

McMaster Nuclear Reactor

McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1
NPROL-01.00/2024

Annual Compliance Monitoring and Operational Performance 2023

Summary Data for Public Information

Approved/Issued by:

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Executive Summary

The McMaster Nuclear Reactor was operated safely, securely, and effectively in 2023.

The McMaster Nuclear Reactor continued to support the educational and research goals of the University throughout the year in a wide variety of areas including nuclear science and engineering, environmental science, medical and health physics, materials sciences, health sciences and radiochemistry.

The costs associated with the safe and secure operation and maintenance of the facility were offset through a variety of irradiation services, medical isotope production activities and government grants.

Reactor availability was 79.8% with no major unplanned outages taking place during the year.

There were no Reportable Events related to radiation safety or operations at the McMaster Nuclear Reactor in 2023.

There were no lost time injuries, near misses or major safety findings in 2023.

Doses to workers and releases to the environment remained as low as reasonably achievable throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2023. The results of an independent environmental monitoring program conducted by the Canadian Nuclear Safety Commission staff supported their assessment that the environmental protection program at the McMaster Nuclear Reactor is effective.

The McMaster Nuclear Reactor continues to support material scientists and the medical isotope community from across Canada as they relocate their research to McMaster. The University is actively engaged in the development and deployment of Small Modular Reactor (SMR) technologies.

Announcements were made by the federal and provincial governments allocating \$13.6 million to McMaster University to support medical isotope research and innovation. This funding will be used in part to expand the operation of the McMaster Nuclear Reactor to a 24-hour, 5 days a week operations cycle. A trial period of 24-hour operation was completed in 2023.

An application was submitted by McMaster University staff to the Canadian Nuclear Safety Commission, requesting a renewal of the McMaster Nuclear Reactor operating licence for a period of 20 years.

INTRODUCTION

General Introduction

McMaster Nuclear Reactor (MNR) is operated by McMaster University for research, education, and commercial service. 2023 saw a period of expanded operating hours with a trial period of 24-hour operation, and expansion to research beamport equipment.

The reactor was operated between 2.5 and 3.0 MW to accommodate research and production requirements. The standard operating schedule in 2023 was two shifts per day, Monday to Friday. Start-up took place as soon after 0800 as the scheduled safety checks would allow; shutdown was normally scheduled for 2245. Exceptions included short duration low power runs for researchers and laboratory classes, occasional extra operation for research or production purposes, planned outages for facility modifications, and unscheduled shutdowns. A six-week trial period of 24 hour per day 5 day per week operation was conducted in October and November 2023. During this period the reactor was occupied at 06:30 Monday morning, started up after required safety checks and run until 06:30 Saturday morning.

The MNR is operated under a CNSC licence (NPROL-01.00/2024). Further to that license, the McMaster document AP 1111, "Operating Limits and Conditions", contains statements about the operation of the reactor. These documents and associated specific policies and procedures ensure that MNR is operated in a manner which meets the requirements of the Nuclear Safety and Control Act (NSCA) and associated regulations. The MNR is operated in accordance with the applicable laws of the province of Ontario.

The operating licence for the McMaster Nuclear Reactor expires on June 30, 2024. An application was submitted to the Canadian Nuclear Safety Commission (CNSC) in April 2023 requesting a renewal of the operating licence for a 20 year period. The CNSC will conduct a hearing based on written submissions to consider this renewal application during the second quarter of 2024.

There were no reportable incidents related to radiation safety or operations in 2023.

Several unused fuel assemblies were received from the shutdown Greek Research Reactor as part of an agreement between McMaster University and the National Centre for Scientific Research Demokritos in Athens. This fuel will be used to support MNR operations over the next few years.

Throughout the year, McMaster Nuclear Operations and Facilities (NOF) staff continued to expand the significant role of the MNR in the leadership of neutron-based science and medical isotope production within Canada.

Commissioning of a new processing facility for a Holmium-166 based radiotherapeutic product was completed in early 2023 and regular clinical production has been running since. This project leverages the success MNR has demonstrated in the irradiation of the target material and is key to supporting North American clinical trials scheduled over the next few years.

University and NOF staff have been working with various institutions and vendors to support the development and deployment of SMR technologies in Canada. A feasibility study investigating the deployment of a micro modular reactor on the McMaster campus was completed in 2023.

In 2023, \$13.6 million in funding was announced by the Canadian and Ontario governments, allocated to McMaster University to support medical isotope research and innovation. This funding is being used in part to expand the operation of the MNR to a 24-hour, 5 days a week cycle starting in early 2024. A six-week trial of 24 hour operation was completed in 2023. The trial was successful and demonstrated that NOF staff will be able to run the MNR on a 24 hour cycle as planned in 2024.

Facility Operation

Reactor operation proceeded normally throughout 2023. Overall performance continues to be positive. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

There were eight (8) unscheduled shutdowns in 2023. There was no evidence of any trends or significant changes.

There were no significant issues with equipment or systems during 2023. Minor repairs and replacements were performed as required.

A major initiative to reorganize the Nuclear Operations and Facilities department at McMaster University was initiated in January 2023. A new Director, Reactor Operations and Maintenance was hired to assume all responsibility for MNR operations and maintenance in place of the former Director of Nuclear Operations and Facilities. This department wide reorganization continues and is expected to be finalized in 2024.

Radiation Protection

Dose Control Data

Three worker groups within MNR regularly receive significant occupational exposures: Operations Personnel, Iodine Production Personnel and NRay Radiographers. In addition, Health Physics personnel occasionally receive annual effective doses in excess of 1 mSv, however, no Health Physics staff members exceeded 1 mSv in 2023 for activities on the MNR licence. All other personnel associated with the operation of the facility receive annual effective doses of less than 1 mSv. The licensed dosimetry service provider is Mirion. TLDs are issued and reviewed on a quarterly dosimetry period.

Operations Personnel

Operations Personnel in 2023 comprise the Director of Nuclear Operations and Facilities, the Director of Reactor Operations and Maintenance, the Manager, Reactor Operations, Reactor

Supervisors, Reactor Operators, and Assistant Reactor Operators. Student Operators are also included in this group. The 2023 occupational exposures for the group are presented in **Table 2.3.1-1**.

Dose performance goals for the Operations Group are established annually and are based on the collective effective dose per unit output, with output taken as normalized MW-h energy output of the reactor (adjusted by a constant arbitrary normalizing factor). For 2023, the goal was 0.35 person mSv per unit relative output. The result for 2023 was 0.24 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-2**. The value is among historic lows for this metric.

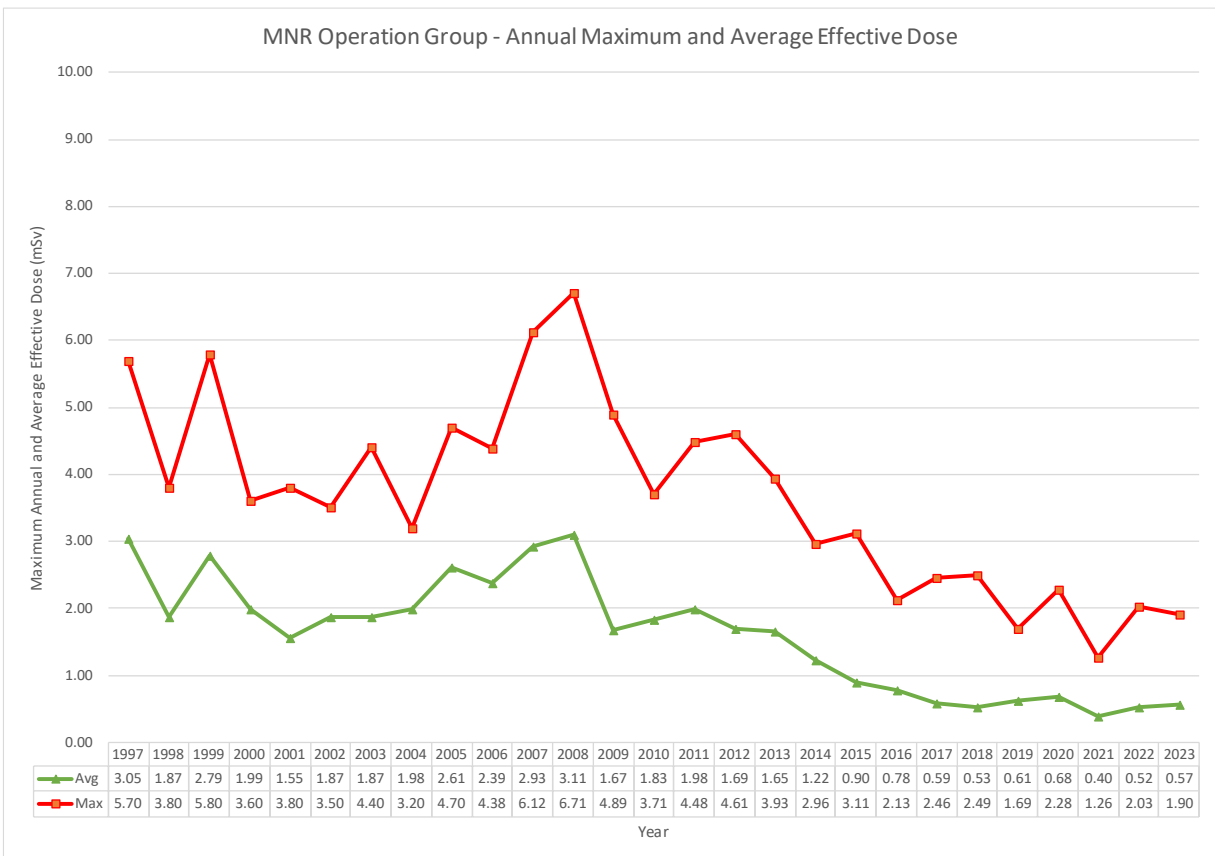


Figure 2.3.1-1

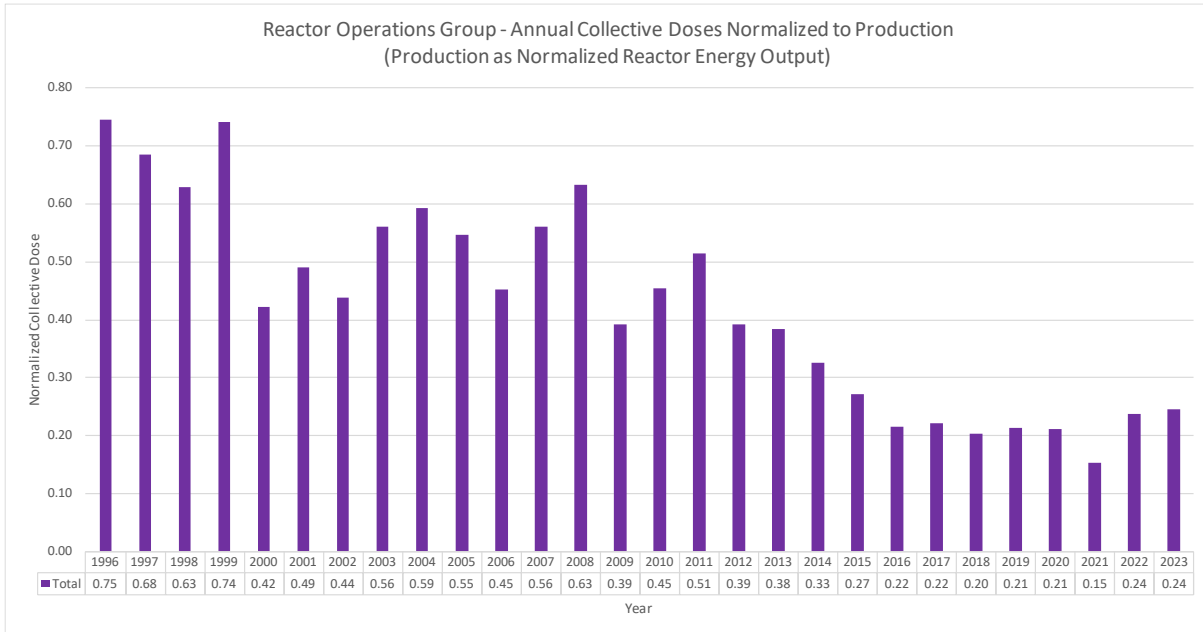


Figure 2.3.1- 2

Iodine Production Personnel

Iodine Production Personnel comprise the Production Manager, Production Technologists, and Production Assistants. The 2023 occupational exposures for the group are presented in **Table 2.3.1-3**.

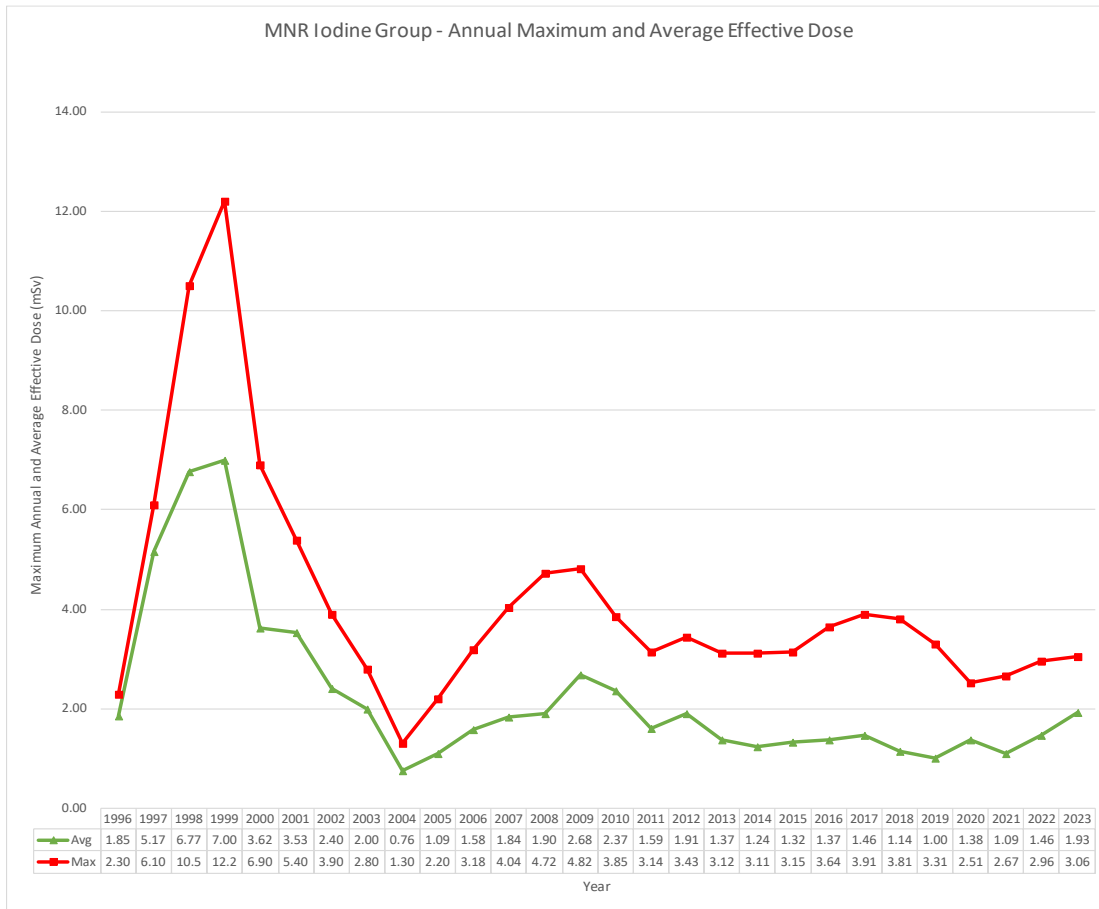


FIGURE 2.3.1-3

Dose performance goals for the Iodine Production Group are established annually and are based on the collective effective dose per unit output, with output taken as activity of I-125 produced (adjusted by a constant arbitrary normalizing factor). For 2023, the goal was 0.25 person mSv per unit relative output. The result for 2023 was 0.22 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-4**. A continuing trend of excellent performance is evident, with the 2023 value among the lowest historical values for the facility.

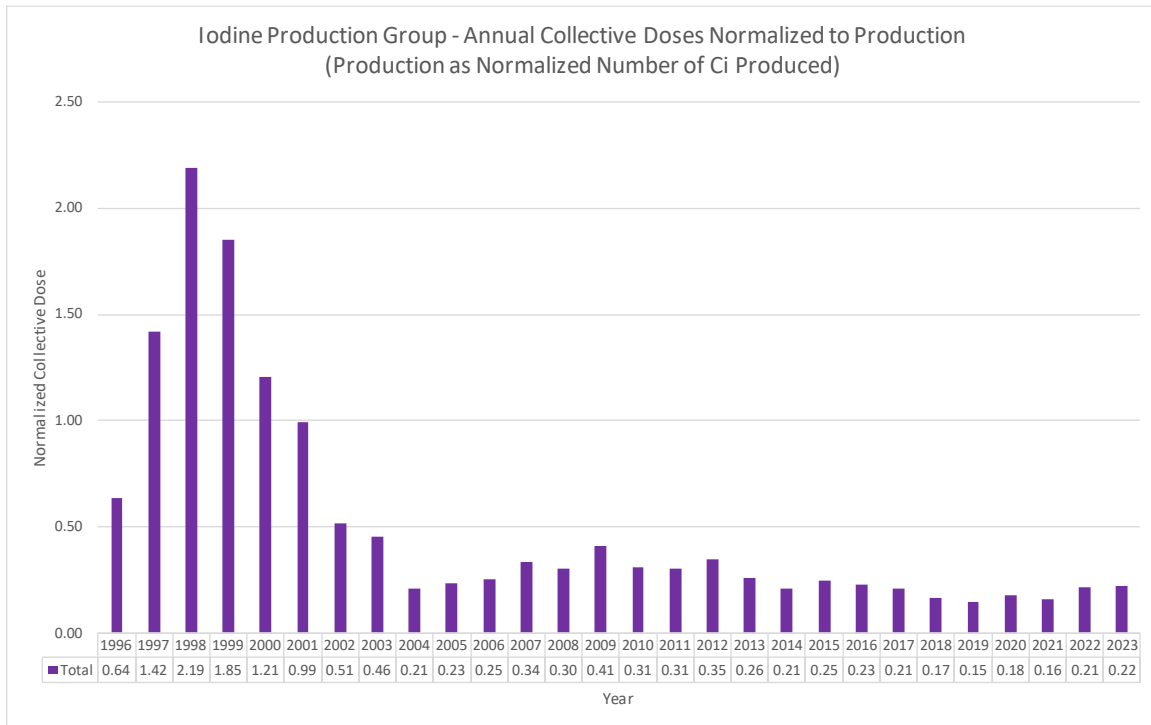


Figure 2.3.1-4

NRay Radiographers

The NRay Radiographers group comprises the Operations Manager, the Development Officer, the Radiography Manager, the Radiography Supervisors, and the Material Handlers. All are employees of NRay Inc., a private company that utilizes beam ports in the reactor under contract. There is no distinction for users based on employer under the MNR radiation safety program. The 2023 occupational exposures for the group are presented in **Table 2.3.1-5**.

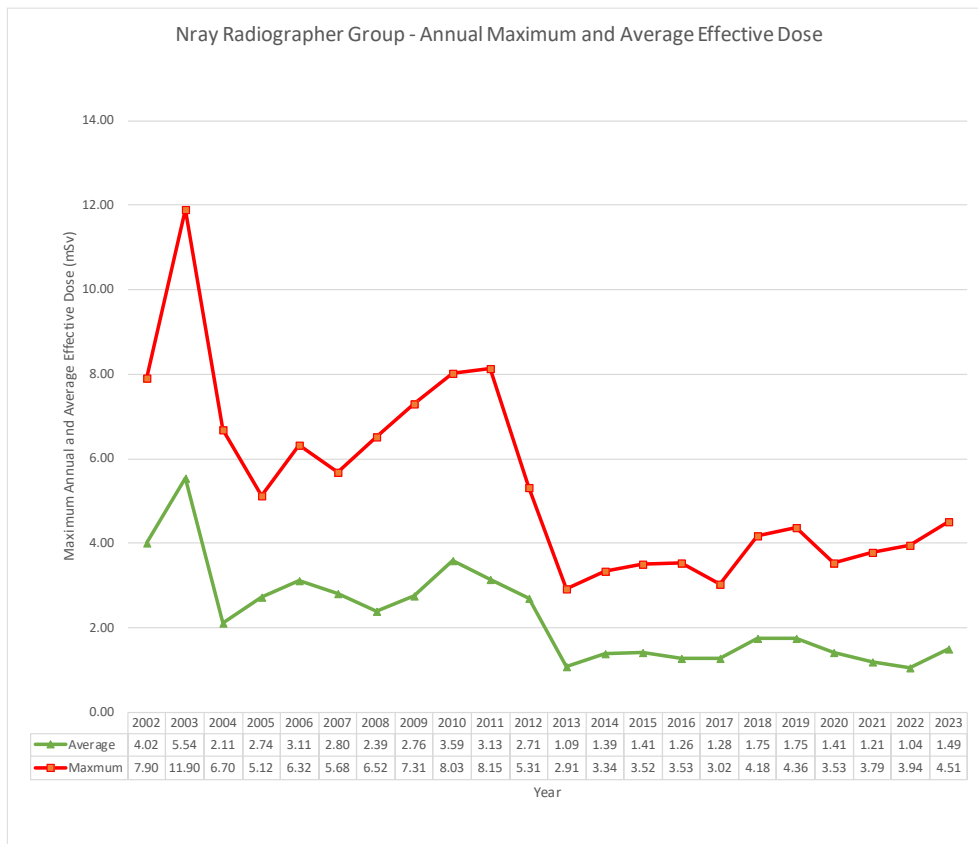


Figure 2.3.1-5

Dose performance goals for the Radiographers Group are established annually and are based on the collective effective dose per unit output, with output taken as the normalized number of radiographs produced (adjusted by a constant arbitrary normalizing factor). For 2023, the goal was 0.20 person mSv per unit relative output. The result for 2023 was 0.20 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-6**. Performance continues to be excellent, near historically low values.

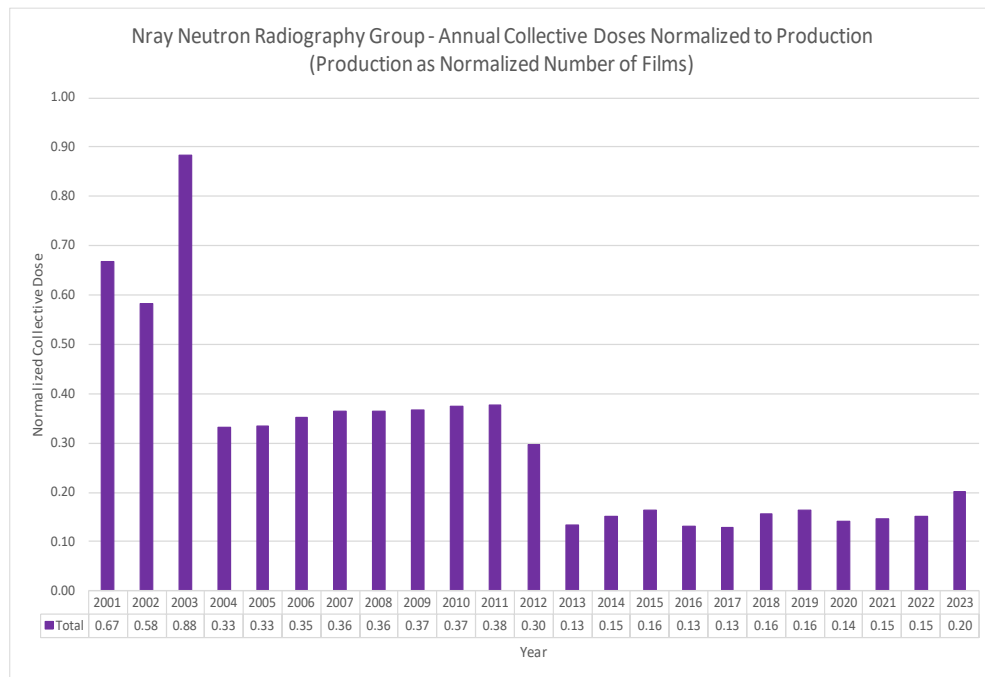


Figure 2.3.1-6

Health Physics

No members of the Health Physics Department received an annual effective dose over 1 mSv for work at the McMaster Nuclear Reactor. The maximum dose for a member of the Health Physics department supporting MNR was 0.96 mSv during 2023. The dose was accumulated gradually through the year on various tasks in the Reactor Building and other McMaster facilities. Dose was accumulated during routine support operations and in support of radiological work plans. All other Health Physics department members were below 1 mSv for 2023.

Overall Performance

The historical values of the overall facility collective dose are shown in **Figure 2.3.1-7**. The facility collective dose was comparatively high in 2010 and 2011, largely as a result of extensive maintenance and waste inventory reduction efforts during those years. The value for 2023 was slightly higher than the previous year but is still low in the historical context. In general, the increased dose can be attributed to overall increased facility utilization in 2023. All NEWs have their doses tracked by TLDs. Visitors and Non-NEWs have their doses tracked by electronic personal dosimeters (EPDs). The highest dose to a non-NEW was 0.027 mSv.

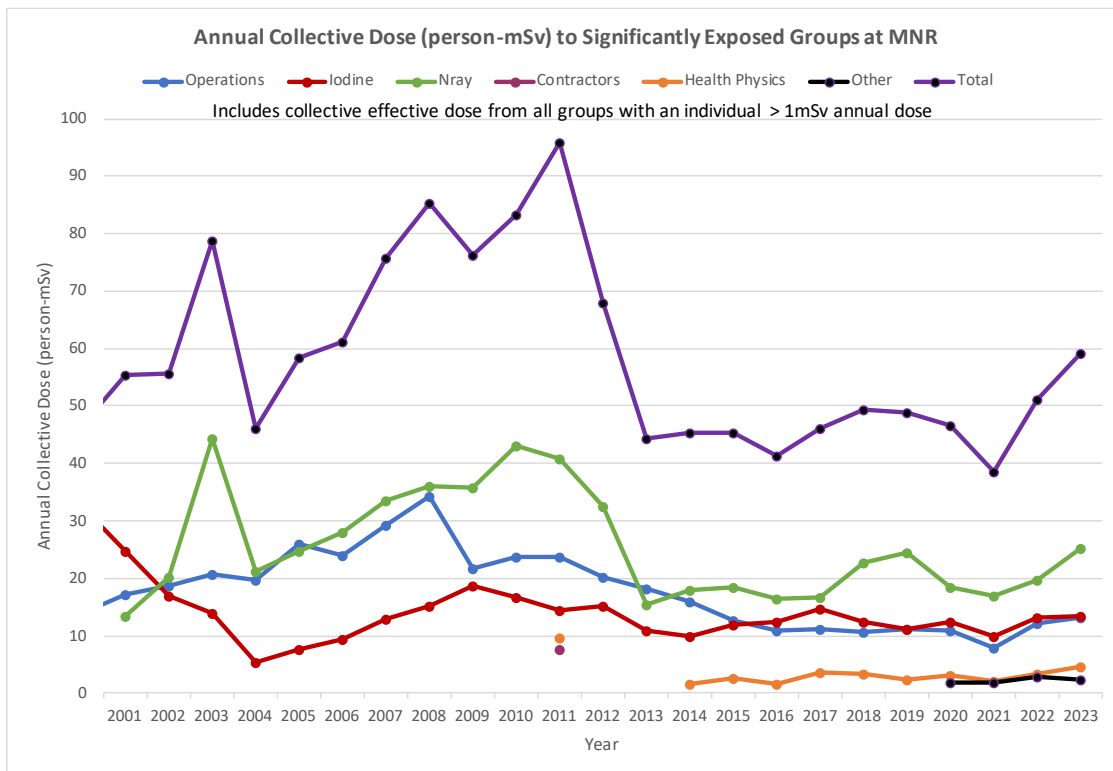


Figure 2.3.1-7

Significant Radiological Incidents

During 2023:

- There were no incidents in which Action Levels (Administrative Control Levels) were exceeded;
- There were no incidents in which Regulatory Limits were exceeded; and
- There were no incidents which constituted reportable information, or a reportable occurrence related to the radiation safety program.

Conventional Health and Safety

McMaster University has a comprehensive Health and Safety Program. The Program is in full compliance with the Occupational Health and Safety Act of the province of Ontario. The program is administered by Employee Occupational Health and Support Services. A University Central Committee monitors activities and programs for the entire campus; local committees comprising workers and managers work together to promote and provide a safe work environment. MNR is part of the McMaster Nuclear Operations (MNO) local safety committee.

The University provides many safety training courses. Relevant courses (determined by the individual's duties) are compulsory for all workers at MNR.

To highlight and promote the priority of safety on campus all members of the management team (including MNR managers) have explicit safety goals embedded in their annual performance appraisals. All 2023 goals were met or exceeded.

During 2023, the committee met virtually on several occasions. Workplace inspections continued throughout the year. Deficiencies or findings noted during facility inspections were reviewed and corrective actions were identified.

There were no lost time injuries, no First Aid injuries and no incident reports of injuries with first aid in 2023.

Fire safety systems were checked regularly by MNR and Facility Services personnel in compliance with fire code requirements.

Environmental Protection

Effluent Monitoring

Air effluents from the Reactor Building are continuously sampled for particulates and radioiodines. Samples are collected weekly and assessed for activity by windowless proportional counting for gross beta and by gamma spectrometry for ^{125}I . Results compared to the applicable Administrative Control Levels (ACLs) are presented in **Tables 2.3.3-1 and 2.3.3-2**.

Table 2.3.3- 1: Comparison of MNR Exhaust Particulate Concentrations with Applicable Limit – 2023

Annual Average Concentration: $5.8 \times 10^{-3} \text{ Bq m}^{-3}$
 Maximum Weekly Average Concentration: $4.4 \times 10^{-2} \text{ Bq m}^{-3}$

Annual Release			Maximum Weekly Release Rate		
Activity Released	ACL	Release as % of ACL	Activity Release Rate	ACL	Release as % of ACL
Bq	Bq	%	Bq / week	Bq / week	%
4.1E+05	5E+08	0.08%	6.1E+04	9E+06	0.67%

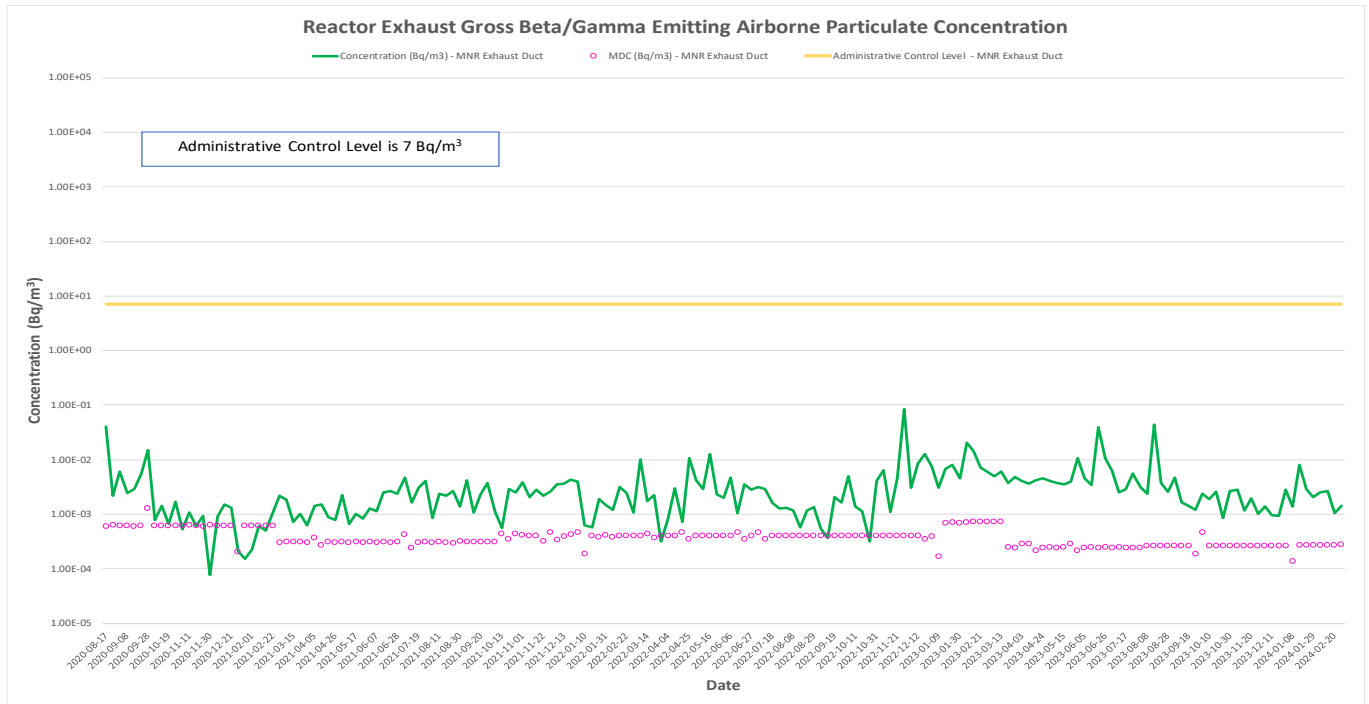


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2023

Annual Average Concentration: 1.27 Bq m⁻³
 Maximum Weekly Average Concentration: 9.86 Bq m⁻³

Activity Released	Annual Release			Maximum Weekly Release Rate			
	ACL	Derived Release Limit	Release as % of DRL	Activity Release Rate	ACL	Derived Release Limit	Release as % of DRL
	Bq	Bq	%	Bq / week	Bq / week	Bq / week	%
	1.0E+10	9.4E+12	0.0010%	1.4E+07	1.9E+08	1.8E+11	0.0075%

Boundary Dose = 0.023 micro-Sv

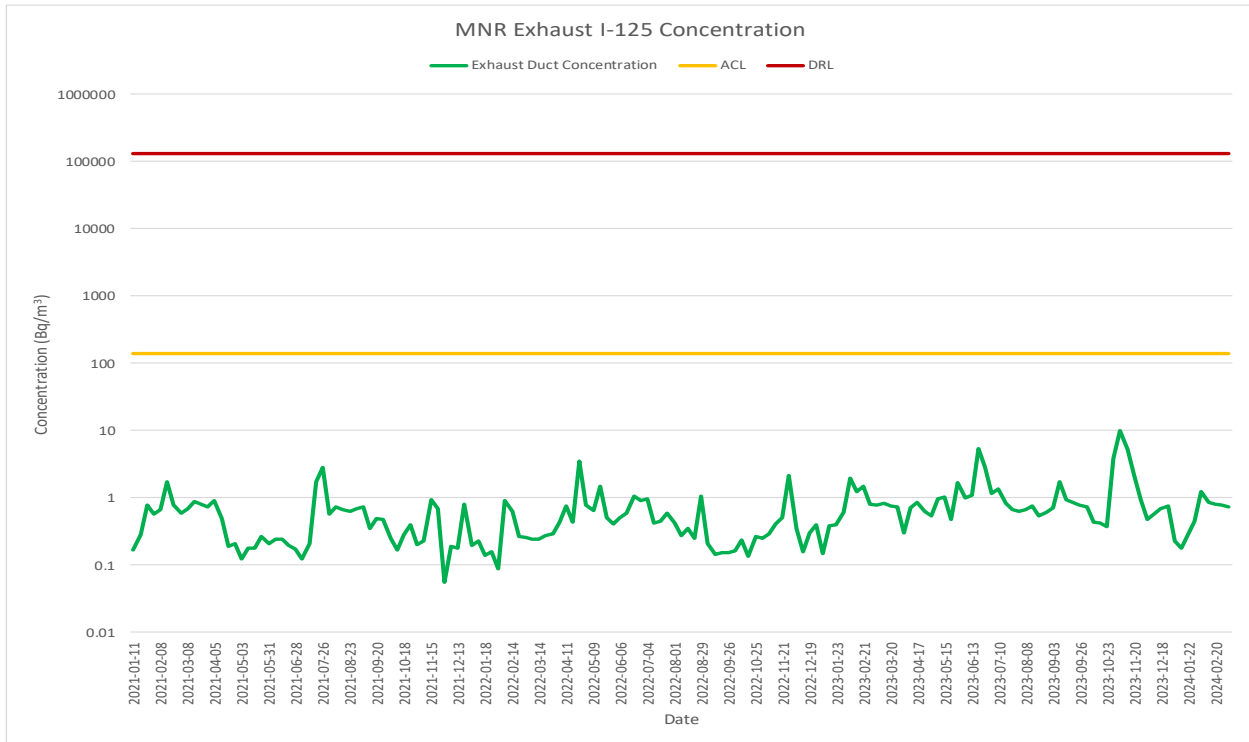


Figure 2.3.3-2

During reactor operation, daily measurements of ⁴¹Ar concentrations in the exhaust are made using a gas counting chamber. ⁴¹Ar concentrations are a function of pool water temperature, pool water turbulence, flow rate, reactor power, time since start-up, external temperature, ambient pressure, and ventilation rate. Values obtained on Wednesdays are taken as representative of the week. Results compared to the applicable Administrative Control Level (ACLs) and Regulatory Limit are presented in **Table 2.3.3-3**. Recent results are presented in **Figure 2.3.3-3**. There are no trends of concern evident and values are consistent with recent history.

Table 2.3.3-3: Comparison of Ar-41 Concentrations with Applicable Limits – 2023

Annual Average Concentration: $6.0 \times 10^4 \text{ Bq m}^{-3}$
 Maximum Weekly Average Concentration: $1.56 \times 10^5 \text{ Bq m}^{-3}$

Annual Release				Maximum Weekly Release Rate			
Activity Released	ACL	Derived Release Limit	Release as % of DRL	Activity Release Rate	ACL	Derived Release Limit	Release as % of DRL
Bq	Bq	Bq	%	Bq / week	Bq / week	Bq / week	%
1.8E+12	1.6E+13	1.3E+15	0.13%	8.8E+10	3.1E+11	2.5E+13	0.35%

Boundary Dose = 3.66 micro-Sv

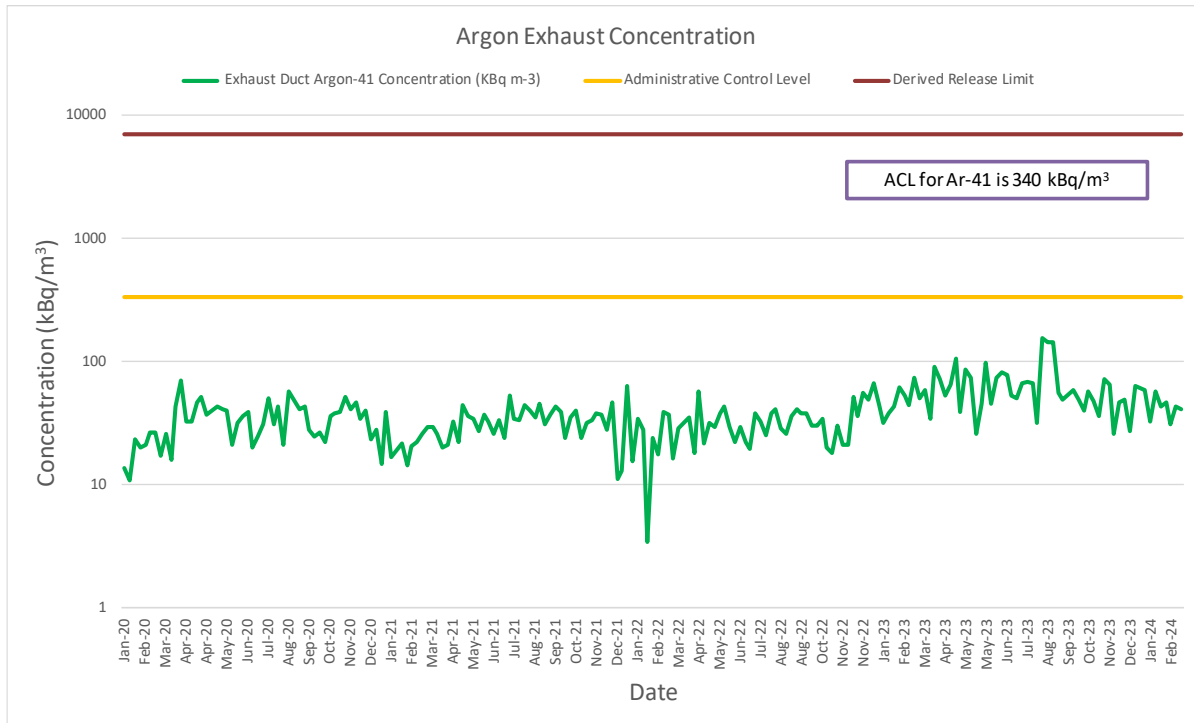


Figure 2.3.3-3

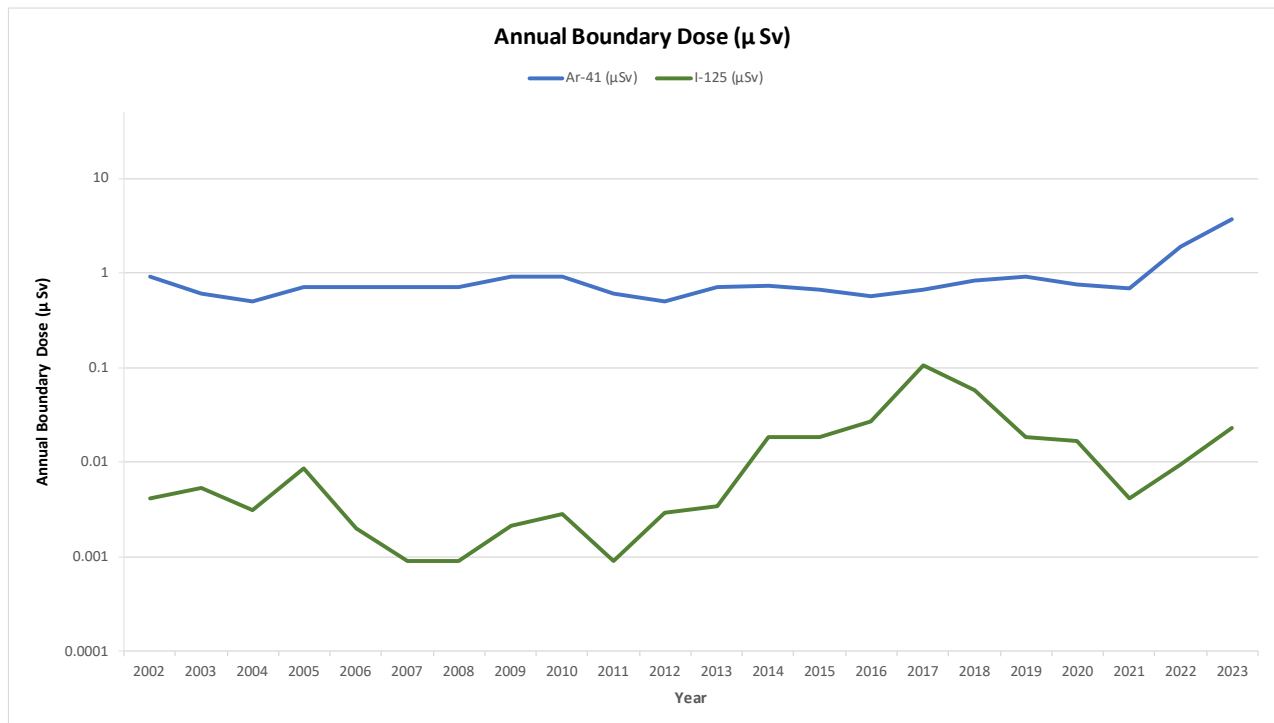


Figure 2.3.3-4

The dose to a hypothetical person at the point of maximum ground level concentration (the “Boundary Dose”) is calculated according to the method used to specify the facility Derived Release Limits. Historical values are presented in Figure 2.3.3-4.

There are two potential pathways for liquid releases from the facility; deliberate pump out from the building sumps to the municipal sewer and breakthrough of primary water to the secondary side of the heat exchanger.

There were no releases of contaminated liquids to the municipal sewer system in 2023. Liquid waste continues to be captured and processed or evaporated in the facility. The last release to the municipal sewer system occurred in 1988.

The gross beta emitting activity concentration of the secondary water in the heat exchanger is assessed weekly. Recent data from this monitoring are presented in **Figure 2.3.3-5**. There is no indication of any breakthrough to this system in 2023.

Environmental Monitoring

Several air monitoring stations are operated at locations surrounding the Reactor Building to sample environmental air for particulates and radioiodines. The particulate samples are changed weekly to prevent excessive dirt loading of the filter and the charcoal cartridges for radioiodines are collected monthly to maintain the minimum detectable concentrations at the lowest reasonable levels. The particulate samples are assessed for gross beta-emitting activity using a low-background sample counter and the cartridges are analyzed for ^{125}I by gamma

spectroscopy. Results of the monitoring for the past several years are shown in **Figures 2.3.3-6** and **2.3.3-7**. The results for 2023 are tabulated in **Table 2.3.3-4** and **Table 2.3.3-5**.

There was one spike identified in the concentration for three locations for the gross beta particulate in June 2023. The result was investigated but could not be reproduced and was not observed again. Possible explanations include sample cross-contamination or instrument issues for that one instance.

The environmental monitoring program results confirm the conclusion from the effluent monitoring program results that releases from MNR do not pose an unreasonable hazard to members of the public. There are no trends of concern evident, and values are consistent with recent history. There were no spills to the environment in 2023. MNR contributed no adverse environmental impact.

The effectiveness of the environmental monitoring program at the MNR was supported by the results of an independent environmental monitoring program conducted by CNSC staff in May 2023.

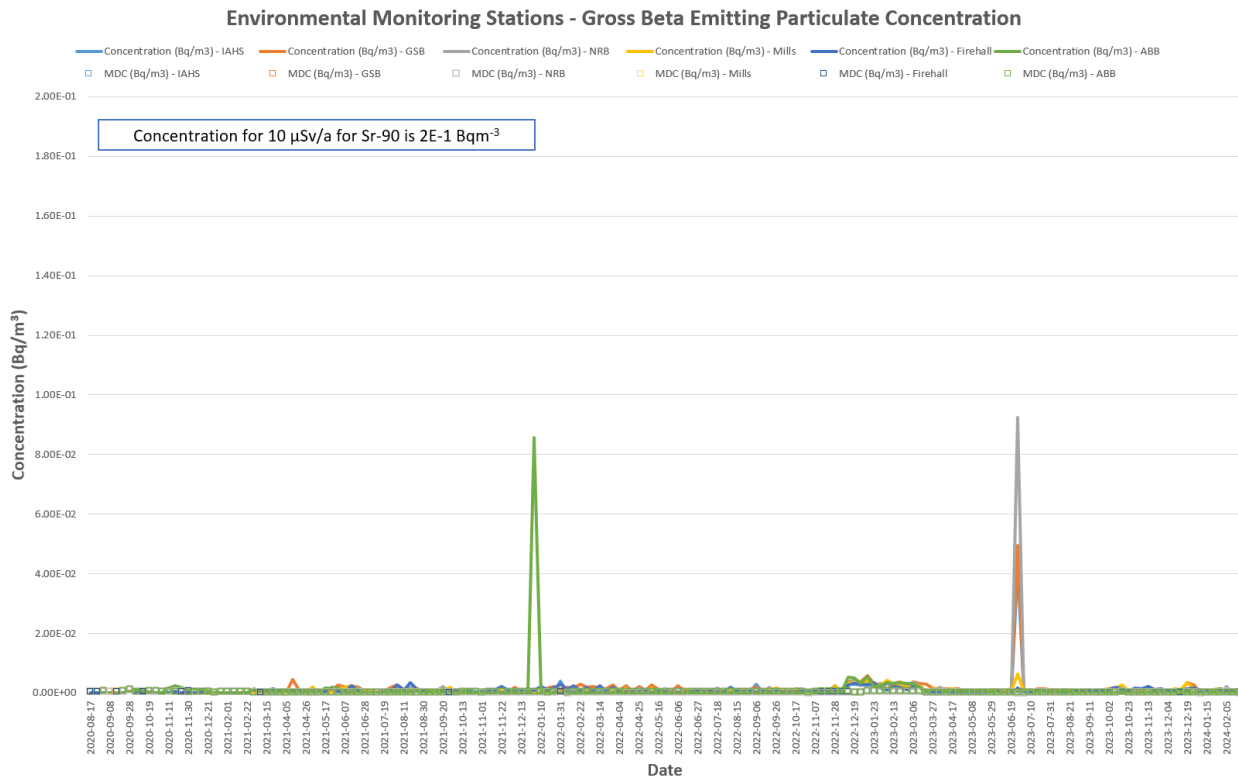


Figure 2.3.3-6

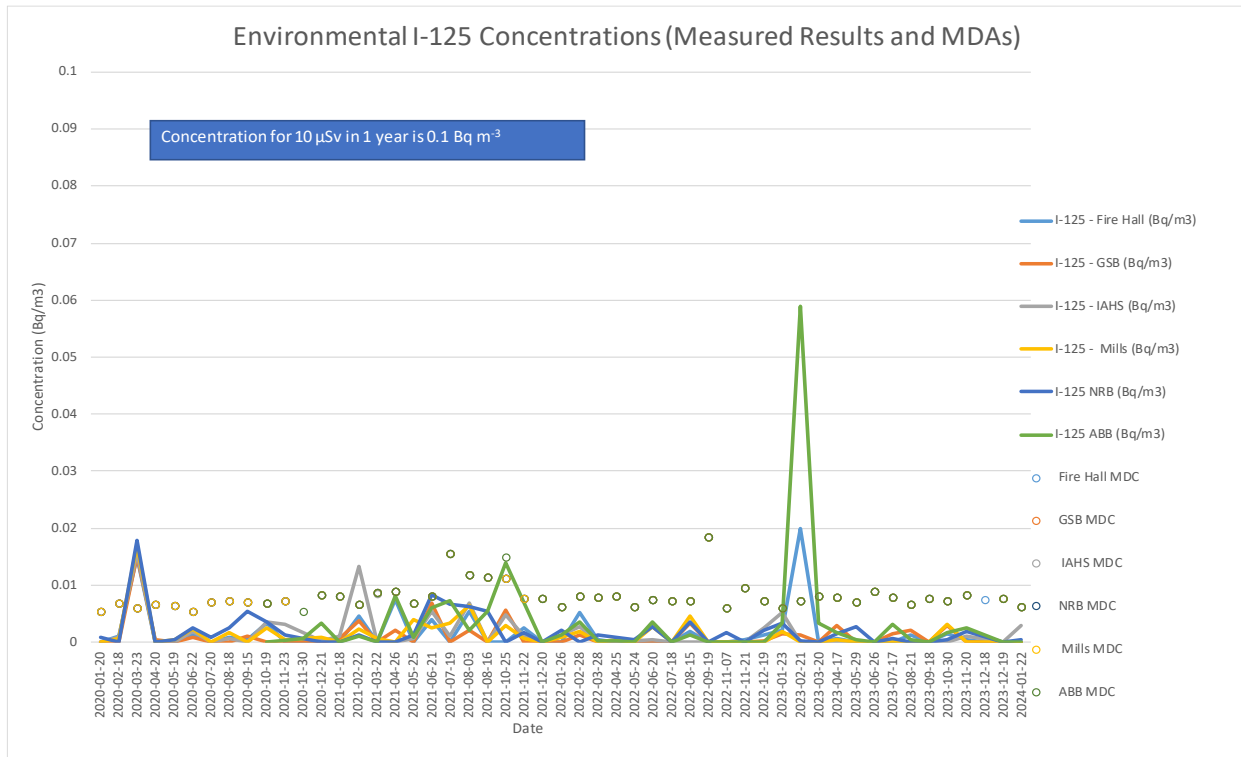


Figure 2.3.3-7

Emergency Management and Response

Emergency Preparedness Program

There were a number of improvements made to the MNR Emergency Preparedness Program in 2023. Revisions to the governing procedure EP-7000 were approved by the internal Nuclear Facilities and Controls Committee in 2023. The Emergency Preparedness Program is considered effective.

Additional changes in Emergency Response include:

- EP-7700 – Type B Transportation Emergency Response Procedure issued
- HP-PROC-EP-00002 – Transportation Emergency Response Procedure issued

Annual review of the Type D emergency procedures with University, City and Provincial emergency responders was held in February 2023.

Emergency contact list drills were conducted twice in conjunction with McMaster Security service and the “Send Word Now” system. A TERP drill was conducted in 2023. No additional drills were completed in 2023.

CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely, and effectively in 2023 and continued to support the educational and research goals of McMaster University. The reactor continued to operate normally supporting the needs of Researchers and providing life-saving medical isotopes throughout 2023.

There were no Reportable Events related to radiation safety or operations at MNR in 2023.

There were no lost time injuries, near misses or major safety findings in 2023.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2023.

Major projects planned for 2024 include:

- 1) Completion of the commissioning of the SANS instrumentation.
- 2) Planning and engineering will continue on the new CFI-IF infrastructure award focussed on expansion of neutron beam science at MNR.
- 3) A new organizational structure for the Nuclear Operations and Facilities department intended to enhance the University's Nuclear profile and mission will continue into 2024

The reactor had a very strong year providing expanded support for Canadian researchers, students and industries to its best ability given the realities of self-funding constraints.

A significant expansion to materials research and medical isotope research, development and supply continues.