1 Executive Summary

TRIUMF operates a Class I research particle accelerator and seven Class II particle accelerators for research and medical isotope production. The most significant hazards with the Class I accelerator are the prompt radiation fields present inside shielded enclosures during accelerator operations. These pose a risk only to TRIUMF personnel which is effectively mitigated by shielding and an access control system designed and built to industry standards for such engineered safeguards. Additional risk to personnel from residual radiation is mitigated by both engineered and administrative controls. Personnel dose is monitored for all work with the potential for radiation exposure. The most significant environmental hazard associated with the Class I accelerator is the activation of ambient air inside the shielded accelerator and beamline enclosures. The activated air is exhausted continuously through a dedicated nuclear grade ventilation system equipped with HEPA and, in areas where required, charcoal filtration. This exhaust presents a very small, though measurable, radiation hazard to the surrounding environment and community.

According to CSA-N288.6-12, a retrospective risk assessment is required to substantiate the identification and quantification of contaminants and physical stressors associated with TRIUMF operation which may pose a risk to the environment, and to establish which of these need further monitoring and analysis. The following captures a tier-1 environmental risk assessment (ERA) for accelerator operation using the existing source emissions monitoring data and environmental monitoring data from decades of operation at TRIUMF.

Source Terms and Contaminants

The modelling of the site begins with the characterization of principal emissions that constitute source terms. For accelerator operation, the principal source term is exhausted air activation products originating within the shielded enclosures of the 520 MeV accelerator and beamlines, and to a significantly lesser extent, from the three low-energy cyclotrons. There are smaller air effluent source terms from gaseous and volatile emissions associated with radioisotope production and manipulation of production targets in containment hot cells. These are considered as well in the ERA and have an impact that are less than a part in a thousand of that from the principal source terms.

The source term for liquid effluents comes from activation products formed in the cooling water for targets and beam stops, the treated process water for BWXT medical isotope production, as well as water used for laundry and cleaning of contaminated clothing, equipment and shielded enclosures.

Radionuclides are the principal Contaminants of Potential Concern (COPCs) associated with both air and liquid effluents. The principal contributors to the airborne source term and their respective half lives are C-11 (20 m), N-13 (10 m), O-15 (2 m), and Ar-41 (1.8 h). For liquid effluents, a neutralizer is added to effluent water to ensure the pH is appropriate for release to the sanitary sewer which goes to Iona Island sewage treatment plant.

Atmospheric and Aquatic Transport Mechanisms

Exposure of possible human receptors to the COPC was calculated using a pathways modelling approach as specified in CSA-N288.6-12. Pathways modelling combined the receptor characteristics described below with the environmental media concentrations of the COPC to determine the exposure of each receptor. These exposures are then compared with toxicological data to assess the risk and identify areas of concern.

Environmental media concentrations were estimated using atmospheric transport modelling, aquatic modelling, and a pathways model. Relevant atmospheric transport mechanisms included dispersion, deposition, and wind erosion. Atmospheric dispersion was based on five years of site meteorological data. Figure 3 is a wind rose for the TRIUMF site showing the frequency distribution of the direction from which the wind is blowing. This indicates that wind is predominantly from the north and east.

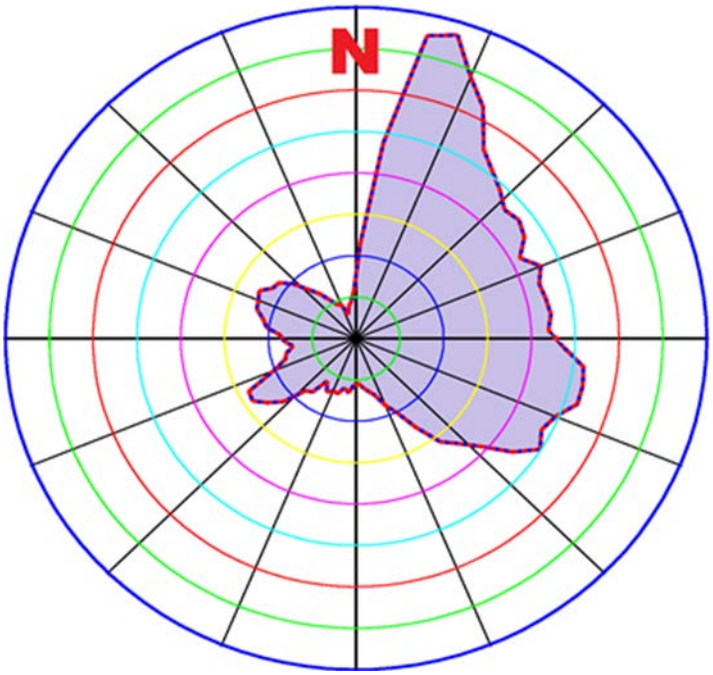

Figure 1 Wind rose for the TRIUMF site showing average relative wind direction frequency

The only aquatic transport mechanism with potential environmental impact is the release radioactive liquid effluents to the sanitary sewer and subsequently to the Strait of Georgia via the Iona Island waste treatment plant. Dilution used in the modelling was based on the ratio of TRIUMF's annual volume emissions compared to the annual flow of the Fraser River. The liquid waste is pumped out into Georgia Strait where it is diffused. Using the average volumetric flow rate of the Fraser River (3.54×10^3 m^3s^{-1}), the dispersion for the aquatic pathway is 2.9×10^{-7} sec/Liter.

Other Stressors

The cooling water temperature for the primary cooling loop can rise to 35C. However, at the time of its release to the sanitary sewer—always during shutdown—the temperature of the 100 L cooling water volume is 20-25C. This water is directed to the sewage treatment plant via the sanitary sewer and does not present a stressor to the environment.

At the time of release for the TR30 release tank (5.7E3 Litres), sodium hydroxide neutralizer is sometimes added to adjust the pH of the water between 5.5 and 10.5. The pH adjustment, when required to bring the pH in the acceptable range, is usually small (typically, from 5.0 to 5.5), requiring only about 0.1 Litre of weak sodium hydroxide solution (10^{-3} molar) to be added per tank release.

Comparison of Contaminant Level to Screening or Background Level

Airborne contaminant environmental monitoring, using data from a large Health Canada sodium iodide detector located on the roof of the nearby Emerging Technologies Centre of Canada and China (ETC3) building, has been carried out at TRIUMF. The location of the detector is in a direction close to that of the nearest neighbours and at a distance that is comparable. The detector is one of a network of detectors operated by Health Canada. It has been calibrated by the RPG using the β^+-emitter Na-22 to measure the dominant contributions to air activation products. The extracted and analyzed environmental data provide the measured dose at this location due to the air activation emissions. The results analyzed since 2014 are shown in the table below. The table also includes the predicted dose based on the source measurements and the atmospheric dispersion model. The comparison between the predicted and measured shows that the model over-predicts dose to the critical group by a factor of two to three. The results indicate an annual dose impact for a member of the critical group of 3 micro-Sieverts which is 0.15% of dose from natural background (2 mSv annually).

Measured and predicted doses (nSv) for Airborne Contaminants

Year	Measured Dose (nSv)			Predicted Dose (nSv)	Ratio
	511 keV	1294 keV	Total		
2014	3.17E+03	1.85E+02	3.35E+03	8.89E+03	2.65
2015	2.61E+03	1.28E+02	2.73E+03	7.50E+03	2.74
2016	2.37E+03	1.10E+02	2.48E+03	7.86E+03	3.17
2017	2.63E+03	1.17E+02	2.75E+03	8.32E+03	3.02
2018	2.55E+03	1.00E+02	2.65E+03	6.28E+03	2.37
2019	3.01E+03	1.20E+02	3.12E+03	6.14E+03	1.97

Only source measurements are made for liquid effluents. The modelling shows that even for a conservative maximum concentration there is a negligible human health dose impact (<<1 nSv) for all waterborne effluents.

Similarly, using the conservative dilution factor for the chemical stressor sodium hydroxide as neutralizer, the environmental concentration in the water is 10^{-08} mg/Litre. Exposure to sodium hydroxide in a basic solution (i.e. pH>7) can cause skin and eye irritation, although contact with weak solutions will not cause any harm. In the context of its use by TRIUMF, there should be no ill effects at all because the water treated with it starts out slightly acidic and remains slightly acidic even after the NaOH has been added.

Conclusion

The largest environmental risk posed by TRIUMF's operation is that associated with radioactive airborne effluents. The dose impact for a member of the critical group is less than 0.2% of dose from natural background (2 mSv annually) and is consistent with the annual benchmark threshold provided by Health Canada.

The existing environmental monitoring program is sufficient to address the risks associated with the current facility operations and no changes to the program are recommended at this time. TRIUMF is committed to reviewing the monitoring program requirements if the risk analysis for new projects identifies the need for expansion of the existing program.