Sizewell C Project

Radioactive Substances Regulation (RSR) Permit Application

Appendix B

Support Document B - Discharge Limits for Radioactive Waste

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1 INTRODUCTION

1.1 Purpose

1. This document describes the selection of radionuclides for the setting of limits and levels for radioactive discharges from the proposed main gaseous and liquid discharge outlets at Sizewell C (SZC), and outlines the associated twelve-rolling-month limits and Quarterly Notification Levels (QNLs). The approach used to determine these limits and levels is presented and discussed in the subsequent sections.

2. This document is based on information from the Pre-Construction Environmental Report presented in the Generic Design Assessment (GDA) [Ref 4] but also considers the lessons learnt from the Hinkley Point C (HPC) permit application process, design development and SZC design. The detailed information provided in the GDA has not been repeated here. Instead, the information presented here is intended to demonstrate that the discharge limits and levels proposed for the selected radionuclides will comply with UK regulatory requirements.

3. This document ensures that the necessary arrangements for setting discharge limits and levels on radioactive gaseous and liquid discharges from SZC are in place; and that, once granted, the conditions of the Radioactive Substances Regulation (RSR) environmental permit can be complied with.

4. The principal objective of the arrangements for setting limits and levels on radioactive gaseous and liquid discharges for SZC is to ensure minimisation of the radiological impact, through application of Best Available Techniques (BAT) and compliance with conditions of the RSR environmental permit.

5. It is important to note that the limits and levels proposed here are the same as those granted by the Environment Agency for HPC [Ref 8], on the basis that the SZC and HPC Nuclear Island designs have the same mechanisms for:

   - Generating/Minimising Waste;
   - Waste Storage;
   - Abatement; and,
   - Monitoring and Discharge Systems.

6. This document, alongside other parts of this application, demonstrates that although the receiving environment and local receptors are slightly different at SZC; compared to HPC, the limits proposed and the resulting doses at SZC are optimised and are well below the dose limit and constraint values as identified in RSR permit application support documents D1 & D2 [Ref 10 & 12].

1.2 Scope

7. This document is specific to the gaseous and liquid effluent discharges from SZC, and their proposed twelve-rolling-month limits and QNLs.

1.3 Structure

8. This document is structured into a series of sections:

   - Section 2: Sets out the approach for proposing annual limits and QNLs for the SZC RSR environmental permit application.

- Section 3: Sets out the approach and results in terms of what are considered significant radionuclides under RSR for gaseous and liquid discharges from SZC.
- Section 4: Presents the proposed twelve-rolling-month limits and QNL for: Tritium; Carbon-14 (C-14); Iodine-131 (I-131); noble gases; and, beta emitting radionuclides associated with particulate matter respectively, in gaseous discharges from SZC.
- Section 5: Presents the proposed twelve-rolling-month limit and QNL for: Tritium; Carbon-14 (C-14); and, other radionuclides respectively, in liquid discharges from SZC.

1.4 Definitions

1.4.1 Abbreviations

Term / Abbreviation	Definition
BAT	Best Available Technique
EBP	Expected Best Performance
EU	European Union
FA3	Flamanville 3
GDA	Generic Design Assessment
HEPA	High Efficiency Particulate Air
HPC	Hinkley Point C
HVAC	Heating, Ventilation and Air Conditioning
NHB	Non-Human Biota
SZC Co.	NNB Generation Company (SZC) Limited
OEF	Operational Experience Feedback
PWR	Pressurised Water Reactor
QNL	Quarterly Notification Level
RCV	Chemical Volume and Control System
RSR	Radioactive Substances Regulation
SoDA	Statement of Design Acceptability
SZB	Sizewell B
SZC	Sizewell C
TEG	Gaseous Waste Processing System
UKSDR	UK Strategy for Radioactive Discharges

1.4.2 Radionuclides

Radionuclides	Full name
Ar-41	Argon-41
Ag-110m	Silver-110m
C-14	Carbon 14
Ce-144	Cerium-144
Co-58	Cobalt-58
Co-60	Cobalt-60
Cr-51	Chromium-51
Cs-134	Caesium-134
Cs-137	Caesium-137
Fe-55	Iron-55
Fe-59	Iron-59
I-131	Iodine-131
Kr-85	Krypton-85
Kr-85m	Krypton-85m (meta-stable)
Kr-87	Krypton-87
Kr-88	Krypton-88
Kr-89	Krypton-89
Mn-54	Manganese-54
Nb-95	Niobium-95
Ni-63	Nickel-63
Sb-124	Antimony-124
Sb-125	Antimony-125
Sr-90	Strontium-90
Te-123m	Tellurium-123m
Xe-131m	Xenon-131m (meta-stable)
Xe-133	Xenon-133
Xe-133m	Xenon-133m (meta-stable)
Xe-135	Xenon-135
Xe-135m	Xenon-135m (meta-stable)
Xe-137	Xenon-137
Xe-138	Xenon-138
Zn-65	Zinc-65
Zr-95	Zirconium-95

1.5 References

Ref	Title	Document No.	Version	Location	Author
1.	SZC RSR Permit Application Support Document A1 – Environment Case	100198762	1	EDRMS	SZC Co.
2.	SZC RSR Permit Application Support Document A2 – Integrated Radioactive Waste Strategy	100197505	1	EDRMS	SZC Co.
3.	Generic Design Assessment, UK EPR nuclear power plant design by AREVA NP SAS and Electricité de France SA, Consultation Document	GEHO0510BRUV-E-P	-	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/292844/geho0510bruv-e-e.pdf	Environment Agency
4.	UK EPR™ – Generic Design Assessment	-		http://www.epr-reactor.co.uk/scripts/ssmod/publigen/content/templates/show.asp?P=290&L=EN	EDF Energy/Areva NP
5.	Nuclear Technologies Report to support SZC RSR and WDA permit applications – Radionuclide and chemical discharge data review	100133799	1	EDRMS	Nuclear Technologies
6.	SZC RSR Permit Application Support Document C1 – Plant Monitoring	100199173	1	EDRMS	SZC Co.
7.	SZC RSR Permit Application Support Document C2 – Environmental Monitoring	100199174	1	EDRMS	SZC Co.
8.	Hinkley Point: decisions on environmental permit applications for a proposed new nuclear power station	EPR/ZP3690SY	-	https://www.gov.uk/government/publications/hinkley-point-decisions-on-environmental-permit-applications-for-a-proposed-new-nuclear-power-station	Environment Agency
9.	Criteria for setting limits on the discharge of radioactive waste from nuclear sites	-	1	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296486/geho0612bugp-e-e.pdf	Environment Agency
10.	SZC RSR Permit Application Support Document D1 – Human Radiological Impact Assessment	100197432	1	EDRMS	SZC Co.
11.	GDA UK EPR - BAT Demonstration	UKEPR-0011-001	6	http://www.epr-reactor.co.uk/ssmod/liblocal/docs/Supporting%20Documents/BAT%20Demonstration.pdf	EDF Energy/Areva NP
12.	SZC RSR Permit Application Support Document D2 – Non-Human Biota Radiological Impact Assessment	100199175	1	EDRMS	SZC Co.
13.	Commission recommendation of 18 December 2003 (6th January 2004)	2004/2/Euratom		https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004H0002&from=EN	European Commission
14.	Developing guidance for setting limits on radioactive discharges to the environment from nuclear-licensed sites	SC010034/SR	1	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/290442/scho1205bivk-e-e.pdf	Environment Agency
15.	Statement of design acceptability for the UK EPR™ design, Generic assessment of candidate nuclear power plant designs	LIT 7566	-	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/301517/LIT_7566_df69bf_1_.pdf	Environment Agency
16.	Radioactive Substances Regulation – Environmental Principles	No. RSR 1	2	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296388/geho0709bqsb-e-e.pdf	Environment Agency

Ref	Title	Document No.	Version	Location	Author
17.	Radioactive Substances Regulation Environmental Permit Application for Hinkley Point C	NNB-OSL-REP-000169	8	file://personalstoragearea.bhe.live/NNB3707$/My%20Documents/Downloads/Radioactive%20Substances%20Regulation%20Permit%20Submission%20Summary.pdf	NNB GenCo (HPC)
18.	SZC RSR Permit Application Head Document	100115743	1	EDRMS	SZC Co.
19.	laying down Basic Safety Standards for the Protection against the Dangers arising from Exposure to Ionising Radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom.	2013/59/EURATOM	-	https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2014:013:0001:0073:EN:PDF	Official Journal of the European Union

2 APPROACH FOR PROPOSING ANNUAL LIMITS AND QUARTERLY NOTIFICATION LEVELS

2.1 Introduction

9. This section sets out the approach for determining the proposed annual discharge limits and QNLs for the NNB Generation Company (SZC) Ltd (SZC Co.) RSR environmental permit application for SZC. It includes discussion on the Expected Best Performance (EBP) discharges and the contingencies anticipated within operational discharge limits, to ensure the limits provide adequate protection without unduly constraining routine operation.

10. Section 3 provides information on which radionuclides are deemed significant and the approach taken to identify them. Waste stream (gaseous and liquid) and radionuclide specific details are then provided in Sections 4 & 5.

2.1.1 Regulatory Requirements and Expectations for Setting Limits

11. The setting of annual limits should consider the baseline of past plant discharges, future plant operations, and improvement schemes that will be implemented during the period of authorisation. This includes:

- Identification of EBP and contingencies to identify the maximum expected discharge;
- Establishment of radionuclides that require discharge limits; and,
- Assessment of representative person annual effective dose and consideration of the Environment Agency limit setting criteria against dose constraints and biota dose rates.

2.2 SZC Co. Approach

12. The SZC Co. approach is consistent with the regulatory requirements and expectations for setting limits. It includes establishing the EBP for radioactive waste discharge from SZC and proposing rolling annual limits that take into account matters, including trends and events, expected to occur during routine operations. These include reactor shutdowns, maintenance activities, fuel defects and the performance of the waste management systems. These are described in more detail in the following sections. Summary results for the annual effective dose to the representative person and dose rates to Non-Human Biota (NHB) are given in the following chapters and discussed in detail in [Refs 10 & 12].

13. SZC will be a replica of HPC, both in terms of design and construction, commissioning, and decommissioning of the Nuclear Island. This means that the nuclear island is identical and therefore the method of generating radioactive waste, minimisation at source, storage, treatment, monitoring and disposal are the same. The same BAT arguments, and ongoing RSR compliance at HPC, apply to both sites derived from the GDA process [Ref 11]. Supporting Document A1 demonstrates the application of BAT to SZC from the common nuclear island design shared between HPC and SZC, and as a result the proposed discharges from SZC are the same as those granted for the operation of the HPC [Ref 8]. Although the local environments and receptors are slightly different, there are small differences in the predicted doses [Ref 12]. These differences are considered to be small with the impacts being broadly comparable, and the dose being well below the regulatory requirements.

14. The SZC Co. approach undertaken for identifying and proposing limits is illustrated in **Error! Not a valid bookmark self-reference.**.

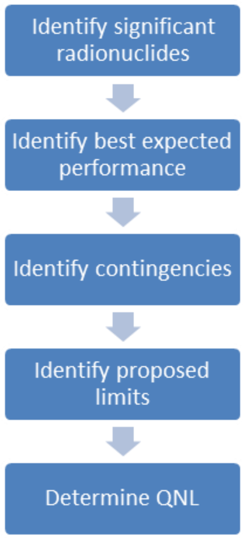


Figure 2-1 SZC Co. Approach for identifying limits

15. The SZC proposed limits are based on those granted for HPC. There is currently limited data available from Taishan 1, therefore SZC Co. continues to rely on GDA [Ref 4], the Statement of Design Acceptability (SoDA), and the review of design changes to demonstrate that there should be no impact on the limits granted for SZC compared to HPC. Further operational data, where available, will be reviewed and incorporated as appropriate (See Section 8.2 of the RSR permit application head document [Ref 18]).

2.2.1 Determination of Significant Radionuclides

16. Further detail on the approach adopted for the determination of significant radionuclides is given in Section 3.

17. In summary the significant radionuclides that are proposed for setting discharge limits on radioactive **gaseous** discharges from SZC are:

- Tritium;
- C-14;
- Iodine-131 (I-131);
- Noble gases; and,
- Beta-emitting radionuclides associated with particulate matter.

18. The significant radionuclides that are proposed for setting discharge limits on radioactive **liquid** discharges from SZC are:

- Tritium;
- C-14;
- Cobalt-60 (Co-60);
- Caesium-137 (Cs-137); and,

- Other radionuclides.

2.2.2 Determination of Expected Best Performance Discharges

19. The EBP is determined through consideration of discharges from the UK and French fleet, considered to be indicative EPR™ precursors. Given the evolutionary EPR™ design, the EBP considers that SZC will perform in the top 25% of the fleet. The EBP for a single unit was presented for GDA [Ref 4], and throughout the calculations presented in this document, consideration is given to the figures presented in GDA and adjusted accordingly.

20. The following sections present the operational experience data used to determine the EBP figures referred to throughout this document. More information is presented in the RSR permit application head document on the use of Operational Experience Feedback (OEF).

2.2.2.1 Indicative EPR™ Precursors

21. It is noted that although based on HPC, there is no operational data currently available from HPC or other EPR™ worldwide[1]. Since no data is available for an operating EPR™, the future radioactive discharges from SZC have been assessed based on OEF data from indicative Pressurised Water Reactor (PWR) predecessors. In the context of this submission, OEF is defined as information (including discharge data and information on operational contingencies) obtained from representative French and German PWR stations, including the UK EPR™ reference design at Flamanville 3 (FA3).

22. SZC Co. continues to use the GDA [Ref 4] and SoDA, as well as the review of design changes to demonstrate there should be no impact on the limits granted for SZC.

23. As presented in the GDA [Ref 4], the eight 1,300 MWe PWR sites in France are considered as indicative predecessors as they provide a significant amount of recent and representative OEF data. The UK EPR™ design has similarities with the French PWRs. Notwithstanding this, operational data have been considered taking account of certain design features and taking into account quantifiable gains during the 2001 - 2003 reference period.

24. The period 2001 - 2003 was selected for consistency with the French regulator's public consultation document for the French EPR™ in Flamanville, which was published the same year as the start of the GDA for the UK EPR™. This reference period had been selected initially for FA3 because it provided annual OEF data that were:

    - Reported against the new methods in place for the French fleet;
    - Sufficiently recent so that they were representative of the sites in operation;
    - Providing the equivalent of 60 years of operating experience; and
    - Representative of the fluctuations of discharges over the cycles.

25. This OEF is still deemed relevant for determining potential discharges and is within the ten-year period of SoDA applicability [Ref 15] issued by the Environment Agency following GDA [Ref 4].

[1] Flamanville 3 and Olkiluoto 3 have not entered operations yet. Taishan 1 and 2 have entered commercial operation in 2018 and 2019 respectively, however, no discharge data is currently available for these plants. Given the large number of PWR years of experience from predecessor plant on which the UK EPR™ design is based, this provides a better dataset for prospective discharges than a smaller dataset over a shorter duration. SZC Co. will review other EPR™ operators' data as it becomes available to benchmark its performance.

26. SZC Co. has undertaken analysis of more recent data from EDF (2008-2012) [Ref 5] in addition to the information provided at GDA, which supported the HPC application[2]. This analysis looked at predecessor plant to the EPR™ design and only plants identified as significant for each radionuclide were included in the review. This data did not show any significant differences to the original GDA data and supported the previous estimates of best performance and subsequent limits. Relevant points from this analysis are included in subsequent sections where appropriate. As a learning organisation, SZC Co. will keep under review operational data from predecessor plant (and other EPR™s as discharge data becomes available) to inform future operations (see RSR Commitment 1).

27. Annual discharges do not provide full visibility on the effect of monthly fluctuations on discharge profiles. To allow further analysis of the fluctuations of discharges related to normal transients and expected contingencies, additional monthly OEF data have been presented in the GDA [Ref 4]. OEF data from FA3 (2 units) and Paluel (4 units) have been analysed over the period 2002 - 2007. This period has been studied to take account of more recent data that were available at the time of assessment. These two sites have been selected as they provided data that was considered to be representative of the fleet over the period studied.

2.2.2.2 Evolutionary EPR™ Design

28. The UK EPR™ design has evolved from combining experience from earlier separate PWR designs operating in France and Germany (77 operational plants). The most recent French design was the N4, brought into commercial operation in 1996 (Chooz B1). The most recent German design was the KONVOI, brought into commercial operation in 1988 (Isar 2). The EPR™ has undergone design assessment by the nuclear regulators in Finland, China and France and has been granted construction licences. Two units are now operational (Taishan, China) and two more EPR™ plants are near to completion and operation: one at Olkiluoto in Finland; another one at Flamanville in France.

29. The environmental improvements incorporated into the UK EPR™ design have been assessed based on:

- Global analysis of OEF data from the French fleet and a number of KONVOI reactors (GKN2, KKI2 and KKP2).
- Detailed analysis, for a number of radionuclides, of OEF data from three 1,300 MWe sites (Golfech, Cattenom and Penly). These sites were selected because:
  - Golfech provides a significant amount of representative OEF data;
  - Cattenom is a 4-unit site which is of specific interest for the basic design of the Effluent Treatment Building; and,
  - Penly is a coastal site which is of specific interest for FA3 and equally applicable to SZC.

30. The EBP as discussed in Section 2.2 considers that SZC will perform in the top 25% of indicative precursor plants, this is based on the improvements made as well as the following design features.

31. The UK EPR™ incorporates some new features designed to reduce radioactive gaseous waste at source and provide efficient abatement for that which does arise. In particular:

- All of the ventilation systems for the controlled areas of the Nuclear Auxiliary Building, the Safeguard Buildings and the Fuel Building can be routed to iodine traps prior to discharge if required;
- No flushing of the intermediary primary coolant tank, which is the main source of radioactive

[2] It is noted that the data used to undertake the SZC assessments is no longer the most recent data, however, this was the latest available data when the SZC assessments were first conducted. Given the modelling impacts are so small and to ensure consistency with other studies the original dataset was retained.

gaseous discharges in the 1,300 MWe PWR units. The main source of radioactive gaseous discharges, in the UK EPR™, is evaporation from the spent fuel pool; and,

- Improved design of the Gaseous Waste Processing System (TEG) based on the German KONVOI design.

32. The UK EPR™ is expected to have a better environmental performance compared to the existing reactors. Compared to the 1,300 MWe PWR units the UK EPR™ produces 25% more energy and offers efficiencies in terms of utilisation of fuel.

33. EBP discharges and their determination are described in Section 4 for gaseous discharges and Sections 5 for liquid discharges.

2.2.3 Relevant Contingencies

34. The EBP discharges require justified contingency to allow there to be some headroom between these discharge levels and the proposed limits to allow for normal operational transients. The graph below presents a simplistic visual representation of how discharges may fluctuate, and how the EBP/actual discharges during an isolated period may be substantially different therefore, allowances are required when considering annual limits.

35. As illustrated in the graph above, relevant contingency includes planned situations such as: routine start-up;

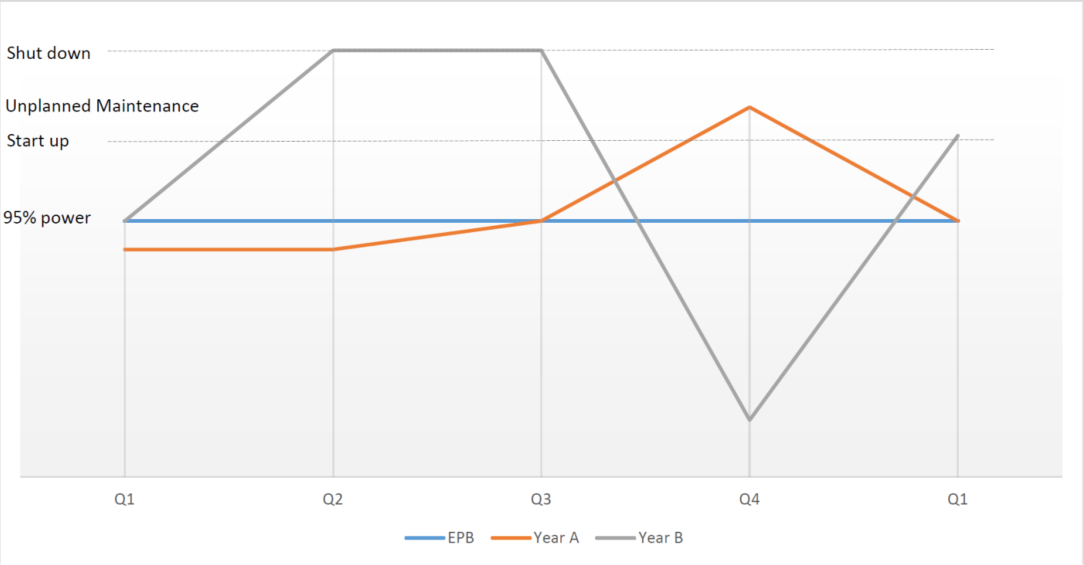


Figure 2-2 Simplified graph showing example discharge fluctuations around the calculated EBP

shutdowns and maintenance of systems; and those events which, while unplanned, are not unexpected during the lifetime of the plant. It also considers operating variables, which give the operator the flexibility to choose the most suitable operating regime, without disproportionate restrictions on discharges.

36. Some of the main contingencies associated with gaseous and liquid discharges come from unplanned shutdown, coolant chemistry changes, fuel failure as well as leaks from the primary coolant containment and changes in the way coolant is recycled or discharged.

37. The contingencies relevant to the radionuclide/groups of radionuclides concerned are discussed in the relevant Section 4 gaseous discharges and Section 5 for liquid discharges.

2.3 Annual Discharge Limits

2.3.1 Definition

38. This chapter refers to two types of annual discharge limits:

- Annual limits as originally proposed for one UK EPR^{TM} unit in the GDA submission [Ref 4] these correspond to values that limit discharges on a calendar yearly basis; and,
- Twelve-rolling-month limits for SZC (for two UK EPR^{TM} units). These correspond to values that limit the discharges from the last consecutive 12 months of operations, i.e. each month, the total discharge over the last consecutive 12 months is assessed against the twelve-rolling-month limit.

39. The transition from the annual limits proposed for GDA [Ref 4] to the twelve-rolling-month limits proposed for SZC is addressed in the following sub-chapters. Overall, the main difference between these two types of limits is that where discharges are assessed on a twelve-rolling-month basis they account for operational contingencies and start-up or shutdown phases that may have occurred over the preceding full 12 months of operations. Therefore, it can be expected that twelve-rolling-month limits may need to be higher than annual limits, as they account for a 'build-up' effect of any higher monthly discharges encountered over a twelve-rolling-month period.

2.3.2 Proposed Limits (12-month Rolling Basis)

40. Annual limits proposed for one UK EPR^{TM} unit in the GDA submission [Ref 4] correspond to values that limit discharges on a calendar yearly basis. As for the HPC site (two UK EPR^{TM} units), the limits for discharges from SZC are proposed over consecutive 12 rolling months of operations, i.e. each month, the total discharge over the last consecutive 12-months is assessed against the twelve-rolling-month limit.

41. This allows for operational contingencies and start-up or shutdown phases that may occur over the preceding full 12-months of operations. However, assessing discharges on a calendar yearly basis does not provide visibility over a rolling period of time. Therefore, it can be expected that twelve-rolling-month limits may need to be higher than annual limits.

42. Proposed limits and their determination are described in Section 4 for gaseous discharges and Section 5 for liquid discharges. Proposed annual limits are shown in Table 2-1.

Table 2-1 Proposed Limits (12-month Rolling Basis)

Gaseous Discharges (GBq)		**Aqueous Discharges (GBq)**	
Tritium	6,000	Tritium	200,000
Carbon-14	1,400	Carbon-14	190
Noble gases	45,000	Cobalt-60	6
Iodine-131	0.4	Caesium-137	1.9
Beta emitting radionuclides associated with particulate matter	0.12	Other radionuclides	12

2.4 Quarterly Notification Levels

2.4.1 Definition

43. QNLs are set for significant radionuclides used as indicators of plant and process performance [Ref 14]. The purpose of QNLs is to signal when discharges in any consecutive 3-month period are above expected levels giving the plant operator an ongoing indication of possible deterioration in plant performance. QNLs are normally set above the level for normal transients but below those for unplanned (although foreseeable) plant faults, such as fuel leaks.

44. The purpose of the QNLs is consistent with the standard conditions of the RSR environmental permit and the Environmental Principles detailed by the Environment Agency in its RSR – Environmental Principles document [Ref 16], notably Principle RSMDP12 (limits and levels on discharges), which states that that advisory levels should be set to:

- Prompt review of whether BAT is being used; and,
- Ensure early assessment of the potential impact of increased discharges.

45. Exceeding a QNL is not a breach of the RSR environmental permit although the exceedance must be reported to the Environment Agency giving the reasons for the exceedance, the procedures that will be in place to address this and a demonstration of the continuing use of BAT to control discharges.

2.4.2 Proposed Levels

46. The general methodology developed for determining QNLs should be tailored for each radionuclide discharged, taking into consideration specific factors that may cause discharges to fluctuate over time due to changes in operational activities or abatement efficiency.

47. QNLs were proposed in the Environment Agency GDA Public Consultation Document [Ref 3] based on a single UK EPR™ unit, derived from the EBP data and the Environment Agency's regulatory experience and insight. Importantly, the EBP data assumes a long-term plant availability of 91%. This availability corresponds to an average over 60 years, which is the expected operational life span of the UK EPR™. It is possible that no shutdown will occur over rolling quarters, in which case the availability will be equal to 100%. Where the discharges of certain radionuclides are directly linked to their production, the QNLs should be set based on 100% availability. The calculations in the following sections will include a Kd factor adjustment to account for availability where applicable.

48. QNLs are based on historical performance and OEF, given that HPC will be the first UK EPR™ built and operated and this has yet to occur, the Environment Agency guidance on the setting of discharge limits [Refs 9 & 14] has been used. This Environment Agency guidance indicates that in the absence of previous experience, QNLs could be set on 25% of the annual limits. This simple approach does not consider the discharge practice that may prevail for UK EPR™. The QNLs proposed in this submission are based on an assessment of indicative predecessor plants and are identical to those agreed by the Environment Agency for the HPC site [Ref 8] and therefore include either a correction factor (R) or a peak factor (P) in the calculations in the following sections where applicable.

49. The QNLs proposed also account for two units which is reflected in the calculations in the following sections.

50. Once the UK EPR™ units are commissioned and operational, future performance will inform possible updates to QNLs. As OEF becomes available for the UK EPR™ this will be reviewed and assessed to better understand suitable levels at SZC, the QNL and proposed limits for SZC may be adjusted in the future if considered appropriate.

51. Proposed QNLs are described in Section 4 for gaseous discharges, and Section 5 for liquid discharges; and summarised in Table 2-2. For clarity, the calculations used are entirely consistent with those used in the HPC permit application however, the proposed SZC QNL also takes into account the response from the Environment Agency so that QNLs for SZC remain consistent with those granted for HPC.

Table 2-2 Proposed Quarterly Notification Levels

Gaseous Discharges (GBq)		**Aqueous Discharges (GBq)**	
Tritium	400	Tritium	60,000
Carbon-14	300	Carbon-14	18
Noble gases	1,500	Cobalt-60	0.3
Iodine-131	0.064	Caesium-137	0.1
Beta emitting radionuclides associated with particulate matter	0.008	Other radionuclides	0.6

2.5 Consideration of Monthly, Weekly and Daily Advisory Levels

52. The time periods on which limits and levels should be based needs to be consistent with the intent of the limit or level. Such periods could include annual, quarterly, monthly, weekly and daily, and be calendar or rolling. To ensure that effective management controls are in place during operation, limits should be set for periods of less than one year (or advisory levels where the limit could conflict with the safe operation of a plant). Based on [Ref 14], the criterion used in deciding whether short-term limits and levels are needed is the representative person dose. This takes into account any possible fluctuations in dose per unit discharge as a result of, for example, weather conditions, or seasonal agricultural and fishing practices. For aerial discharges, weekly limits (or advisory levels) are proposed if it seems that the dose to the representative person from a short-term discharge could exceed 20 µSv. For SZC the dose to the adult member of the farming family from exposure to short-term discharges of gaseous radionuclides from SZC, summed across the relevant terrestrial pathways, is calculated to be 3.8 µSv/y [Ref 10].

53. Only short-term doses arising from gaseous discharges to the atmosphere were assessed [Ref 10] on the basis that liquid discharges to sea are normally considered as part of continuous discharge assessments on account of the practice of accumulating operational aqueous effluents in tanks for short periods of time prior to discharge, resulting in a semi-continuous discharge pattern. Furthermore, National Dose Assessment Working Group believes that the assessment of dose from short-term aqueous discharges to coastal or estuarine environments is unlikely to be needed. This is due to the low and predictable variability in the frequency of tidal currents, which drive dispersion in coastal environments, and on account of the high mobility of fish (the dominant pathway for exposure to aqueous discharges to the marine environment), [Ref 10].

54. On this basis, monthly, weekly or daily advisory levels are not therefore considered appropriate for SZC and this is consistent with the RSR environmental permit granted for HPC [Ref 8].

3 GASEOUS AND LIQUID DISCHARGES – SIGNIFICANT RADIONUCLIDES

3.1 Introduction

55. The production of liquid and gaseous discharges are described in RSR permit application support document A2 [Ref 2], and are minimised where possible through the application of BAT, presented in RSR permit application support document A1 [Ref 1]. These discharges require limits which are an important part of the RSR environmental permit conditions to ensure that the impact of the facility is As Low As Reasonably Achievable in terms of radiation exposure to the public, and discharge to the environment; whilst also providing a reference for the operational discharge performance of the plant. Not every radionuclide discharged may be subject to a specific discharge limit. Some of the radionuclides discharged are proposed to be grouped according to similarities in how they are generated, managed and abated. This section identifies the radionuclides deemed significant are therefore subject to such limits.

3.2 Definitions

56. The 'key radionuclides' in gaseous and liquid radioactive discharges from nuclear power stations are defined in The European Union (EU) Commission recommendation [Ref 13] as:

"*The radionuclides to which requirements for detection limits should apply. These key nuclides should represent categories of radionuclides or a specific type of radiation, be significant in terms of radiological impact and be suitable measurement sensitivity indicators*."

57. Environment Agency guidance [Refs 9 & 14] defines 'significant' radionuclides as those which:

- 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/hour);
- 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 is of concern internationally[3];
- Are indicators of plant performance, if not otherwise limited on the above criteria; and,
- For the appropriate generic categories from the RSR Pollution Inventory (e.g. "alpha particulate" and "beta/gamma particulate" for discharges to air) to limit any radionuclides not otherwise covered by the limits set on the above criteria[4].

[3] The Environment Agency do not set limits to give effect to the targets in the UK Strategy for Radioactive Discharges (UKSDR) and do not set limits for the substances reported under the UKSDR.

[4] Where no limit is specified in the permit for any given radionuclide, discharges are still controlled by the BAT conditions in the permit. The generic categories can be used to limit all radionuclides not otherwise specifically limited in the permit.

58. The Environment Agency also recommends that the significant radionuclides include the 'key nuclides' defined in EU Commission Recommendation 2004/2/Euratom [Ref 13].

59. The definitions of significant/key radionuclides above have been adopted and are given further considerations in the following section.

3.3 Approach to Identification

60. Identification of significant radionuclides considers the following three sources of information:

- EU Commission Recommendation 2004/2/Euratom [Ref 13];
- Limits granted for HPC [Ref 8]; and,
- Information presented for GDA [Ref 4] – the radionuclides of interest presented for the GDA correspond to those currently limited in France. A study into more recent EDF OEF (2008-2012) re-affirmed the validity of the GDA data, showing no significant difference.

61. Table 3-1 and Table 3-2 present the output from these three sources of input for gaseous discharges and liquid effluents, respectively. Radionuclides in bold are the 'key nuclides' as defined in EU Commission Recommendation

Table 3-1 Comparison of significant radionuclides in gaseous discharges for SZC.

EU Commission Recommendation 2004/2/Euratom	GDA submission	HPC/SZC RSR Environmental Permits	Environment Agency GDA Public Consultation Document
H-3	H-3	H-3	H-3
C-14	C-14	C-14	C-14
Noble gases: Ar-41 **Kr-85** Kr-85m Kr-87 Kr-88 Kr-89 Xe-131m Xe-133 Xe-133m Xe-135 Xe-135m Xe-137 Xe-138	Noble gases: Ar-41 **Kr-85** Kr-85m Kr-87 Kr-88 Xe-131m Xe-133 Xe-133m Xe-135 Xe-138	Noble gases	Noble gases
Iodines: **I-131** I-132 I-133 I-135	Iodines: **I-131** I-132 I-133 I-134 I-135	**I-131**	**I-131**
Total alpha: **Pu-239 + Pu-240** **Am-241** Cm-242 Cm-243 Cm-244	-	-	-

EU Commission Recommendation 2004/2/Euratom	GDA submission	HPC/SZC RSR Environmental Permits	Environment Agency GDA Public Consultation Document
Particulates: Cr-51 Mn-54 Fe-59 Co-58 **Co-60** Zn-65 Sr-89 **Sr-90** Nb-95 Zr-95 Ag-110m Sb-122 Sb-124 Sb-125 Cs-134 **Cs-137** Ba-140 La-140 Ce-141 Ce-144 Pu-238	Other fission and activation products: Co-58 **Co-60** Cs-134 **Cs-137**	Beta emitting radionuclides associated with particulate matter	All other fission and activation products

Table 3-2 Comparison of significant radionuclides in liquid discharges for SZC.

EU Commission Recommendation 2004/2/Euratom	GDA submission	HPC/SZC RSR Environmental Permits	Environment Agency GDA Public Consultation Document
H-3	H-3	H-3	H-3
-	C-14	C-14	C-14
-	Iodines: **I-131** I-132 I-133 I-134 I-135 (as a single group)	-	-
-	-	**Cs-137**	**Cs-137**
Total alpha : **Pu-239 + Pu-240** **Am-241** Cm-242 Cm-243 Cm-244	-	-	
		Co-60	**Co-60**
Other radionuclides: Cr-51 Mn-54 Fe-55 Fe-59 Co-58 **Co-60** Ni-63 Zn-65 Sr-89 **Sr-90** Nb-95 Zr-95 Ru-103 Ru-106 Ag-110m Sb-122 Te-123m Sb-124 Cs-134 **I-131** Cs-134 **Cs-137** Ba-140 La-140 Ce-141 Ce-144 Pu-238	Other fission and activation products: Cr-51 Mn-54 Co-58 **Co-60** Ni-63 Ag-110m Te-123m Sb-124 Sb-125 Cs-134 **Cs-137** (as a single group)	All other radionuclides	All other fission and activation products

62. Radionuclides regarded as significant by the EU Commission, with some exclusions to account for relevance for gaseous and liquid discharges as discussed below, have then been compared against the Environment Agency

criteria given in Section 3.2. The comparisons are given in Table 3-3 and Table 3-4 for gaseous and liquid effluent discharges, respectively.

Table 3-3 Comparison of radionuclides against Environment Agency criteria to establish basis for gaseous discharge limits

Radionuclides \ Criteria	Quantity discharged: maximum annual activity discharged ≥ 1 TBq y^{-1}	Contribution to site discharges: maximum annual activity discharged > 50 % of total discharges	Critical group dose > 1 µSv y^{-1}	Collective dose > 0.1 man. Sv y^{-1} over 500 years	Good indicator of plant performance or process control	Specific discharge limit required
H-3	Y	N	N	N	Y	Y
C-14	Y	N	Y	Y	N	Y
Kr-85	Y	N	N	N	N	N
Noble gases (total)	Y	Y	N	N	Y	Y
I -131	N	N	N	N	Y	Y
Iodines (total)	N	N	N	N	Y	N
Co-60	N	N	N	N	Y	N
Cs-137	N	N	N	N	N	N
Other fission and activation products * (including Co-60, Sr-90 and Cs-137)	N	N	N	N	Y	Y

*Other fission and activation products was the term used in GDA. For SZC, as used for HPC, the group for which limits are proposed is termed *'Beta emitting radionuclides associated with particulate matter'*.

Table 3-4 Comparison of radionuclides against Environment Agency criteria to establish basis for liquid effluent discharge limits.

Radionuclides \ Criteria	Quantity discharged: maximum annual activity discharged ≥ 1 TBq y-1	Contribution to site discharges: maximum annual activity discharged > 50 % of total discharges	Critical group dose > 1 µSv y-1	Collective dose > 0.1 man.Sv y-1 over 500 years	Good indicator of plant performance or process control	Half-life > 10 years and concentration factor in any environmental material > 1,000	Specific discharge limit required
H-3	Y	Y	N	N	Y	N	Y
C-14	N	N	Y	Y	N	Y	Y
Iodines (total)	N	N	N	N	N	N	N
Co-60	N	N	N	N	Y	N	Y
Sr-90	N	N	N	N	N	Y	N
Cs-137	N	N	N	N	Y	Y	Y
Other radionulcides	N	N	N	N	Y	Y	Y

63. In theory, any of the radionuclides or groups of radionuclides assessed that meets at least one criterion should be proposed for a specific discharge limit. However, considerations should also be given to the suitability of a single radionuclide for substituting to a group of radionuclides that it belongs to. Note, the Environment Agency expect to set site limits, regardless of whether the total prospective annual effective dose to people is above or below the exemption criteria of 10 µSv/y, set out in the Basic Safety Standards Directive [Ref 19].

3.4 Significant Radionuclides

3.4.1 Gaseous Discharges

64. For GDA, BAT demonstration forms [11] were prepared for all radionuclides identified as significant in terms of half-life, radiation dose, magnitude of source term or because they are indicators of plant performance. Following consideration of the Environment Agency criteria (see Section 3.2) the BAT forms concluded that significant radionuclides are tritium, C-14, iodines (as I-131), noble gases and other fission or activation products emitting beta or beta/gamma radiation (excluding tritium, C-14 and iodines) noting that for SZC this latter group for which a limit has been proposed has been termed 'Beta emitting radionuclides associated with particulate matter'.

65. There are some differences between the significant radionuclides considered for gaseous discharge limits for SZC compared to the GDA submission for the UK EPR™ [Ref 4], the recommendations of the EU Commission [Ref 13] and the Environment Agency criteria (Section 3.2). These are identified and explained below.

- Total iodines are regarded as being significant in gaseous discharges in the GDA [Ref 4] submission and were proposed to have a separate discharge limit, whereas HPC has a separate limit on the gaseous discharges of I-131 only. Before April 2007, total halogens were limited in gaseous discharges at Sizewell B (SZB). The discharge authorisation changed to a single I-131 limit after that time. The argument for both was that I-131 is the most radiologically significant radionuclide within the halogen group and is representative of the whole group given that all halogens have a similar chemical behaviour in the primary effluent and the treatment systems. A limit on I-131 alone is considered adequate for control of the discharges of all iodine isotopes and the exposures from such discharges given that it is easy to detect as it has a longer half-life relative to the others;

- The dose assessment presented for Cobalt-60 (Co-60) in gaseous discharges in the GDA [Ref 4] submission is regarded as significant according to the Environment Agency's criteria. However, the site-specific dose assessments carried out for SZC [Ref 10] shows that Co-60 is not regarded as significant in gaseous discharges for SZC, this matches the significant radionuclides listed in the HPC RSR permit. Co-60 is not regarded as significant either in terms of activity discharged and contribution to the total gaseous discharges. It is a corrosion product formed by neutron activation of primary circuit structural materials, such as cobalt-59 (Co-59) and is largely removed from liquid effluent at source via filtration and ion exchange media. Like other particulates, the only way it is abated in gaseous discharges is via High Efficiency Particulate Air (HEPA) filters. As such, Co-60 can be regarded as representative of the plant performance but this is also true for a number of other radionuclides, such as cobalt-58 (Co-58), caesium-134 (Cs-134) and caesium-137 (Cs-137 as particulate). Taking into consideration the low radiological significance of Co-60 when compared to the EA's criteria, no specific discharge limit is proposed for Co-60 in gaseous discharges. The gaseous discharges of Co-60 would be adequately controlled by a numerical limit on beta emitting radionuclides associated with particulate matter to allow identification of any issues relating to plant performance; and,
- Alpha activity is considered in the EU Commission Recommendations however given that historical measurements carried out at PWR units confirm that discharges are below detection levels, alpha activity was not presented as a significant group of radionuclides for GDA [Ref 4], and is not considered significant for SZC for the same reason.

66. In the light of the above discussions, the significant radionuclides that are proposed for setting discharge limits on radioactive gaseous discharges from SZC and therefore the basis for Section 4 are:

- Tritium;
- C-14;
- I-131;
- Noble gases (limit expressed as 'Noble Gases'); comprising isotopes: argon-41 (Ar-41), krypton-85 (Kr-85), krypton-85m (Kr-85m), krypton-87 (Kr-87), krypton-88 (Kr-88), krypton-89 (Kr-89), xenon-131m (Xe-131m), xenon-133 (Xe-133), xenon-133m (Xe-133m), xenon-135 (Xe-135), xenon-135m (Xe-135m), xenon-137 (Xe-137), xenon-138 (Xe-138); and,
- Beta emitting radionuclides associated with particulate matter; comprising of isotopes chromium-41 (Cr-41), manganese-54 (Mn-54), iron-59 (Fe-59), Co-58, Co-60, Cs-134, Cs-137. This is a combination of the list of 'other fission and activation products' presented for GDA [Ref 4] and 'Any Other Activity', which is RSR limited for SZB and SZC.

67. It should be noted that not all of these key radionuclides would be expected to be directly measured at source as it is not practicable to do so. However, measurements of specific indicator radionuclides will ensure that the total values obtained adequately cover the nuclides in each group that are included in the RSR environmental permit [Ref 5].

NOT PROTECTIVELY MARKED

68. As discussed above, the grouping of radionuclides selected for the setting of gaseous discharge limits for SZC differs slightly from the grouping presented for the GDA [Ref 4]. Although discharges will be assessed differently from those presented for the GDA, this does not change the design of the treatment systems and the way that radioactive gaseous discharges will be undertaken, which remains consistent with the information presented in the GDA. The final group does not include alpha activity for the reasons explained above.

3.4.2 Liquid Discharges

69. As for gaseous discharges, BAT forms presented for GDA [Ref 11] identified radionuclides as significant in terms of half-life, radiation dose, magnitude of source term or because they are indicators of plant performance. The BAT demonstration concluded that significant radionuclides for liquid discharges are tritium, C-14, and other fission or activation products emitting beta or beta/gamma radiation (excluding tritium, C-14 and isotopes of iodine).

70. There are some differences between the significant radionuclides considered for liquid discharge limits in the GDA submission for the UK EPR™, the recommendations of the EU Commission, and those subject to discharge limits at SZB; whilst noting that those identified for HPC are considered for the SZC submission. These are identified and explained below.

- At SZB, C-14 is largely degassed in the Volume Control Tank, then passed through a closed loop gaseous waste processing system and discharged via the ventilation discharge stacks. This process means that very little C-14 is transferred to liquid effluent and, therefore, the contribution of C-14 to the liquid discharges at SZB is very small. A limit on liquid discharges of C-14 is neither applied at SZB, nor recommended for consideration by the EU Commission. There are differences between the design of SZB and that of the UK EPR™, for which C-14 is regarded as being significant in liquid discharges for SZC. The TEG in the UK EPR™ is a semi-closed loop system, based on the German KONVOI design. A small proportion of the C-14 remaining in the primary effluents may be retained on filters and resins before the Coolant Storage and Treatment System. Although C-14 is mainly discharged in gaseous effluent, there are uncertainties on the distribution between liquid, solid and gaseous discharges and in particular between solid and liquid waste therefore C-14 is considered appropriate for liquid discharge limits for SZC;
- Isotopes of iodine are not regarded as being significant in liquid discharges for the UK EPR™ (see Table 3-4). They are not subject to a specific discharge limit for liquid discharges at SZB. As isotopes of iodine are mainly present in the form of iodide during normal operation, they will be treated on filters and demineralisers with the liquid effluents. Hence, isotopes of iodine discharges are considered to be very low both in terms of activity discharged and radiological impact. Even with significant fuel failures, the performance of abatement plant and the ability to delay and decay liquid effluent prior to discharge will reduce iodine in liquid discharges to very low levels. Iodine concentration in liquid effluent or liquid discharge is consequently not regarded as a good indicator of plant performance. It is therefore proposed that isotopes of iodine in liquid discharges do not require a specific discharge limit at SZC. This is consistent with the Environment Agency GDA Public Consultation Document [Ref 3];
- Before April 2007, there was no specific limit for the liquid discharges of Cs-137 in place at SZB. These were reported as part of the 'other fission and activation products' category. The discharge authorisation changed after that time to a specific limit for Cs-137, in addition to a limit on other fission and activation products (excluding Cs-137). The current practice for the French fleet is to include Cs-137 to the 'other fission and activation products' limit. Cs-137 is a fission product and so

it is an indicator of fuel integrity. It is relatively mobile in the fuel, highly soluble in the reactor cooling water and can be readily measured at very low levels of detection. It has a relatively long-half life so that as well as giving indications of fuel leaks in the primary circuit, it can also assist in providing an indication of the longer-term performance of the down-stream abatement systems against fission product spikes. As such, the quantity of Cs-137 in liquid discharges is regarded as a good indicator of fuel and plant performance. Moreover, Cs-137 is persistent in the environment. It indicates that a specific discharge limit for Cs-137 in liquid effluent is appropriate for SZC as it meets two of the five criteria as defined by the Environment Agency (see Table 3-4);

- A specific discharge limit for Co-60 in liquid effluent is not necessary as it does not meet any of the criteria defined by the Environment Agency (see Table 3-4). However, it is included to be consistent with the HPC environmental permit [Ref 8] as Co-60 releases are a good indicator of any issues relating to corrosion and can be identified by measurement in liquid discharges;
- Alpha activity is considered in the EU Commission Recommendations however given that historical measurements carried out at PWR units confirm that discharges are below detection levels, alpha activity was not presented as a significant group of radionuclides for GDA [Ref 4], and is not considered significant for SZC for the same reason; and,
- Strontium-90 (Sr-90) is defined as a key nuclide in EU Commission Recommendation 2004/2/Euratom [Ref 13], but is neither regarded as being significant in liquid discharges in the GDA submission [Ref 4] nor HPC RSR environmental permit [Ref 17]. Detection of Sr-90 is expensive and not very reliable in comparison to the detection of other fission products such as Cs-137, which can give indication of fuel leak data more quickly and reliably than Sr-90. At SZB, Sr-90 is assessed once per year from the bulk of four quarterly samples and measurements are consistently less than the limit of detection. Therefore, there is no proposal to include Sr-90 in the monitoring programme for SZC or in the discharge limits.

71. In the light of the above discussions, and in line with EU Commission Recommendation 2004/2/Euratom [Ref 13] and Environment Agency guidance [Refs 9 & 14], the significant radionuclides that are proposed for setting discharge limits on radioactive liquid discharges from SZC and therefore the basis for Section 5 are:

    - Tritium;
    - C-14;
    - Co-60;
    - Cs-137; and,
    - Other fission and activation products comprising isotopes: Cr-51, Mn-54, iron-55 (Fe-55), Fe-59, Co-58, nickel-63 (Ni-63), zinc-65 (Zn-65), niobium-95 (Nb-95), zirconium-95 (Zr-95), silver-110m (Ag-110m), tellurium-123m (Te-123m), antimony-124 (Sb-124), antimony-125 (Sb-125), Cs-134 and cerium-144 (Ce-144).

72. The final group does not include alpha activity for the reasons explained above. The various radionuclides will be monitored and expressed under a single grouping (‘other radionuclides’). It should be noted that not all of these radionuclides would be expected to be directly measured at source. However, measurements will ensure that the total values obtained adequately cover the nuclides in each group that are included in the RSR environmental permit.

4 GASEOUS DISCHARGES

4.1 Introduction

73. The following sub-chapters present the proposed twelve-rolling-month limits and QNLs for: Tritium; C-14; I-131; Noble gases; and beta emitting radionuclides associated with particulate matter respectively, in gaseous discharges from SZC. Further details on the production and treatment processes for these radionuclides are provided in both the RSR permit application support documents A1 and A2 [Refs 1 & 2], the GDA [Ref 4] and the Environment Agency GDA Public Consultation Document [Ref 3].

74. The SZC UK EPR™ design, developed from the GDA [Ref 4], will allow for adequate and appropriate sampling, measurement and assessment of all gaseous radioactive discharges. Discharge monitoring and measurement will be applied at each of the main gaseous discharge outlets at SZC to demonstrate compliance with discharge limits and to meet other objectives, as defined in RSR permit application support documents A1 and C1 [Refs 1 & 6]. The radionuclides that will be included in the discharge monitoring programme at SZC are presented in RSR permit application support documents C1 and C2 [Refs 6 & 7].

75. The limit proposed helps to optimise the protection of the public given that the expected doses are minimised as far as reasonably practicable and are well below recommended figures. The limit is also consistent with the limit agreed for HPC [Ref 8] and the Environment Agency GDA Public Consultation Document [Ref 3]. An overview of how these limits and levels are derived is discussed in Section 2 with specific detail below, as well as in Section 4.3 of the RSR permit application head document [Ref 18].

76. As described in Section 2.2.2, the EBP for each significant radionuclide is determined through consideration of indicative EPR™ precursors and the evolutionary EPR™ design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR™ units on the SZC site the total EBP is estimated for each radionuclide - or group of radionuclides - by doubling the values presented at GDA. An analysis was performed of more recent EDF OEF data (2008-2012) to compare to the GDA data, which found no significant difference; hence supporting the previous HPC estimates of EBP and limits.

4.2 Proposed Discharge Limit for Sizewell C - Tritium

4.2.1 Expected Best Performance

77. On the basis outlined in Section 4.1 the annual EBP at SZC for gaseous discharges of tritium is 1 TBq y^{-1}.

4.2.2 Contingency and Headroom

78. Although arising from an overall well-defined source term in the primary coolant, the impact on potential discharges of gaseous tritium are more difficult to predict than those of liquid tritium [Refs 1 & 4]. Some of the main contingencies associated with the gaseous discharges of tritium are the same as those of liquid discharges and associated with this single source term:

- Unplanned shutdown - since the production of tritium is dependent on the energy production, fluctuations during a fuel cycle are observed. In particular, the annual discharge of gaseous tritium is lower if a reactor has experienced unplanned trips during the year than if it has been operational and with higher load factor.
- Increased overall area of pools during refuelling.

79. In addition, there are a number of indirect contingencies that may affect the production of tritium and/or the surrounding conditions of the pools and thus indirectly affect the evaporative tritium losses, such as:

- The conditions surrounding the pools, such as hygrometric conditions, temperature, and other weather conditions that can affect the evaporation rates of tritium in the pools.
- Leaks from the primary coolant containment.
- Changes in the way coolant is recycled or discharged.
- Incidental tritium contamination of the fuel storage pools during transfer of spent fuel which, given the 12.3-year half-life of tritium, could affect the tritium levels present in the pools for several fuel cycles.

80. In light of the above considerations, the maximum value for gaseous discharges of tritium from SZC is considered to be 6 TBq per twelve-rolling-month period. This provides adequate headroom to the SZC EBP in order to provide sufficient margin for normal operating conditions. Figure 4-1 below demonstrates how these contingencies could result in an increase from the EBP value of 1TBq to the maximum value of 6TBq.

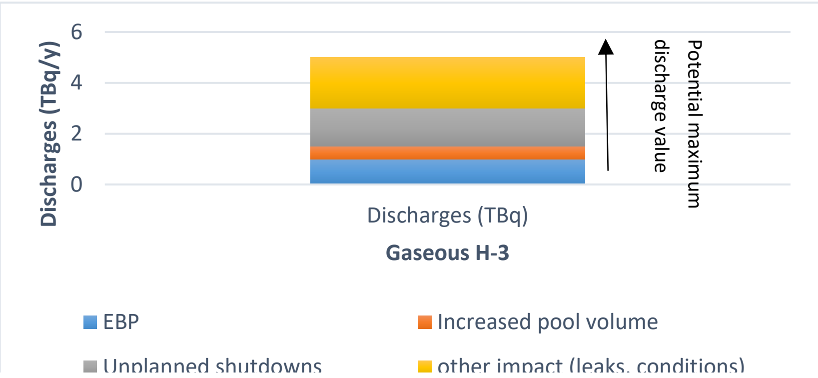


Figure 4-1 Indication of contingency build-up from EBP to the discharge limit for gaseous Tritium

4.2.3 Proposed Limit

81. The following points have been taken into account in the proposed twelve-rolling-month limit for the gaseous discharges of tritium from SZC:

- As part of the GDA [Ref 4], the Environment Agency has recognised that the UK EPR^{TM} uses BAT to minimise the discharge of gaseous tritium, with an EBP of 500 GBq y^{-1} per unit for the UK EPR^{TM} [Ref 3] which is consistent with that calculated for HPC.
- When this is normalised to 1,000 MWe output and compared to other similar reactors this equates to a discharge of 290 GBq y^{-1}. This represents performance in the best 10% for the range of discharges (100 - 3,600 GBq y^{-1} per 1,000 MWe) presented in the Environment Agency GDA Public Consultation Document [Ref 3].
- BAT has been applied to minimise tritium at source through the management of primary coolant chemistry (i.e. use of enriched boron and depleted lithium), use of fuel cladding to retain tritium in the fuel, use of gadolinium rods and reduction of beryllium in neutron sources.
- The Environment Agency has accepted in their review of the GDA [Ref 4] that there are no viable

means to abate the tritium from the gaseous effluents.

- BAT has been applied to design of the stack to optimise dispersion and minimise the impact of any discharges to atmosphere.
- The limit proposed accounts for the contingencies, primarily those associated with a change in primary coolant chemistry or with unplanned shutdowns.
- The annual effective dose to a member of the public for gaseous tritium from SZC is calculated at 0.15µSv [Ref 10] and the dose rate to the most exposed NHB is $3.3x10^{-2}$ µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst tritium is considered a significant radionuclide because of the total activity released, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

82. Based on the annual EBP of 1 TBq y^{-1} and the points considered above, SZC Co. is applying for a RSR environmental permit with a proposed limit to discharge 6 TBq of tritium from SZC to atmosphere in a twelve-rolling-month period.

83. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 14].

4.3 Proposed QNL for Sizewell C - Tritium

84. Gaseous tritium discharges resulting from normal operations of the UK EPR™ will present trends with peaks. These trends are due to normal transients and QNLs should not be reached with such peaks as these are part of normal operations.

85. The following approach outlined in Section 2.4, has been applied to assess an initial suitable QNL value:

- OEF data was analysed for the two N4 sites, between 2002 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was filtered to remove known events with contingencies but include normal transients.
- The data set obtained is then representative of normal operating fluctuation. This shows that peaks of discharge linked to planned events (as opposed to contingencies) are only observed at (planned) shutdown. Discharges also vary seasonally depending on weather conditions. In fact, the higher the temperature surrounding the various pools in the Fuel Building and Reactor Building, the higher the evaporation rate of tritium from these pools and hence the higher discharges. Analysis of OEF data shows that for normal operating conditions discharges significantly increased during the two hottest months of each year.
- For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of ratios of two-month peaks to yearly discharge.
- These ratios have been averaged to obtain the overall normal fluctuation ‘R’. used in the equation below.

86. The QNL has been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance\ \times 1.1\ \times 2\ \times (2R+1)}{12}$$

where;

- The annual EBP value used is for a single unit (as the equation allows for 2 units below).
- The multiplication by 1.1 is because the gaseous discharge of tritium is highly linked to its production therefore the availability rate (Kd) will influence discharges. Since a 100% Kd will be achieved in the UK EPR^{TM} in a number of rolling quarters, a 10% increase is applied (i.e. factor of 1.1) to account for the difference with the 91% Kd that has been used to assess the annual EBP.
- The multiplication by 2 is because the annual EBP value for a single unit (500GBq) is doubled to allow for two units.
- The multiplication by (2R+1) is because discharges at normal fluctuation level are accounted for two months thus 'R' is applied to 2 months' values with one month at EBP. Discharges at the EBP value are accounted for one month thus the EBP value is multiplied by (2 R + 1). The ratio value 'R' is regarded as a correction factor which allows incorporation of normal expected fluctuations into the EBP. It is directly multiplied to the EBP value. R = 1.54, meaning that on average the normal gaseous discharges without tritium contingency are expected to vary by a factor of 1.54 compared to the normal average, this figure is taken from and remains consistent with that presented for HPC.
- The annual EBP value is then divided by 12 to obtain a monthly value.

87. Application of the formula presented above gives an initial QNL estimate of 375 GBq. Taking into consideration feedback in the Environment Agency decision document for HPC [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 400GBq for the discharge of tritium from SZC to atmosphere on a three-rolling-month basis. This is liable to be adjusted once OEF data from the UK EPR^{TM} becomes available at which point limits may be reviewed as per the Environment Agency expectations.

4.4 Proposed Discharge Limit for Sizewell C – Carbon-14

4.4.1 Expected Best Performance (EPB)

88. On the basis outlined in Section 4.1 the annual EBP at SZC for gaseous discharges of C-14 is 700 GBq y^{-1}.

4.4.2 Contingency and Headroom

89. Contingencies potentially affecting the discharges of C-14, both liquid and gaseous are:

- High nitrogen concentration in the primary circuit;
- Unplanned shutdown - since the production of C-14 is dependent on the power production, fluctuations during any fuel cycle with unplanned shutdowns would be observed

90. The above contingencies are applicable to gaseous C-14 discharges given that gaseous C-14 discharges are sensitive to the nitrogen level in the primary circuit.

91. In addition, it is known that the discharge profile of C-14 shows cyclic variation either due to reactor trips (involving mid-cycle dilution), faults of the TEG or changes of demineralisers in the Chemical Volume and Control System (RCV) that may affect the partitioning of C-14 in solid, liquid and gaseous phase.

92. The headroom between EBP and annual maximum discharges includes the uncertainty on the split between the liquid and gas discharges (currently assumed at 20/80 ratio) and the proportion of C-14 discharged in solid waste, which may be more favourable to liquid discharges and less to gaseous (i.e. 5/95 for example). Overall, the UK EPR™ maximum annual discharges of C-14 are equivalent to SZB C-14 gaseous discharge limit, normalised to the power produced.

93. The maximum value estimated for the gaseous discharges of C-14 from SZC is 1.4 TBq per twelve-rolling-month period based on the contingencies identified as illustrated in Figure 4-2 below.

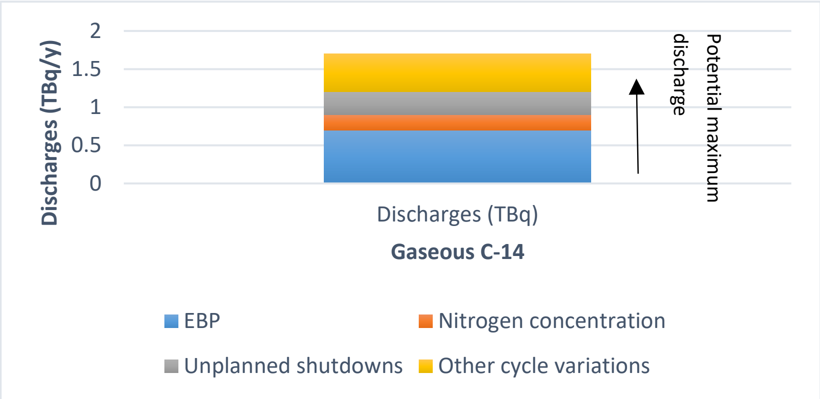


Figure 4-2 Indication of contingency build-up from EBP to the discharge limit for gaseous Carbon-14

4.4.3 Proposed Limit

94. The following points have been taken into account in the proposed twelve-rolling-month limit for the gaseous discharges of C-14 from SZC:

- As part of the GDA [Ref 4], the Environment Agency has recognised that the UK EPR™ uses BAT to minimise the discharge of gaseous C-14, with an EBP of 350 GBq y^{-1} per unit for the UK EPR™ [Ref 3] which is consistent with that calculated for HPC.
- When this is normalised to 1,000 MWe output and compared to other similar reactors this is equal to a discharge of 203 GBq y^{-1}. This is within the range of discharges (40 – 350 GBq y^{-1} per 1,000 MWe) presented in the Environment Agency GDA Public Consultation Document [Ref 3]. It should be noted that the use of a nitrogen cover gas to purge tanks does lead to an increase in C-14 discharges but the overall impact has been demonstrated as BAT for the additional safety features provided by the use of nitrogen (see RSR permit application support document A1 [Ref 1]).
- At the time of writing, in its GDA Consultation Document [Ref 3], the Environment Agency recognised that there were no viable techniques available for the abatement of liquid C-14 applicable to the UK EPR™. C-14 is planned to be discharged to the atmosphere via the NAB stack. Available techniques have been reviewed in the development of HPC and SZC, it is still considered that there are currently no viable means to abate C-14. It is noted that the degassing of liquid means that more C-14 ends up in the gaseous effluent where generally it has a lower impact on the environment.

- BAT has been applied to design of the stack to optimise dispersion and minimise the impact of any discharges to atmosphere.
- The limit proposed accounts for the uncertainty in partitioning of C-14 between solids, liquids and gases and the other contingencies presented. The discharge profile for liquid discharges of C-14 is similar to that of tritium.
- The annual effective dose to a member of the public for gaseous C-14 from SZC is calculated at 3.8µSv [Ref 10] and the dose rate to the most exposed NHB is 4.4×10^{-3} µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst C-14 is considered a significant radionuclide because of the total activity released, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

95. Based on the annual EBP of 700 GBq y^{-1} and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 1.4 TBq of C-14 from SZC to atmosphere on a twelve-rolling-month period.

96. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 14] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

4.5 Proposed QNL for Sizewell C – Carbon-14

97. Gaseous C-14 discharges resulting from normal operations of the UK EPR™ will present trends with peaks. These trends are due to normal transients and QNLs should not be reached within such peaks as these are part of normal operations.

98. The following approach outlined in Section 2.4, has been applied to assess an initial suitable QNL value:

- OEF data was analysed for a number of 1,300 MWe PWRs between 2002 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was filtered to remove events with known contingencies but include normal transients. As stated previously, the practice at these sites is to measure gaseous C-14 discharges quarterly as opposed to monthly for all other radionuclides.
- The data set obtained is then representative of normal operating fluctuation. For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of ratios of quarterly to annual discharges.

99. The QNL has then been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance \times 1.1 \times 2 \times R}{4}$$

where;

- The annual EBP value used is for a single unit (as the equation allows for 2 units below).
- The multiplication by 1.1 is because the gaseous discharge of C-14 is highly linked to its production therefore the availability rate (Kd) will influence discharges. Since a 100% Kd will be achieved in the UK EPR™ in a number of rolling quarters, a 10% increase is applied (i.e. factor of 1.1) to account for the difference with the 91% Kd that has been used to assess the annual EBP.
- The multiplication of 2 is because the annual EBP value is doubled to allow for two units.
- The multiplication by R is because the ratio value 'R' is regarded as a correction factor which allows incorporation of normal expected fluctuations into the EBP. It is directly multiplied to the EBP value. R = 1.58 meaning that on average the normal gaseous discharges without C-14 contingency are expected to vary by a factor of 1.58 compared to the normal average. This value does not require adjustment for monthly fluctuation as seen for tritium and this value is both taken from and remains consistent with that presented for HPC.
- Only quarterly OEF data is available for gaseous C-14 therefore the normal fluctuation ratio is based on quarterly fluctuations hence the QNL requires division by 4.

100. Application of the formula presented above gives an initial QNL estimate of 305 GBq. Taking into consideration Environment Agency feedback for HPC [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 300 GBq for the discharge of C-14 from SZC to atmosphere on a three-rolling-month basis. Although this is marginally lower than the figure estimated above, SZC Co. are satisfied with the conclusions made by the Environment Agency and agree that this QNL remains appropriate for SZC noting that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

4.6 Proposed Discharge Limit for Sizewell C – Iodine-131

101. As explained in RSR permit application support document A1 [Ref 1], I-131 will be used as a surrogate for all iodine isotopes and therefore a discharge limit is proposed on this isotope alone.

4.6.1 Expected Best Performance

102. On the basis outlined in Section 4.1 and noting that the GDA values are given for total iodine, this is equivalent to applying the GDA values directly to I-131; therefore, the annual EBP at SZC for gaseous discharges of I-131 is 50 MBq y^{-1}.

4.6.2 Contingency and Headroom

103. Contingencies potentially affecting the gaseous discharges of I-131 are:

- Fuel contingencies including fuel leaks;
- Leakage from pipes;
- Faults of the gaseous effluent treatment system, especially bypass of the charcoal delay beds; and,
- Faults in the iodine traps.

104. Gaseous I-131 discharges are not expected to be high in normal operational conditions, due to the formation process of iodines and to the various treatment systems existing prior to discharge (especially the transfer to the aqueous phase in the TEG). This justifies the low EBP value for the site (50 MBq y^{-1}) [Ref 3], estimated at Penly

in absence of contingency. However, as explained above, contingencies associated with fuel leaks and faults of treatment systems could have a significant impact on the production and thus on the discharges of gaseous iodines. It was estimated at Penly that the presence of small fuel leaks could increase iodine discharges at plant shutdown at least 10-fold compared to the absence of fuel leaks. This shows the high sensitivity associated with gaseous I-131 discharges as the annual maximum discharge value - estimated as 400 MBq y^{-1} - does not allow for major contingencies. In addition, OEF has shown that higher discharges due to fuel leaks impacted on the future fuel cycles as well as on the cycle considered.

105. In 2005, at Nogent, a value as high as 1.78 GBq y^{-1} was reached for the total discharges of gaseous iodines. Although such discharges are not expected for the UK EPR™ considering the design improvements, this example illustrates how seriously the contingencies are affected by the gaseous iodine discharges, and subsequently affect the overall discharges.

106. Like other fission products, discharges of radioiodine isotopes in particular are highly dependent on fuel quality to minimise external contamination, fuel cladding defects to prevent migration of fission products (including iodine) and fuel monitoring to identify failed fuel that can be removed at shut down; and are expected to peak when fuel failures occur.

107. Other contingencies that may have an impact on the gaseous discharges of iodines are the potential unavailability of the TEG for a period of time (due to the unavailability of the two compressors downstream of the recombiner and/or reversible or irreversible contamination of the recombiner's catalyst), or bypass of the charcoal delay beds. Based on the assessment done on halogens for SZB and considering a ratio of 50 % between discharges of I-131 and total halogens, a bypass of the delay beds for one week could increase discharges by approximately 450 MBq. However, the bypass would be routed to the iodine traps and alarms would be taken to a lower level. Assuming a decontamination factor of 40 for the iodine filters under normal operations, the contribution of the bypass would be negligible.

108. If the TEG were unavailable, the level of I-131 in the primary coolant would increase and there would be an enhanced short-term discharge through the charcoal delay beds when the system is returned to service. However, since discharges through the TEG are relatively low, there is little effect on release.

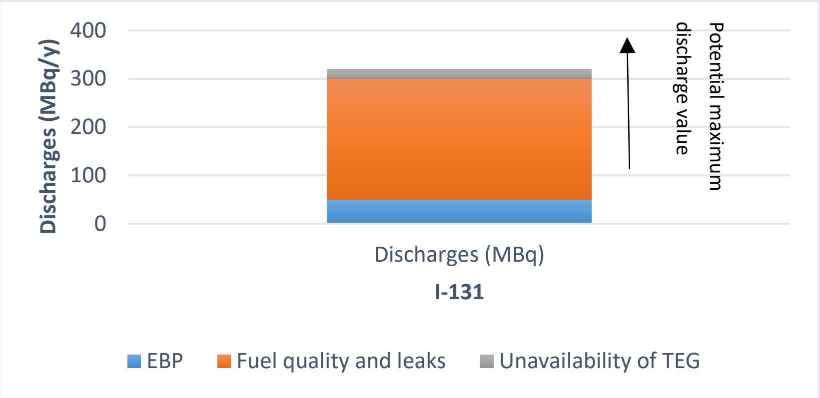
109. Overall, significant headroom should be allowed in the discharge limit for operational contingencies, including fuel leaks and expected minor faults in the iodine traps. If the iodine traps were unavailable, there would be no abatement alternative for gaseous effluents from the ventilation systems. However, the majority of gaseous iodines are treated in the TEG where, under normal operating conditions, they are allowed to decay in the charcoal delay beds and through recirculation in the system. In addition, it is not realistic to consider a scenario where the delay beds be bypassed and the iodine traps unavailable, considering that the redundancy rule applies.

110. As such, it has been identified that this maximum discharge value for SZC (400 MBq y^{-1}), already low, constitutes one of the most rigid frameworks and does not allow for operational margin contingencies observed in current plants. In addition, the headroom provided between the EBP and maximum discharge value is not considered to be very large in light of the OEF above. Indeed, it was reported in a number of cases that a high discharge in a limited time can represent up to 90 % of the total annual gaseous iodine discharge. This means that occurrence of two contingencies over a twelve-month period could provide difficulties for the site to remain below the authorised limit. In addition, this limit is low compared to those in force at other power stations in the world, and, for example, represents just over half of the limit in force at SZB when normalised to 1,000 MWe (0.42 GBq y^{-1} for SZB vs. 0.23 GBq y^{-1} for the UK EPR™ at 1,000 MWe). Figure 4-3 below presents a visual representation of the potential impact of contingencies on the EBP value.

4.6.3 Proposed Limit

111. The following points have been taken into account in the proposed twelve-rolling-month limit for the gaseous discharges of I-131 from SZC:

- As part of the GDA [Ref 4], the Environment Agency has recognised that the UK EPR™ uses BAT to minimise the discharge of gaseous I-131, with an EBP of 50 MBq y^{-1} per unit for the UK EPR™ [Ref 3] which is consistent with that calculated for HPC.
- When this is normalised to 1,000 MWe output and compared to other similar reactors this is equal to a discharge of 29 MBq y^{-1}. This represents performance at the lowest decile and is within the range of discharges (1 - 2,000 GBq y^{-1} per 1,000 MWe) presented in the Environment Agency GDA Public Consultation Document [Ref 3].



- BAT will be used to minimise at source the production of I-131 through quality assured fuel manufacturing arrangements to minimise the trace quantities of uranium found on the exterior of the fuel. The generation of iodine from the activity inside the fuel cannot be minimised.
- BAT has been applied to minimise the discharge of I-131 through the management of fuel and use of M5 fuel cladding to reduce the transfer of iodine gases into the primary coolant and the use of carbon delay beds and iodine traps to abate iodine.
- I-131 (and other Iodines) is abated by the TEG delay beds but if discharged in significant quantities, they can also be abated via iodine traps in the active Heating, Ventilation and Air Conditioning (HVAC) systems.
- BAT has been applied to design of the stack to optimise dispersion and minimise the impact of any discharges to atmosphere.
- Contingency has been applied to account for any fuel defects, whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant impact is very small. Any defective fuel will be replaced at the next shutdown.
- The difference between EBP and the proposed limit are due to the potential for fuel failures. The proposed QNL is set at a level close to the EBP at a level where fuel failures would initiate a review. In this way close oversight is maintained.
- The annual effective dose to a member of the public for gaseous iodine from SZC is calculated at 4.8×10^{-2}µSv [Ref 10] and the dose rate to the most exposed NHB is 1.4×10^{-2} µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a significant

risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.

- Whilst iodine is considered a significant radionuclide because it indicates plant performance, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

112. Based on the annual EBP of 50 MBq y^{-1} and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 400 MBq of I-131 from SZC to atmosphere in a twelve-rolling-month period.

113. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3].

4.7 Proposed QNL for Sizewell C – Iodine-131

114. Gaseous iodine discharges resulting from normal operations of the UK EPR™ will present trends with peaks. These trends are due to normal transients and QNLs should not be reached with such peaks as these are part of normal operations. However, QNLs should identify the occurrence of contingencies.

115. The following approach outlined in Section 2.4, has been applied to assess an initial suitable QNL value:

- OEF data have been analysed for all 1,300 MWe and N4 PWRs between 2004 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was available with exhaustive supporting data to identify all contingencies. This allowed filtration of the discharge data to remove events with known contingencies but include normal transients.
- The OEF data set obtained is then representative of normal operating fluctuation. It corresponds typically to levels of detections with peaks observed at shutdown.
- For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of maximum values of monthly discharges (i.e. peaks, in MBq) in normal operating conditions[5].

116. The QNL has been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance}{6} + P \times 2$$

where;

- The annual EBP value used is for a single unit (as the equation allows for 2 units below).
- The division by 6 is because the EBP value is accounted for 2 months, therefore rather than divide the annual figure by 12 to obtain a monthly value, the EBP should instead be divided by 6.
- The addition of P is to allow for the peak (normal fluctuation) as a separate discharge value since it

[5] This differs from the ratio-type values assessed for tritium and C-14. In the case of I-131, the discharge profiles present distinct peaks and therefore it is not necessary to take the ratio of this increase over the average discharge in order to obtain a representative variation.

corresponds to a peak of discharge and not a correction factor (Factor R as seen for tritium and C-14) that can be multiplied to the EBP value.

- The value for P as taken from the HPC application = 28 MBq meaning that the normal gaseous discharges of I-131 are expected to increase up to 28 MBq, without any contingency.
- The total is doubled to allow for two reactor units.

117. Application of the formula presented above gives an initial QNL estimate of 64 MBq. Therefore, SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 64 MBq for the discharges of I-131 from SZC to atmosphere on a three-rolling-month basis. This is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

4.8 Proposed Discharge Limit for Sizewell C – Noble Gases

4.8.1 Expected Best Performance

118. On the basis outlined in Section 4.1, the annual EBP at SZC for discharges of noble gases is 1.6 TBq y^{-1}.

4.8.2 Contingency and Headroom

119. There are two main contingencies potentially affecting the discharges of noble gases:

- Fuel contingencies including fuel leaks; and,
- Faults of the TEG, especially any requirement to bypass the charcoal delay beds.

120. Discharges of noble gases are expected to peak at reactor shutdown and start-up, and during degassing of the RCV and opening of the primary circuit. The discharges are highly dependent on the operating conditions, and, in particular, to any contingency associated with fuel. This is illustrated by the peak of 8.6 TBq y^{-1} reported at Nogent sur Seine in 2006, which was caused by fuel issues.

121. Moreover, as seen previously for SZB fuel leaks combined with bypass of the delay beds for a period of time have a significant impact on the discharges of noble gases. As assessed for SZB, a reasonable scenario, involving a bypass of the delay beds (excluding any other contingency) for a week with specific activity levels just below the alarm levels, would result in a discharge of Xe-133 of 1 TBq. Potential operational reasons for bypassing the delay beds would be unavailability of the two compressors downstream of the recombiner or reversible/irreversible contamination of the recombiner’s catalyst.

122. Another contingency that may affect the discharges of noble gases would be the unavailability of the TEG. If the TEG was unavailable, the level of noble gases in the primary coolant would increase and there would be an enhanced short-term discharge through the charcoal delay beds when the system is returned to service. This short-term increase is not deemed significant given that they are short half-life radionuclides which will be delayed and decayed within the charcoal filters meaning the radiological impact is negligible.

123. The maximum value for discharges of noble gases from SZC is 45 TBq per twelve-rolling-month period. Figure 4-4 below presents a visual representation of the potential impact of contingencies on the EBP value.

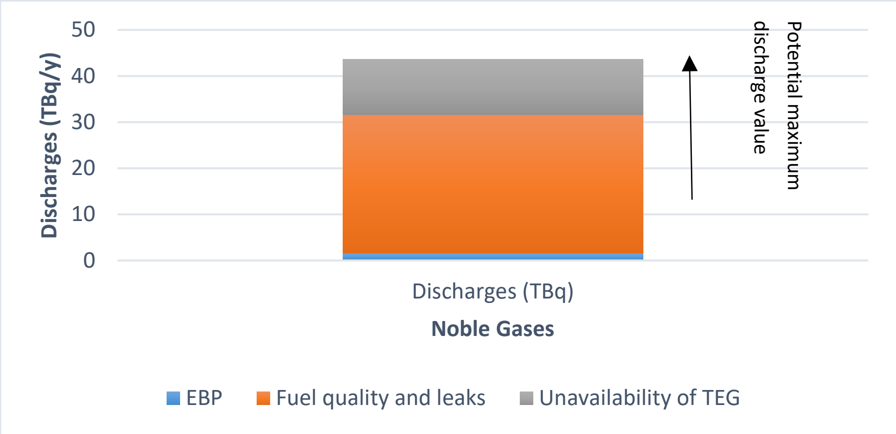


Figure 4-4 Indication of contingency build-up from EBP to the discharge limit for Noble Gases

4.8.3 Proposed Limit

124. The following points have been taken into account in the proposed twelve-rolling-month limit for the discharges of noble gases from SZC:

- As part of the GDA [Ref 4], the Environment Agency has recognised that the UK EPR™ uses BAT to minimise the discharge of noble gases, with an EBP of 800 GBq y^{-1} per unit for the UK EPR™ [Ref 3] which is consistent with that calculated for HPC.
- When this is normalised to 1,000 MWe output and compared to other similar reactors this is equal to a discharge of 460 GBq y^{-1}. This represents performance in the best 5% of the range of discharges (100 - 10,000 GBq y^{-1} per 1,000 MWe) presented in the Environment Agency GDA Public Consultation Document [Ref 3].
- BAT will be used to minimise at source the production of noble gases through quality assured fuel manufacturing arrangements to minimise the quantities of external contamination of uranium on the fuel. The generation of fission products from the activity inside the fuel cannot be minimised.
- BAT has been applied to minimise the discharge of noble gases through the management of fuel and use of M5 fuel cladding to reduce the transfer of noble gases into the primary coolant and the use of carbon delay beds to abate noble gases.
- BAT has been applied to design of the stack to optimise dispersion and minimise the impact of any discharges to atmosphere.
- Contingency has been applied to account for any fuel defects, whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a nuclear power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant dose impact is very small. Any defective fuel will be replaced at the next shutdown.
- The difference between EBP and the proposed limit are due to the potential for fuel failures. The proposed QNL is set at a level close to the EBP at a level where fuel failures would initiate a review.

In this way close oversight is maintained.

- The annual effective dose to a member of the public for discharges of noble gases from SZC has been calculated as 0.02µSv [Ref 10] and the dose rate to the most exposed NHB 0.0018 µGy/h [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst noble gases are considered significant because of the total activity released, the application of BAT to minimise their generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

125. Based on the annual EBP of 1.6 TBq y^{-1} and the identified contingencies described above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 45 TBq of noble gases from SZC to atmosphere in a twelve-rolling-month period.

126. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3].

4.9 Proposed QNL for Sizewell C – Noble Gases

127. Noble gases resulting from normal operations of the UK EPR™ will present trends with peaks. These trends are due to normal transients and QNLs should not be reached within such peaks as these are part of normal operations. However, QNLs should identify the occurrence of contingencies.

128. The following approach has been applied to assess an initial suitable QNL value:

- OEF data has been analysed for all 1,300 MWe and N4 PWRs between 2004 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was available with exhaustive supporting data to identify all contingencies. This allowed filtration of the discharge data to remove events with known contingencies but include normal transients.
- The OEF data set obtained is then representative of normal operating fluctuation. It corresponds typically to levels of detections with peaks observed at shutdown.
- For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of maximum values of monthly discharges (i.e. peaks, in GBq) in normal operating conditions[6].

129. The QNL has been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance}{6} + P \times 2$$

[6] This differs from the ratio-type values assessed for tritium and C-14. In the case of noble gases, the discharge profiles present distinct peaks and therefore it is not necessary to take the ratio of this increase over the average discharge in order to obtain a representative variation.

where;

- The annual EBP value used is for a single unit (as the equation allows for 2 units below).
- The division by 6 is because the EBP value is accounted for 2 months, therefore rather than divide the annual figure by 12 to obtain a monthly value, the Annual EBP should instead be divided by 6.
- The addition of P is to allow for the peak (normal fluctuation) to be added as a separate discharge value since it corresponds to a peak of discharge and not a correction factor that can be multiplied to the EBP value.
- The value for P as taken from the HPC application = 607 GBq meaning that the normal discharges of noble gases are expected to increase up to 607 GBq, without any contingency.
- The total is doubled to allow for two reactor units.

130. Application of the formula presented above gives an initial QNL estimate of 1,480 GBq. Taking into consideration feedback from the Environment Agency for HPC limits [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 1.5TBq for the discharges of noble gases from SZC to atmosphere on a three-rolling-month basis. This limit is lower than the 2.25TBq proposed by the Environment Agency at GDA however SZC Co. are satisfied that the proposed level, which is consistent with that granted for HPC, is appropriate for SZC recognising that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

4.10 Proposed Discharge Limit for Sizewell C – Beta Emitting Radionuclides associated with Particulate Matter

4.10.1 Expected Best Performance

131. On the basis outlined in Section 4.1, the annual EBP at SZC for gaseous discharges of 'beta emitting radionuclides associated with particulate matter' is 8 MBq y^{-1}.

4.10.2 Contingency and Headroom

132. The two main contingencies potentially affecting the gaseous discharges of 'beta emitting radionuclides associated with particulate matter' are:

- Fuel contingencies including fuel leaks; and
- Faults of HEPA filters leading to loss of abatement for a short period of time until the ventilation is diverted and the filter replaced.

133. As reflected in OEF, fuel leaks can affect the gaseous discharges of 'beta emitting radionuclides associated with particulate matter' however most 'beta emitting radionuclides associated with particulate matter' are discharged via the liquid route and those remaining in gaseous effluents are retained by the HEPA filters of the various HVAC systems. Only in the highly improbably situation where a fuel leak, maintenance operations and a fault with a HEPA occur simultaneously could there be an increase to discharges (by a factor of 10 to 50) over a very short period of time. The likelihood of this scenario however is highly improbable and the ability to switch to standby HEPA filters ensures that appropriate mitigation can be readily put in place should such a scenario occur.

134. The potential for short-term spikes in monthly discharges is not unreasonable and situations where a monthly discharge accounts for 50% of the annual activity discharged is not unrealistic (reported at Paluel 1 in 2007).

Thus, in the unlikely event of fuel leaks combined with failure of the treatment systems, the monthly discharges would increase, and it can be expected that values as high as 60 MBq per month for one unit representing 50% of the UK EPR™ proposed annual maximum discharge value for a single unit, might need to be considered. Headroom is therefore required between the annual EBP and the maximum discharge value, as well as for the equivalent monthly figures, even though the periods of time over which faults and excursions in discharges occurs might be small relative to the overall fuel cycle of up to 22 months.

135. Some sites historically reported higher discharges due to the sensitivity of sampling or measurement equipment used. For example, at SZB, routine maintenance operations of the normal sampling equipment on both the unit vent stack and the radwaste building HVAC stack required to use less sensitive equipment temporarily. Consequently, the limit of detection during this period was higher than normal, resulting in a peak that had an impact on monthly and rolling annual discharges [Ref 3].

136. Discharges may also appear to be higher when the frequency of measurement is higher, if the values reported are the sum of limits of detection. Higher frequency sampling is carried out when the reactor is shut down for refuelling, which is one reason why discharges appear higher at these times. For example, increased sampling occurred during an unplanned shutdown at SZB, which resulted in an apparent increase in the particulate radioactivity discharged [Ref 3].

137. The potential impact of contingencies, together with the uncertainty in the percentage improvement between the 1,300 MWe unit and the UK EPR™, justifies the need for reasonable headroom between the EBP without contingency (8 MBq y^{-1}) and the maximum discharge for SZC.

138. The maximum value for the gaseous discharge of 'beta emitting radionuclides associated with particulate matter' is estimated at 240 MBq per twelve-rolling-month period, however SZC Co. acknowledges feedback from the Environment Agency for HPC [Ref 8] which considered this to be a significant amount of headroom. This is taken into consideration in the proposed limit for SZC below. Figure 4-5 below presents a visual representation of the potential impact of contingencies on the EBP value.

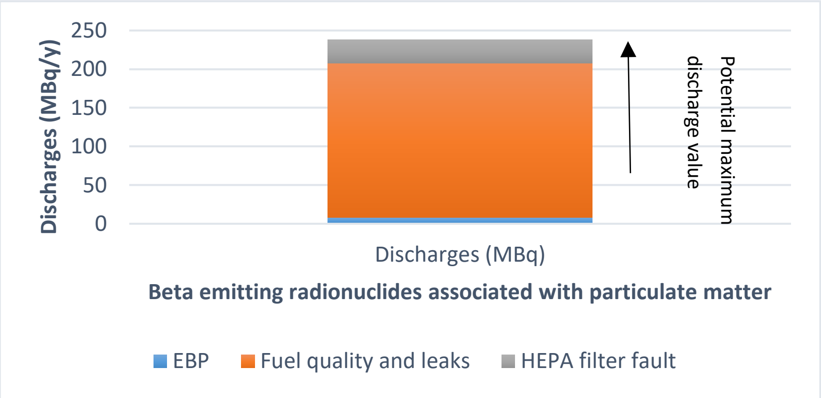


Figure 4-5 Indication of contingency build-up from EBP to the discharge limit for gaseous Beta-emitting radionuclides

4.10.3 Proposed Limit

139. The following points have been taken into account in the proposed twelve-rolling-month limit for the gaseous discharges of 'beta emitting radionuclides associated with particulate matter' from SZC:

- As part of the GDA [Ref 4], the Environment Agency has recognised that the UK EPR™ uses BAT to minimise the discharge of other fission and activation products, with an EBP of 4 MBq y^{-1} per unit for the UK EPR™ [Ref 3] which is consistent with that calculated for HPC.

- When this is normalised to 1,000 MWe output and compared to other similar reactors this is equal to a discharge of 2.3 MBq y^{-1}. This represents performance at the lowest decile and is within the range of discharges (1 - 1,000 MBq y^{-1} per 1,000 MWe) presented in the Environment Agency GDA Public Consultation Document [Ref 3].
- BAT has been applied to minimise the generation of 'beta emitting radionuclides associated with particulate matter' through:
  - Minimising the cobalt content of steel;
  - Reducing Stellite;
  - Use of helicoflex seals;
  - Avoiding use of antimony in bearings;
  - Use of zinc injection;
  - Passivation of the primary circuit achieved through hot functional testing; and,
  - Measures to minimise the presence of external uranium contamination on fuel.
- BAT has been applied to minimise discharges by the use of HEPA filters to abate particulate discharges.
- BAT has been applied to design of the stack to optimise dispersion and minimise the impact of any discharges to atmosphere.
- Contingency has been applied to account for any fuel defects. Whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant impact is very small. Any defective fuel will be replaced at the next shutdown. Contingency is also necessary to account for any short term discharges that could occur if HEPA filters are unavailable. When unavailable filters will be replaced or ventilation diverted away from the affected filters, however, there may be some increased release before this happens.
- The level of discharge is comparable to SZB, the only other PWR in the UK, when normalised to power output.
- The annual effective dose to a member of the public for beta emitting radionuclides associated with particulate matter is calculated at 3.2×10^{-3}µSv [Ref 10] and the dose rate to the most exposed NHB is 0.1µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Beta emitting radionuclides associated with particulate matter are not considered significant because of total activity or dose accrued however they are considered an indicator of plant performance. The application of BAT minimises the generation, discharge and impact of beta emitting radionuclides associated with particulate matter meaning that discharges are expected to be very low and comparable to best performance across the world.

140. Based on the annual EBP of 8 MBq y^{-1},the points considered above, and feedback from the Environment Agency for HPC [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 120MBq of 'beta emitting radionuclides associated with particulate matter' from SZC in a twelve-rolling-month period. Although this is significantly less than the calculated headroom, SZC Co. has reviewed this limit and the analysis carried out by the Environment Agency [Ref 8] to determine the impact of a reduction in the limit, which concluded that a reduction would not impact operations. Overall SZC Co. is satisfied that this limit is proportionate to both the environmental and operational risks and is therefore appropriate for SZC.

141. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

4.11 Proposed QNL for Sizewell C - Beta Emitting Radionuclides associated with Particulate Matter

142. Fission and activation products other than noble gases and iodine in gaseous discharges resulting from normal operations of the UK EPR[TM] will present trends with peaks. These trends are due to normal transients and QNLs should not be reached with such peaks as these are part of normal operations. However, QNLs should identify the occurrence of contingencies.

143. The following approach has been applied to assess an initial suitable QNL value:

- OEF data has been analysed for all 1,300 MWe and N4 PWRs between 2004 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was available with exhaustive supporting data to identify all contingencies. This allowed filtration of the discharge data to remove events with known contingency but include normal transients.
- The OEF data set obtained is then representative of normal operating fluctuation. It corresponds typically to levels of detections with peaks observed at shutdown.
- For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of maximum values of monthly discharges (i.e. peaks, in MBq) in normal operating conditions[7].

144. The initial QNL has been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance}{6} + P \times 2$$

where;

- The annual EBP value used is for a single unit (as the equation allows for 2 units below)
- The division by 6 is because the EBP value is accounted for 2 months, therefore rather than divide the annual figure by 12 to obtain a monthly value, the Annual EBP should instead be divided by 6.
- The addition of P is to account for the peak (normal fluctuation) as a separate discharge value since

[7] This differs from the ratio-type values assessed for tritium and carbon-14. In the case of other fission and activation products, the discharge profiles present distinct peaks and therefore it is not necessary to take the ratio of this increase over the average discharge in order to obtain a representative variation.

it corresponds to a peak of discharge and not a correction factor that can be multiplied to the EBP value. The value of P is consistent with that presented for HPC and was estimated at P = 28.4 MBq meaning that the normal gaseous discharges of other fission and activation products are expected to increase up to 28.4 MBq, without any contingency. A 15 % reduction has also been applied to allow for the environmental improvements of the UK EPR™ as assessed in the GDA [Ref 4].

- The total is doubled to allow for two reactor units.

145. Application of the formula presented above gives an initial QNL estimate of 58 MBq. Taking into consideration the Environment Agency feedback for HPC [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 8MBq for the discharge of Beta emitting radionuclides associated with particulate matter from SZC to atmosphere on a three-rolling-month basis. As stated above, although this is less than the calculated QNL, SZC Co. has reviewed this level and is satisfied that this proportionate and appropriate for SZC on the basis that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

5 LIQUID DISCHARGES

5.1 Introduction

146. The following sub-chapters present the proposed twelve-rolling-month limit and associated QNL for: Tritium; C-14; and, Other Radionuclides respectively, in liquid discharges from SZC. Further details on the production and treatment processes for these radionuclides in liquid effluent are provided in RSR permit application support documents A1 and A2 [Refs 1 & 2], the GDA [Ref 4] and the Environment Agency GDA Public Consultation Document [Ref 3].

147. The SZC UK EPR™ design, developed from the GDA [Ref 4], will allow for adequate and appropriate sampling, measurement and assessment of liquid radioactive discharges. Discharge assessment will be applied at each main SZC liquid discharge outlet to demonstrate compliance with discharge limits and to meet other objectives, as defined in RSR permit application support documents A1 and C1 [Refs 1 & 6]. As indicated in RSR permit application support documents C1 and C2 [Refs 6 & 7], the radionuclides will be included in the liquid discharge monitoring programme at SZC.

148. The limit proposed helps to optimise the protection of the public given that the expected doses are minimised as far as reasonably practicable and are well below recommended figures. The limit is also consistent with the limit agreed for HPC [Ref 8] and the Environment Agency GDA Public Consultation Document [Ref 3]. An overview of how these are derived is discussed in Section 2.

5.2 Proposed Discharge Limit for Sizewell C - Tritium

5.2.1 Expected Best Performance

149. As described in Section 2.2.2, the EBP is determined through consideration of indicative EPR™ precursors and the evolutionary EPR™ design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR™ units on the SZC site the total EBP is estimated by doubling the values presented at GDA.

150. The SZC annual discharge value has been calculated considering a bounding scenario (i.e. reactor load factor of 100%, a lithium concentration of 6 ppm and a fuel cycle of up to 22 months) that accommodates dry fuel storage.

151. The EBP for SZC is 104 TBq y^{-1} which is equivalent to only twice the maximum discharge reported at SZB, despite a significantly greater than double output in power. This is due in part to the fact that the secondary source rods used in the UK EPR™, whilst remaining a significant source of tritium, will contain half the mass of beryllium than those used at SZB.

5.2.2 Contingency and Headroom

152. As described for gaseous discharges, some of the main contingencies associated with the liquid discharges of tritium are the same as those of gaseous discharges and associated with this single source term:

- Unplanned shutdown. In general, the discharge of effluent may be delayed until the planned shutdown period however where there are additional unplanned shutdowns this delay may not occur and it is possible that unplanned discharges will impact the 12 month rolling figure.
- Fuel defects, leading to a higher tritium concentration in the primary circuit and therefore higher tritium discharges given that abatement is not possible.
- Unplanned or more frequent changes in coolant chemistry or boration of the circuit to achieve safe shutdowns (or for load following, if required).
- Contamination of the fuel storage pool by leaking fuel (including that specifically removed from the reactor for this reason). Given the half-life of tritium, this could have a long-term effect on the levels of tritium present in the pools. If these levels needed to be managed to control airborne contaminations in these working areas, some discharge or purging of pool water might be required that could therefore affect discharges for several fuel cycles.
- Figure 5-1 below presents a visual representation of the potential impact of contingencies on the EBP value.

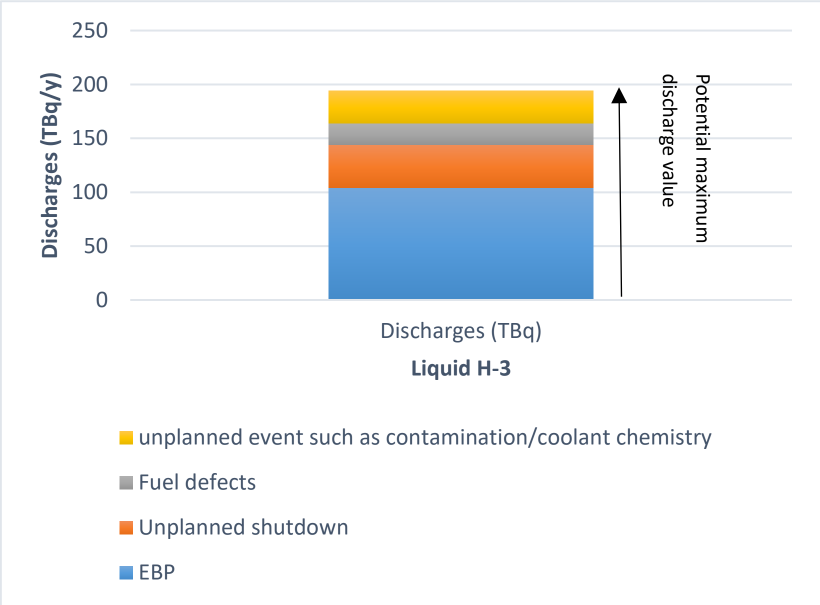


Figure 5-1 Indication of contingency build-up from EBP to the discharge limit for aqueous Tritium

5.2.3 Proposed Limit

153. The following points have been taken into account in the proposed twelve-rolling-month limit for the liquid discharges of tritium from SZC:

- The Environment Agency has recognised in its GDA Public Consultation Document [Ref 3] that BAT has been applied to the UK EPR™ to minimise the generation of tritium at source and therefore discharges of liquid tritium.
- When normalised to 1,000 MWe output, it is comparable to other similar reactors as presented by the Environment Agency in the GDA Public Consultation Document [Ref 3]. It is noted that this is near the top of the range indicated. However, tritium is preferentially discharged via the liquid effluent waste stream where it has a lower environmental impact. Therefore, accounting for gaseous discharges of tritium in the top decile of performance with comparable stations means the management of tritium across all environmental media has been optimised.
- BAT has been applied to minimise tritium at source through the management of primary coolant chemistry (i.e. use of enriched boron and depleted lithium), use of fuel cladding to retain tritium in the fuel, use of gadolinium rods and reduction of beryllium in neutron sources.
- The Environment Agency has recognised in its GDA Public Consultation Document [Ref 3] that there are no viable techniques to abate liquid discharges of tritium.
- BAT has been applied to the design of the outfall structure (for example, the discharge pipeline will extend 3.5 km offshore [Ref 1]) to optimise dispersion and minimise the impact of any discharges to the marine environment.
- The contingency considered relate primarily to any perturbations in primary coolant chemistry.
- The GDA [Ref 4] presents limits on a calendar year basis. Experience from SZB indicates that nearly a whole cycle's worth of tritium (approximately 18 months with regards to SZB) can be discharged

within a twelve-month period. Typically, this results in an uplift of approximately 30%.

- The annual effective dose to a member of the public for liquid tritium from SZC is calculated at 1.8×10^{-2} µSv [Ref 10] and the dose rate to the most exposed NHB is 1.5×10^{-4} µGyh^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst tritium is considered a significant radionuclide because of the total activity released, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

154. Based on the annual EBP of 104 TBq y^{-1}, the potential impact of rolling limits and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed discharge limit of 200 TBq of liquid tritium from SZC to the environment in a twelve–rolling-month period.

155. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

5.3 Proposed QNL for Sizewell C - Tritium

156. The operational practice at SZC could include periodic discharge, typically before a planned shutdown. In which case, most of the tritium produced in liquid effluent over a fuel cycle will be removed from the circuit by removing primary coolant and making up the volume with clean coolant, this will reduce the tritium content of the primary coolant and increase discharges of tritium in advance of a shutdown. As mentioned in RSR permit application support document A1 [Ref 1], experience at SZB where this practice is applied shows that up to 80% of the tritium produced in a year can be discharged over 2 months around a planned shutdown.

157. The expected performance is estimated based on 91% availability, which represents an estimate over the operational life span of the UK EPR™. However, 100% availability will be routinely achieved over rolling quarters where no shutdown occurs. Given the potential for 80% to be discharged within a quarter, the QNL for SZC was first determined to be 80% of the EBP value (104TBq), corrected to allow for 100% plant availability.

158. SZC Co. recognise following the HPC RSR permit application process that this justification is very conservative and agree with the Environment Agency position [Ref 8] that 60TBq is a suitable QNL. This takes into consideration 45TBq as a maximum discharge for one unit with an additional 25% of the EBP for the other unit (15TBq). Therefore, SZC Co. is applying for a RSR environmental permit for SZC that includes a proposed QNL set at 60 TBq for the discharge of tritium to the marine environment on a three-rolling-month basis which is consistent with the QNL for HPC with the acceptance that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectation.

5.4 Proposed Discharge Limit for Sizewell C – Carbon-14

5.4.1 Expected Best Performance

159. As described in Section 2.2.2, the EBP is determined through consideration of indicative EPR™ precursors and the evolutionary EPR™ design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR™ units on the SZC site the total EBP is estimated by doubling the values presented at GDA, which was the same approach used at HPC.

160. On this basis the annual EBP at SZC for liquid discharges of C-14 is 46 GBq y^{-1}.

5.4.2 Contingency and Headroom

161. Contingencies potentially affecting the discharges of C-14 in liquid discharges are similar to those affecting gaseous discharges:

- High nitrogen concentration in the primary circuit;
- Unplanned shutdown - since the production of C-14 is dependent on the power production, fluctuations during any fuel cycle with unplanned shutdowns would be observed

162. In addition, it is known that the discharge profile of C-14 shows cyclic variation either due to reactor trips (involving mid-cycle dilution), faults of the TEG or changes of demineralisers in the RCV that may affect the partitioning of C-14 in solid, liquid and gaseous phase.

163. The headroom between EBP and annual maximum discharges includes the uncertainty on the split between the liquid and gas discharges (currently assumed at 20/80 ratio) and the proportion of C-14 discharged in solid waste, which may be more favourable to liquid discharges and less to gaseous (i.e. 5/95 for example). Overall, the UK EPR^{TM} maximum annual discharges of C-14 are equivalent to SZB C-14 gaseous discharge limit, normalised to the power produced.

164. The maximum value estimated for liquid discharges of C-14 from SZC is 190 GBq per twelve-rolling-month period. Figure 5-2 below demonstrates how these contingencies could result in an increase from the EBP figure of 46GBq to the maximum value estimated for liquid discharges of 190GBq.

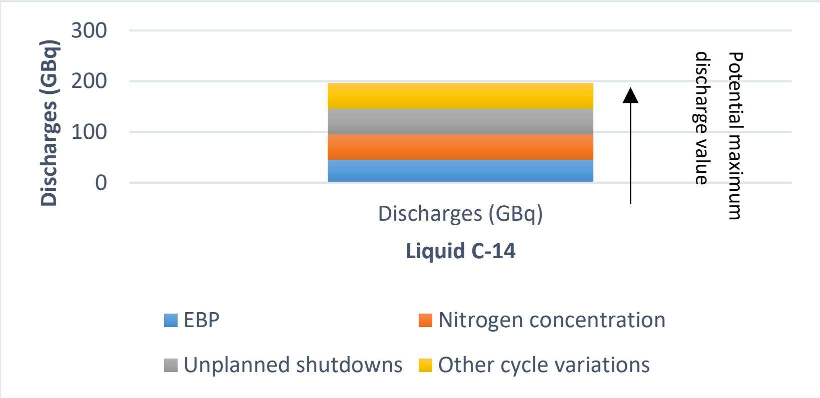


Figure 5-2 Indication of contingency build-up from EBP to the discharge limit for aqueous Carbon-14

5.4.3 Proposed Limit

165. The following points have been taken into account in the proposed twelve-rolling-month limit for the liquid discharges of C-14 from SZC:

- The Environment Agency has recognised that the UK EPR^{TM} uses BAT to minimise the discharge of liquid C-14 [Ref 4], with an EBP of 46 GBq y^{-1} [Ref 3].
- When normalised to 1000 MWe output and compared to other similar reactors, this is equal to a discharge of 13.3 GBq y^{-1} and within the range of discharges (3 – 45 GBq y^{-1} per 1000 MWe) as presented in the Environment Agency GDA Public Consultation Document [Ref 3].
- The Environment Agency recognised in its GDA Public Consultation Document [Ref 3] that there are

no viable techniques available to abate liquid C-14. However, the degassing of liquids means that more C-14 ends up in the gaseous effluent where generally it has a lower impact on the environment.

- BAT has been applied to the design of the outfall structure to optimise dispersion and minimise the impact of any discharges to the marine environment.
- The limit proposed accounts for the uncertainty about C-14 partitioning between solid, liquid and gaseous wastes.
- The annual effective dose to a member of the public for liquid discharges of C-14 from SZC is calculated at 9.5µSv [Ref 10] and the dose rate to the most exposed NHB is 5.0×10^{-3} µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a significant risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst C-14 is considered a significant radionuclide because of the dose being greater than 1 µSv per year, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world. We therefore consider the limit is appropriate.

166. Based on the annual EBP of 46 GBq y^{-1} and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 190 GBq of liquid C-14 from SZC to the environment in a twelve-rolling-month period.

167. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

5.5 Proposed QNL for Sizewell C – Carbon-14

168. As described for tritium liquid discharges, it is considered that up to 80% of the C-14 produced in liquid effluent could be discharged over 2 months around a planned shutdown. Therefore, the QNL for SZC was initially calculated at 80% of the EBP and corrected to allow for 100% availability.

169. Given the conservative nature of this figure, and in order to be consistent with the HPC QNL, SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 18 GBq for the discharges of C-14 from SZC to the marine environment on a three-rolling-month basis with the acceptance that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

5.6 Proposed Discharge Limits for Sizewell C – Other Radionuclides

170. Discharge limits have been proposed for individual radionuclides, Co-60 and Cs-137, and a specific group of radionuclides, referred to as ‘other radionuclides’ that comprise of all expected radionuclides taken together, but excluding Co-60 and Cs-137.

5.6.1 Cobalt-60

5.6.1.1 Expected Best Performance

171. As described in Section 2.2.2, the EBP is determined through consideration of indicative EPR^{TM} precursors and the evolutionary EPR^{TM} design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR^{TM} units on the SZC site the total EBP is estimated by doubling the values presented at GDA, which was the same approach used at HPC on this basis, the annual EBP at SZC for liquid discharges of Co-60 for SZC is 395 MBq y^{-1} [Ref 10].

5.6.1.2 Contingency and Headroom

172. Contingencies identified from OEF potentially affecting the liquid discharges are:

- Fuel failures; and,
- Accidental contamination of the primary coolant during oxygenation undertaken prior to shutdown.

173. Taking into consideration OEF on the impact on discharges during plant shutdown, as demonstrated for Cs-137, discharges can be as much as 6 times higher during shutdown. Taking into account this, and other factors including that the refuelling activities for SZC is much more condensed that existing plants, the maximum value estimated for liquid discharges of Co-60 from SZC is 6GBq per twelve-rolling-month period. Figure 5-3 below demonstrates how these contingencies could result in an increase from 0.4GBq to 6GBq.

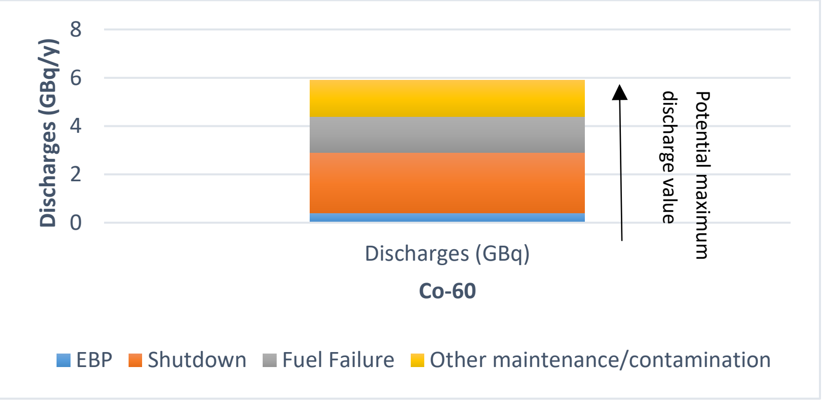


Figure 5-3 Indication of contingency build-up from EBP to the discharge limit for aqueous Cobalt-60

5.6.1.3 Proposed Limits

174. The following points have been taken into account in the proposed twelve-rolling-month limit for the liquid discharges of Co-60 from SZC:

- BAT has been applied to minimise the generation of other fission and activation products through minimising the cobalt content of steel, reducing Stellite, use of helicoflex seals, avoiding use of antimony in bearings, use of zinc injection and hot functional testing, as well as measures to minimise the presence of traces of residual uranium on the surface of the fuel.
- BAT has been used to minimise the transfer of activity from the fuel into the primary coolant.
- The Environment Agency has recognised in its GDA Public Consultation Document [Ref 3] that the use of filtration, demineralisation and evaporation are BAT for minimising the activity discharged.

- BAT has been applied to the design of the outfall structure to optimise dispersion and minimise the impact of any discharges to the marine environment.
- The difference between EBP and the proposed limits are due to the potential for fuel failures. Headroom has been applied to account for any fuel defects, whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant impact is very small. Any defective fuel will be replaced at the next shutdown.
- The annual effective dose to a member of the public for Co-60 is calculated at 0.57µSv [Ref 10] and the dose rate to the most exposed NHB is 0.26µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a significant risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.
- Whilst Co-60 is considered a significant radionuclide because it is an indicator of plant performance, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

175. Based on the annual EBP, Environment Agency feedback on HPC [Ref 8] and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 6 GBq of liquid Co-60 from SZC to the environment in a twelve–rolling-month period.

176. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8]. The increased discharges of spent fuel preparation for dry storage has been included in these estimates, and offset the discharge that would have been seen through longer-term wet storage of fuel.

5.6.1.4 Proposed QNL

177. For Co-60, the discharges resulting from normal operations of the UK EPR™ will present trends with peaks. These trends are due to normal transients and QNLs should not be reached with such peaks as these are part of normal operations. However, they should allow notification of contingencies. In practice, QNLs may not systematically be reached or exceeded if contingencies lead to increases of discharges that are not higher than those observed normally and no other increase adds up over three rolling months.

178. The following approach has been applied to assess an initial suitable QNL value:

- OEF data has been analysed for all 1,300 MWe and N4 PWRs between 2004 and 2009 with more recent data from EDF (2008-2013) demonstrating that this data remains valid. This data was available with exhaustive supporting data to identify all contingencies. This allowed filtration of the discharge data to remove events with known contingency but include normal transients.
- The OEF data set obtained is then representative of normal operating fluctuations. It corresponds typically to levels of detection with, punctually, significant peaks.
- For each site examined, maximal fluctuations have been obtained over the years studied. These maximal fluctuations are in the form of maximum values of monthly discharges (i.e. peaks, in MBq) in normal operating conditions.

- Finally, the maximum value of these peaks has been retained to obtain the overall normal fluctuation 'P'. For SZV, the overall normal fluctuation of P is consistent with that presented for HPC which was estimated at P = 46.6MBq meaning that the normal liquid discharges of Co-60 are expected to increase up to 46.6MBq, without any contingency.
- The QNL therefore has been calculated using the following formula:

$$QNL = \frac{Annual\ Expected\ Best\ Performance}{6} + P \times 2$$

Where;

- The AEBP value used is for a single unit (as the equation allows for 2 units below)
- The division by 6 is because the EBP value is accounted for 2 months, therefore rather than divide the annual figure by 12 to obtain a monthly value, the Annual EBP should instead be divided by 6.
- The addition of P is to account for the peak (normal fluctuation) as a separate discharge value since it corresponds to a peak of discharge and not a correction factor that can be multiplied to the EBP value. The value of P is given above (46.6MBq).
- The total is doubled to allow for two reactor units.

179. Application of the formula presented above gives an initial QNL estimate of 0.22GBq. Therefore, SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 0.3GBq for the discharges of Co-60 from SZC to the marine environment on a three-rolling-month basis. This is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

180. This is the same QNL as granted for HPC [Ref 8].

5.6.2 Caesium-137

5.6.2.1 Expected Best Performance

181. As described in Section 2.2.2, the EBP is determined through consideration of indicative EPR™ precursors and the evolutionary EPR™ design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR™ units on the SZC site the total EBP is estimated by doubling the values presented at GDA, which was the same approach used at HPC on this basis the annual EBP value for liquid Cs-137 for SZC is 114 MBq y^{-1} [Ref 8].

5.6.2.2 Contingency and Headroom

182. Bounding contingencies identified from OEF potentially affecting the liquid discharges are:

- Fuel failures;
- Accidental contamination of the primary coolant during oxygenation undertaken prior to shut down.

183. It was reported at Penly that discharges following a short, planned shutdown were around 6 times higher than during normal operation, and in the case of a very short outage, this phenomenon is expected to be even more pronounced as the activity in the primary fluid will be even higher and therefore the discharges will increase over a more condensed period of time, these impacts can be a result of contamination of the primary circuit

during oxygenation undertaken prior to shut down or unavailability of tanks preventing natural decay before discharge. The consequences of shutdown on discharges is discussed more in the RSR permit application head document. However, in general the shorter the shutdown, the higher these discharges are expected to be. Considering that the UK EPR™ refuelling activities are expected to last for around 11 days (much shorter than for existing units), a significant proportion of the annual discharges could potentially be released in this shutdown period (less than a month).

184. The maximum value for liquid discharges of Cs-137 from SZC is 1.9 GBq per twelve-rolling-month period [Ref 8]. Figure 5-4 below demonstrates how these contingencies could result in an increase from the EBP value of 0.1GBq to 1.9GBq.

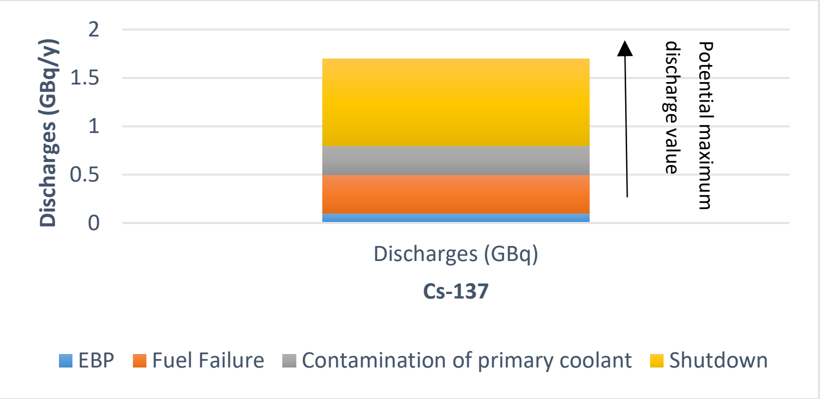


Figure 5-4 Indication of contingency build-up from EBP to the discharge limit for aqueous Caesium-137

5.6.2.3 Proposed Limits

185. The following points have been taken into account in the proposed twelve-rolling-month limit for the liquid discharges of Cs-137 from SZC:

- BAT will be used to minimise at source the production of Cs-137 through quality assured fuel manufacturing arrangements to minimise the quantities of residual traces of uranium present at the surface of the fuel and also in its cladding to minimise fuel leakage. The generation of fission products from the activity inside the fuel cannot be minimised.
- BAT has been used to minimise the transfer of activity from the fuel into the primary coolant.
- The Environment Agency has recognised in its GDA Public Consultation Document [Ref 3] that the use of filters and demineralisers to abate liquid discharges is BAT.
- BAT has been applied to design of the outfall structure to optimise dispersion and minimise the impact of any discharge to the marine environment.
- The difference between EBP and the proposed limit are due to the potential for fuel failures. Headroom has been applied to account for any fuel defects, whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant impact is very small. Any defective fuel will be replaced at the next shutdown.
- The annual effective dose to a member of the public for Cs-137 is calculated at 3.1×10^{-2}µSv [Ref 10] and the dose rate to the most exposed NHB is 2.7×10^{-4} µGy h^{-1} [Ref 12]. These figures demonstrate

that the performance of SZC and the proposed limits do not pose a risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed to for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.

- Whilst Cs-137 is considered a significant radionuclide because it is an indicator of plant performance, the application of BAT to minimise its generation, discharge and impact has been determined and is expected to be very low and comparable to best performance across the world.

186. Based on the annual EBP and the points considered above, SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 1.9 GBq of liquid Cs-137 from SZC to the environment in a twelve–rolling-month period.

187. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

5.6.2.4 Proposed QNL

188. The same approach as for Co-60 has been applied to assess an initial suitable QNL value for other fission and activation products. The overall fluctuation value obtained from analysis of the OEF data is P = 46.6 MBq.

189. Application of the formula presented above gives an initial QNL estimate of 0.1GBq. Therefore, SZC Co. is applying for a RSR environmental permit that includes a proposed QNL set at 0.1GBq for the discharges of Cs-137 from SZC to the marine environment on a three-rolling-month basis. This is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations. The proposed QNL is set at a level close to the EBP at a level where fuel failures would initiate a review. In this way close oversight is maintained.

190. This is the same QNL as granted for HPC [Ref 8].

5.6.3 Other Radionuclides

5.6.3.1 Expected Best Performance

191. As described in Section 2.2.2, the EBP is determined through consideration of indicative EPR™ precursors and the evolutionary EPR™ design. The EBP for a single unit was presented for GDA [Ref 4] and given that there are two UK EPR™ units on the SZC site the total EBP is estimated by doubling the values presented at GDA, which was the same approach used at HPC. Based on calculations in RSR permit application support document D1, the annual EBP for liquid discharges of 'other radionuclides' excluding Cs-137 and Co-60 for SZC is 804 MBq y^{-1} [Ref 10].

5.6.3.2 Contingency and Headroom

192. Bounding contingencies identified from OEF potentially affecting the liquid discharges are:

- Fuel failures;
- Accidental contamination of the primary coolant during oxygenation undertaken prior to shut down; and,
- Unavailability of the discharge tanks preventing natural decay of short lived radionuclides from occurring before discharge.

193. As demonstrated for Cs-137, discharges following a short, planned shutdown can be 6 times higher than during normal operation and in the case of a very short outage, this phenomenon is expected to be even more pronounced.

194. Taking these into consideration the maximum value for liquid discharges of 'other radionuclides' from SZC is estimated at 12GBq per twelve-rolling-month period. Figure 5-5 below demonstrates how these contingencies could result in an increase from 0.8GBq to 12GBq.

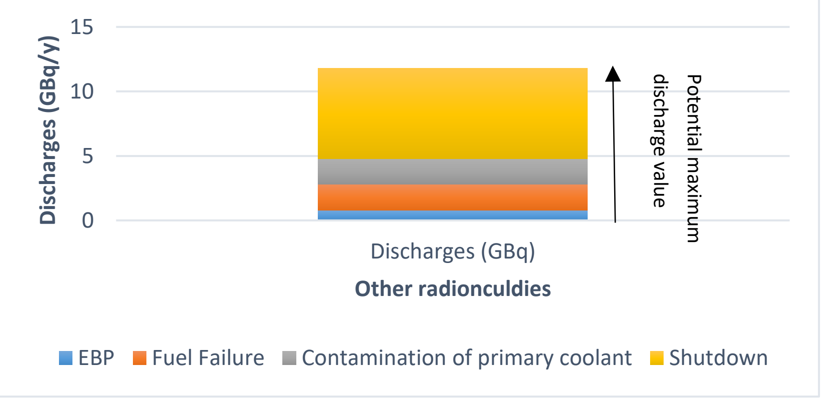


Figure 5-5 Indication of contingency build-up from EBP to the discharge limit for other aqueous radionuclides

5.6.3.3 Proposed Limits

195. The following points have been taken into account in the proposed twelve-rolling-month limit for the liquid discharge of 'other radionuclides' from SZC:

- BAT has been applied to minimise the generation of 'other radionuclides' through minimising the cobalt content of steel, reducing Stellite, use of helicoflex seals, avoiding use of antimony in bearings, use of zinc injection and hot functional testing, as well as measures to minimise the presence of traces of residual uranium on the surface of the fuel.
- BAT has been used to minimise the transfer of activity from the fuel into the primary coolant.
- The Environment Agency has recognised in its GDA Public Consultation Document [Ref 3] that the use of filtration, demineralisation and evaporation are BAT in minimising the activity discharged.
- BAT has been applied to design of the outfall structure to optimise dispersion and minimise the impact of any discharges to the marine environment.
- The difference between EBP and the proposed limit are due to the potential for fuel failures and an allowance for dry fuel storage. Headroom has been applied to account for any fuel defects, whilst high standards are applied and fuel defects are rare events and cannot be predicted, they are not unexpected through the course of operations at a power station. The resultant defect can lead to a large increase in the activity discharged even though the resultant impact is very small. Any defective fuel will be replaced at the next shutdown.
- The annual effective dose to a member of the public for 'other radionuclides' is calculated at $1.2x10^{-2}$ µSv [Ref 10] and the dose rate to the most exposed NHB is 0.1µGy h^{-1} [Ref 12]. These figures demonstrate that the performance of SZC and the proposed limits do not pose a significant risk to the pubic or local habitats. The small variations in the receiving environment at SZC compared to

HPC have negligible impact on the resulting dose. This demonstrates that the limit agreed for HPC [Ref 8] and in the Environment Agency GDA Public Consultation Document [Ref 3] is also proportionate and appropriate for SZC, with the additional benefit of enabling a consistent operating regime across the sites.

196. Based on the annual EBP of 804 MBq y^{-1}, the points considered above and feedback form the Environment Agency for HPC [Ref 8], SZC Co. is applying for a RSR environmental permit that includes a proposed limit to discharge 12GBq of 'other radionuclides' in liquid effluent from SZC to the marine environment in a twelve-rolling-month period.

197. This approach is consistent with Environment Agency guidance on limit setting for new facilities [Ref 9] and as noted, this is consistent with the limit agreed to for HPC [Ref 8].

5.6.3.4 Proposed QNL

198. The same approach as for Co-60 and Cs-137 has been applied to assess an initial indicative QNL value for 'other radionuclides' noting that during the HPC application Co-60 was included in this group. Based on the calculated EPB figure for SZC for 'other radionuclides' not including Co-60, and taking into consideration the overall fluctuation value obtained from analysis OEF data is P = 382 MBq, application of the formula presented in [Ref 8] gives an initial QNL estimate of 1GBq.

199. This figure is recognised as being greater than the QNL figure calculated by the Environment Agency for HPC [Ref 8] however SZC Co. are satisfied that the limit granted for HPC, 0.6GBq, is proportionate and appropriate for SZC on the basis that this is liable to be adjusted once OEF data from the UK EPR™ becomes available at which point limits may be reviewed as per the Environment Agency expectations.

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