BAT Case to justify the removal of the Kr85 and Sb125 gaseous Site discharge limits and respective environmental monitoring requirements from the Radioactive Substances Activities Permit KP3690SX

This summary paper justifies the removal of the gaseous Site discharge limits for radionuclide species Krypton-85 (Kr-85) and Antimony-125 (Sb-125) from the Radioactive Substances Activities (RSA) permit KP3690SX. It also justifies the discontinuation of associated environmental monitoring requirements through changes to the SL Techniques document- (SLSP 2.11.114).

The major permit review and subsequent RSA permit variation application in 2018 presented the case that discharges of these species would reduce significantly following the end of reprocessing. EA accepted the justification and the Permit variation (October 2020) included notification requirements for the end of Magnox reprocessing for removal of the limits.

Following the notification that Magnox bulk reprocessing had ended (July 2022) it was subsequently agreed with EA that Sellafield Ltd. (SL) would continue to collect discharge, modelled and environmental data for a 6-month period in order to demonstrate the reduction in discharges prior to removal of the limits and environmental monitoring requirements.

This paper presents the Kr85 (Thorp and SAV stacks) and Sb125 (FHP stack) discharge and modelled data and the environmental monitoring data (from High Volume Air Samplers on the Sellafield site, and from the dedicated Kr-85 sampler adjacent to the site), to demonstrate the reduction in discharges following the end of reprocessing. The Sellafield Effluent Management Strategy (SEMS) modelled data is also included presenting future discharge projections. This paper demonstrates discharges have reduced significantly and the limits and subsequent reporting requirement should now be removed in line with the EA limit setting methodology and environmental monitoring for Kr85 and Sb125 can be stopped.

Background

Kr-85 is an inert noble gas with a half-life of almost 11 years and is generated as a fission product in the operation of a nuclear reactor. It becomes trapped within the spent fuel rods and a small amount released in the first stages of reprocessing during fuel shearing in the Thermal oxide reprocessing plant (THORP) and decanning in the Magnox reprocessing plant at Sellafield. The majority of Kr-85 was released during fuel dissolution. Kr-85 is solely released during reprocessing and discharges are predictable. The modelling software FISPIN (2000) predicts the composition of spent fuel based on fuel type, tonnes of fuel, irradiation,

U-235 percentage and cooling period. This allows the software to accurately calculate the discharge.

Sb-125 is a metal produced during reactor operations and becomes trapped in the spent fuel. Reprocessing and associated waste treatment operations result in most of the Sb-125 being directed into solid radioactive waste, but a small fraction is discharged into the air, particularly during Magnox fuel decanning operations. Sb-125 has a half-life of just under 3 years.

Now that reprocessing has ceased and SL's mission has moved to decommissioning/ remediation and Site clean-up, there are no future reprocessing activities that will produce Kr-85 & Sb-125 at a level that would meet the site limit setting criteria. Discharges have not been significant in terms of radiological impact on people (<1µSv per year) or the quantity of radioactivity discharged for several years as the sites reprocessing has been run down. Discharges have shown further significant reductions since the end of Thorp reprocessing and more recently the end of Magnox reprocessing. Therefore, removal of these Site limits and corresponding annual plant notification levels (PNLs) aligns with the EA limit setting methodology and should be implemented on EA agreement (through CEAR update initially).

This document supports the EA's following proposal as agreed in the major permit review cited in the decision document:

*"We agree in principle with the proposal to remove these limits at the end of Magnox reprocessing. However, we will require Sellafield Ltd to provide further evidence that discharges have declined as expected before we remove these limits. We expect Sellafield Ltd to provide that information as part of a submission regarding CEAR requirement 4.2.2 part 2 paragraph 14***".**

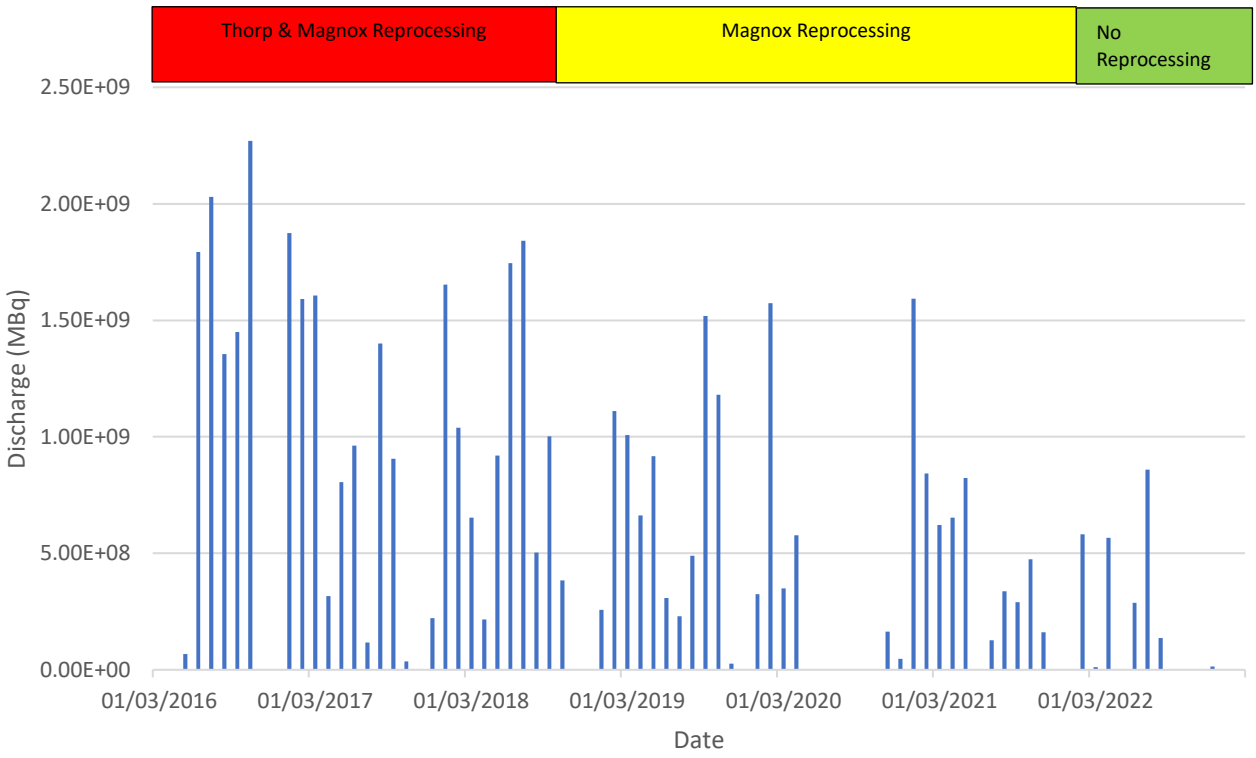
The data provided below provides clear trends that discharges have reduced dramatically for both Kr-85 and Sb-125 since the end of Thorp (2018) and Magnox reprocessing (2022). Please note the following technique is used by NNL to carry out the calculation for Kr-85 discharges at SAV and Thorp:

The Kr85 from the Thorp and SAV stack is determined from the inventory (mass, rating, burn up and cooling using FISPIN relationships) of fuel reprocessed during the month. This calculation is the reported value of Kr-85.

Discharge data

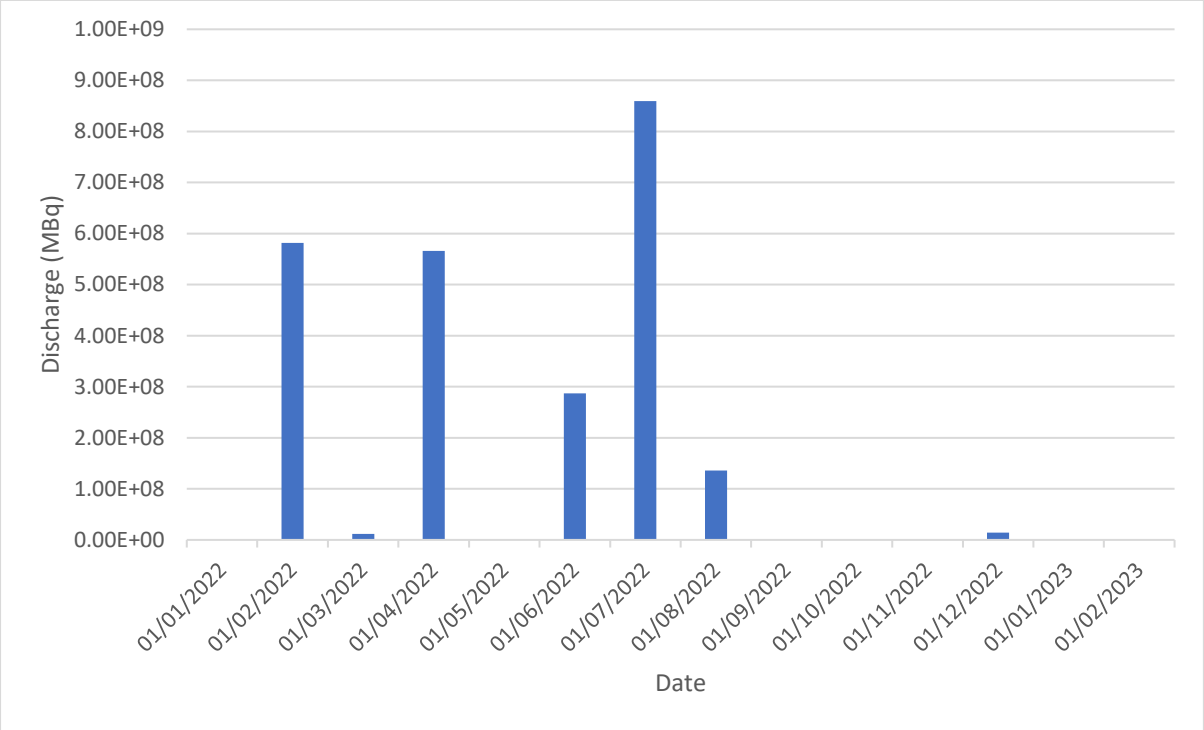
This section provides measured discharge data from FHP stack for Sb-125 discharges and Kr-85 discharges derived from the FISPIN model by NNL from Thorp, SAV and the Magnox stack.

Figure 1: SAV Kr-85 discharge data 2016-2023



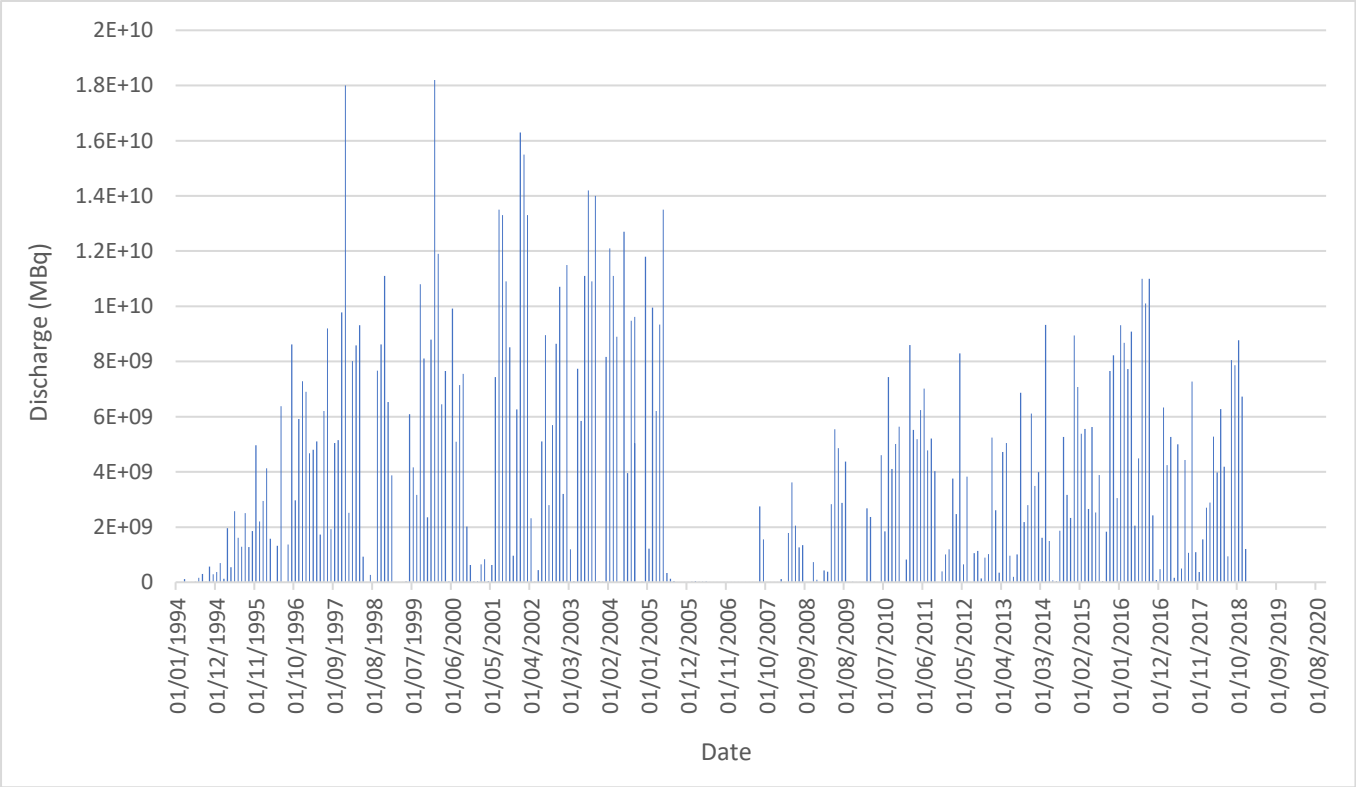
Note: The Discharge (MBq) required to exceed the impact assessment dose threshold of 1.0 uSv/yr equates to 1.86E+11 MBq which is significantly above the scale of the graph.

Figure 2: SAV Kr-85 discharge data 2022-2023



Note: Following the completion of Magnox reprocessing in July 2022 there was a pause to facilitate the site outage and then a restart of the facility in September to enable the operational rundown of the facility, this was finished at the end of the calendar year. The small Krypton-85 discharge that can be seen in December 2022 is as a result of this planned operational rundown. No further discharges are expected in the future from Magnox operations.

Figure 3: Thorp Stack Kr-85 discharge data 1994-2020



Note: The Discharge (MBq) required to exceed the impact assessment dose threshold of 1.0 uSv/yr equates to 1.62+11 MBq which is significantly above the scale of the graph.

Figure 4: Thorp Stack kr-85 discharge data 2018-2020

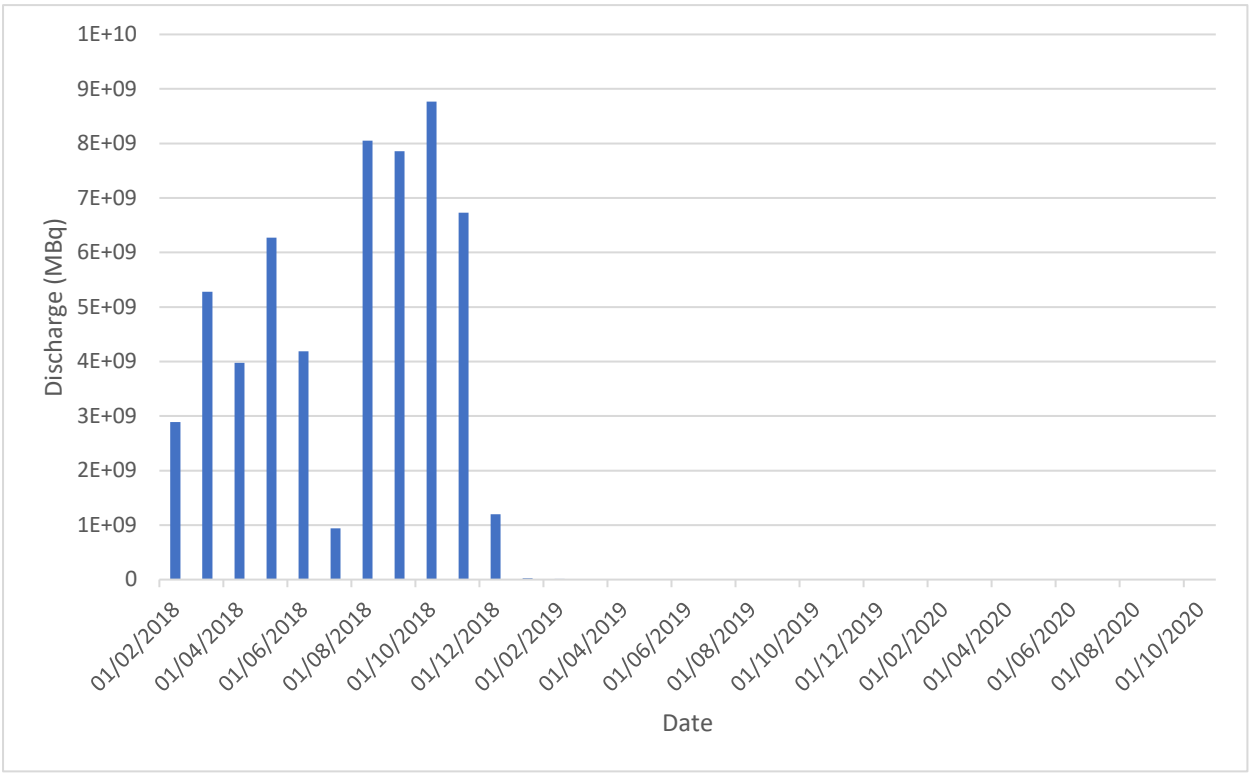


Figure 5: Magnox Stack Kr-85 discharge data 1994-2016 before the active commissioning of SAV stack in 2016

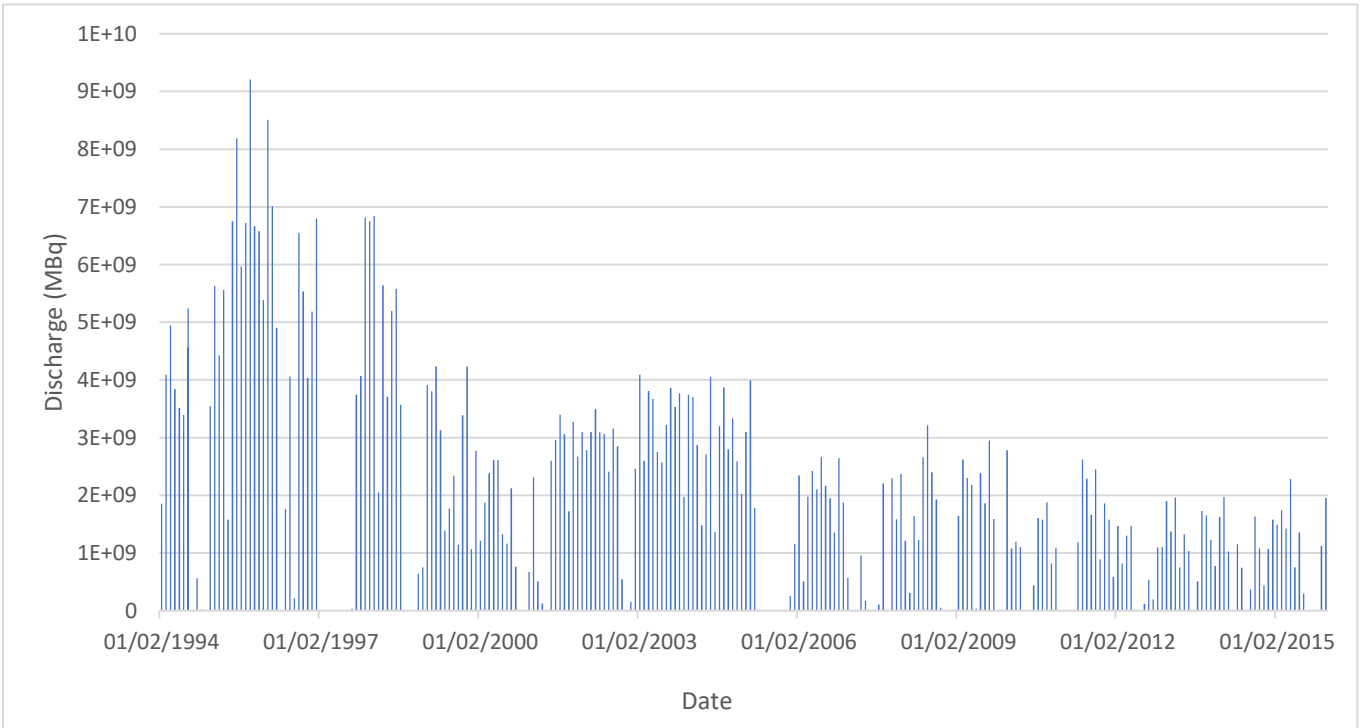
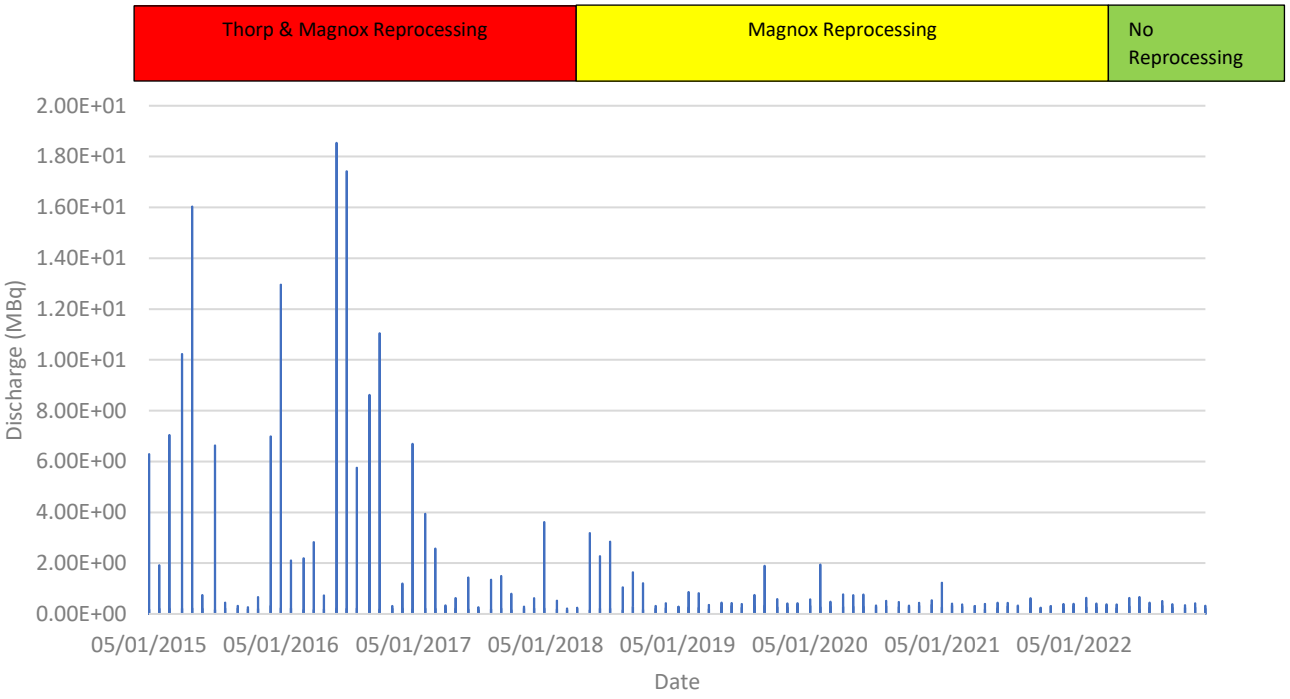


Figure 6: FHP Sb-125 discharge data 2015-2023



Note: The discharge (MBq) required to exceed the impact assessment dose threshold of 1.0 uSv/yr equates to 1.49E+05 MBq which is significantly above the scale of the graph.

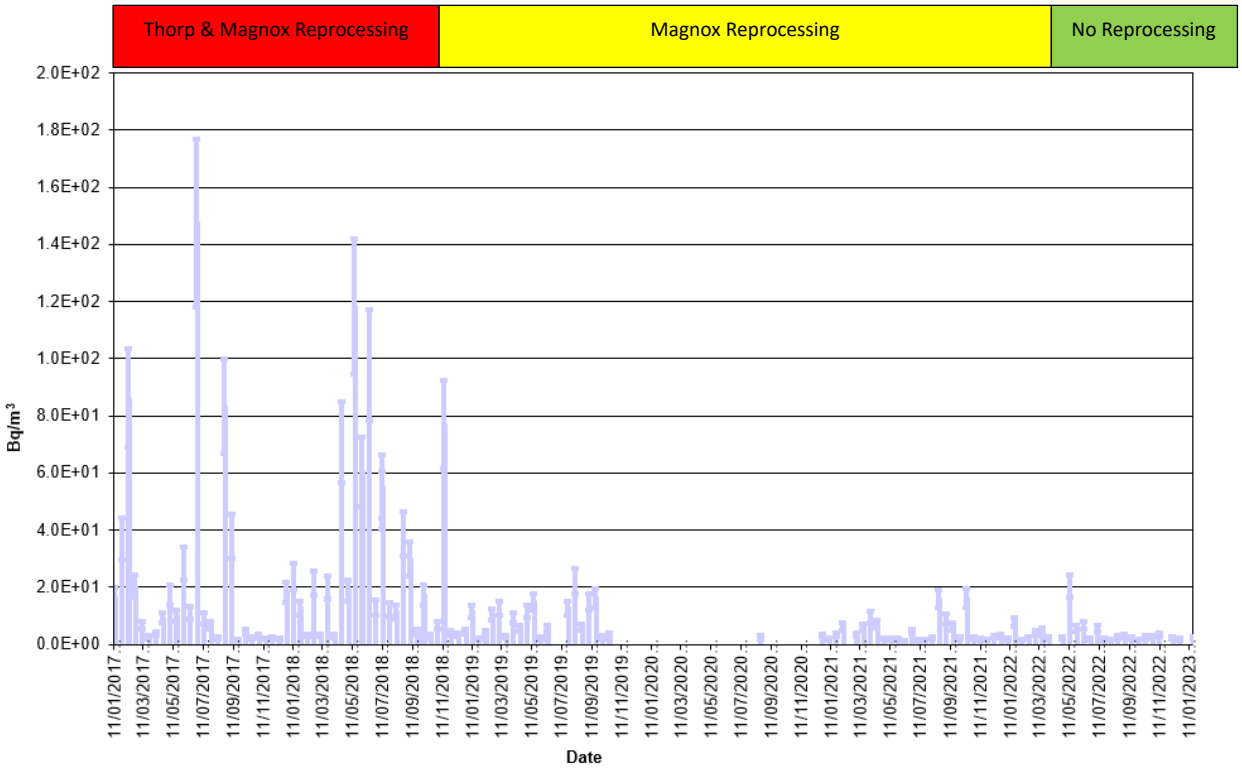
Environmental Monitoring Data (HVAS)

This section provides real data from the dedicated Kr-85 sampler adjacent to the site and the associated HVAS samplers located around the SL Site for Sb-125. As stack Kr-85 discharge data is based upon a FISPIN calculation this data provides real environmental measurements to underpin that the Kr-85 figures are insignificant and the dose is negligible to the critical dose group.

Stability of both Kr-85 and Sb-125 data in the period post Thorp and Magnox reprocessing, given the inherent variation in discharges, indicates that these data are close to background levels. This supports the premise that there is no measurable impact from reprocessing, nor potential for subsequent significant increases, given the well-established sources of these releases.

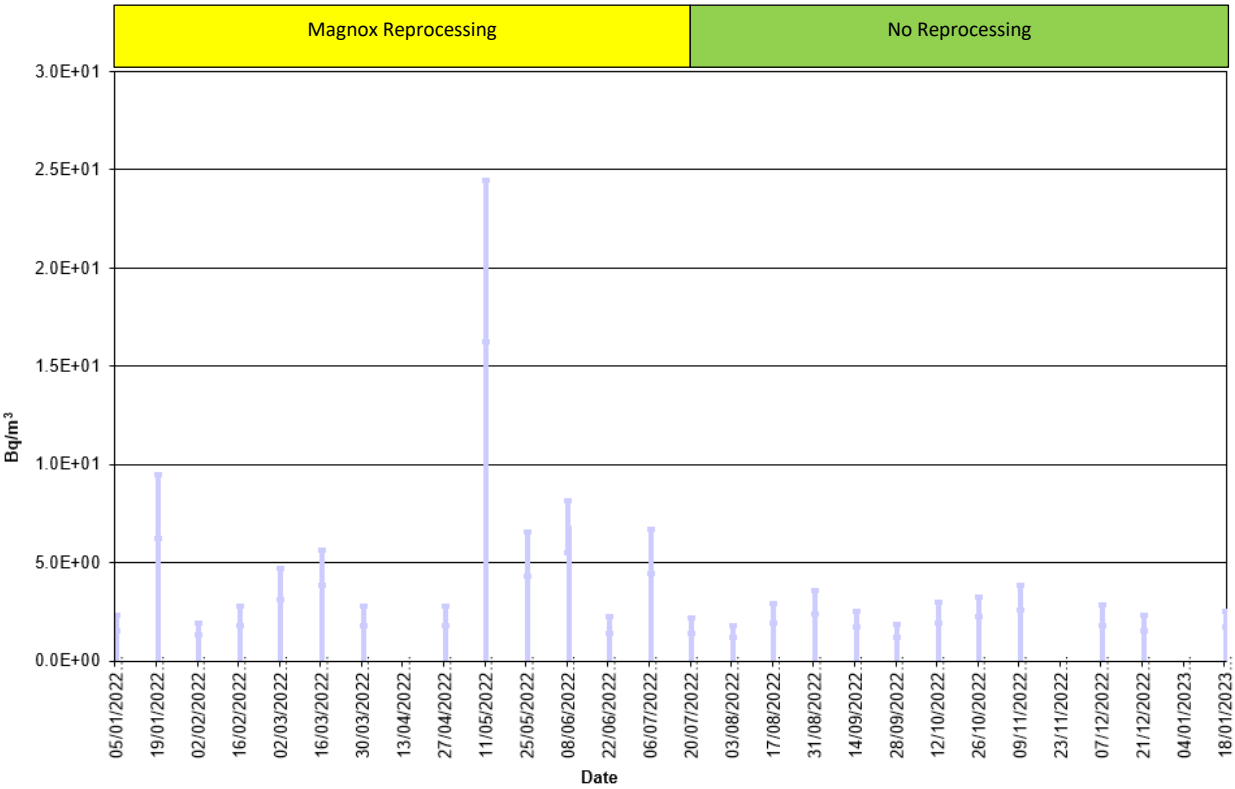
It should be noted that the sample collection and analysis of Kr85 from environmental concentrations at the met station on site is very complicated and time consuming, in fact it makes the dominant contribution to the analytical requirements for the environmental monitoring programme.

Figure 7: Kr-85 Met Station data 2017-2023



Note – Absence of data between end of 2019 and end of 2020 due to COVID-19 pandemic and associated minimum manning arrangements and prioritisation of environmental protection measures. Background levels are around 1.6 Bq m^{-3}.

Figure 8: Kr-85 Met Station data 2022 – 2023



Note: One missing Kr-85 environmental result for 23/11/2022. Background levels are around 1.6 Bq m^{-3}.

Figure 9: Sb-125 data at HVAS UCGATE 2016-2023

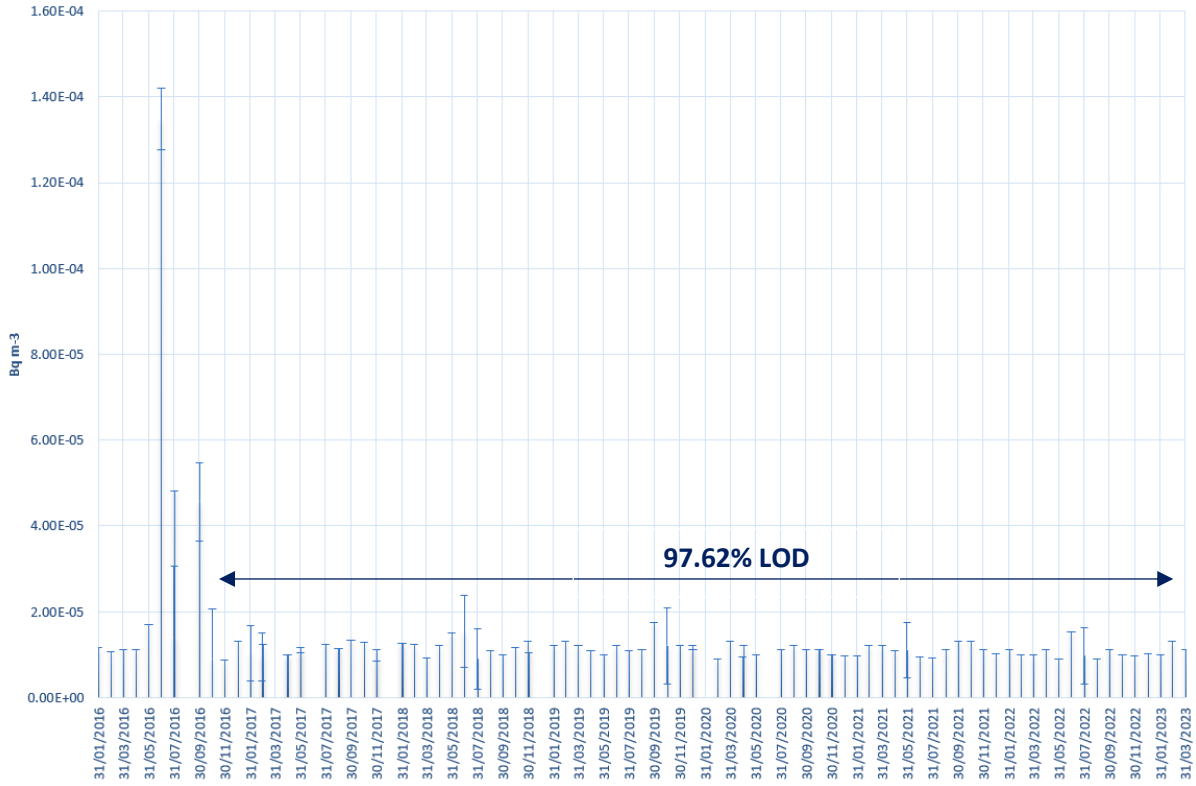


Figure 10: Sb-125 data at HVAS UWESTR 2016-2023

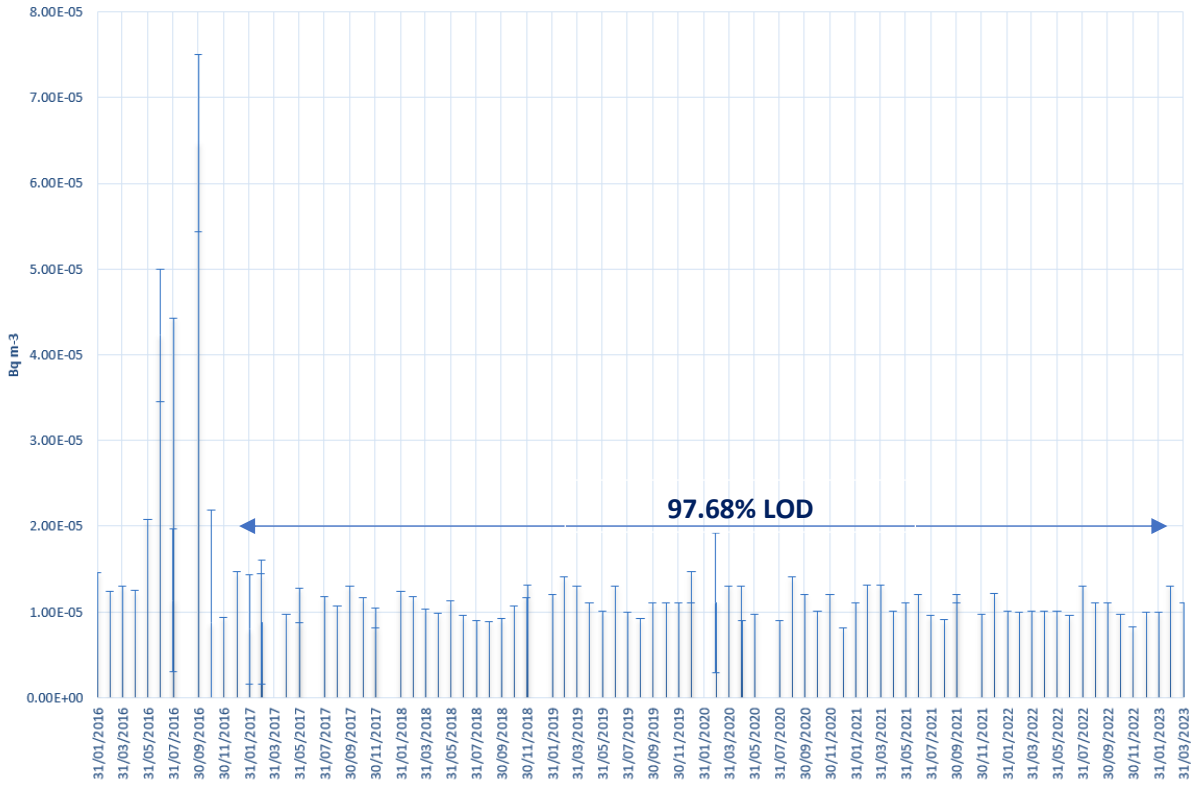


Figure 11: Sb-125 data at HVAS UST120 2016-2023

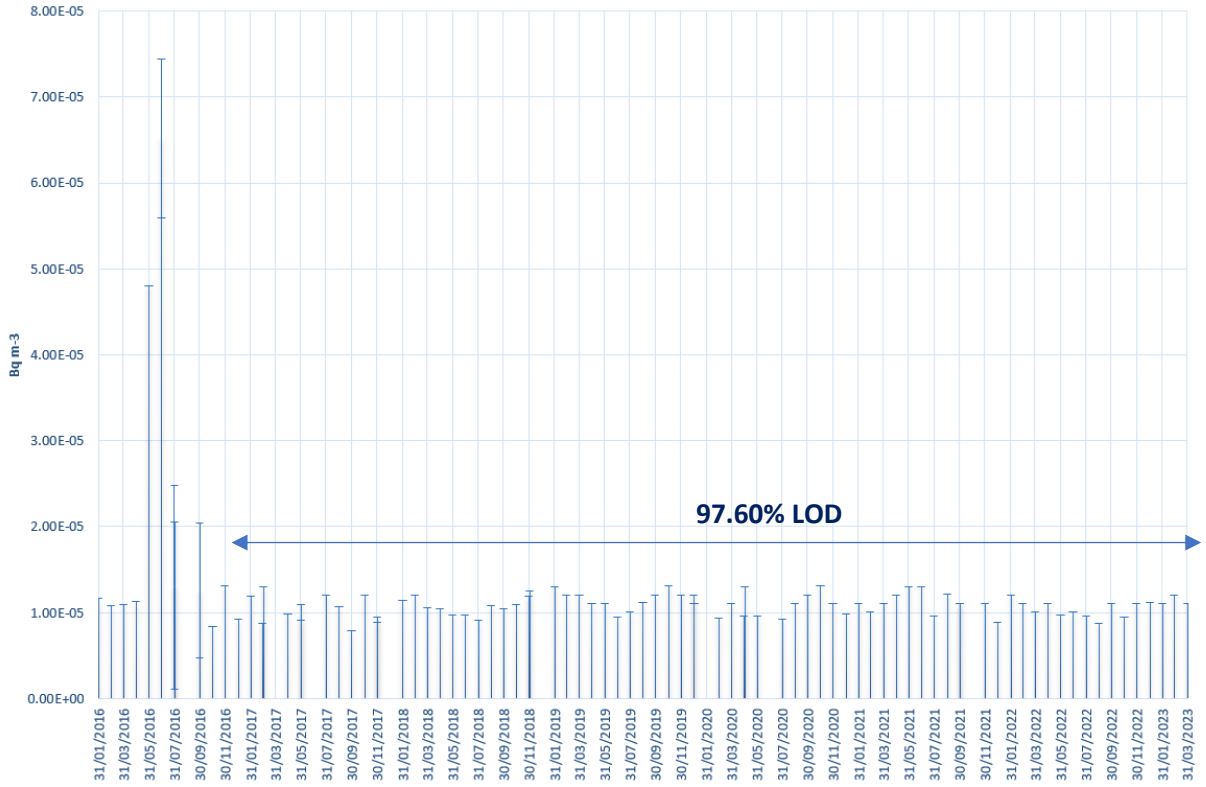


Figure 12: Sb-125 data at UNGATE 2016-2023

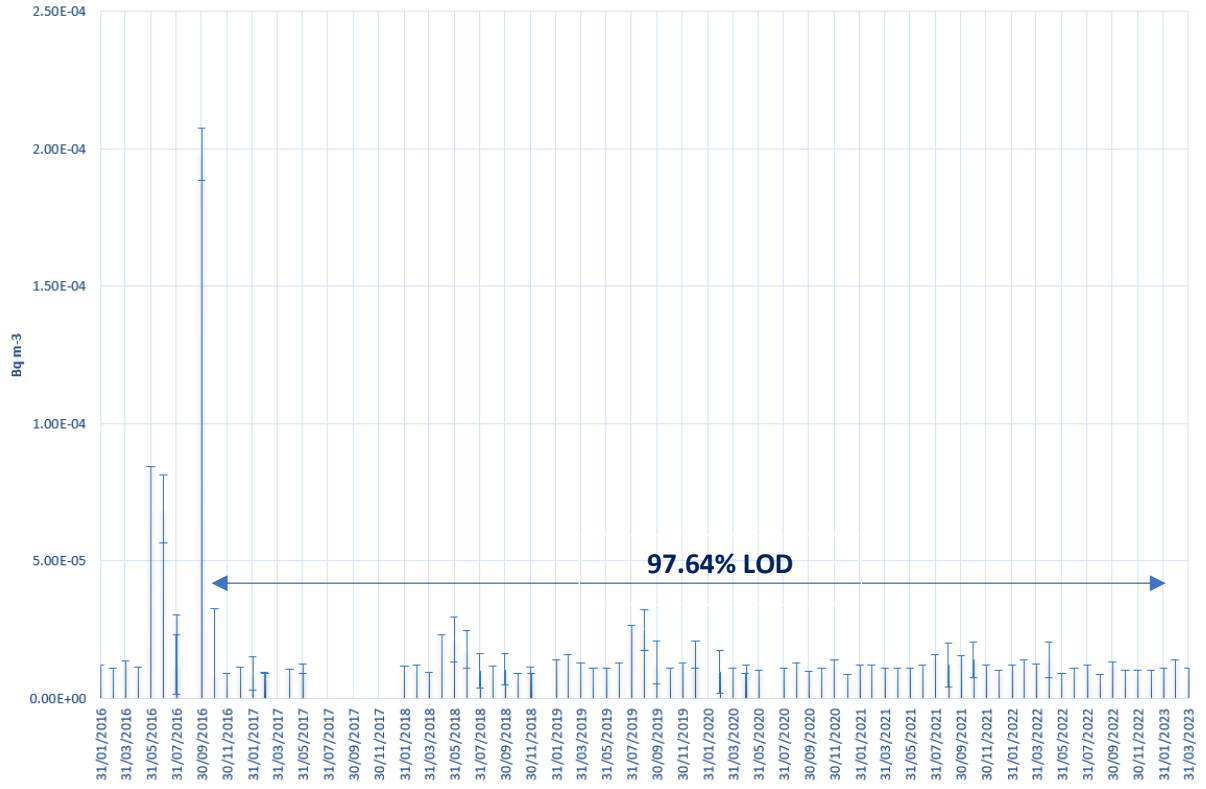
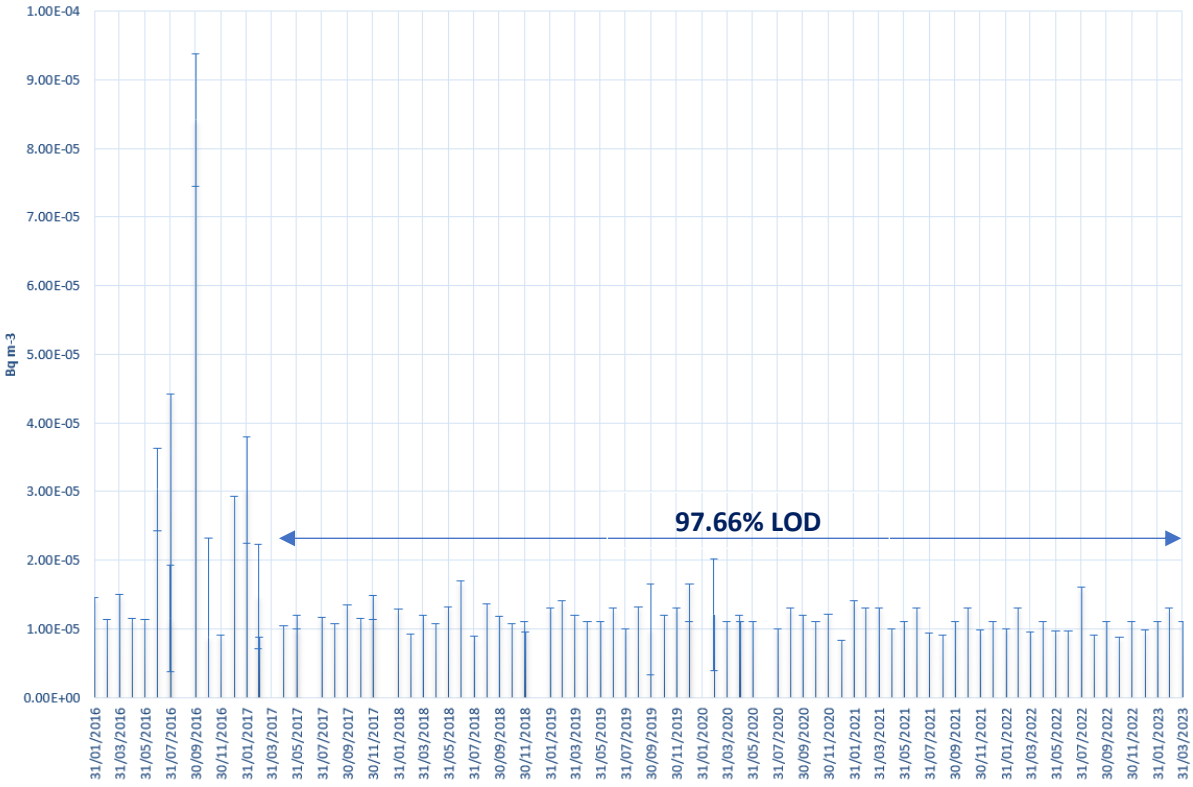


Figure 13: Sb-125 data at UMETST 2016-2023



Environmental Impact Assessments and % LOD

Radiological impact assessments have been produced for SAV, Thorp and FHP discharges to assess the dose impact to the critical group of discharges pre and post Thorp/ Magnox reprocessing. The Sellafield Industry LADRR, Adult all pathways dose was used as a worst-case scenario pessimistic approach. The assessment detailed below demonstrates that post Magnox reprocessing the impact to the critical group remained well below 1.0 uSv/yr for Kr-85 and Sb-125 on SAV, Thorp and FHP and since the end of reprocessing has fallen significantly further to insignificant levels. For the dose assessment threshold it was decided that using 1.0 uSv/yr is the best approach for consistency with the EA site limit setting methodology, so all impacts can be assessed against the EA guidance figure. To calculate the radioactive impact assessment for the stack discharges SLSP 2.11.109 'Determining Public Critical Group and Collective dose' (2017) was used to determine the effective stack heights and SLF 2.11.109.01 (2013) was used to acquire the public dose factors.

SAV

Radionuclide Species	Year	Dose (uSv/yr)
Kr-85	2018	0.05
Kr-85	2019	0.04
Kr-85	2020	0.02
Kr-85	2021	0.02
Kr-85	2022	0.01

Thorp

Radionuclide Species	Year	Dose (uSv/yr)
Kr-85	2018	0.34592
Kr-85	2019	0.00014
Kr-85	2020	0.00000

FHP

Radionuclide Species	Year	Dose (uSv/yr)	LOD%
Sb-125	2016	0.0724	39.58%
Sb-125	2017	0.0136	47.91%
Sb-125	2018	0.0109	41.67%
Sb-125	2019	0.0095	66.66%
Sb-125	2020	0.0066	89.58%
Sb-125	2021	0.0052	68.75%
Sb-125	2022	0.0028	81.25%

Note: All doses are significantly below 1 uSv/yr, which is the key criteria within the EA Site limit setting methodology.

SEMS modelling future projections

The SEMS team provided data to display the future modelled discharges of Kr-85 and Sb-125 and the origins of each nuclide species. Kr85 is shown as zero after 2022 because at the end of Magnox reprocessing no more Kr-85 is released from site operations. The SEMS view on future discharge projections will be formally presented within the CEAR requirement (3.4b) submission during 2023. This will use data provided by Magnox for the period after reprocessing officially ceased (July 2022).

Sb-125 is different as although the bulk of it is generated from FHP decanning operations, SEMS have assigned approximately 12% to the pond hall (11.8%) and vessel ventilation (0.1%) based on historic aerial flow sheeting calculation. Both run until 2039 in the model hence the extended profile of Sb-125. The model then assumes a figure (12%) which remains constant for future years. Again, this will be an assumption that will be revisited based on actual plant data from FHP operations post-reprocessing. Additionally, there is a small activity linked to Open Fuel Storage Ponds and Other Outlets (OFSP&OO) which is sourced from the Miscellaneous Beta Gamma Waste Store (MBGWS) and is based on limited 2009 sampling data. This indicates that Sb-125 was present with the assumption carried forward, untested, into future years, although the activity is very low.

It is important to note that the previous points related to Sb-125 discharges are modelled assumptions based upon data available at the time and that in comparison to previous reprocessing activities the impact of Sb-125 will be minimal as a result of future POCO and decommissioning activities. The estimated discharges are trivial in comparison to those during bulk reprocessing activities when both Thorp and Magnox were operational. Emphasis must therefore be placed on the fact there are no other credible mechanisms for the release of these radionuclides. Future releases as a result of processing this small scale residual material will be diffused over an extended period in comparison to focussed reprocessing activities at high throughput rates. SL is confident there is no credible mechanism to return to previously recorded levels of discharge, which are in turn already below the significance threshold over the period presented in this paper.

Figure 14: Kr-85 Future Years Modelled Discharges Inc Worst Case Assumptions / Uncertainties

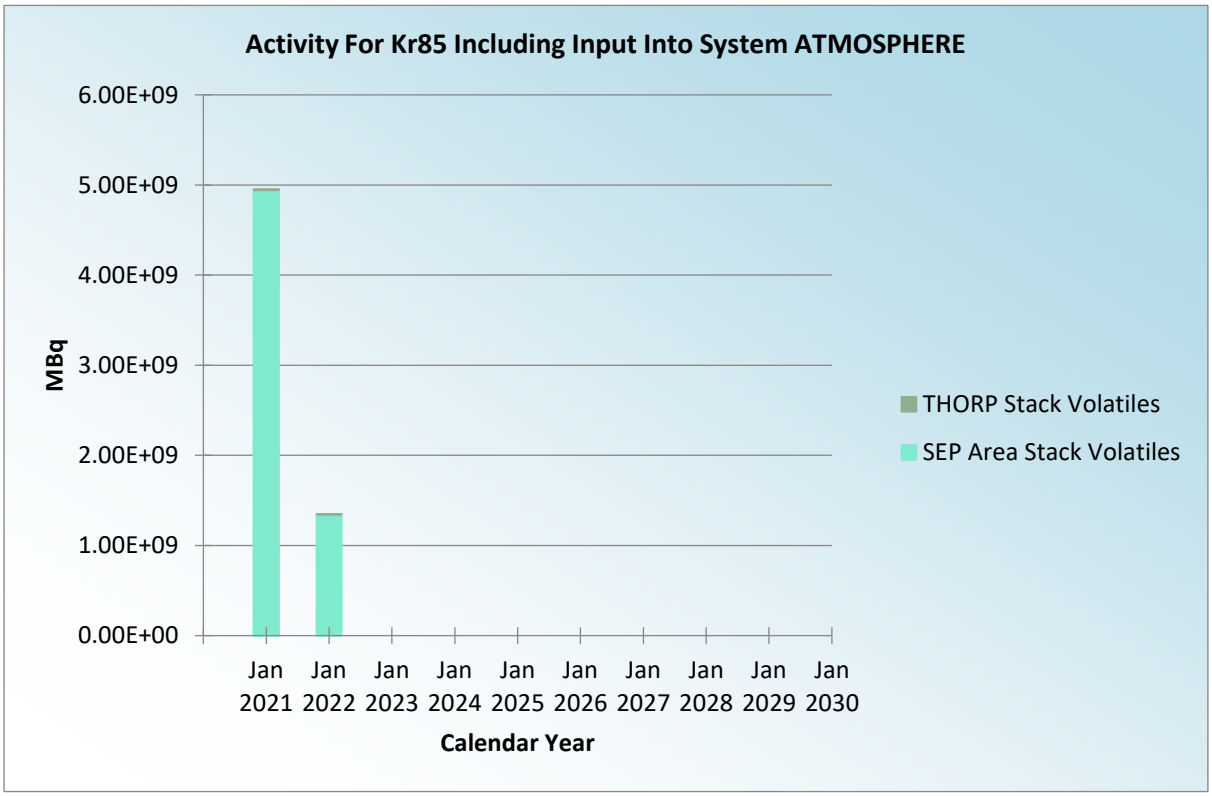
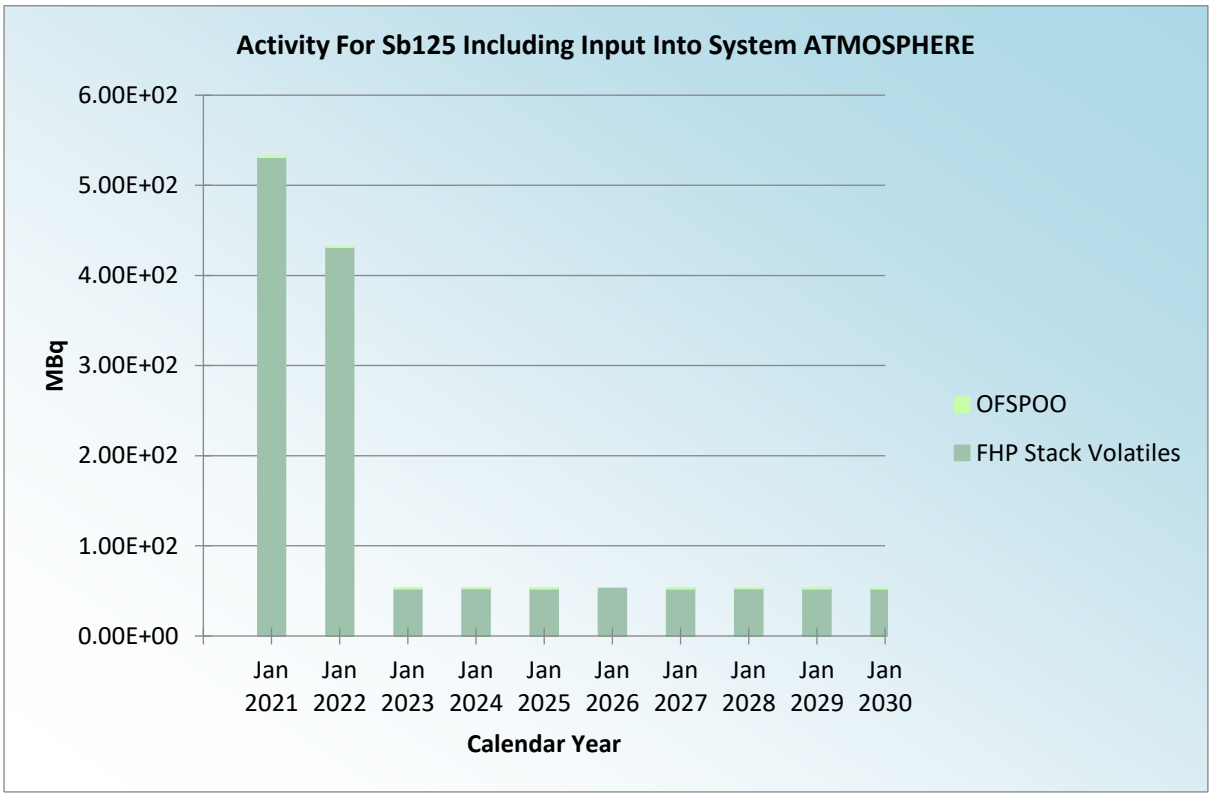


Figure 15: Sb-125 Future Years Modelled Discharges Inc Worst Case Assumptions / Uncertainties



Note: The Discharge (MBq) required to exceed the impact assessment dose threshold of 1.0 uSv/yr equates to 1.49E+05 MBq which is significantly above the scale of the graph.

Conclusion

This paper demonstrates the reductions in site gaseous discharges of Kr85 and Sb125 and these reductions are also reflected in, and verified by, environmental concentrations. Since the end of reprocessing, discharges and environmental concentrations are now at negligible levels. The evidence in this paper is provided as a justification for the pre-agreed removal of the gaseous Kr85 and Sb125 Site limits, PNLs and any corresponding reporting requirements. Similarly, the data justifies stopping environmental sampling and analysis of these parameters.

Recommendation

It is therefore recommended that on agreement with EA, the CEAR is re-issued to reflect the removal of limits as per footnote (2) of Table 1. Specified disposals to air (upper limits as specified in Table S3.1A). Subsequently, during the next RSA Permit variation the PNLs and Annual Site Limits should be removed from Tables S 3.1 A Specified disposals to air – Annual Site Limits and S 3.1 B Specified disposals to air – Annual Plant Notification levels for individual outlets/ group of outlets.

It is also recommended that EA accept this justification to remove the requirement for environmental monitoring through agreement to change SLSP2.11.114 'Techniques defining the Sellafield Ltd Environmental Monitoring programme'. SL will then reissue this document.

References

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

Environment Agency. (2021) Radioactive Substances Activity Permit KP3690SX/V012

SLF 2.11.109.01. (2013) Public dose factor tables

SLSP 2.11.114. (2022) Techniques defining the Sellafield Ltd Environmental Monitoring programme

SLSP 2.11.109. (2017) Determining public critical group and collective doses