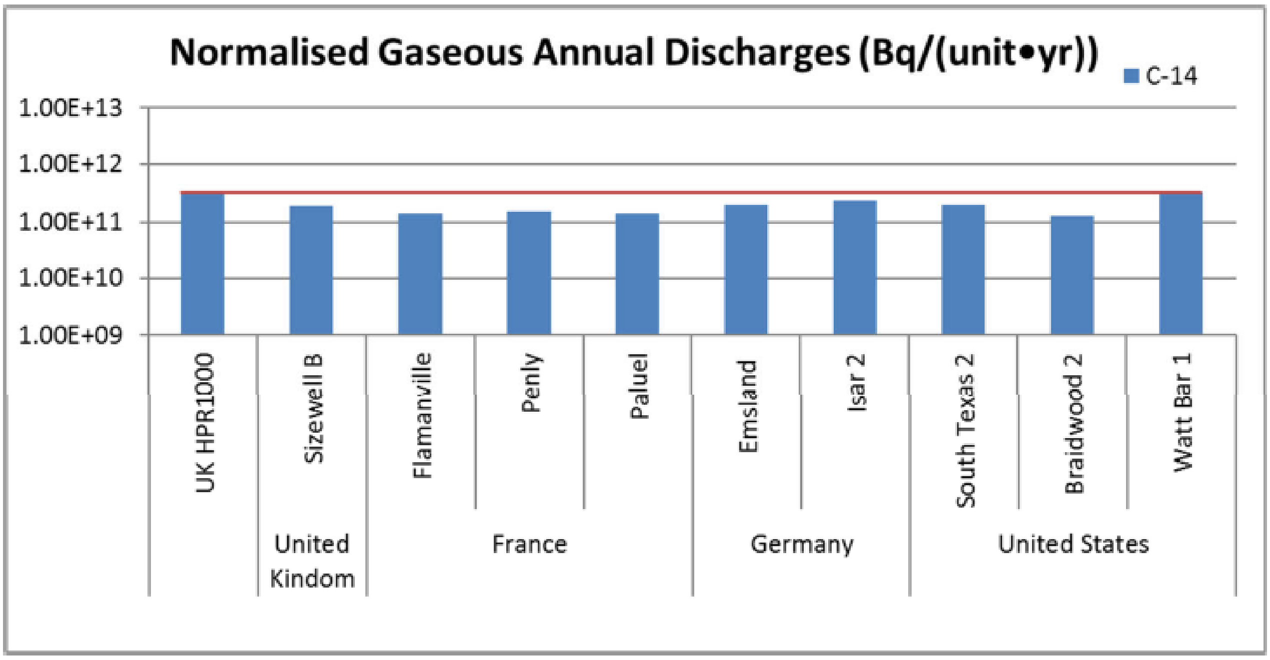
Liquid - other radionuclides - comparison of discharges and limits

Appendix 4 - Graphs showing comparison with international OPEX

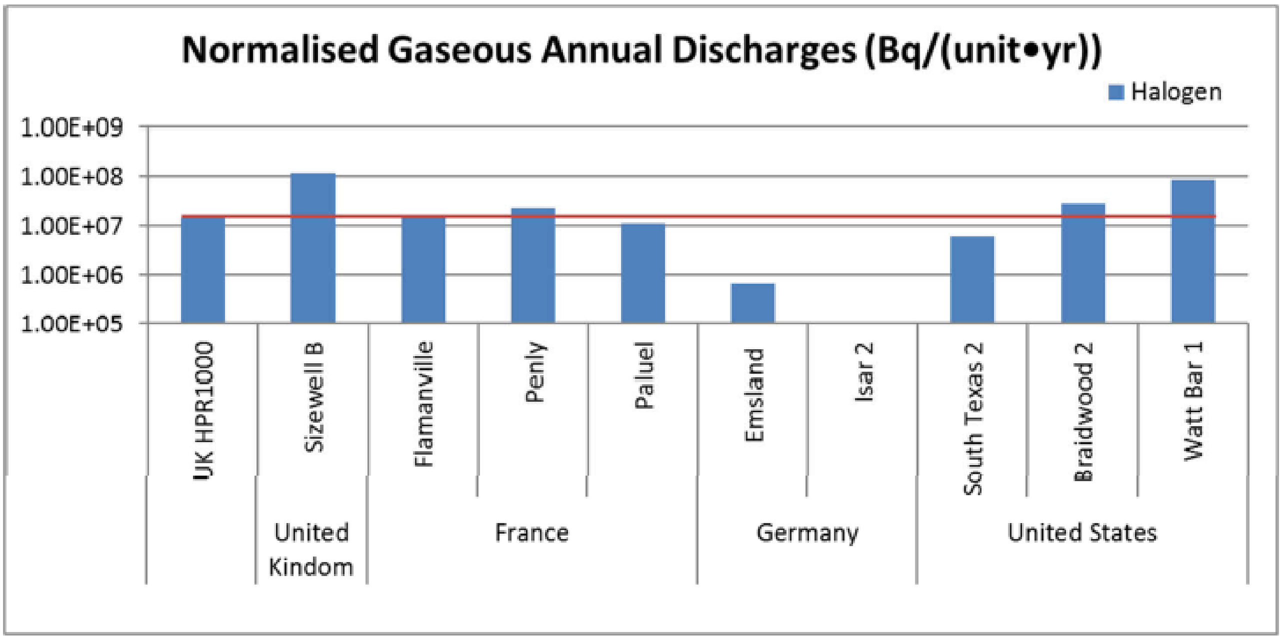
NOTE - all data used in the graphs are normalised to 1,000MWe to enable meaningful comparison (see section 3.4.5 above).



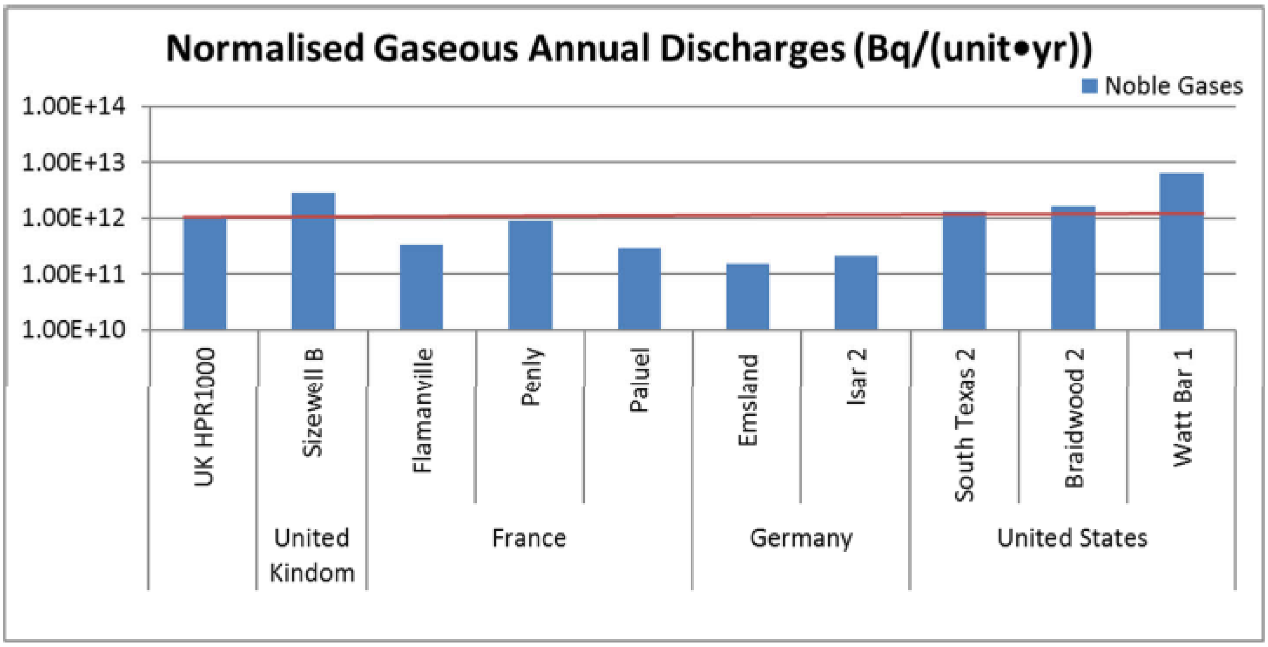
Gaseous - Hydrogen-3 - annual discharges



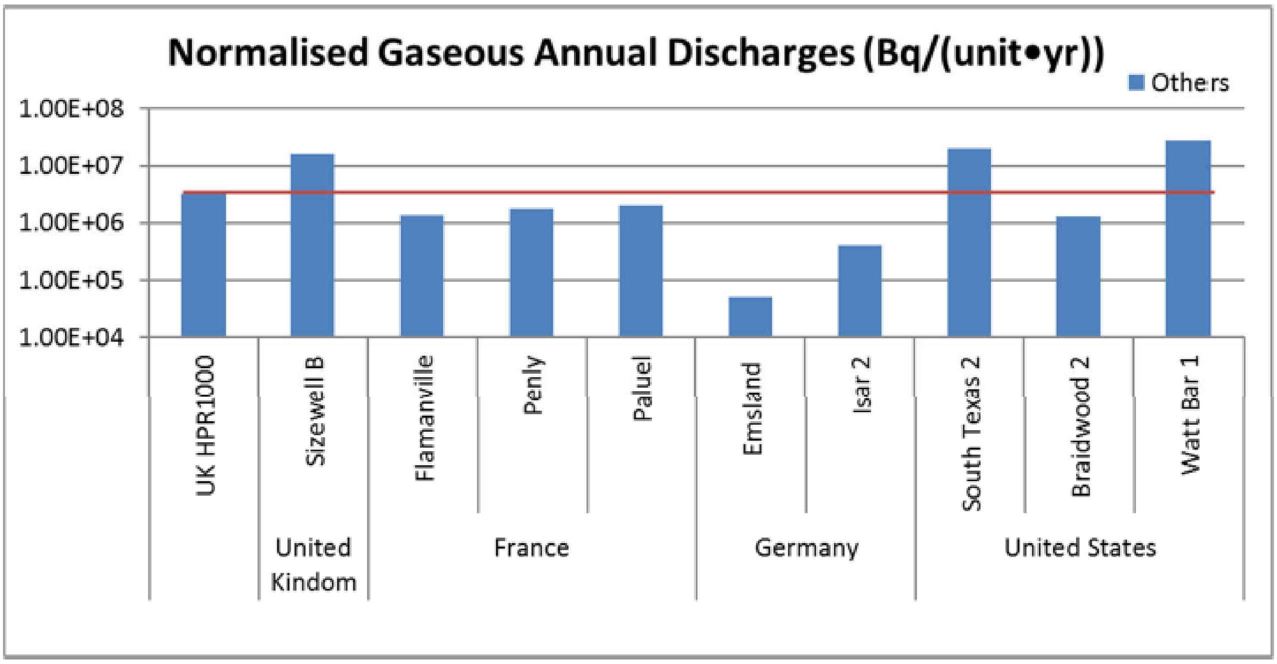
Gaseous - Carbon-14 - annual discharges



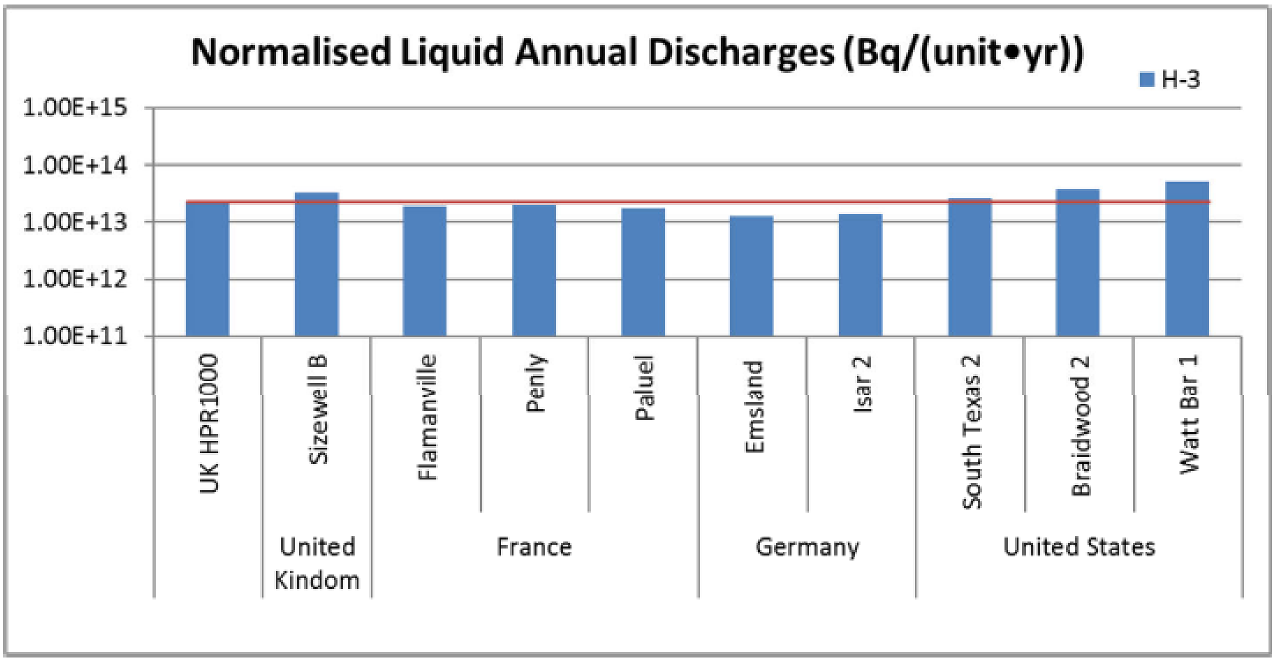
Gaseous - halogens - annual discharges



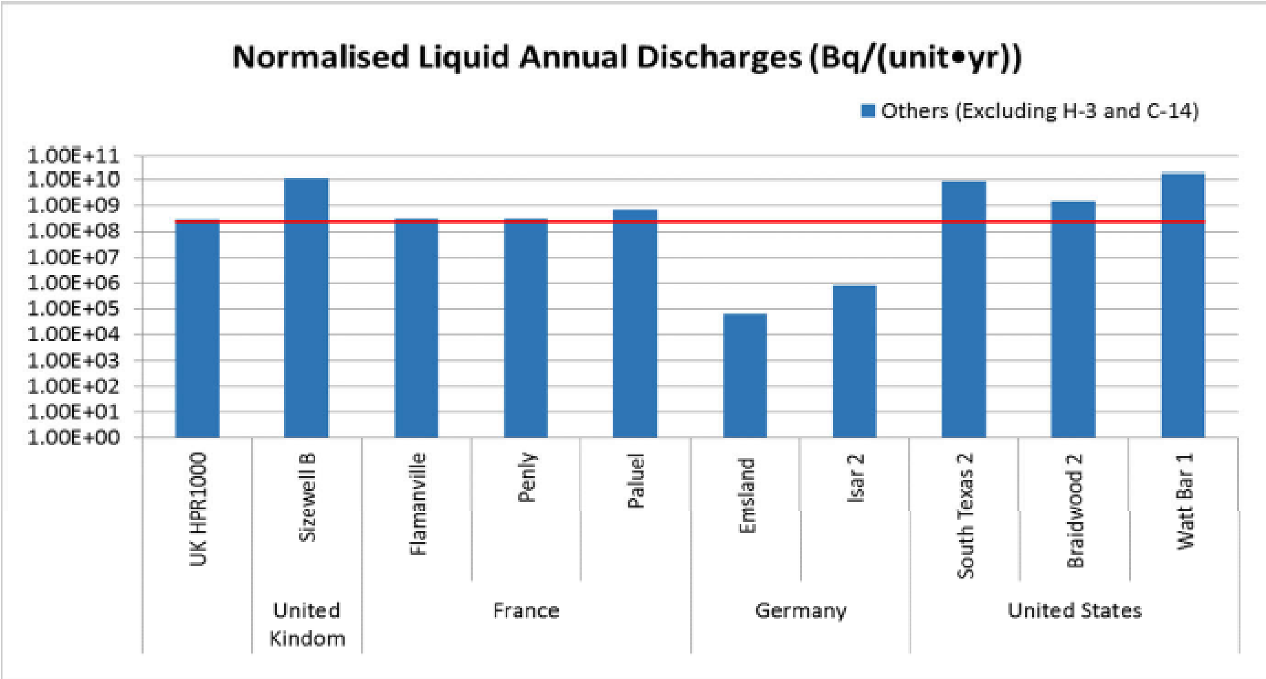
Gaseous - noble gases - annual discharges



Gaseous - other radionuclides - annual discharges



Liquid - Hydrogen-3 - annual discharges



Liquid - other radionuclides - annual discharges

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