McMaster Nuclear Reactor

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

Annual Compliance Monitoring and Operational Performance 2022

Summary Data for Public Information

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Executive Summary

The McMaster Nuclear Reactor (MNR) was operated safely, securely, and effectively in 2022.

MNR continued to support the educational and research goals of the University throughout the year specifically in the areas of nuclear science, environmental science, medical and health physics, engineering physics, health sciences, radiochemistry, biochemistry, and radiation biology.

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

Reactor availability was 80.5% with no major unplanned outages taking place during the year.

There were no Reportable Events related to radiation safety or operations at MNR in 2022. A labour disruption occurred at the university but did not involve personnel required for safe operation of the facility.

There were no lost time injuries, near misses or major safety findings in 2022. A conventional health and safety investigation was conducted after an incident involving the building crane. No injuries resulted, and a corrective action plan to address the root causes will be implemented 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 2022.

Until September 2022, Nuclear Operations and Facilities continued under the Business Continuity Plan for the reactor in response to the pandemic. Routine operation and medical isotope production (essential service) continued normally throughout 2022.

MNR continues to support material scientists and the medical isotope community from across Canada as they relocate their research to MNR. The University is actively engaged in the development and deployment of Small Modular Reactor (SMR) technologies and is pursuing a feasibility study to investigate the deployment of an SMR on campus.

In October 2022, an initiative to restructure the Nuclear Operations and Facilities (NOF) department was announced. This reorganization is intended to support the continued expansion of the departmental profile and mission that has been progressing over the past decade, while bringing with it a renewed focus on supporting Nuclear research and education.

As part of the departmental reorganization, the position of Director, Reactor Operations and Maintenance was created. In January 2023, Dr Derek Cappon was appointed to this new position and assumed responsibility as the signing authority for the MNR non-power reactor operating licence.

INTRODUCTION

General Introduction

McMaster Nuclear Reactor (MNR) is operated by McMaster University for research, education, and commercial service. 2022 was a typical year in terms of operation.

The reactor was operated between 2.5 and 3.0 MW to accommodate research and production requirements. The standard operating schedule 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.

MNR is operated under a CNSC license (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 NSCA and associated regulations. MNR is operated in accordance with the applicable laws of the province of Ontario.

There were no reportable incidents related to radiation safety or operations in 2022. A labour disruption involving education workers at McMaster occurred in November. The union representing operations and Health Physics staff was not involved in the dispute, and no staff required to safely operate the MNR participated in the strike. No significant interruption to facility operations or disruption to the supply of medical isotopes occurred as a result of the dispute.

Throughout the year, MNR continued to expand its significant role in the leadership of neutron-based science and medical isotope production within Canada.

McMaster University completed construction of a new processing facility on campus focussed on the supply of a new liver cancer fighting medical isotope treatment, but commissioning was not yet complete at the end of 2022. The project will leverage the success MNR has demonstrated in the irradiation of the target material and will be key in supporting North American clinical trials scheduled to take place over the next few years.

Throughout the year the University and Nuclear Operations and Facilities have been working with various institutions and vendors to support the development and deployment of SMR technologies here in Canada. A feasibility study investigating the deployment of a micro modular reactor on the McMaster campus was announced in 2022.

In October 2022, a new organizational structure for the McMaster Nuclear Operations and Facilities (NOF) department was announced. This reorganization is intended to advance the university's nuclear profile and mission. Recruitment for three new director roles, each overseeing an area of strategic focus, began in 2022, and the new organizational structure will

be implemented in 2023. In January 2023, Dr Derek Cappon was appointed to the new position of Director, Reactor Operations and Maintenance and assumed responsibility as the signing authority for the MNR non-power reactor operating licence.

Facility Operation

Reactor operation proceeded normally throughout 2022. Overall performance continues to be positive. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

The reactor was operated at power during 2022 for a total of 3,371 hours, for a total energy output of 10,102 megawatt-hours. At year-end MNR had been operated for 219,719 hours for a life-time energy output of 640,392 megawatt-hours. Reactor availability, defined for MNR as the percentage of operating hours relative to available hours, was 80.5%. **Figure 2.1.3-1** shows reactor operation and power output at MNR over the past ten years.

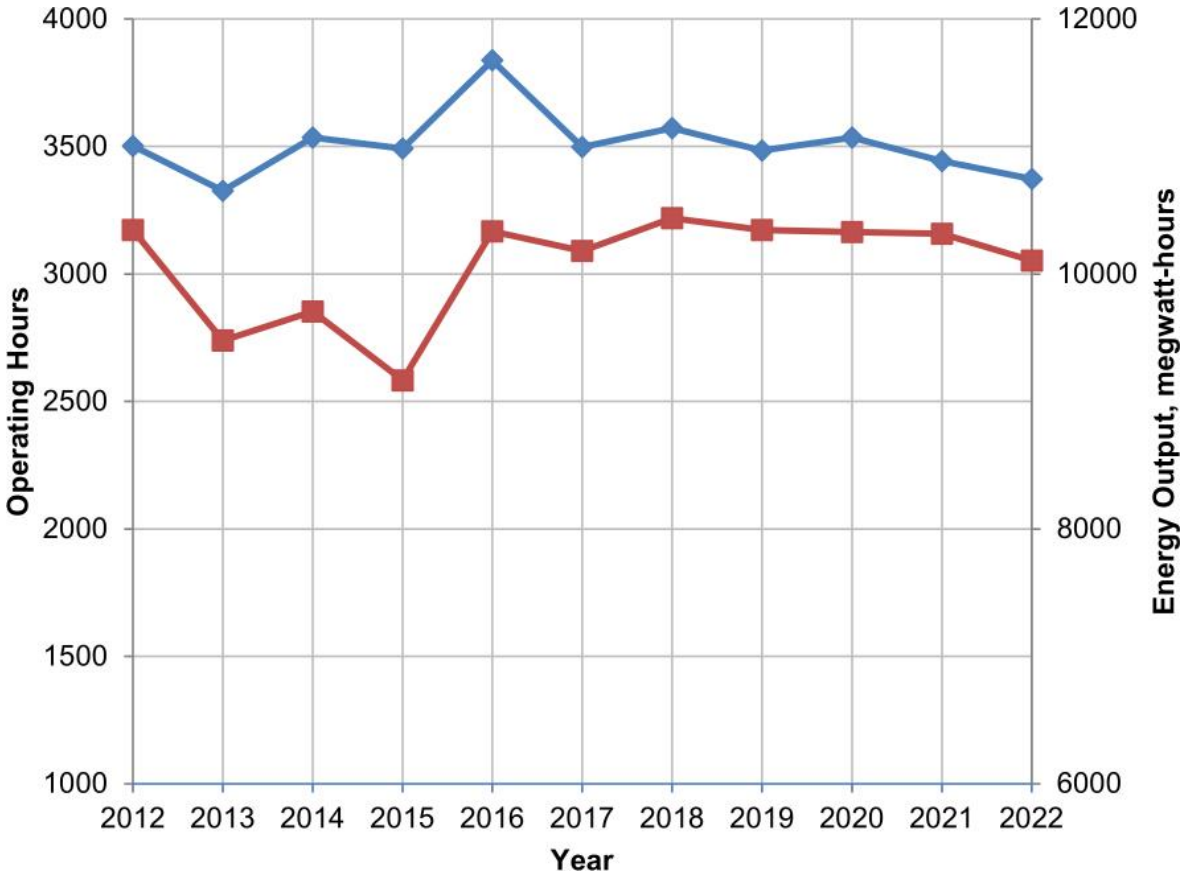


Figure 2.1.3-1 Reactor Operating Hours and Power Output

Work continued on the expansion of Small Angle Neutron Scattering (SANS) capabilities at McMaster. A new beam tube liner was installed in beam port #4.

Work continues to enhance reactor physics codes at MNR through the use of Subject Matter Experts on staff, graduate students at the University and through international collaboration in this area of focus.

Radiation Protection

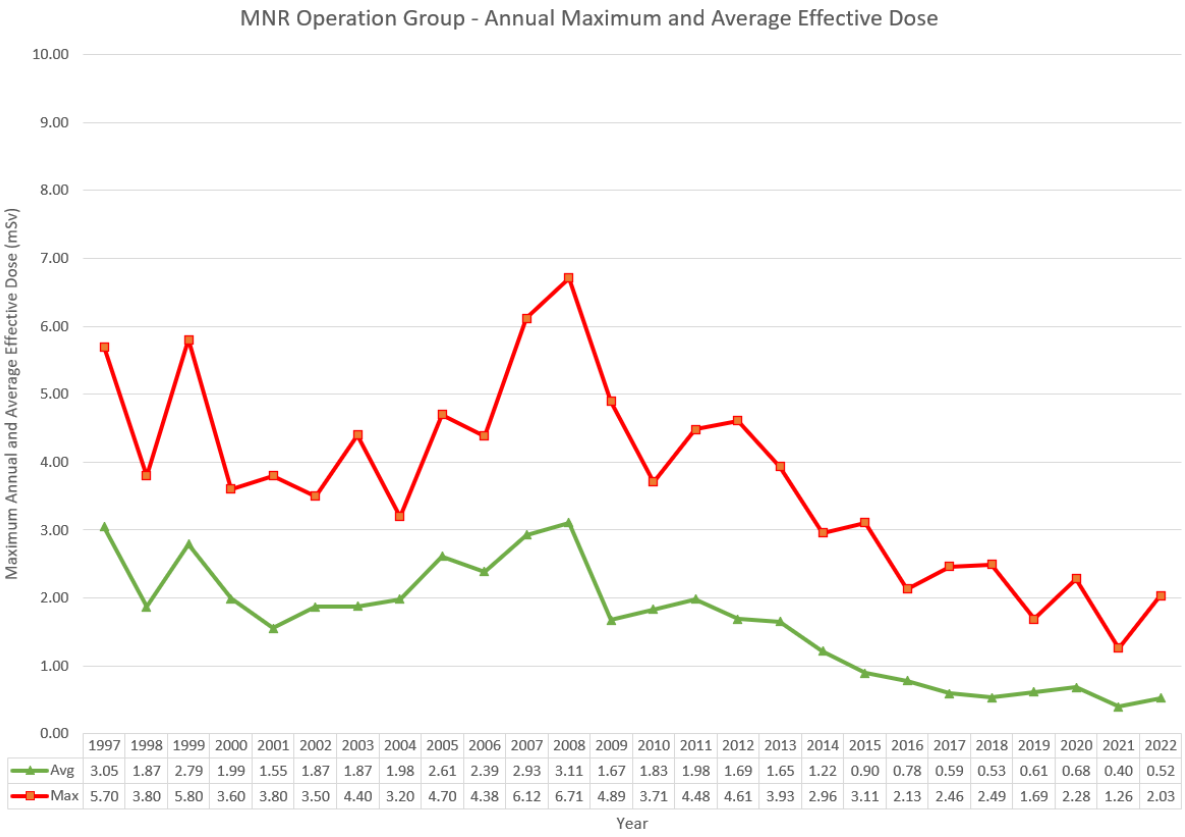
Dose Control Data

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 2022 for MNR 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 licenced dosimetry service provider is Mirion. TLDs are issued and reviewed on a quarterly dosimetry period.

Operations Personnel

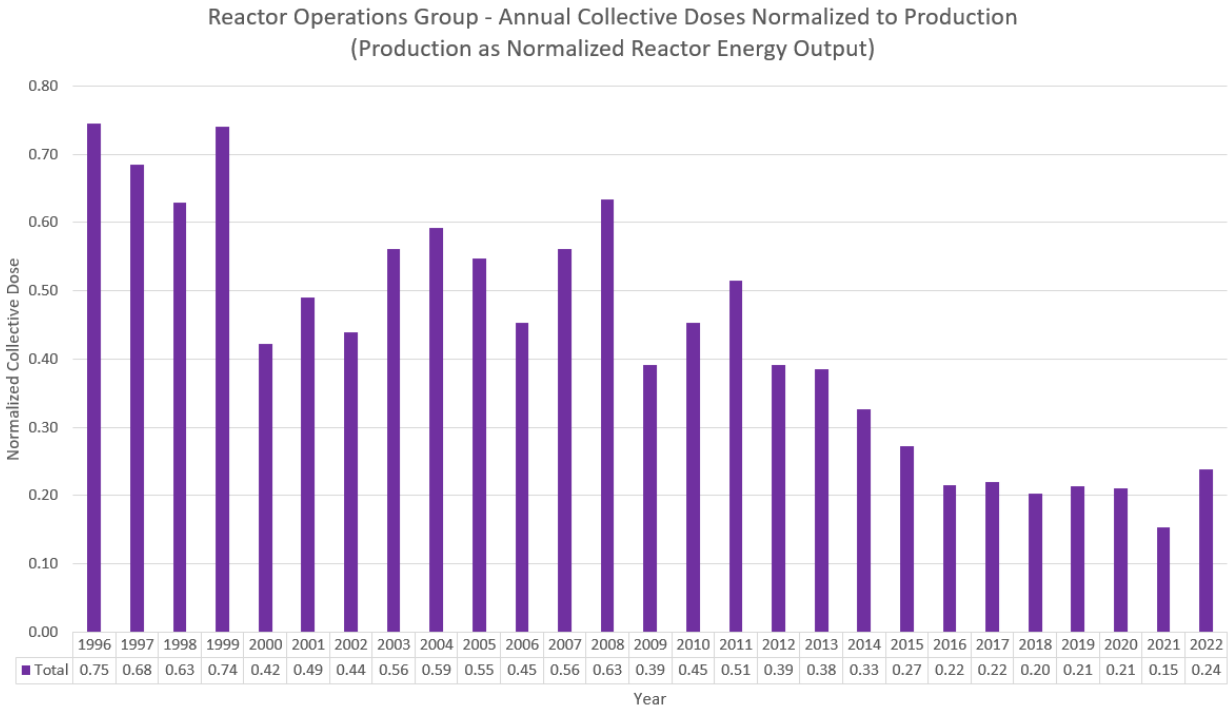
Operations Personnel in 2022 comprise the Director of Nuclear Operations and Facilities, the Manager, Reactor Operations, Reactor Supervisors, Reactor Operators, and Assistant Reactor Operators. Student Operators are also included in this group. The 2022 occupational exposures for the group are presented 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 2022, the goal was 0.3 person mSv per unit relative output. The result for 2022 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.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avg	3.05	1.87	2.79	1.99	1.55	1.87	1.87	1.98	2.61	2.39	2.93	3.11	1.67	1.83	1.98	1.69	1.65	1.22	0.90	0.78	0.59	0.53	0.61	0.68	0.40	0.52
Max	5.70	3.80	5.80	3.60	3.80	3.50	4.40	3.20	4.70	4.38	6.12	6.71	4.89	3.71	4.48	4.61	3.93	2.96	3.11	2.13	2.46	2.49	1.69	2.28	1.26	2.03

Figure 2.3.1-1

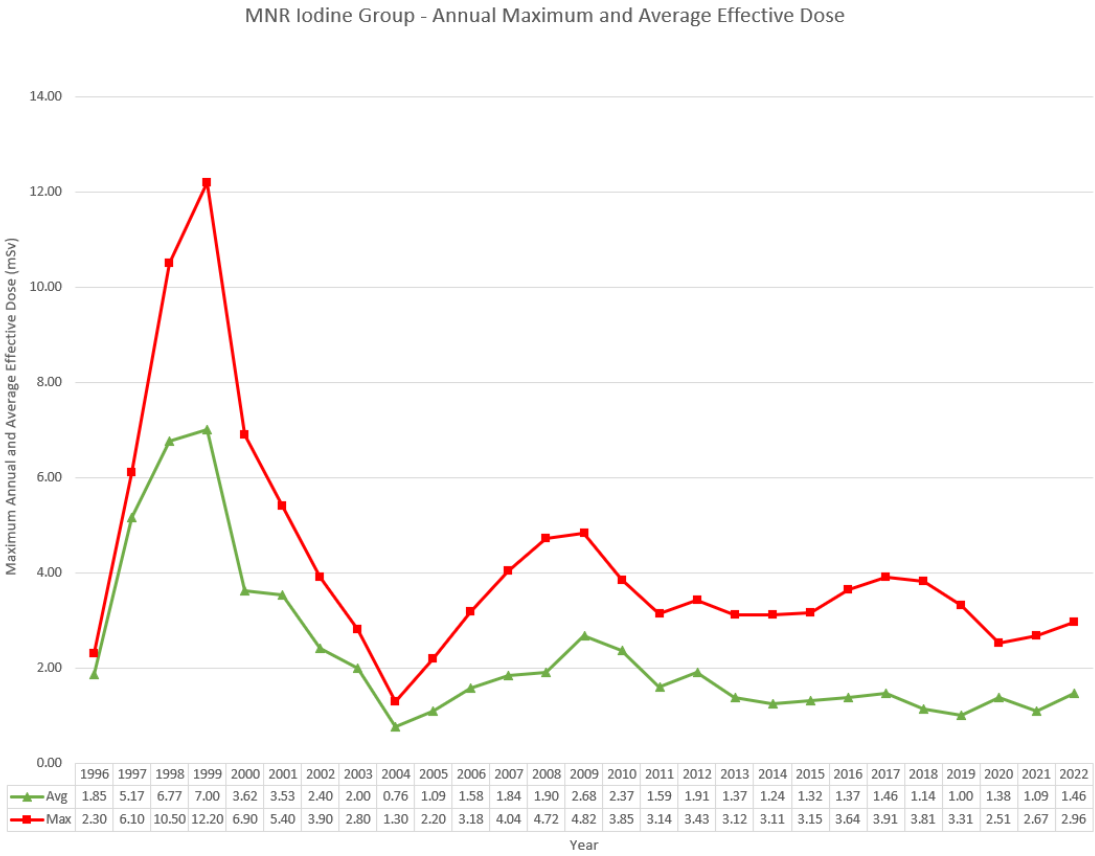


	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total	0.75	0.68	0.63	0.74	0.42	0.49	0.44	0.56	0.59	0.55	0.45	0.56	0.63	0.39	0.45	0.51	0.39	0.38	0.33	0.27	0.22	0.22	0.20	0.21	0.21	0.15	0.24

Figure 2.3.1- 2

Iodine Production Personnel

Iodine Production Personnel comprise the Production Manager, Production Technologists, and Production Assistants. The 2022 occupational exposures for the group are presented in **Table 2.3.1-3**.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Avg	1.85	5.17	6.77	7.00	3.62	3.53	2.40	2.00	0.76	1.09	1.58	1.84	1.90	2.68	2.37	1.59	1.91	1.37	1.24	1.32	1.37	1.46	1.14	1.00	1.38	1.09	1.46
Max	2.30	6.10	10.50	12.20	6.90	5.40	3.90	2.80	1.30	2.20	3.18	4.04	4.72	4.82	3.85	3.14	3.43	3.12	3.11	3.15	3.64	3.91	3.81	3.31	2.51	2.67	2.96

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 2022, the goal was 0.25 person mSv per unit relative output. The result for 2022 was 0.21 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 2022 value among the lowest historical values for the facility.

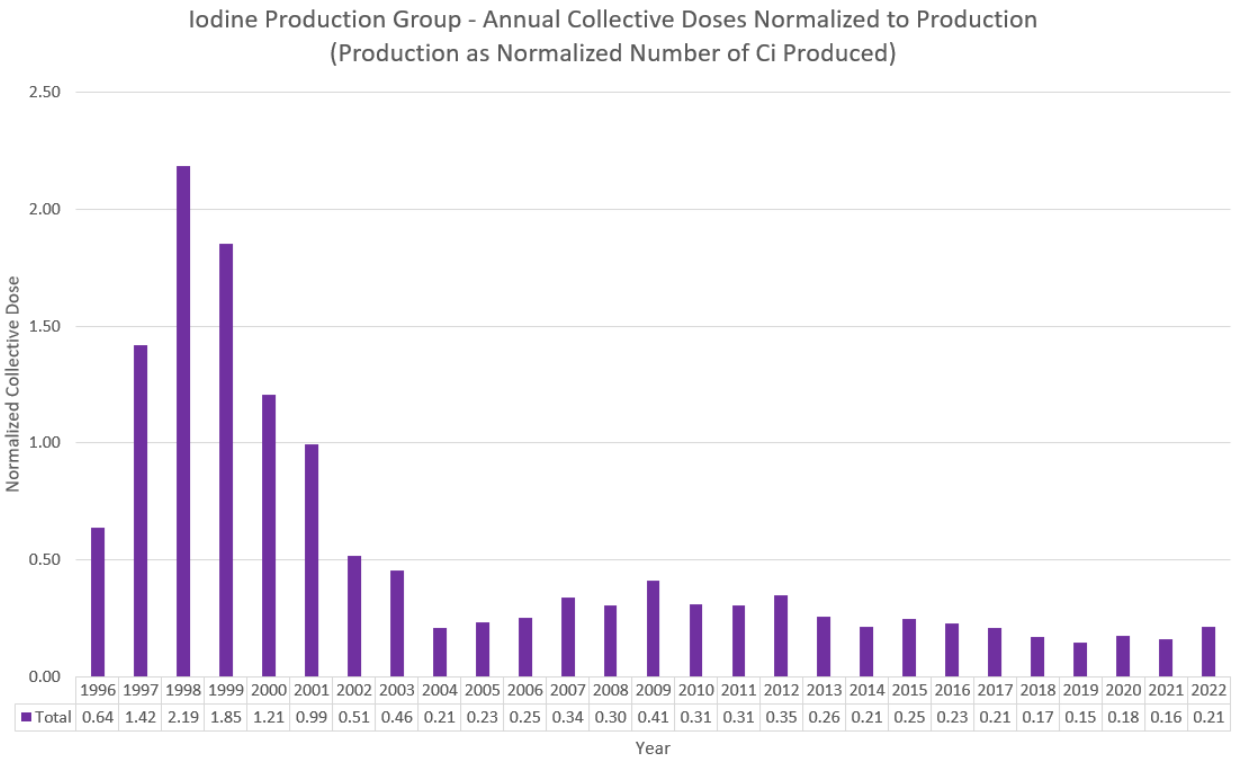
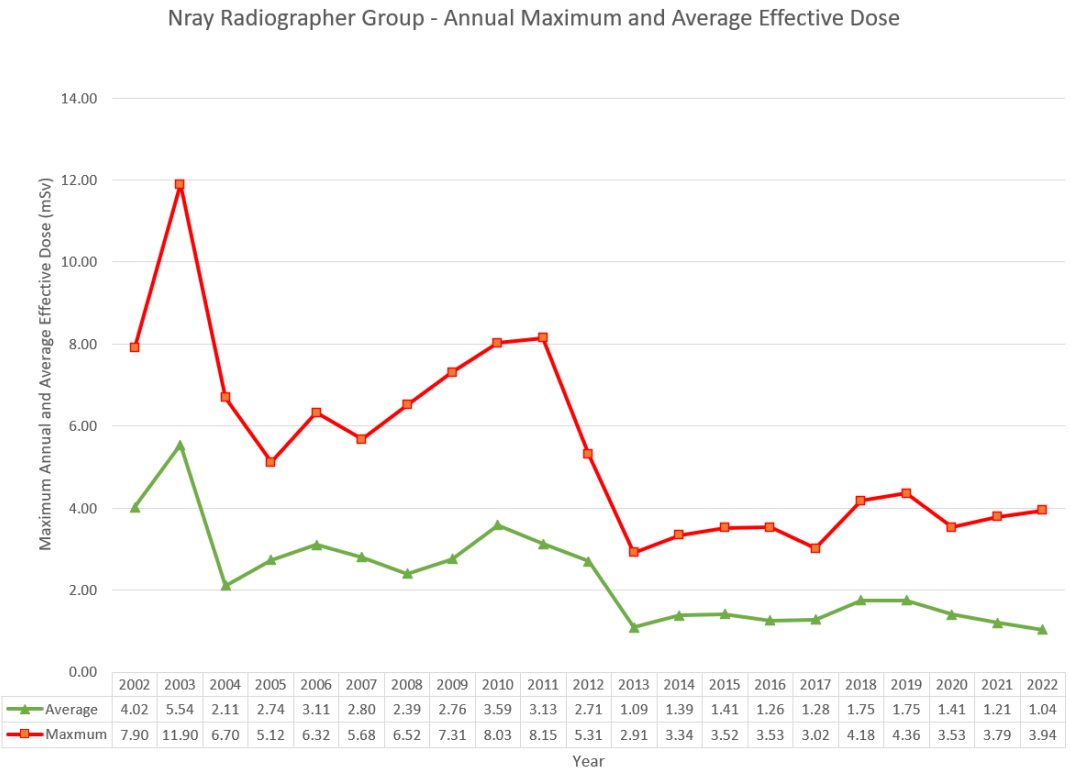


Figure 2.3.1-4

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 2022 occupational exposures for the group are presented in **Table 2.3.1-5**.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Average	4.02	5.54	2.11	2.74	3.11	2.80	2.39	2.76	3.59	3.13	2.71	1.09	1.39	1.41	1.26	1.28	1.75	1.75	1.41	1.21	1.04
Maxmum	7.90	11.90	6.70	5.12	6.32	5.68	6.52	7.31	8.03	8.15	5.31	2.91	3.34	3.52	3.53	3.02	4.18	4.36	3.53	3.79	3.94

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 2022, the goal was 0.20 person mSv per unit relative output. The result for 2022 was 0.15 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.

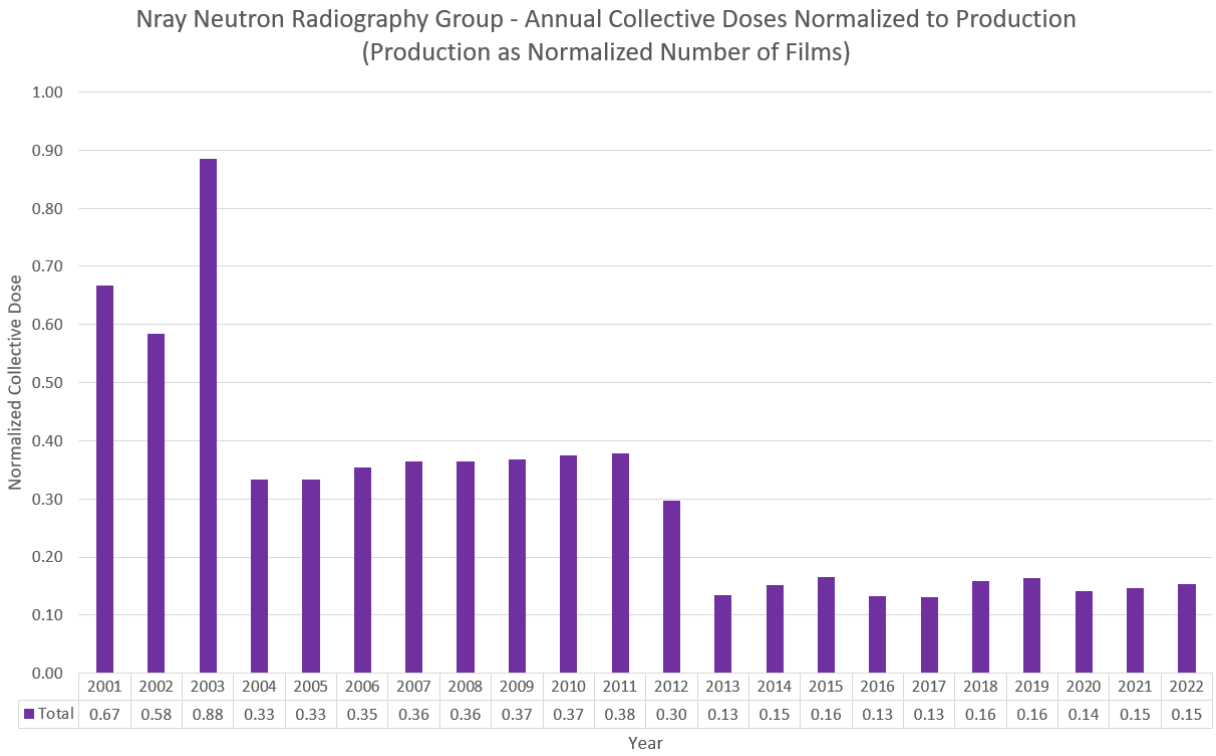


Figure 2.3.1-6

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 0.74 mSv during 2022. 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 2022.

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 2022 was slightly higher than the previous year but is still low in the historical context. In general, the increased dose can be attributed to maintenance work conducted at the end of 2022. 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 0.022 mSv.

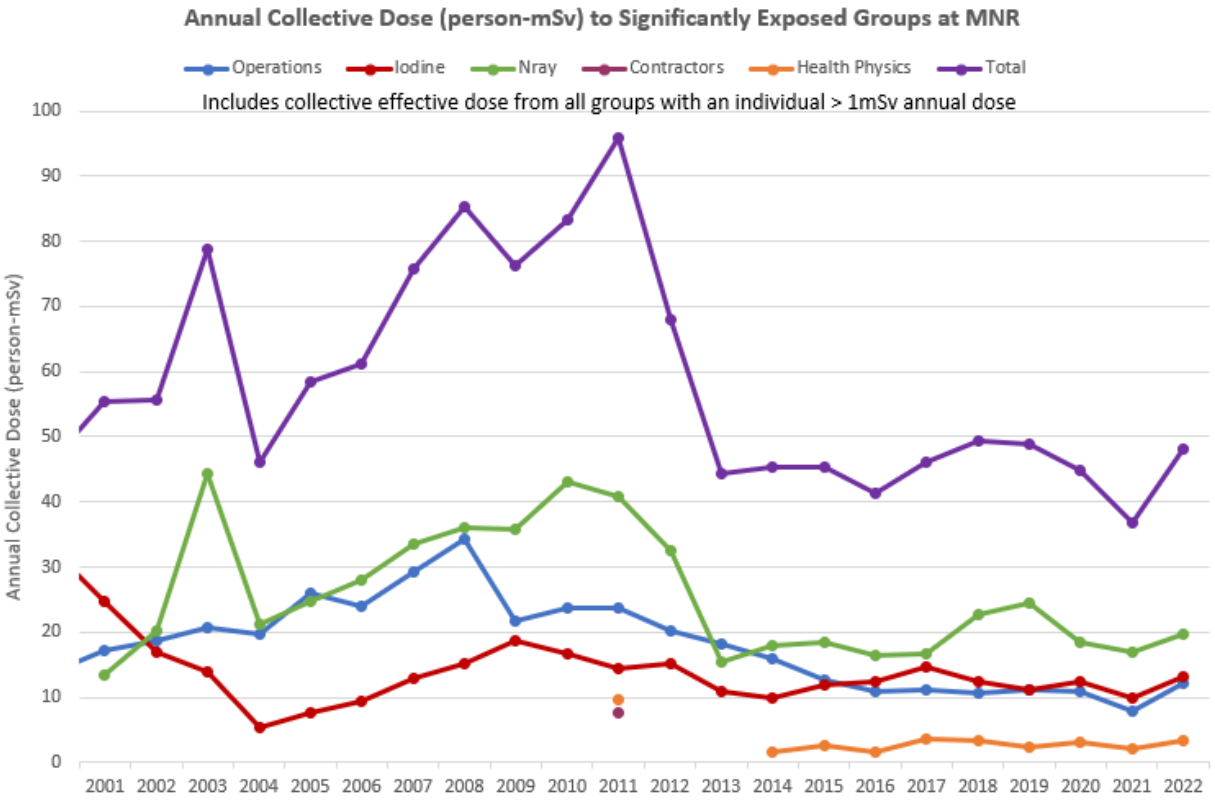


Figure 2.3.1-7

Significant Radiological Incidents

During 2022:

- 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 Institute of Applied Radiation Sciences (McIARS) 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 imbedded in their annual performance appraisals. All 2022 goals were met or exceeded.

During 2022, the committee met virtually on several occasions. Workplace inspections continued throughout the year. All 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 2022. One incident involving the building crane prompted a root cause investigation and report to the local safety committee. No personnel injuries occurred as a result of the incident. The root cause investigation team developed a corrective action plan that is being implemented to improve crane related safety within the facility.

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 – 2022

Annual Average Concentration: 4.6×10^{-3} Bq m^{-3}
Maximum Weekly Average Concentration: 8.5×10^{-2} 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	%
3.3×10^{5}	5.0×10^{8}	0.07	1.2×10^{5}	9.0×10^{6}	1.29

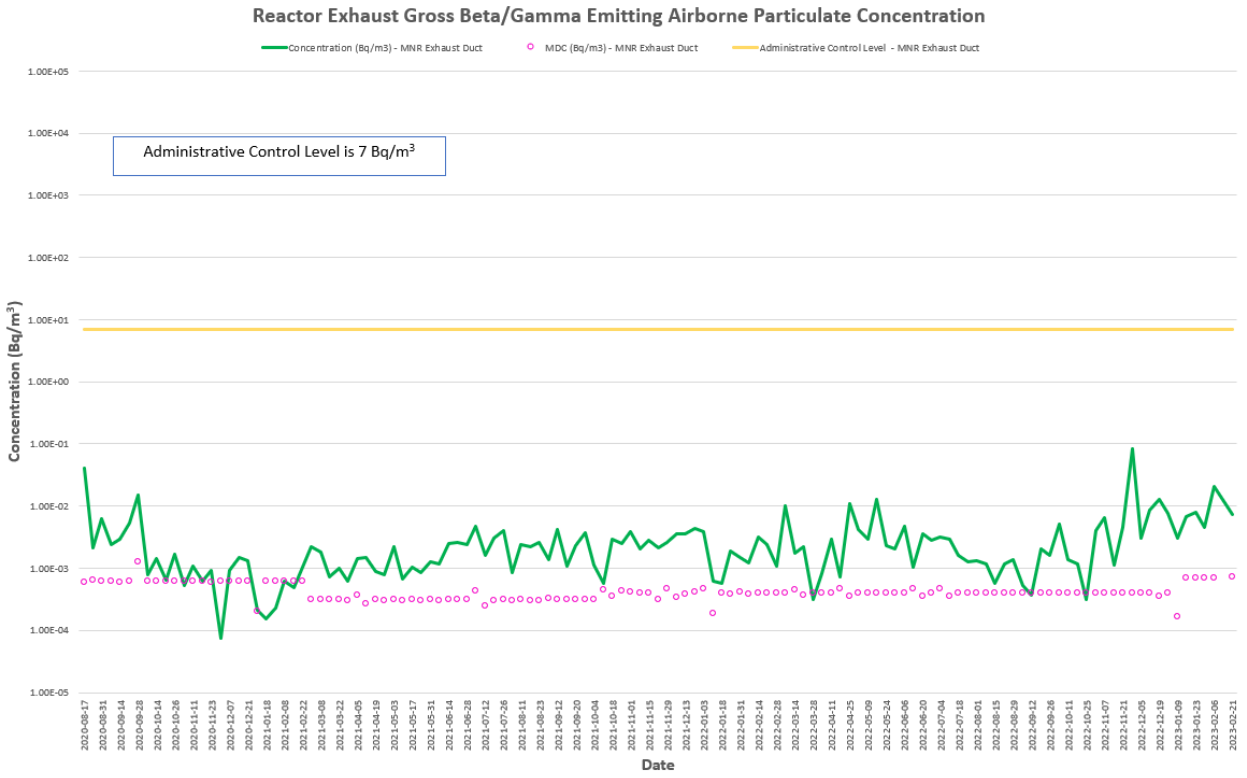


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2022

Annual Average Concentration: 0.5 Bq m^{-3}
Maximum Weekly Average Concentration: 3.5 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	%
3.7×10^{7}	1.0×10^{10}	9.4×10^{12}	0.0004	4.9×10^{6}	2.0×10^{8}	1.8×10^{11}	0.0027

Boundary Dose = 0.009 micro-Sv

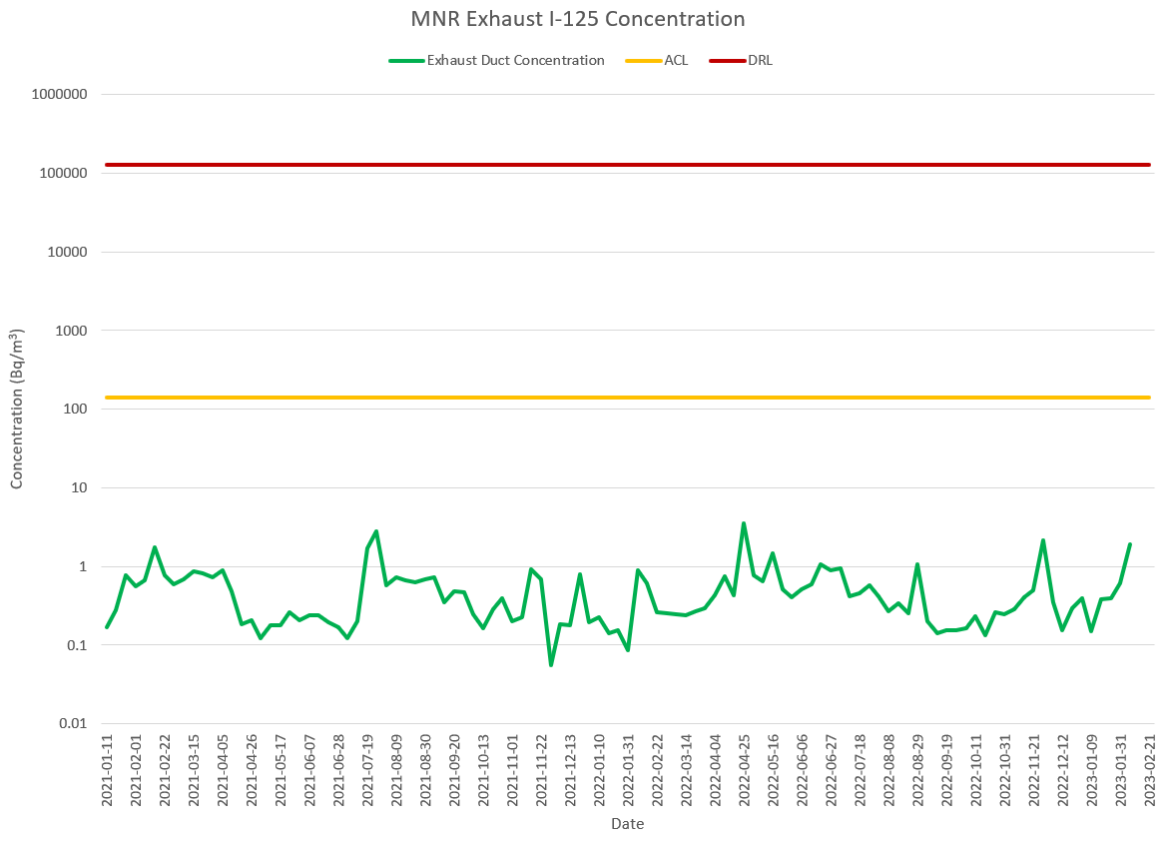


Figure 2.3.3-2

During reactor operation, daily measurements of ^{41}Ar concentrations in the exhaust are made using a gas counting chamber. ^{41}Ar 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 – 2022

Annual Average Concentration: 3.3×10^{4} Bq m^{-3}
Maximum Weekly Average Concentration: 6.8×10^{4} 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	%
9.0×10^{11}	1.6×10^{13}	1.3×10^{15}	0.07	3.6×10^{10}	3.1×10^{11}	2.5×10^{13}	0.14

Boundary Dose = 1.9 micro-Sv

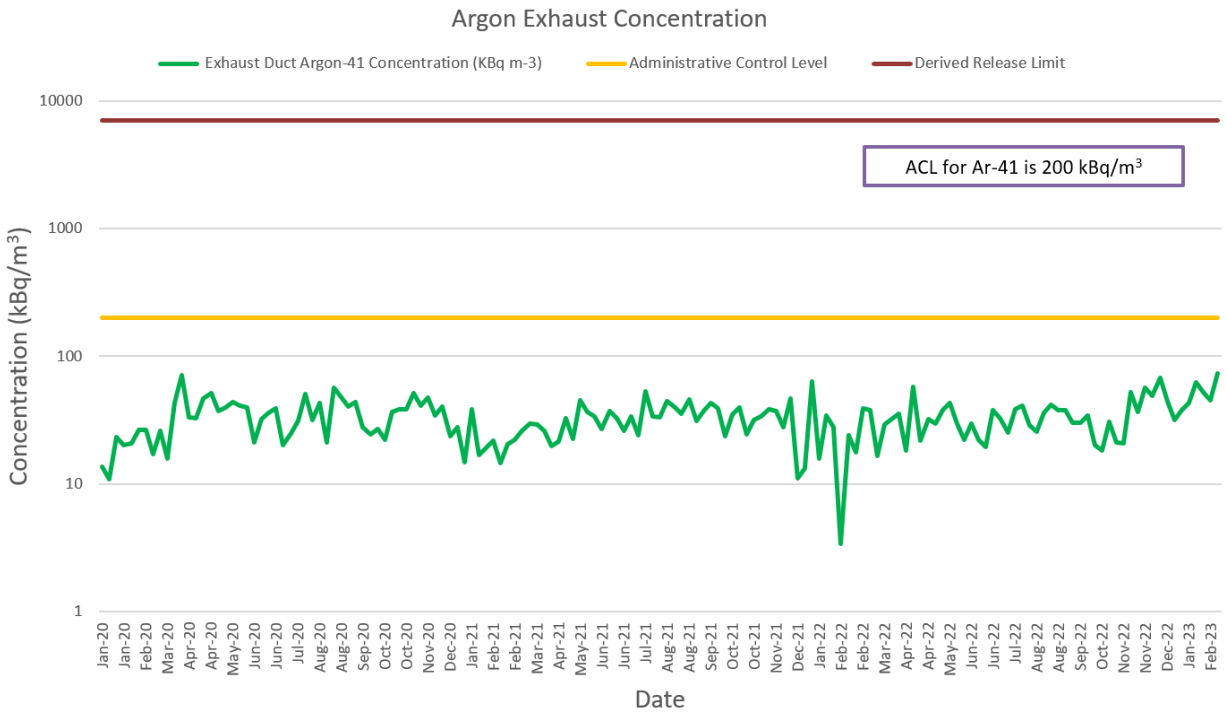

Argon Exhaust Concentration
Exhaust Duct Argon-41 Concentration (KBq m-3)
Administrative Control Level
Derived Release Limit
ACL for Ar-41 is 200 kBq/m3
Concentration (kBq/m3)
10000
1000
100
10
1
Jan-20 Jan-20 Feb-20 Mar-20 Apr-20 Apr-20 May-20 Jun-20 Jun-20 Jul-20 Aug-20 Aug-20 Sep-20 Oct-20 Oct-20 Nov-20 Dec-20 Jan-21 Feb-21 Feb-21 Mar-21 Apr-21 May-21 Jun-21 Jun-21 Jul-21 Aug-21 Aug-21 Sep-21 Oct-21 Oct-21 Nov-21 Dec-21 Jan-22 Feb-22 Feb-22 Mar-22 Apr-22 Apr-22 May-22 Jun-22 Jun-22 Jul-22 Aug-22 Aug-22 Sep-22 Oct-22 Nov-22 Nov-22 Dec-22 Jan-23 Feb-23
Date

Figure 2.3.3-3

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. The values from 2014 through 2022 for ^{41}Ar and ^{125}I are presented in **Table 2.3.3-4.**

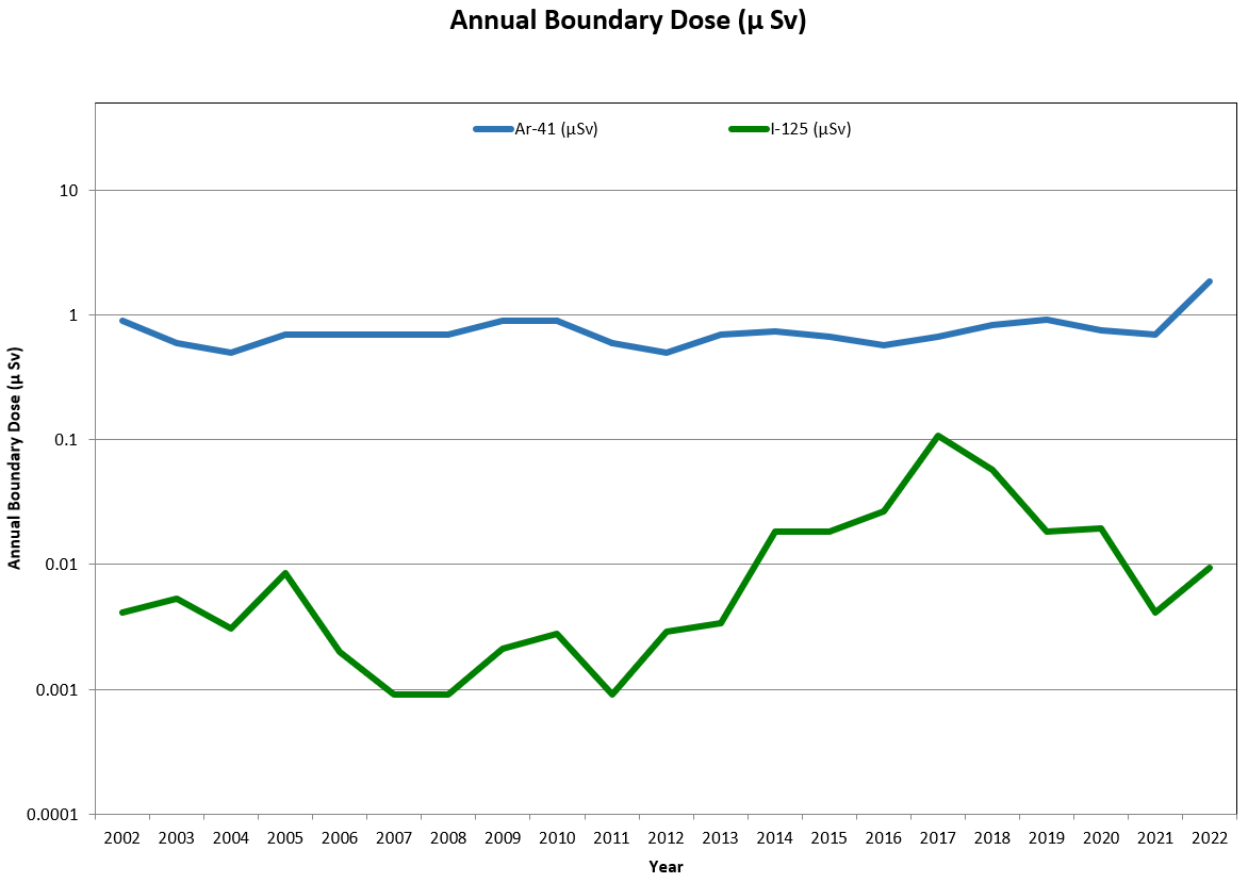


Figure 2.3.3-4

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 2022. 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 2022.

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 2022 are tabulated in **Table 2.3.3-4** and **Table 2.3.3-5.**

There was one spike identified in the concentration for the ABB location for the gross beta particulate in early 2022. 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 sample.

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 2022. MNR contributed no adverse environmental impact.

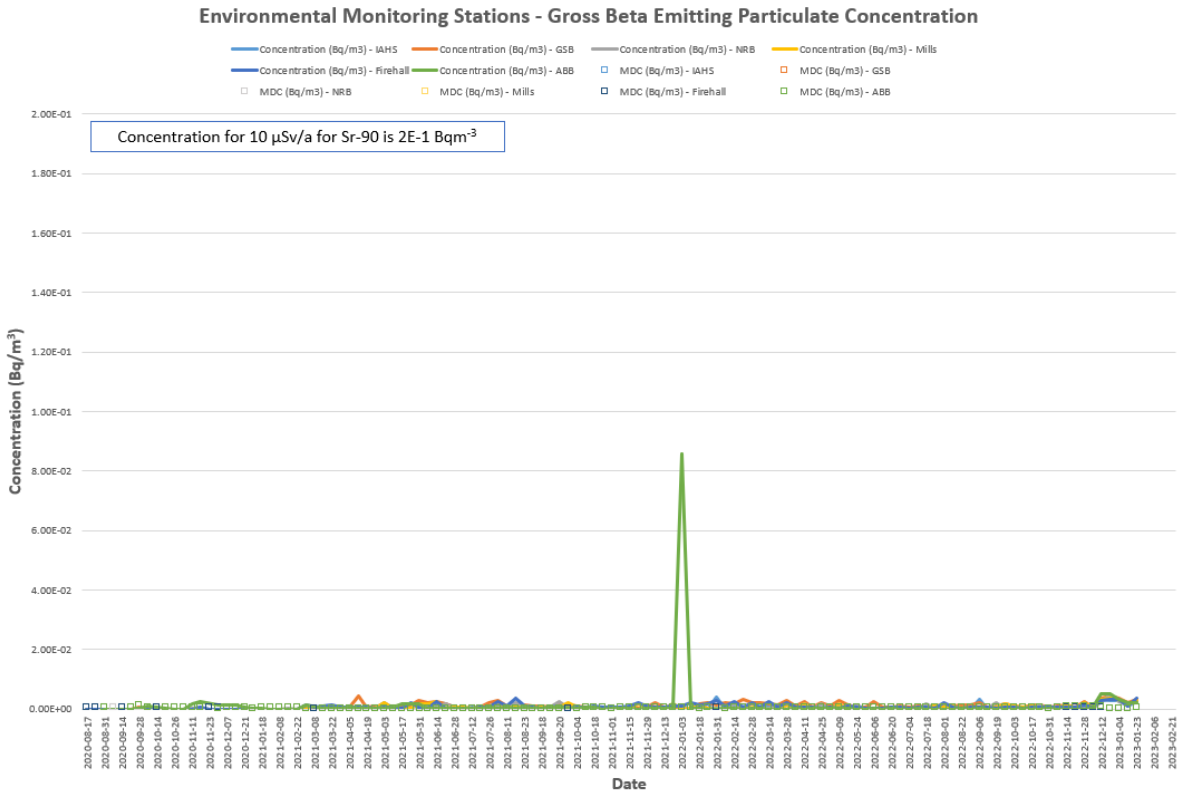


Figure 2.3.3-6

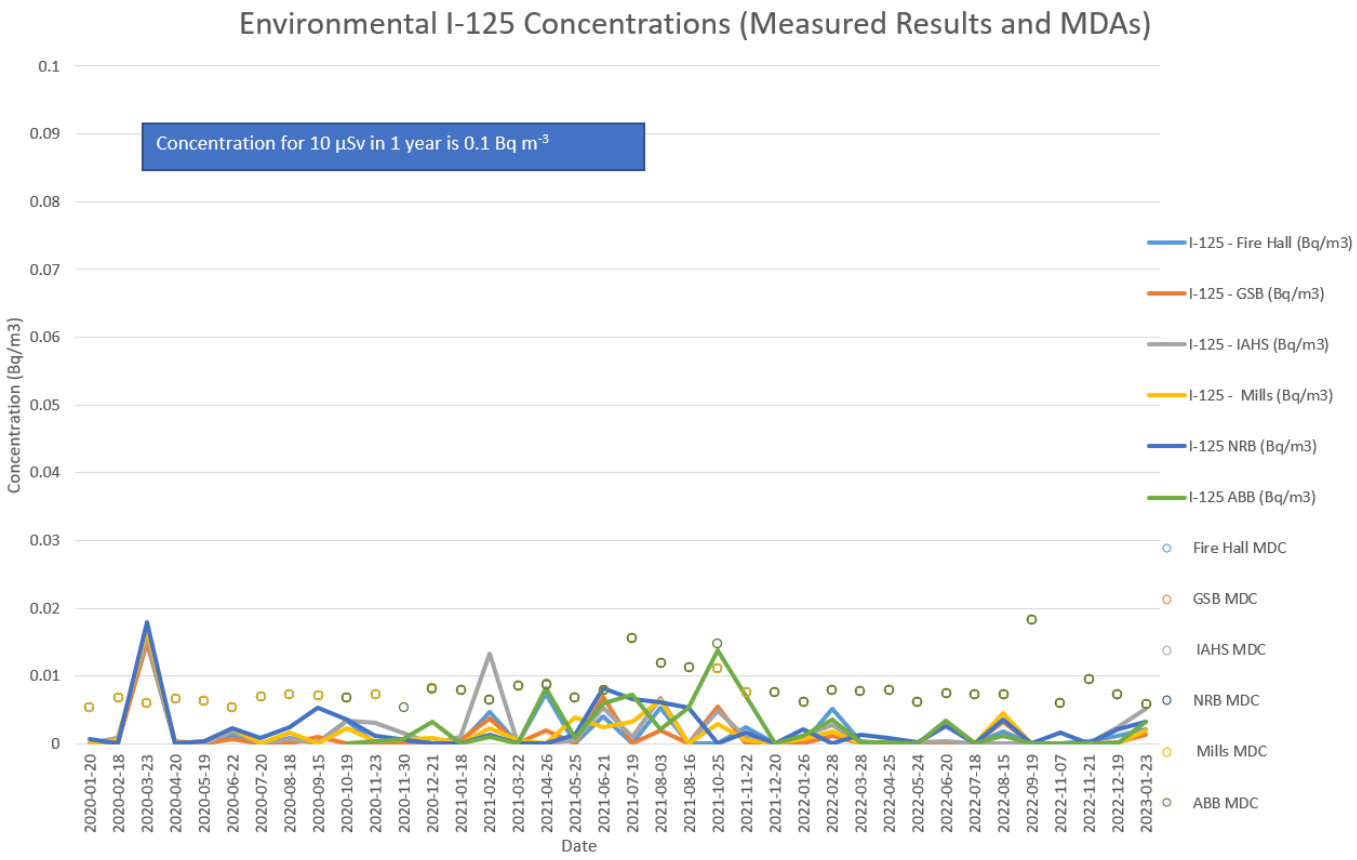


Figure 2.3.3-7

Emergency Management and Response

Emergency Preparedness Program

There were no changes made to the MNR Emergency Preparedness Program in 2022. Revisions to the governing procedure EP-7000 were drafted near the end of the year and were pending approval by the internal Nuclear Facilities and Controls Committee in 2023. The Emergency Preparedness Program is considered effective.

Revisions to the program include:

- Update of Emergency Organization and support groups, to align with current structures and titles.
- Update references to Emergency Facilities and Equipment to reflect current locations and inventories.
- Aligned terminology with the Ontario Provincial Nuclear Emergency Response Plan (PNERP)
- Updated training, to reference current requirements and practices.
- Incorporated best practices applicable to MNR from ANSI/ANS-15.16-2015 Emergency Planning for Research Reactors.

- Formatting and editorial changes

The annual review of the Type D emergency procedures with University, City and Provincial emergency responders was held in February 2022.

Emergency contact list drills were conducted twice in conjunction with McMaster Security service and the "Send Word Now" system. A fire drill was conducted in 2022. No additional drills were completed in 2022.

CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely, and effectively in 2022 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 2022.

There were no Reportable Events related to radiation safety or operations at MNR in 2022. A labour disruption involving education workers at McMaster occurred in November. No staff required to safely operate the MNR participated in the strike. No significant interruption to facility operations or disruption to the supply of medical isotopes occurred as a result of the dispute.

There were no lost time injuries, near misses or major safety findings in 2022. A conventional health and safety investigation was conducted after a load fell from the building crane in 2022, and a corrective action plan to address the findings from this event will be completed 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 2022.

Major projects planned for 2023 include:

1) Completion of the commissioning of the SANS instrumentation.
2) Planning and engineering will be completed on the new CFI-ORF infrastructure award focussed on expansion of neutron beam science at MNR.
3) Commissioning and qualification of the new liver cancer treatment preparation facility will be completed in 2023.
4) Unused fuel from the Greek Research Reactor will be delivered to and used in the MNR
5) A feasibility study for the deployment of a Small Modular Reactor on the McMaster campus will be completed
6) A new organizational structure for the Nuclear Operations and Facilities department intended to enhance the University's Nuclear profile and mission will be implemented in 2023

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 is underway.