# Assessing new nuclear power station designs

# Generic design assessment of Hitachi-GE's Advanced Boiling Water Reactor

## Assessment report - AR05 Aqueous Waste

12 December 2016

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# Executive summary

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|---|---|
| **Protective status** | This document contains no sensitive nuclear information.<br>This document does not contain, but does reference, commercially confidential information. |

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|---|---|
| **Process and information document**[1] | The following sections of Table 1 in our process and information document (P&ID) are relevant to this assessment:<br>Item 5: Quantification of radioactive waste disposals. Provide quantitative estimates for normal operation of discharges of gaseous and aqueous radioactive wastes. Provide proposed limits for gaseous and aqueous discharges |

| | |
|---|---|
| **Radioactive Substances Regulation Environmental Principles**[2] | The following principles are relevant to this assessment:<br>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. |

| | |
|---|---|
| **Report author** | Dr Paula Atkin |

This report presents the findings of the assessment of information relating to aqueous radioactive waste from the Hitachi-GE UK Advance Boiling Water Reactor (ABWR) reactor design submitted to the Environment Agency under the generic design assessment (GDA) process. Non-aqueous liquids are considered in the assessment report on solid waste.

We conclude that:

- all sources of aqueous radioactive waste have been identified
- significant radionuclides have been identified and quantified in line with relevant guidance
- where assumptions have been made, these are appropriate for GDA, although some assumptions may require validation by the operator at a later date
- proposed treatment techniques are comparable to those of similar reactors

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[1] Process and Information Document for Generic Assessment  of Candidate Nuclear Power Plant Designs, Version 2, Environment Agency, Mar 2013. http://webarchive.nationalarchives.gov.uk/20151009003754/https://www.gov.uk/government/publications/assessment-of-candidate-nuclear-power-plant-designs

[2] Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles, Version 2), Environment Agency, April 2010. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/296388/geho0709bqsb-e-e.pdf

- there are no novel or unusual features of the waste treatment techniques selected
- Hitachi-GE has considered the variability in quantity of aqueous radioactive discharges arising, however, possible variability in chemical form has not been considered (an Assessment Finding relating to this has been included)
- the proposed annual limits are clearly derived with conservative, but acceptable headroom factors, taking into account our limit setting guidance
- the aqueous radioactive discharges from the UK ABWR should not exceed those of comparable power stations across the world
- any operational UK ABWR should comply with the aqueous limit set out below (Table 1)

**Table 1. H-GE proposed limits for aqueous discharges**

| Radionuclide | Proposed 12-month rolling limit (Bq) |
|---|---|
| H-3 | 7.6E+11. |

However, our conclusion is subject to a number of issues and findings which will have to be addressed in the future. These are:

**Potential GDA Issue 2 – Source terms for the UK ABWR. We require Hitachi-GE to provide a suitable and sufficient definition and justification for the radioactive source terms in the UK ABWR during normal operations**.

**Assessment Finding 7: A future operator shall provide an evidence based definition of the decontamination factors likely to be achieved for aqueous effluent treatment prior to operation and then compare these with the actual decontamination factors achieved during operation. Differences in expected and actual decontamination factors should be explained.**

**Assessment Finding 8: A future operator shall assess the chemical speciation of radioactivity in aqueous discharges. It shall consider the implications of this for the receiving environment so that discharges are shown to represent best available techniques.**

# Contents

# 1. Introduction

This assessment considers the foreseeable levels of radioactivity in aqueous radioactive waste discharged to the environment. We consider the information Hitachi-GE provided for its UK ABWR design. The assessment aims to establish whether the design could be operated in the UK in line with UK statute, policy and guidance on radioactive waste, and, if so, the important issues that should be taken forward into any discharge permit that may be issued in the form of relevant limitations and conditions. If there are also any areas where not enough information has been provided in GDA, which results in a potential GDA Issue being set out at this stage of our considerations, they will also be documented in this report.

We expect 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 ABWR design, including BAT for gaseous radioactive discharges, in another assessment report (Environment Agency, 2016a).

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 non-human species (Environment Agency, 2016b, 2016c). This allows us to compare the design with our legislative dose limits and dose constraints.

We have also assessed the gaseous radioactive discharges and proposed limits for the UK ABWR; details of this assessment can be found in a separate assessment report (Environment Agency, 2016d).

We also have assessed the non-radioactive discharges from the UK ABWR; details of this assessment can be found in a separate assessment report (Environment Agency, 2016e).

## 1.1. Scope

This assessment considers aqueous radioactive waste generated from all aspects of normal operation, for example start-up, at power, shut-down and outage and discharges resulting from any other reasonably foreseeable events expected to occur during the lifetime of the reactors ('expected events').

Documents submitted up to and including 8 July 2016 are considered as part of this assessment.

This assessment report does not cover aqueous radioactive waste arising from commissioning or from decommissioning at the end of the reactor life cycle. Our assessment of the UK ABWR decommissioning strategy is included in a separate assessment report (Environment Agency, 2016f).

The information Hitachi-GE provided does not consider aqueous discharges from the service building. The structure of the service building is defined in GDA, but the services are not fully defined at this stage. Therefore, the details of the discharges from the service building will not be known until the site-specific stage. Any future operator will need to quantify discharges from the service building.

Discharges from dry solid LLW processing facility, the ILW store and interim spent fuel store are also not provided. These facilities are at concept design stage only and are, therefore, out of scope of GDA. Any future operator will need to quantify aqueous discharges from these facilities.

The process and information document (P&ID) (Environment Agency, 2013) defines normal operations as including start-up, routine operation, shut-down, testing and routine maintenance. We note that in the generic environmental permit (GEP) submission Hitachi-GE does not refer to the possibility of additional discharges occurring from any testing procedures and only refers to start-up, operation, shutdown and outage (routine maintenance). Therefore, any future operator will need to quantify aqueous discharges that may occur as a result of testing.

## 1.2. Statute, policy, guidance and information requirements

The assessment has considered the UK ABWR design in the light of UK statute, policy and guidance.

The main legislative areas that have been taken into account are:

- European Commission (EC) Recommendation 2004/2/Euratom, which sets out requirements for monitoring and reporting on radioactive discharges (EC, 2004).
- Environmental Permitting Regulations (EPR 10), which is aimed at controlling radioactive substances (including waste) (Defra, 2010).
- Statutory guidance to the Environment Agency concerning the Regulation of Radioactive Discharges into the Environment (DECC, 2009), which sets out principles for:
    - regulatory justification of practices by the government
    - optimisation of protection on the basis that radiological doses and risks to workers and members of the public from a source of exposure should be kept as low as reasonably achievable (the ALARA principle)
    - application of limits and conditions to control discharges from justified activities
    - sustainable development
    - the use of BAT
    - the precautionary principle
    - the polluter pays principle
    - the preferred use of ‘concentrate and contain’ in managing radioactive waste over ‘dilute and disperse’ in cases where there would be a definite benefit in reducing environmental pollution, provided that BAT is being applied and worker dose is taken into account.

The requirements of the legislative framework are implemented via our P&ID requirements (Environment Agency, 2013) and our Radioactive Substances Regulation Environmental Principles (REPs) (Environment Agency, 2010).

In our P&ID (Environment Agency, 2013), we set out our requirements to a requesting party (RP). The RP is required to:

- *provide quantitative estimates for normal operation of discharges of aqueous waste*
- *provide estimates for monthly discharges:*
    - *on an individual radionuclides basis for significant radionuclides*
    - *on a group basis for other radionuclides*
    - *via each discharge point and discharge route*
    - *clearly show the contribution to aqueous discharges that each constituent aspect of normal operations makes including:*
        - *routine operation*
        - *start-up and shutdown*
        - *maintenance and testing*

- *infrequent but necessary aspects of operation, for example, plant wash-out; and the foreseeable, undesired deviations from planned operation consistent with the use of BAT, for example, occasional fuel pin failures (called 'expected events')*
- *support aqueous discharge estimates with performance data from similar facilities and explain, where relevant, how changes in design or operation from those facilities affect the expected discharges*
- *demonstrate that discharges and waste arisings will not exceed those of comparable power stations across the world*
- *provide proposed limits for aqueous discharges (on a rolling 12-month basis and explain how these limits were derived*

The P&ID provides more detail on what constitutes 'normal operation' and 'significant radionuclides'.

*Normal operation includes the operational fluctuations, trends and events that are expected to occur over the lifetime of the facility, such as start-up, shutdown, maintenance. It does not include increased discharges arising from other events, inconsistent with the use of BAT, such as accidents, inadequate maintenance and inadequate operation.*

*Significant radionuclides are those which:*

- *are significant in terms of the radiological impact on people or non-human species*
- *are significant in terms of the quantity of radioactivity discharged*
- *have long half-lives, may persist and/or accumulate in the environment, and may contribute significantly to collective dose*
- *are significant indicators of facility performance and process control*

We published our REPs in 2010 (Environment Agency, 2010). The REPs that are most relevant to assessment of aqueous 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.

# 2. Summary of the liquid waste management system

The liquid waste management system (LWMS) consists of 4 interlinked systems:

- low chemical impurity waste (LCW)
- high chemical impurity waste (HCW)
- laundry drain (LD)
- controlled area drain (CAD)

The 4 systems are a result of the application of BAT being to segregate feeds, recycle aqueous effluents where possible and non-dilution of feeds prior to abatement or monitoring. The feeds, treatment methods and reuse or discharge information for each of the 4 systems are summarised below (Table 2). Further details and flow diagrams can be found in the GEP submission for radioactive waste management arrangements (Section 8 and Figure 8.1-1) and in the pre-construction safety report (PCSR) chapter on the liquid radioactive waste management system (Chapter 18.2) (see Table 3).

**Table 2. A summary of the liquid waste management system**

| System | Feeds | Treatment | Discharges |
|---|---|---|---|
| **LCW** | LCW collection tank feeds:<br>Floor drain sumps in the reactor building (R/B), radioactive waste building (Rw/B) and turbine building (T/B)<br>Equipment drain sumps in R/B, Rw/B and T/B<br>Reactor water clean-up system (CUW) blowdown<br>Reactor well drain<br>Residual heat removal system (RHR) blow<br>Condensate demineraliser (CD) backwash<br>Treated LCW liquor for retreatment if reuse criteria are not reached | Filter/demineraliser<br>Hollow fibre membrane filter. When washed, the crud goes to filter crud storage tank and transferred to solid waste system with the washed filter.<br>Spent demineraliser resin is transferred to the bead resin storage tank for transfer into solid waste system | All recycled within primary circuit or spent fuel pool via the condensate storage tank (CST)<br>LCW can be recirculated multiple times, if necessary, until it meets the appropriate criteria for reuse<br>No volume discharged |
| **HCW** | HCW collection tank feeds:<br>Drain sumps in the service building (S/B)<br>Chemical laboratory drain<br>CD bottom drain line<br>Treated HCW liquor for retreatment if reuse criteria are not reached<br>CAD (if treatment is necessary – see CAD below) | Evaporator/demineraliser<br>Evaporator residue is transferred to the concentrated waste tank for transfer into solid waste system<br>Demineraliser spent resin is transferred to the bead resin storage tank for transfer into solid waste management system<br>Treated liquor is recycled into the primary circuit via the CST where | For GDA it is assumed all HCW is discharged.<br>Vol = 560 m3/y<br>Effluent is sampled prior to discharge<br>Interlocks prevent tank filling during discharge |

| System | Feeds | Treatment | Discharges |
|---|---|---|---|
| | | system water balance allows | Note: this is a worst case assumption, as arisings will be transferred to the CST for reuse where there is capacity in the CST to receive the full HCW collection tank volume |
| **LD** | LD collection tank feeds:<br>LD sump tank<br>Laundry<br>Treated LD liquor for retreatment if treated liquor falls outside discharge criteria | Pre-filter/activated carbon adsorption/filter.<br>Filters, filter sludge and bead activated carbon adsorption media are all transferred to the solid waste management system | All LD waste generated is discharged<br>Vol = 2240 m3/y<br>Effluent is sampled prior to discharge<br>Interlocks prevent tank filling during discharge |
| **CAD** | CAD collection tank feeds:<br>CAD sumps in R/B and T/B | Monitored for activity and chemical parameters.<br>If discharge criteria are met, effluent batch is discharged without further treatment<br>If discharge criteria are not met, effluent batch is transferred to the HCW system for treatment | No activity expected in normal operation conditions<br>No radioactive discharges considered for the discharge end user source term |

Aqueous wastes arising from the solid waste management system will be collected and monitored in the individual facility and either pumped or transferred by bowser to the most appropriate system of those summarised above.

Aqueous waste and cooling water are discharged via a single offshore discharge point. Details of the discharge point location and design will be defined at the site-specific stage, optimised to local conditions.

The aqueous effluent is discharged in batches, with each tank being sampled prior to discharge. Because the effluent would be generated over a period of time and is treated to a composition where it can be recycled where possible, Hitachi-GE has made the assumption that the discharge composition over time is unlikely to vary. The total site storage capacity is such that the operator can retain the estimated aqueous waste arisings for over a year.

# 3. Assessment

## 3.1. Assessment method

The basis of our assessment was to:

- consider the documentation submitted by Hitachi-GE that makes up the GEP submission and its supporting documents
- hold technical meetings with Hitachi-GE 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 Hitachi-GE did not provide sufficient information
- consider the proposed discharges and limits in relation to UK legislation and guidance
- compare them to similar operating plants around the world
- decide on any GDA Issues or other findings to carry forward from GDA in our statement of design acceptability (SoDA), if required

## 3.2. Assessment objectives

Important areas of the submission Hitachi-GE made under the GDA arrangements for the UK ABWR design that we have considered are:

- Are all the sources of aqueous radioactive waste identified?
- Are all the significant radionuclides relating to aqueous radioactive waste identified and quantified?
- Are all the assumptions in the submission relating to aqueous radioactive waste valid?
- Have the proposed treatment techniques been identified and are these similar to those used in comparable reactors?
- Are there any novel features of the liquid waste management system?
- Has variability in the nature of aqueous radioactive waste, for example in form and quantity, been identified and explained?
- Have all discharge routes for aqueous radioactive waste been identified?
- Are waste streams segregated and are practicable steps taken to avoid dilution?
- Have the annual limits proposed by Hitachi-GE:
    - been clearly derived?
    - been given acceptable headroom?
    - taken account of our limit setting guidance?
- Do the proposed discharges from the UK ABWR exceed those of comparable stations around the world?

## 3.3. Hitachi-GE documentation

We referred to the following documents to produce this report (Table 3).

**Table 3. A summary of the Hitachi-GE documents reviewed during this assessment**

| Document No | Title |
|---|---|
| GA91-9901-0025-00001_Rev A | Quantification of discharges and limits |
| GA91-9901-0025-00001_Rev B | Quantification of discharges and limits |
| GA91-9901-0025-00001_Rev C | Quantification of discharges and limits |
| GA91-9901-0025-00001_Rev D | Quantification of discharges and limits |
| GA91-9901-0025-00001_Rev E | Quantification of discharges and limits |
| GA91-9901-0025-00001_Rev F | Quantification of discharges and limits |
| GA91-9901-0019-00001_Rev E | Summary of the generic environmental permit applications |
| GA91-9901-0019-00001_Rev F | Summary of the generic environmental permit applications |
| GA91-9901-0019-00001_Rev G | Summary of the generic environmental permit applications |
| GA91-9901-0022-00001_Rev E | Radioactive waste management arrangements (Chapter 8, LWMS) |
| GA91-9901-0022-00001_Rev G | Radioactive waste management arrangements (Chapter 8, LWMS) |
| GA91-9901-0023-00001_Rev E | Demonstration of BAT |
| GA91-9901-0023-00001_Rev F | Demonstration of BAT |
| GA91-9901-0026-00001_Rev E | Prospective dose modelling |
| GA91-9901-0026-00001_Rev F | Prospective dose modelling |
| GA91-9901-0021-00001_Rev E | Approach to optimisation |
| GA91-9901-0028-00001_Rev E | Alignment with the Radioactive Substances Regulation Environmental Principles (REPs) |
| GA91-9101-0101-18002_Rev B | PCSR* Chapter 18.2: Liquid radioactive waste management system |
| GA91-9101-0101-09000_Rev B | PCSR* Chapter 9: General description of the unit (facility) |
| GA91-9201-0001-00217 Rev 0 | Topic report on discharge route identification during normal operation |
| GA91-9201-0003-00976_Rev 0 | End user source term methodology report |
| GA91-9201-0003-00941_Rev 1 | Nuclide selection by end user requirement |
| GA91-9201-0003-00941_Rev 2 | Nuclide selection by end user requirement |
| GA91-9201-0001-00160_Rev 1 | Topic report on discharge assessment during normal operation |
| GA91-9201-0001-00160_Rev 2 | Topic report on discharge assessment during normal operation |
| GA91-9201-0003-00353_Rev 1 | Methodology for expected event selection |
| GA91-9201-0003-00353_Rev 2 | Methodology for expected event selection |

| Document No | Title |
|---|---|
| GA91-9201-0003-00942_Rev 1 | Source term manual general report |
| GA91-9201-0003-00945_Rev 1 | Process source term supporting report |

*PCSR = Pre-construction safety report

## 3.4. Our assessment

Hitachi-GE provided its initial submission (Revision A) to GDA in December 2013. This was updated to include a separate section on regulatory context and consideration of the REPs for revision B (14 March 2014) and Revision C was issued for web publication on 31 March 2014.

We carried out our initial assessment on Revision D as issued on 6 August 2014. Our initial assessment for aqueous radioactive waste consisted of a brief assessment of the contents of the Hitachi-GE submission against the P&ID requirements and was not an in-depth assessment of the discharges. Our initial assessment feedback (Environment Agency, 2014) noted that some further information would be needed to undertake the detailed assessment, specifically:

- appropriate and robust evidence to support the estimates of aqueous (and gaseous) discharges (see RO-ABWR-0006 and RI-ABWR-0001 on source term below)
- details on the contribution that each phase of normal operations makes to discharges, for example, start-up, operation, maintenance and shut-down (see RQ-ABWR-0369 below)
- demonstration that expected discharges will not exceed those of comparable power stations across the world (see RQ-ABWR-0355 below)

Assessment and ongoing discussions of Revisions D and E resulted in the RQs, RO and RI described in the following section that related to the aqueous waste management system and aqueous discharges. Some we issued and others we issued together with the Office for Nuclear Regulation (ONR).

### 3.4.1. RO and RI relating to the UK ABWR source term

We and ONR raised RO-ABWR-0006 on the Source term on 28 April 2014. Two of the actions under the RO requested the definition and justification of the radiological source terms for UK ABWR design. This was raised because the GDA submission from Hitachi-GE lacked information regarding radionuclides in the UK ABWR during normal operation. The submission also lacked evidence to support the gaseous and aqueous discharge estimates and proposed limits. We received a resolution plan for this RO on 15 July 2014 and we met regularly with Hitachi-GE between July and December 2014. Two reports were submitted to us in January 2015, which we and ONR assessed. These reports were intended to address the definition and justification of source terms for the UK ABWR. These reports did not meet our expectations, and together with ONR, we provided feedback to Hitachi-GE outlining shortfalls in the reports. We challenged the approach and methods used to derive the UK ABWR source terms, the limited use of operation and experience (OPEX) data from other operating ABWRs and the evidence on which discharge estimates were based.

Together with ONR, we escalated the RO to an RI. A workshop was held on 19, 20 and 22 May 2015, at which we and ONR presented our requirements to Hitachi-GE and gave some examples of source terms that we have assessed for other nuclear power plants designers and operators. RI-ABWR-0001 was raised on 3 June 2015. Regular meetings were held between the regulators and Hitachi-GE from June 2015 to date. Hitachi-GE has changed its approach to deriving and justifying source terms for the UK

ABWR, using more OPEX data and providing more explanation of the methods it used. Between November 2015 and February 2016 we received a number of reports documenting the derivation and justification of the UK ABWR source term. These provided information on the primary source term (PST) (radionuclides in the reactor water and steam), process source terms (PrST) (radionuclides in different downstream systems within the plant) and end-user source terms (EUST) (which included source term for gaseous and aqueous discharges).

At the time of writing this report (5 August 2016), both RI-ABWR-0001 and RO-ABWR-0006 remain open. A workshop was held between 26 and 29 July 2016 to discuss progress in this area. Information Hitachi-GE provided is adequate and our technical assessor and ONR inspectors have now recommended closure of RI-ABWR-0001 to the GDA project.

However, until the RI and RO are formally closed, the estimated gaseous and aqueous radioactive discharges, estimated solid radioactive waste arisings, decommissioning source term and radiological impact assessments could potentially change and impact on our draft conclusions on the acceptability of the UK ABWR design. However, we now believe there to be a low risk of significant change to the source term.

As this work has not yet been completed, we have identified the following potential GDA Issue:

**Potential GDA Issue 2 – Source terms for the UK ABWR. We require Hitachi-GE to provide a suitable and sufficient definition and justification for the radioactive source terms in the UK ABWR during normal operations**

There are a number of assumptions made in the source term work that are important to the expected aqueous discharges, these are:

- tritium partitions in the reactor, 50% to the steam and 50% to the water
- tritium is not reduced by any of the abatement techniques used on the UK ABWR
- 100% of the carbon-14 is partitioned into the gaseous waste stream

The assumptions relating to tritium are as expected and the proposed treatments are not effective for tritium abatement. However, the assumption that no C-14 enters the aqueous waste streams and, therefore, cannot adsorb onto the demineraliser resins or be discharged is not a conservative assumption for aqueous discharges. We expect that this assumption may need consideration or validating in the early stages of operation. We have, therefore, included an Assessment Finding (AF) related to this assumption, which can be found in our assessment report for BAT (Environment Agency, 2016a).

### 3.4.2. Other RQs raised during our assessment

RQ-ABWR-0239 decontamination factors (DFs) for HCW system demineralisers was raised on 3 October 2014. We asked Hitachi-GE to provide further information on:

- the likely DF for the demineralisers
- supporting evidence for aqueous waste volumes and activities
- how the HCW volume estimates inform the activity estimates

The response from Hitachi-GE provided DFs based on a requirement in United States regulatory documentation (US NRC, 1979), which we believe to be a conservative assumption of what should be achievable. The submission was not supported by OPEX as the RP (Hitachi-GE) is not an operator and they do not wish to constrain the future operator in the choice of demineraliser resins. We have accepted the response as being acceptable for the purpose of GDA as it is very conservative, but note that we would expect a future operator to be able to demonstrate the DFs expected and achieved and that they are greater than those assumed for GDA.

**Assessment Finding 7: A future operator shall provide an evidence based definition of the decontamination factors likely to be achieved for aqueous effluent treatment prior to operation and then compare thee with the actual decontamination factors achieved during operation. Differences in expected and actual decontamination factors should be explained.**

Hitachi-GE noted that the estimates of aqueous discharge volumes are based on the assumption that all HCW produced is discharged to the marine environment. This is a worst case assumption, as it is likely that HCW effluent will be reused in the reactor circuit unless the water balance is such that it cannot be transferred to the CST. We find this response acceptable for the purpose of GDA.

RQ-ABWR-0355 Discharges and waste arisings: a comparison with other power stations was raised on 7 January 2015. We asked Hitachi-GE to provide further information on how the discharges and waste arising compare with those of comparable stations worldwide. In response to this RQ, Hitachi-GE provided some detail on discharges from comparable reactors. However, the response lacked discussion on comparison of UK ABWR discharges with that of the other reactors, particularly reasons for differences. We provided feedback to Hitachi-GE at a GEP progress meeting held on 28 to 29 July 2015. Hitachi-GE provided more information and improved discussion in the GEP submission, Revision E. We accepted this response as being suitable for the purposes of GDA.

RQ-ABWR-0369 Discharges - frequency, magnitude and temporal variability was raised on 28 January 2016. We asked Hitachi-GE to provide further information on:

- how discharges vary with operational phase and power fluctuations for a system operating with hydrogen water chemistry (HWC)
- management of liquids during pool maintenance to minimise discharges

In response to the RQ on fluctuations in discharges with operating phase or power output Hitachi-GE provided information on the discharges at each phase of operation (start-up, operation, outage and shut-down) from the source terms work. It was noted that as the information was modelled data, the fluctuations within each operation phase could not be presented. However, we are content that the case presented represents an upper bound for each operational phase, therefore we expect actual discharges to be lower than those defined for GDA. We have accepted this as being appropriate for the purpose of GDA.

In response to the RQ regarding management of discharges as a result of maintenance activities, Hitachi-GE noted that any liquid drained from equipment during maintenance will be returned to the reactor circuit via the HCW system. Therefore, maintenance does not result in additional discharges as treated HCW liquor is reused wherever possible. We clarified that we were also questioning maintenance inspection of tanks and pools. Hitachi-GE provided information to show that sufficient tank capacity was available to manage activities such as pool inspections without generating additional discharges, although the actual management procedures of tank and pool inspections will be an operator decision.

We are content that the response to this RQ was appropriate for the purpose of GDA.

RQ-ABWR-0593 Draining of the reactor pressure vessel and liquid discharges was raised on 25 August 2015. We asked Hitachi-GE to provide further information on whether the reactor is drained via the bottom drain line during normal operations, and if there are any contributions to aqueous discharges from this task. Hitachi-GE provided a response demonstrating that liquid taken from the bottom drain line is returned to the reactor circuit via the LCW system and that no discharges to the environment are made. We have accepted the response as being appropriate for the purpose of GDA.

RQ-ABWR-0722 Related to the nuclide selection document was raised on 15 January 2016. We asked Hitachi-GE to clarify the methods it used to select nuclides. Hitachi-GE responded with details of how it had selected the radionuclides for the gaseous and aqueous discharges, based on OPEX, dose modelling and European Commission recommendations. We accepted this response as being appropriate for GDA.

RQ-ABWR-0850 headroom factor was raised on the 18 April 2016. We asked Hitachi-GE to provide:

- justification for the assumed linear relationship between primary source term (PST) and discharges
- discussion on the quality of underpinning data used to justify the assumed normal distribution

Hitachi-GE responded that the source term calculation methodology uses partitioning factors between streams at each stage of the reactor circuit process, which will result in a linear relationship between the PST and discharges. We accepted this response as being appropriate for GDA.

Hitachi-GE provided plots of the deviation of the OPEX data from the quoted mean against the quoted mean and standard deviation. The resulting plots of the theoretical versus the actual data show that there is a reasonable fit to the normal distribution for all data except iodine, where only one data point is above the mean value. Given that using the normal data distribution is a conservative assumption, we think this is an appropriate response for the purpose of GDA.

RQ-ABWR-0851 Discharge volumes was raised on 18 April 2016. We asked Hitachi-GE to provide information on discharge volumes for LD and HCW systems in its 'Quantification of discharges and limits' submission, as it was not included in Revision E. Revision F has been updated to include this data.

In the absence of the volume data in Revision E, we derived discharge volumes using the activity concentrations and annual discharges that were included. It was noted that the volumes matched those in the 'Topic report on discharge assessment during normal operations' report, but did not match those presented in the 'Demonstration of BAT' report. We requested clarification on this discrepancy. Hitachi-GE responded, noting that one was the annual maximum and one was a cycle average volume. It is the annual maximum volume that is used to calculate discharges and we agree that this is appropriate for GDA. The reports have been amended to make this difference clear where discharge volumes are quoted.

All the above RQs have now been responded to, discussed in technical meetings and the responses incorporated into Revisions E or F of the GEP submission, where appropriate.

The following observations are based on the latest revision of the GEP submission (July 2016).

From the LWMS summary above it can be seen the discharges are only made from the LD and HCW systems. Discharges are only made from the HCW system if the treated liquid cannot be transferred to the CST to be reused, due to excess liquid in the water balance. However, for the purposes of GDA, Hitachi-GE has taken a worst case scenario and has assumed that all HCW generated is discharged. This ensures an upper bound for discharges is taken through to radiological impact assessment for the public and non-human species. We believe that this assumption represents a conservative approach and is appropriate for the purposes of GDA. Therefore, the discharges from an operating unit are expected to be lower than those stated in the GEP submission.

Hitachi-GE suggests that individual tanks will buffer any variability over one or 2 days and the total site storage capacity is such that the operator can retain the estimated aqueous waste arisings over a year, therefore there will be minimal variation over time for aqueous discharges. We accept this assumption is applicable for the purposes of GDA. However, for site-specific stages or permitting, assessment of operational management of aqueous waste volumes should consider impact on waste composition variability.

It is noted that the GEP submission contains no information on the expected chemical speciation of activity within the aqueous waste discharged. Speciation is the physio-chemical form of the activity in the aqueous waste which may affect the behaviour of the radioactivity in the receiving environment. While it is recognised that the data is not available at this stage to consider this aspect, a future operator should consider the physio-chemical properties of the discharges.

**Assessment Finding 8: A future operator shall assess the chemical speciation of radioactivity in aqueous discharges. It shall consider the implications of this for the receiving environment so that discharges are shown to represent the best available techniques.**

### 3.4.3. Estimates of annual aqueous radioactive waste discharges

The estimated activity concentrations for aqueous effluents from both the LD and HCW systems are presented in Table 7.2-2 of the ‘Quantification of discharges and limits’ report and are also presented in Appendix A of this report. The nuclides presented were derived from the PrST. Nuclides included were those with greatest impact or activity concentration and those deemed relevant in the European Commission recommendation (2004/2/Euratom) (EC, 2004). We agree that this is an appropriate approach for GDA and there are no nuclides that we would expect to see missing from the list.

Estimated annual discharges from the LD and HCW activity concentrations, based on expected aqueous effluent volumes of 560 m3/y from HCW and 2240 m3/y from LD are presented in Table 7.2-4 of the ‘Quantification of discharges and limits’ report and are also presented in Appendix B of this report.

Each aqueous waste stream is subject to abatement tailored to the original composition and required quality criteria for either reuse or discharge. HCW is abated using evaporation and demineralisation (ion exchange), which will remove many particulates and soluble radioactive species, but not tritium. Waste from the LD is treated using activated carbon and filtration. The BAT aspects of the LWMS and the selection of the abatement techniques are assessed in detail in a separate assessment report (Environment Agency, 2016a). However, we note that the proposed abatement techniques are standard abatement techniques applied routinely in the nuclear industry for treating reactor effluent and are proven and reliable technologies.

The aqueous discharge activity is dominated by tritium (H-3), which is not abated and constitutes over 99.99% of the activity in the aqueous discharges. The second largest contributor of activity to the discharges is iron-55 (Fe-55), which only constitutes 0.0009% of the activity discharged. It is noted that the dose impact contribution is likely to differ in proportion. The assessment of radiological impact on members of the public can be found in our dose impact assessment report (Environment Agency, 2016b).

### 3.4.4. UK ABWR discharges compared with other similar reactors

The government white paper on nuclear power (BERR, 2008) notes that discharges from the UK ABWR not should be greater than those of other comparable stations worldwide.

*Tritium*

Tritium discharges, normalised for power output, from comparable reactors (BWRs and ABWRs) were taken from our report of discharges from existing BWRs and ABWRs (Environment Agency, 2016g). The mean discharges (normalised to power output) (Table 4) were compared to those estimated from the UK ABWR, also normalised for predicted energy output (Figure 1). It can be seen that for tritium, the predominant nuclide in aqueous discharges, the UK ABWR estimated discharges are well below those from existing comparable reactors.

**Table 4: Normalised annual aqueous tritium discharges from BWRs and normalised estimated annual aqueous tritium discharges for the UK ABWR**

| | Year | Mean aqueous H-3 discharges (GBq/GWeh) | | | n |
|---|---|---|---|---|---|
| | | Mean | Minimum | Maximum | |
| **BWR** | 2005 | 1.19E-01 | 2.57E-04 | 5.53E-01 | 18 |
| | 2006 | 9.92E-02 | 1.02E-03 | 5.00E-01 | 20 |
| | 2007 | 1.34E-01 | 5.31E-04 | 6.75E-01 | 19 |
| | 2008 | 1.10E-01 | 4.97E-04 | 4.49E-01 | 19 |
| | 2009 | 1.08E-01 | 6.63E-03 | 3.09E-01 | 19 |
| | 2010 | 9.74E-02 | 1.58E-03 | 4.67E-01 | 20 |
| | 2011 | 1.16E-01 | 3.88E-03 | 3.61E-01 | 19 |
| | 2012 | 1.48E-01 | 3.31E-02 | 5.14E-01 | 13 |
| | 2013 | 1.30E-01 | 7.73E-03 | 2.93E-01 | 12 |
| **UK ABWR** | | 1.70-02 | | | |

n = number of plants for which data were obtained

*Other beta-gamma*

Other beta/gamma discharges, normalised for power output, from comparable reactors, BWRs and ABWRs, were taken from our report of discharges from existing BWRs and ABWRs (Environment Agency, 2016g). The mean discharges (normalised to power output) were compared to those estimated from the UK ABWR, also normalised for energy output (Figure 2). It can be seen that for other beta gamma activity in aqueous discharges, the UK ABWR estimated discharges are well below those we see from existing comparable reactors.

**Table 5: Normalised annual aqueous beta-gamma discharges from BWRs and normalised estimated annual aqueous beta-gamma discharges for THE UK ABWR**

| | Year | Mean aqueous beta-gamma discharges (GBq/GWeh) | | | n |
|---|---|---|---|---|---|
| | | Mean | Minimum | Maximum | |
| **BWR** | 2005 | 1.21E-04 | 1.23E-05 | 4.98E-04 | 11 |
| | 2006 | 8.45E-05 | 1.66E-09 | 4.27E-04 | 14 |
| | 2007 | 1.77E-04 | 8.93E-07 | 1.66E-03 | 12 |
| | 2008 | 1.56E-04 | 2.51E-06 | 1.46E-03 | 13 |
| | 2009 | 9.93E-05 | 5.39E-06 | 4.99E-04 | 12 |
| | 2010 | 6.45E-05 | 1.14E-06 | 2.76E-04 | 13 |
| | 2011 | 5.22E-05 | 2.51E-07 | 2.48E-04 | 13 |
| | 2012 | 5.74E-05 | 2.93E-07 | 4.23E-04 | 11 |
| | 2013 | 9.17E-05 | 6.14E-07 | 4.17E-04 | 12 |
| **UK ABWR** | | 2.60E-07 | | | |

n = number of plants for which data were obtained

*Normalisation*

To normalise the the UK ABWR discharges from GBq/y to GBq/GWe.h the proposed discharge in GBq/y was divided by the annual power output taken from the ‘Quantification of discharges and limits’ report. The 11,826 GWh is based on the UK ABWR being a 1.35 GW station and running for 8,760 hours annually, which assumes the reactor is at maximum power output 100% of the time.

To normalise the discharges from existing reactors, the actual power output figures were used. These were taken from the internet public access International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS) database (IAEA, 2016).

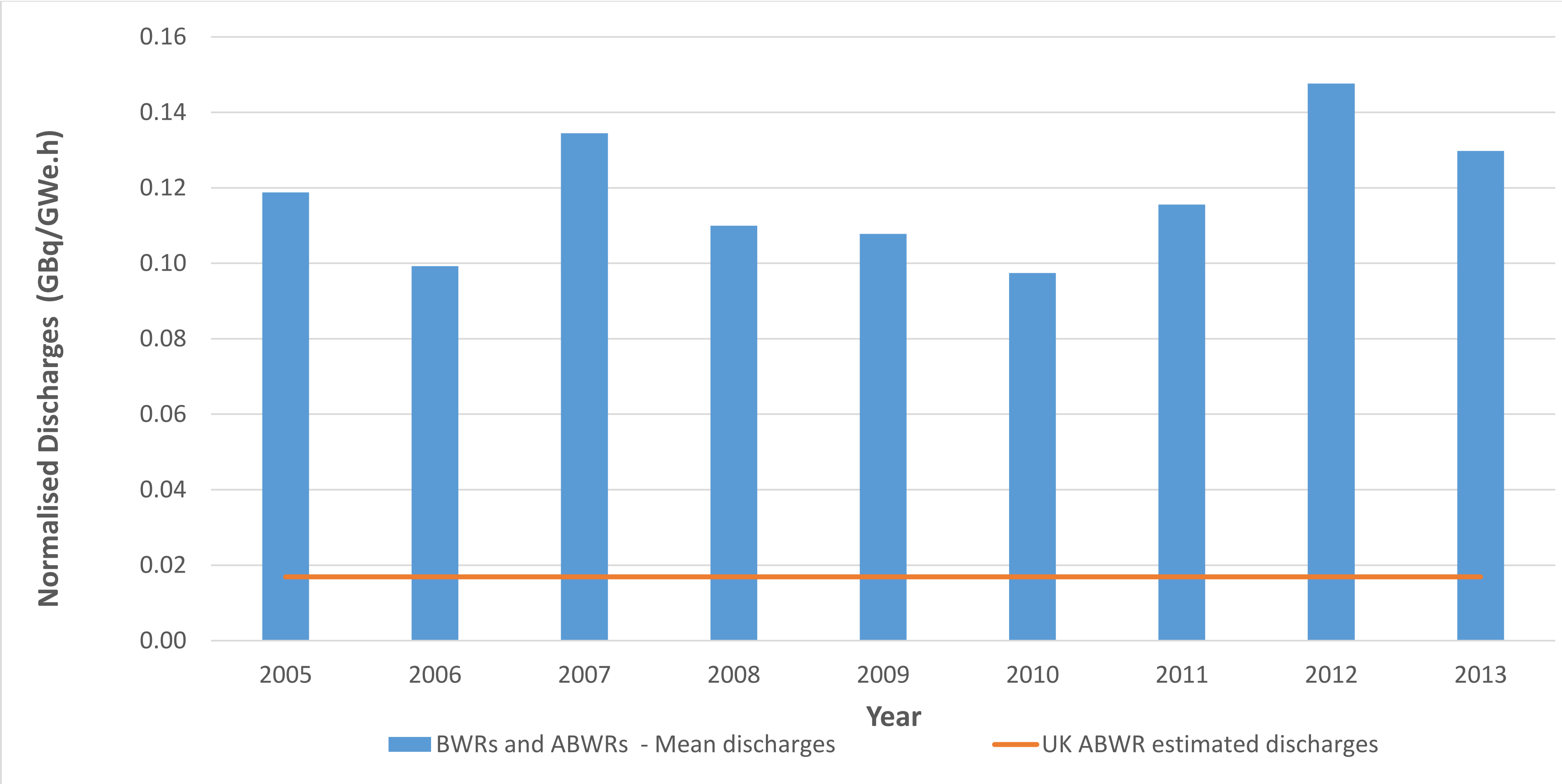


**Figure 1. UK ABWR aqueous tritium normalised discharges compared to mean aqueous tritium normalised discharges (GBq/GWe.h) from similar plants worldwide (BWRs and ABWRs) 2005 to 2013**

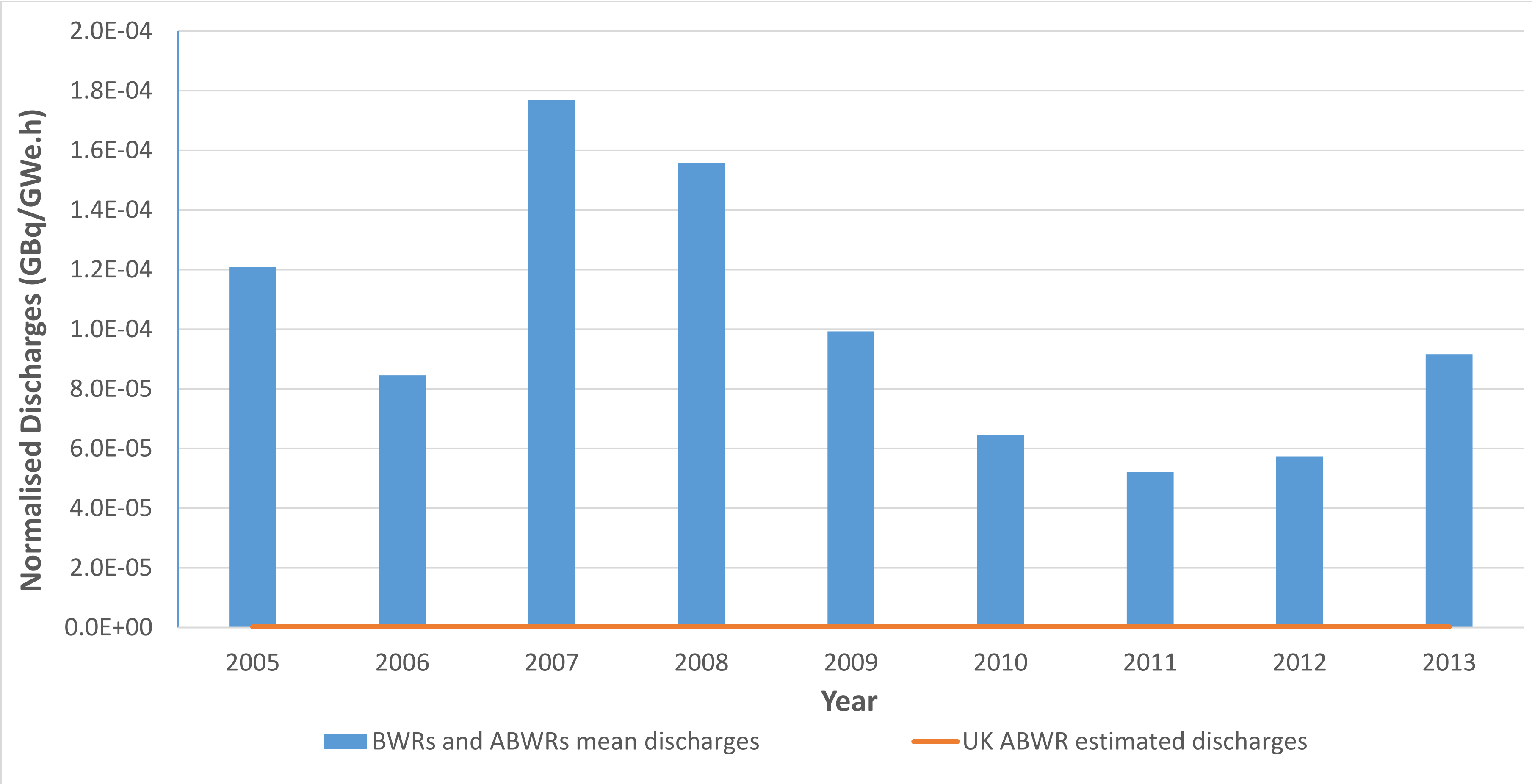


**Figure 2. UK ABWR aqueous normalised discharges (GBq/GWe.h) for other beta-gamma compared to mean aqueous other normalised discharges (GBq/GWe.h) from similar plants worldwide (BWRs and ABWRs) 2005 to 2013**

## 3.5. Proposed discharge limits

Limits on discharges are considered in our REPs, in RSMDP12, and in our 'Criteria for setting limits on the discharge of radioactive waste from nuclear sites' (Environment Agency, 2012). We expect limits to be set on a 12-month rolling basis and for each nuclide (or group of nuclides) deemed significant based on the criteria in our guidance. Limits set an upper bound on the amount of radioactive waste that an operator may discharge into the environment. The difference between the estimated discharges and proposed limits is referred to as the 'headroom factor'.

For an operating station the headroom factor can be determined by assessing the variability in discharges necessary during normal operations. However, for a new plant this data does not yet exist. Therefore, Hitachi-GE has taken a statistical approach based on the OPEX used to support the source term derivation.

Hitachi-GE has looked at the spread of data used to derive the PST to assess the likely variability of the discharges and, therefore, the likely headroom factor required. This method makes the following assumptions, that:

- the variability in the PST (the reactor water) has a linear relationship with the variability in the aqueous discharges
- the data follow a normal distribution
- the DF achieved by the aqueous effluent abatement remains constant over the complete operating cycle

The first assumption is a fundamental assumption that arises from the way the source term is calculated, which uses partitioning factors at multiple stages in the reactor circuit. We previously submitted an RQ asking for a justification of that assumption (RQ-ABWR-0850), which has now been responded to satisfactorily.

The second assumption may be true, but other data distributions do exist, for example log-normal data. It is noted in the 'Quantification of discharges and limits' document that the OPEX data used to underpin the source term is not sufficient to determine the true data distribution, therefore no evidence was given to support this assumption. We submitted an RQ asking for justification of this assumption relating to real data (RQ-ABWR-0850). Information relating to the variation of the OPEX data from the predicted normal distribution data has now been provided and it seems likely that a normal distribution is an acceptable approach. This is compounded by the fact that assuming normal distribution is a more conservative approach than assuming a log-normal distribution.

The third assumption is a simplification as a result of the initial assumption and is unlikely to have a significant impact on the calculation of the headroom factor. We feel this assumption is appropriate for GDA.

Hitachi-GE has selected a confidence interval of 99.9% for headroom calculation, based on the need to ensure that there is a very low risk of any discharges exceeding the permitted limits. We note that this is a conservative approach that will result in larger headroom factors than if a lower confidence interval were selected. However, we agree it is an acceptable approach for the purpose of GDA. Headroom factors should be reviewed, based on actual discharge data, during the early stages of operation.

The headroom factors are derived for all nuclides (or groups of nuclides) expected to be permitted. Using the approach defined above, Hitachi-GE has been able to derive nuclide specific headroom factors rather than applying a single factor to all discharges. This has been possible as OPEX data used to support the source term are nuclide specific data.

Hitachi-GE has derived headroom factors for tritium, particulates (assumed to be cobalt-60) and iodine radionuclides (assumed to be iodine-131) as being 3.8, 4.1 and 1.7 respectively. Using Co-60 and I-131 for particulates and iodine radionuclides is a worse case assumption respectively. We note that these do not appear to be excessive, given the uncertainty associated with a new build reactor. These 3 factors derived have then been applied to the full list of nuclides, assuming that all nuclides except tritium and iodine are particulates to give a discharge limits data set from which to consider dose impact.

We expect permit limits to be applied to those nuclides that are considered as 'significant' as set out in our limit setting guidance (Environment Agency, 2012). In summary, significant nuclides are those that:

- are significant in terms of radiological impact on people (that is, the dose to the most exposed group at the proposed limit exceeds 1 μSv per year)
- are significant in terms of radiological impact on non-human species (this only needs to be considered where the impact on reference organisms from the discharges of all radionuclides at the proposed limits exceeds 40 μGy/h)
- are significant in terms of the quantity of radioactivity discharged (that is, the discharge of a radionuclide exceeds 1 TBq per year)
- may contribute significantly to collective dose (this only needs to be considered where the collective dose, truncated at 500 years, from the discharges of all radionuclides at the proposed limits exceeds 1 man sievert per year to any of the UK, European or World populations)
- are constrained under national or international agreements or are of concern internationally
- are indicators of plant performance, if not otherwise limited on the above criteria

We also expect to see consideration of appropriate generic categories from the Radioactive Substances Regulation (RSR) pollution inventory, for example 'alpha particulate' and to limit any radionuclides not otherwise covered by the limits set on the above criteria.

Of the selected nuclides only tritium is considered to be significant, based on the third category of our limit setting guidance (Environment Agency, 2012), although the discharge is actually below the 1TBq/y threshold. Given the discharges are low and dose impact from aqueous discharges is low, we agree that the only significant nuclide for aqueous radioactive discharges is tritium.

**Table 6. H-GE proposed limits for aqueous discharges**

| Radionuclide | Proposed 12-month rolling limit (Bq) |
|---|---|
| H-3 | 7.6E+11. |

It is noted that Hitachi-GE has considered whether total beta-gamma or other parameters should be considered for the permit, under the category of 'plant performance indicators', but that the activity concentrations in aqueous discharges are so low that they could not be monitored. However, as monitoring technology develops, this may become feasible in the future. Therefore, any future operator should consider occasionally reviewing the significance of radionuclides and the ability to permit additional parameters, such as total beta-gamma.

**Table 7. Compliance with Environment Agency requirements**

| P&ID Table 1 Section or REP | Compliance comments |
|---|---|
| Item 5: Quantification of radioactive waste disposals.<br><br>Provide quantitative estimates for normal operation of discharges of gaseous and aqueous radioactive waste. | Hitachi-GE has provided estimates of aqueous radioactive waste disposals for normal operation and proposed limits for the disposal of aqueous radioactive waste. |

| P&ID Table 1 Section or REP | Compliance comments |
|---|---|
| Provide proposed limits for gaseous discharges. | Our assessment of discharges of gaseous radioactive waste is provided in a separate assessment report (Environment Agency, 2016d). |
| RSMDP12 – Limits and levels on discharges<br>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. | Hitachi-GE has proposed limits for the UK ABWR aqueous waste disposals. |

# 4. Public comments

No public comments were received via the Hitachi-GE public comments process during the assessment, up to 8 July 2016, which related to discharges of aqueous radioactive waste.

# 5. Conclusion

We have reviewed the assessment objectives and conclude that:

- all sources of aqueous radioactive waste have been identified
- significant radionuclides have been identified and quantified in line with relevant guidance
- where assumptions have been made, these are appropriate for GDA, although some assumptions may require validation by the operator at a later date
- proposed treatment techniques are comparable to those of similar reactors
- there are no novel or unusual features of the waste treatment techniques selected
- the variability in quantity of aqueous radioactive discharges arising has been considered by Hitachi-GE, however, possible variability in chemical form has not been considered (an AF relating to this has been included)
- the proposed annual limits are clearly derived with conservative, but acceptable headroom factors, taking into account our limit setting guidance
- the aqueous radioactive discharges from the UK ABWR should not exceed those of comparable power stations across the world
- any operational UK ABWR should comply with the aqueous limit set out below

**Table 8. H-GE proposed limits for aqueous discharges**

| Radionuclide | Proposed 12-month rolling limit (Bq) |
|---|---|
| H-3 | . 7.6E+11 |

However, our conclusion is subject to a number of ongoing issues, which will have to be addressed in the future.

**Potential GDA Issue:**

**Potential GDA Issue 2 – Source terms for the UK ABWR. We require Hitachi-GE to provide a suitable and sufficient definition and justification for the radioactive source terms in the UK ABWR during normal operations**.

**Assessment Findings:**

**Assessment Finding 7: A future operator shall provide an evidence based definition of the decontamination factors likely to be achieved for aqueous effluent treatment prior to operation and then compare these with the actual decontamination factors achieved during operation. Differences in expected and actual decontamination factors should be explained.**

**Assessment Finding 8: A future operator shall assess the chemical speciation of radioactivity in aqueous discharges. It shall consider the implications of this for the receiving environment so that discharges are shown to represent best available techniques.**

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# List of abbreviations

| Abbreviation | Details |
|---|---|
| ABWR | Advance Boiling Water Reactor |
| AF | Assessment Finding |
| BAT | Best available techniques |
| BERR | Business Enterprise and Regulatory Reform |
| BWR | Boiling water reactor |
| CAD | Controlled area drain |
| CD | Condensate demineraliser |
| CST | Condensate storage tank |
| CUW | Reactor water clean-up system |
| DECC | Department of Energy and Climate Change |
| Defra | Department for Environment, Food and Rural Affairs |
| DF | Decontamination factor |
| EC | European Commission |
| EPR | Environmental Permitting Regulations |
| EUST | End user source term |
| GDA | Generic design assessment |
| GEP | Generic environmental permit |
| HCW | High chemical impurity waste |
| HWC | Hydrogen water chemistry |
| IAEA | International Atomic Energy Agency |
| LCW | Low chemical impurity waste |

| Abbreviation | Details |
| --- | --- |
| LD | Laundry drain |
| LWMS | Liquid waste management system |
| ONR | Office for Nuclear Regulation |
| OPEX | Operation and experience |
| P&ID | Process and information document |
| PCSR | Pre-construction safety report |
| PRIS | Power reactor information system |
| PrST | Process source term |
| PST | Primary source term |
| R/B | Reactor building |
| Rw/B | Radioactive waste building |
| REPs | (Radioactive Substances) Regulation Environmental Principles |
| RHR | Residual heat removal system |
| RI | Regulatory Issue |
| RO | Regulatory Observation |
| RP | Requesting party |
| RQ | Regulatory Query |
| RSMDP | Radioactive substance management (including waste disposal) principle |
| RSR | Radioactive Substances Regulation |
| S/B | Service building |
| SoDA | Statement of design acceptability |
| T/B | Turbine building |

| Abbreviation | Details |
|---|---|
| UK | United Kingdom |
| US NRC | United States Nuclear Regulatory Commission |

# APPENDIX A: UK ABWR HCW and LD activity concentrations

| Radionuclides | HCW sample tank concentration (Bq/m3)<br>PrST value : HCW-6-CA-BE | LD sample tank concentration (Bq/m3)<br>PrST value: LD-8-CA-BE |
|---|---|---|
| H-3 | 3.50E+08 | 1.30E-02 |
| Cr-51 | 1.50E+01 | 1.80E-01 |
| Mn-54 | 1.60E+01 | 4.00E+01 |
| Fe-55 | 5.80E+01 | 1.00E+03 |
| Fe-59 | 1.60E+00 | 1.80E+00 |
| Co-58 | 2.20E+01 | 3.40E+00 |
| Co-60 | 7.00E+01 | 7.10E+01 |
| Ni-63 | 3.50E+00 | 9.40E+01 |
| Zn-65 | 1.40E+01 | 8.10E+00 |
| Sr-89 | 3.80E+00 | 6.90E-03 |
| Sr-90 | 1.80E+00 | 4.50E-02 |
| Zr-95 | 5.70E+00 | 7.60E+00 |
| Nb-95 | 1.30E+01 | 1.70E+01 |
| Ru-103 | 2.20E+00 | 2.40E+00 |
| Ru-106 | 8.30E-01 | 1.90E+00 |
| Ag-110m | 1.80E-03 | 1.70E-04 |
| Sb-122 | 1.30E-02 | 1.00E-02 |
| Te-123m | 1.30E-03 | 6.30E-03 |
| Sb-124 | 2.20E+00 | 5.10E+00 |
| Sb-125 | 1.20E+00 | 8.50E+00 |
| I-131 | 6.20E+01 | 7.00E-04 |
| Cs-134 | 2.50E+00 | 7.50E-03 |
| Cs-137 | 2.70E+00 | 4.10E-02 |
| Ba-140 | 2.70E+00 | 2.60E-03 |
| La-140 | 3.10E+00 | 3.00E-03 |
| Ce-141 | 4.00E+00 | 3.90E+00 |

| Radionuclides | HCW sample tank concentration (Bq/m3)<br>PrST value : HCW-6-CA-BE | LD sample tank concentration (Bq/m3)<br>PrST value: LD-8-CA-BE |
|---|---|---|
| Ce-144 | 1.10E+01 | 2.30E+01 |
| Pu-238 | 7.00E-06 | 3.90E-04 |
| Pu-239 | 9.10E-07 | 6.20E-05 |
| Pu-240 | 1.50E-06 | 9.90E-05 |
| Am-241 | 4.90E-07 | 1.20E-05 |
| Cm-242 | 1.20E-04 | 1.90E-04 |
| Cm-243 | 3.70E-08 | 5.30E-07 |
| Cm-244 | 4.60E-06 | 5.00E-05 |
| Data taken from Table 7.2-2: HCW and LD activity concentrations, ‘Quantification of discharges and limits’, Rev F. | | |

# APPENDIX B: UK ABWR Annual aqueous discharges from the HCW and LD sample tanks

| Radionuclide | Annual discharge from HCW sample tank (Bq/y) | Annual discharge from LD sample tank (Bq/y) | Total annual discharge (Bq/y) |
|---|---|---|---|
| H-3 | 2.00E+11 | 3.00E+01 | 2.00E+11 |
| Cr-51 | 8.60E+03 | 4.10E+02 | 9.00E+03 |
| Mn-54 | 9.00E+03 | 8.90E+04 | 9.80E+04 |
| Fe-55 | 3.30E+04 | 2.30E+06 | 2.30E+06 |
| Fe-59 | 9.00E+02 | 4.10E+03 | 5.00E+03 |
| Co-58 | 1.20E+04 | 7.70E+03 | 2.00E+04 |
| Co-60 | 3.90E+04 | 1.60E+05 | 2.00E+05 |
| Ni-63 | 1.90E+03 | 2.10E+05 | 2.10E+05 |
| Zn-65 | 7.90E+03 | 1.80E+04 | 2.60E+04 |
| Sr-89 | 2.10E+03 | 1.50E+01 | 2.20E+03 |
| Sr-90 | 1.00E+03 | 1.00E+02 | 1.10E+03 |
| Zr-95 | 3.20E+03 | 1.70E+04 | 2.00E+04 |
| Nb-95 | 7.10E+03 | 3.80E+04 | 4.50E+04 |
| Ru-103 | 1.20E+03 | 5.30E+03 | 6.60E+03 |
| Ru-106 | 4.70E+02 | 4.20E+03 | 4.70E+03 |
| Ag-110m | 1.00E+00 | 3.70E-01 | 1.40E+00 |
| Sb-122 | 7.40E+00 | 2.30E+01 | 3.00E+01 |
| Te-123m | 7.30E-01 | 1.40E+01 | 1.50E+01 |
| Sb-124 | 1.20E+03 | 1.10E+04 | 1.30E+04 |
| Sb-125 | 6.80E+02 | 1.90E+04 | 2.00E+04 |
| I-131 | 3.50E+04 | 1.60E+00 | 3.50E+04 |
| Cs-134 | 1.40E+03 | 1.70E+01 | 1.40E+03 |
| Cs-137 | 1.50E+03 | 9.20E+01 | 1.60E+03 |
| Ba-140 | 1.50E+03 | 5.90E+00 | 1.50E+03 |
| La-140 | 1.70E+03 | 6.80E+00 | 1.70E+03 |
| Ce-141 | 2.20E+03 | 8.80E+03 | 1.10E+04 |
| Ce-144 | 6.00E+03 | 5.20E+04 | 5.80E+04 |

| Radionuclide | Annual discharge from HCW sample tank (Bq/y) | Annual discharge from LD sample tank (Bq/y) | Total annual discharge (Bq/y) |
|---|---|---|---|
| Pu-238 | 3.90E-03 | 8.70E-01 | 8.70E-01 |
| Pu-239 | 5.10E-04 | 1.40E-01 | 1.40E-01 |
| Pu-240 | 8.20E-04 | 2.20E-01 | 2.20E-01 |
| Am-241 | 2.70E-04 | 2.60E-02 | 2.70E-02 |
| Cm-242 | 6.80E-02 | 4.30E-01 | 5.00E-01 |
| Cm-243 | 2.10E-05 | 1.20E-03 | 1.20E-03 |
| Cm-244 | 2.60E-03 | 1.10E-01 | 1.10E-01 |
| Data taken from Table 7.2-4: Annual liquid discharges from the HCW and LD sample tanks, ‘Quantification of discharges and limits’, Rev F. | | | |

## NRW Customer Care Centre 0300 065 3000 (Mon-Fri, 9am-5pm)

Our Customer Care Centre handles everything from straightforward general enquiries to more complex questions about registering for various permits and can provide information about the following topics:

- water and waste exemptions
- lower and Upper Tier Carrier & Broker registrations
- hazardous waste registrations
- fish net licences
- cockling licences
- water resources permit applications
- waste permit applications
- water quality permit applications
- permit applications for installations
- marine licence applications
- planning applications
- publications

## Email

enquiries@naturalresourceswales.gov.uk

## By post

Natural Resources Wales
c/o Customer Care Centre
Ty Cambria
29 Newport Rd
Cardiff
CF24 0TP

## Incident Hotline 0800 80 70 60 (24 hour service)

You should use the Incident Hotline to report incidents such as pollution. You can see a full list of the incidents we deal with on our report it page.

## Floodline 0345 988 1188 (24 hour service)

Contact Floodline for information about flooding.
Floodline Type Talk: 0345 602 6340 (for hard of hearing customers).

## Would you like to find out more about us or about your environment?

Then call us on
**03708 506 506** (Monday to Friday, 8am to 6pm)

email
**enquiries@environment-agency.gov.uk**

or visit our website
**www.gov.uk/environment-agency**

incident hotline **0800 807060** (24 hours)
floodline **0345 988 1188** (24 hours)

Find out about call charges (www.gov.uk/call-charges)



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