McMaster Nuclear Reactor

McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1
NPROL-01.01/2024

Annual Compliance Monitoring and Operational Performance 2021

Summary Data for Public Information

Approved/Issued by:

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Executive Summary

The McMaster Nuclear Reactor (MNR) was operated safely, securely, and effectively in 2021.

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 80.3% with no major unplanned outages taking place during the year.

There were no Reportable Events at MNR in 2021.

There were no lost time injuries, near misses or major safety findings in 2021.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2021.

Throughout most of 2021, Nuclear Operations and Facilities continued operations under the Business Continuity Plan for the reactor in response to the pandemic. The plan was successfully managed throughout 2021. Routine operation and medical isotope production (essential service) continued normally throughout the rest of 2021.

Due to the pandemic, significant challenges were encountered for the medical isotopes produced at MNR. As a result of outages at other suppliers and severe disruptions to the supply chain, staff at the facility were required to work extra shifts, change their routine schedules, and explore and develop new transportation routes from our facility to our international customers. These challenges coupled with those presented by the Covid-19 pandemic made for an extremely demanding year for MNR. Staff demonstrated a high level of ingenuity, resiliency, and dedication. As a result of these efforts, Staff were awarded the University's prestigious President's Award for Outstanding Service in 2021.

MNR continues to support material scientists and the medical isotope community from across Canada as they relocate their research to MNR. The University is also actively engaged in the development and deployment of SMR technologies and are currently working with various government departments and vendors to help enable this crucial technology here in Canada.

A wide array of research projects is both planned and anticipated to take place at Nuclear Operations and Facilities over the next five years. The University is reviewing how best to maximize the research impacts of our nuclear facilities and capabilities.

INTRODUCTION

General Introduction

McMaster Nuclear Reactor (MNR) is operated by McMaster University for research, education, and commercial service. 2021 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-01.01/2024). 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 NCSA and associated regulations. Additionally, MNR is operated in accordance with the applicable laws of the province of Ontario.

There were no reportable incidents in 2021.

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

Late in 2021, McMaster University began construction and commissioning of a new processing facility on campus focussed on the supply of a new liver cancer fighting medical isotope treatment. 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. It is anticipated that this support will ramp up over the next two years.

Facility Operation

Reactor operation proceeded normally throughout 2021. Overall performance continues to be good. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

The reactor was operated at power during 2021 for a total of 3,442 hours, for a total energy output of 10,314 megawatt-hours. At year-end MNR had been operated for 216,350 hours for a life-time energy output of 629,976 megawatt-hours. Reactor availability, defined for MNR as

the percentage of operating hours relative to available hours, was 80.3%. **Figure 1.3-1** shows reactor operation and power output at MNR over the past ten years.

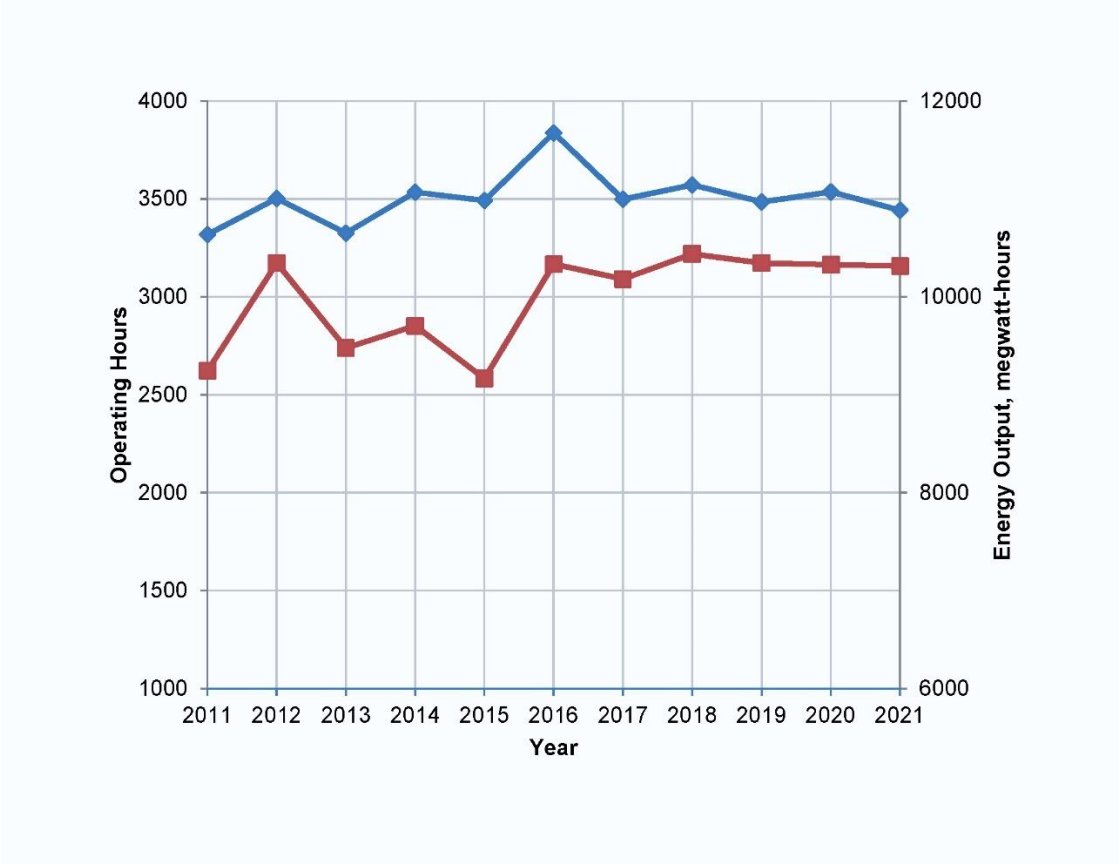


Figure 1.3-1 Reactor Operating Hours and Power Output

Work was completed to add new medical isotope irradiation and processing equipment in the facility to allow MNR to expand its research and production capabilities.

No major facility modifications were completed at MNR in 2021.

Radiation Protection

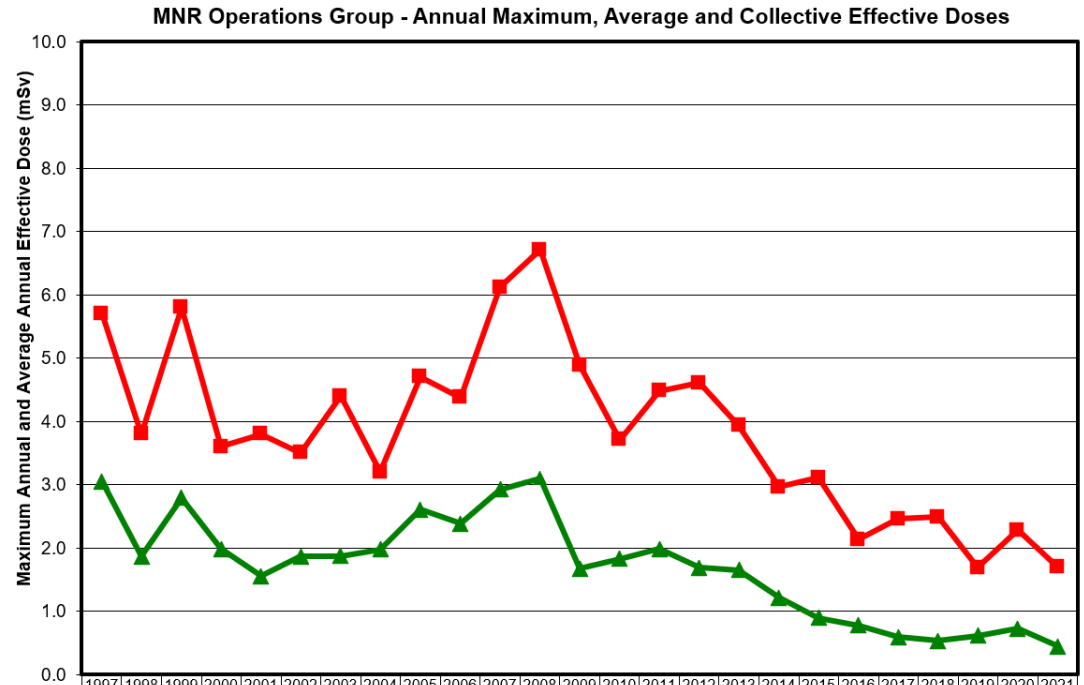
Dose Control Data

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 2021. All other personnel associated with the operation of the facility receive annual effective doses of less than 1 mSv.

In 2020, at the start of the COVID-19 restrictions, TLDs were moved to a quarterly dosimetry period. Please note that due to issues with the licenced dosimetry service provider, complete dose results for 2021 were not received and are unavailable. The results shown in this section are projected from the dose data that has been received thus far for 2021. Note that EPD data is reviewed monthly, and no significant trends were noted.

Operations Personnel

Operations Personnel 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 2021 occupational exposures for the group are presented in **Table 2.3.1-1**.



	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
Avg	3.1	1.9	2.8	2.0	1.6	1.9	1.9	2.0	2.6	2.4	2.9	3.1	1.7	1.8	1.98	1.69	1.65	1.22	0.90	0.78	0.59	0.53	0.61	0.73	0.44
Max	5.7	3.8	5.8	3.6	3.8	3.5	4.4	3.2	4.7	4.4	6.1	6.7	4.9	3.7	4.48	4.61	3.93	2.96	3.11	2.13	2.46	2.49	1.69	2.28	1.70

Figure 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 2021, the goal was 0.3 person mSv per unit relative output. The result for 2021 was 0.16 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**. A generally improving trend in this performance is evident.

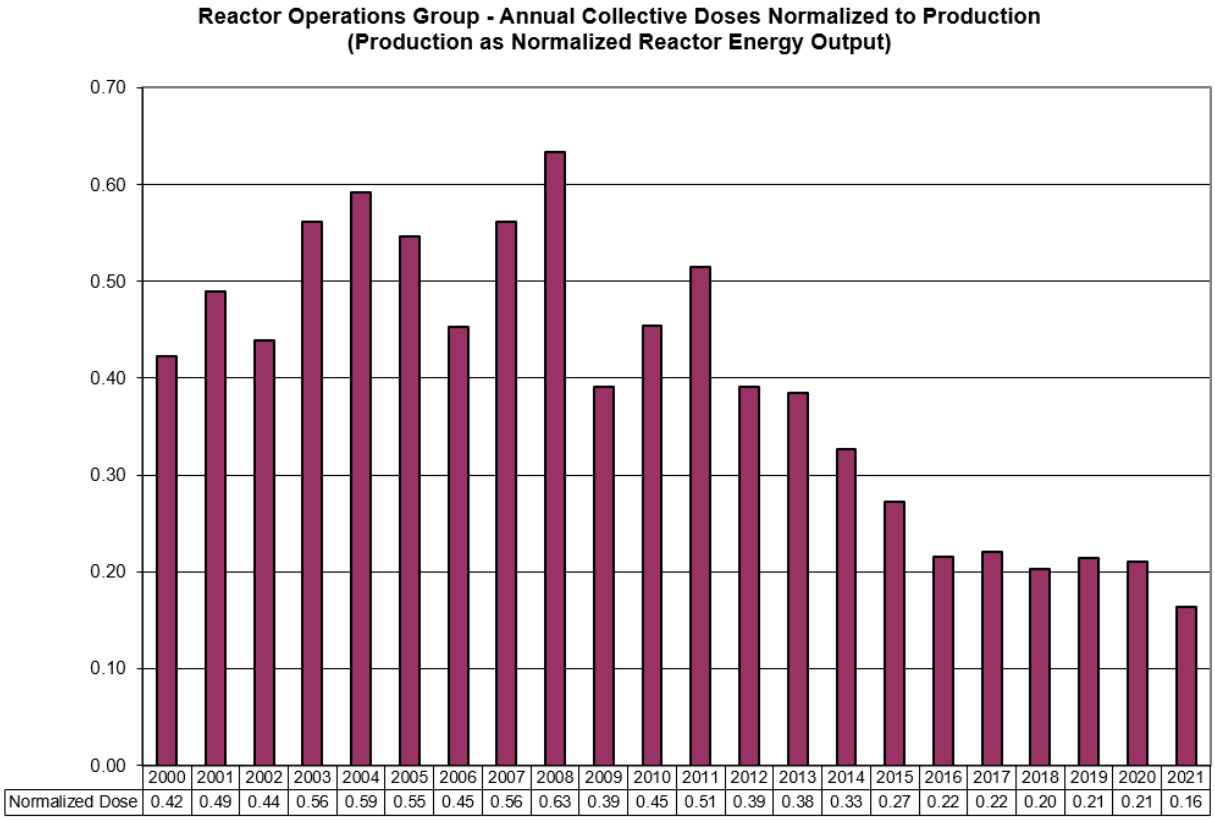
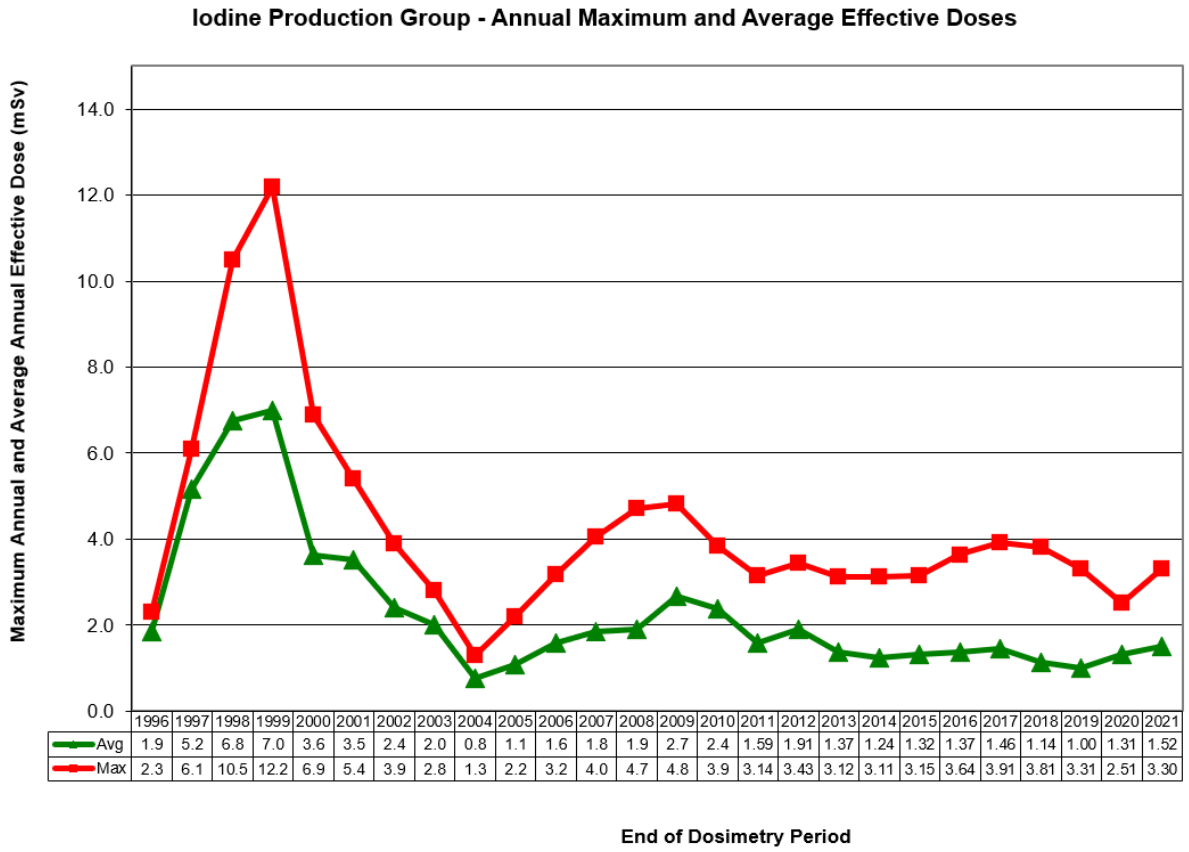


Figure 2.3.1- 2

Iodine Production Personnel

Iodine Production Personnel comprise the Production Manager, Production Technologists, the Manager of Laboratory Services and Production Assistants. The 2021 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
Avg	1.9	5.2	6.8	7.0	3.6	3.5	2.4	2.0	0.8	1.1	1.6	1.8	1.9	2.7	2.4	1.59	1.91	1.37	1.24	1.32	1.37	1.46	1.14	1.00	1.31	1.52
Max	2.3	6.1	10.5	12.2	6.9	5.4	3.9	2.8	1.3	2.2	3.2	4.0	4.7	4.8	3.9	3.14	3.43	3.12	3.11	3.15	3.64	3.91	3.81	3.31	2.51	3.30

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 2021, the goal was 0.25 person mSv per unit relative output. The result for 2021 was 0.17 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 2021 value among the lowest historical values for the facility.

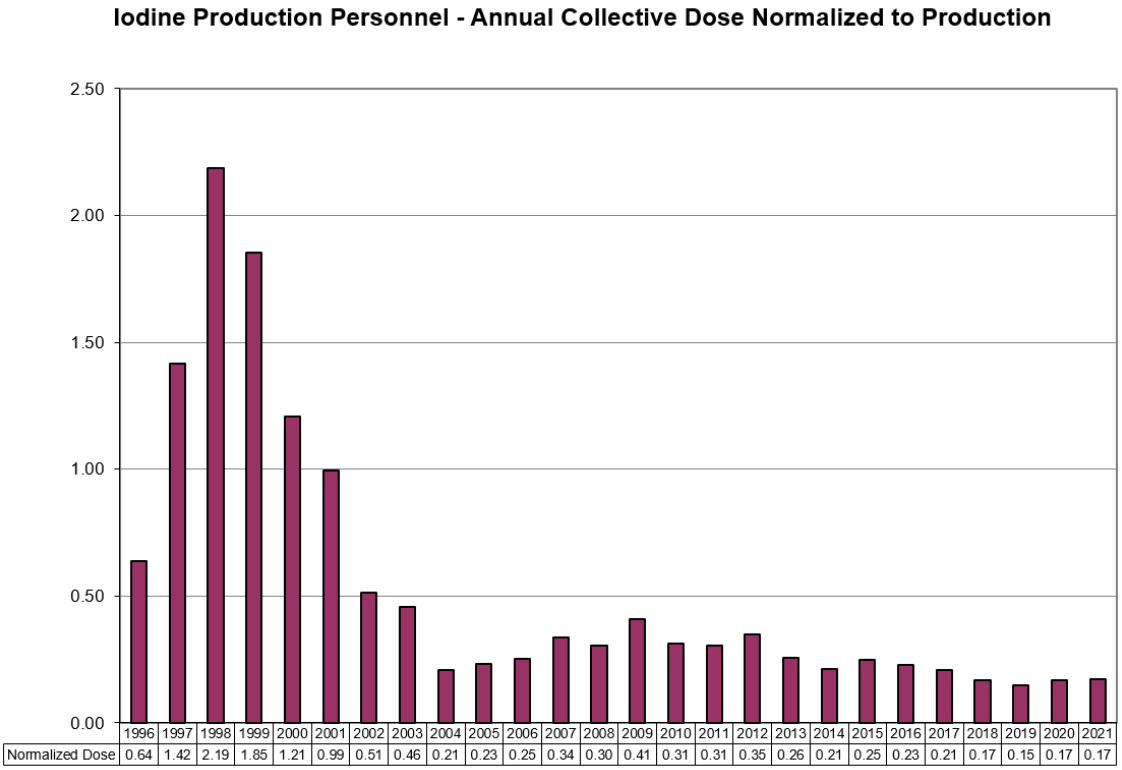
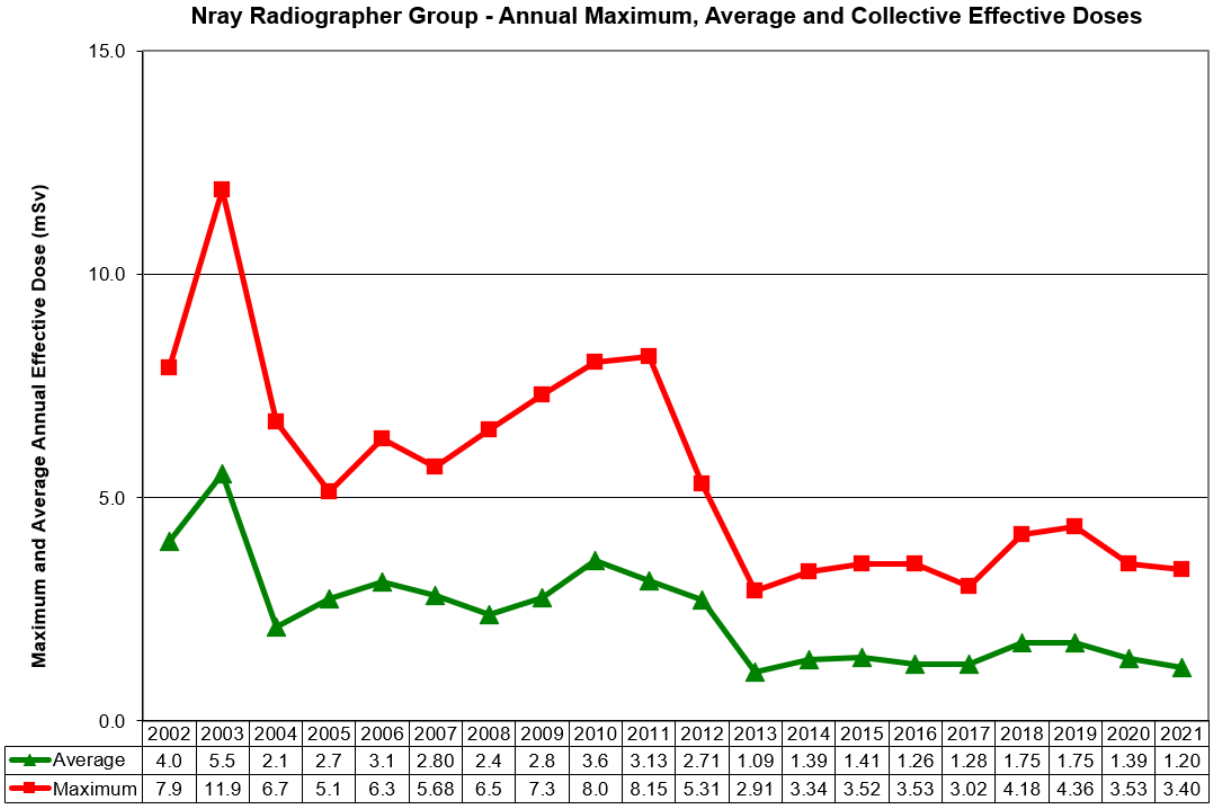


Figure 2.3.1-4

NRay Radiographers

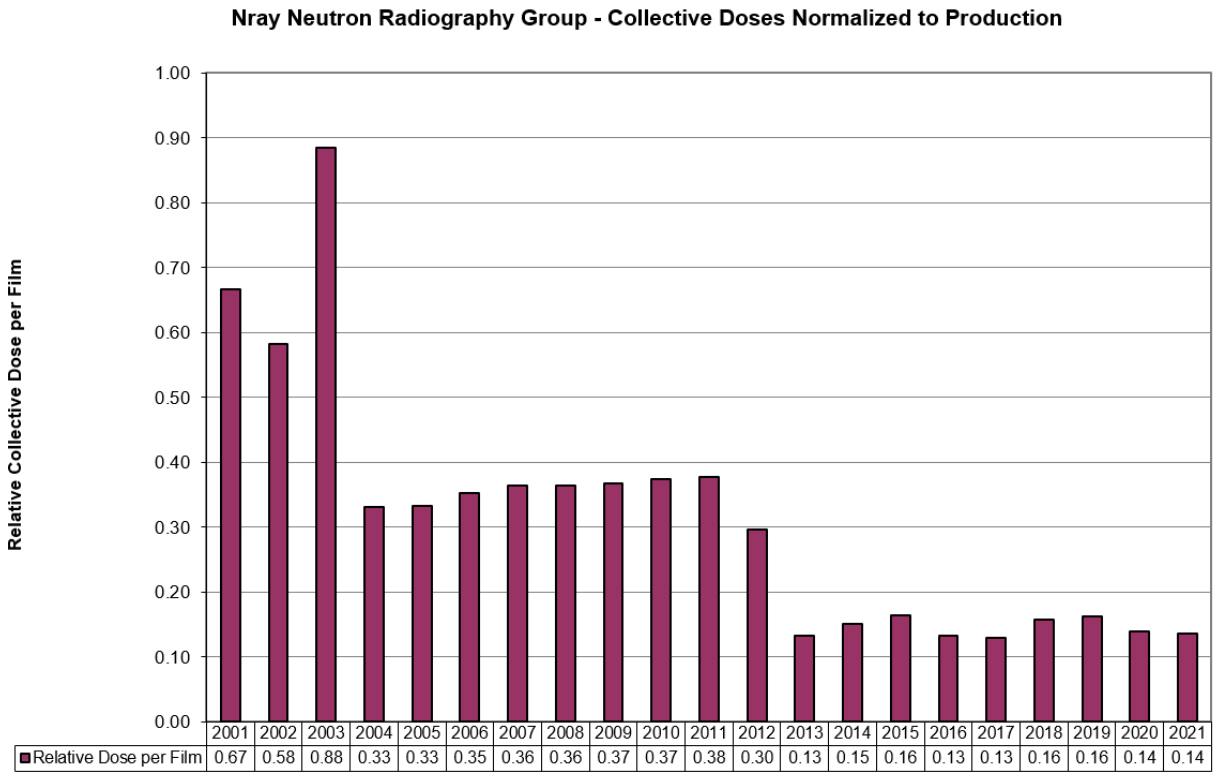
The NRay Radiographers group comprises the Operations Manager, the Development Officer, the Radiography Manager, the Radiography Supervisors, and the Material Handlers. All are employees of NRay Inc., a private company that utilizes beam ports in the reactor under contract. There is no distinction for users based on employer under the MNR radiation safety program. The 2021 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
Average	4.0	5.5	2.1	2.7	3.1	2.80	2.4	2.8	3.6	3.13	2.71	1.09	1.39	1.41	1.26	1.28	1.75	1.75	1.39	1.20
Maximum	7.9	11.9	6.7	5.1	6.3	5.68	6.5	7.3	8.0	8.15	5.31	2.91	3.34	3.52	3.53	3.02	4.18	4.36	3.53	3.40

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 2021, the goal was 0.20 person mSv per unit relative output. The result for 2021 was 0.14 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.



	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Relative Dose per Film	0.67	0.58	0.88	0.33	0.33	0.35	0.36	0.36	0.37	0.37	0.38	0.30	0.13	0.15	0.16	0.13	0.13	0.16	0.16	0.14	0.14

Figure 2.3.1-6

Health Physics

No members of the Health Physics Department received an annual effective dose over 1 mSv. The maximum dose for a member of the Health Physics department was 0.24 mSv during 2021. 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 2021.

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 2021 was slightly lower than the previous year and is among the lowest collective dose result in the recent operating history of the facility, despite generally higher utilization.

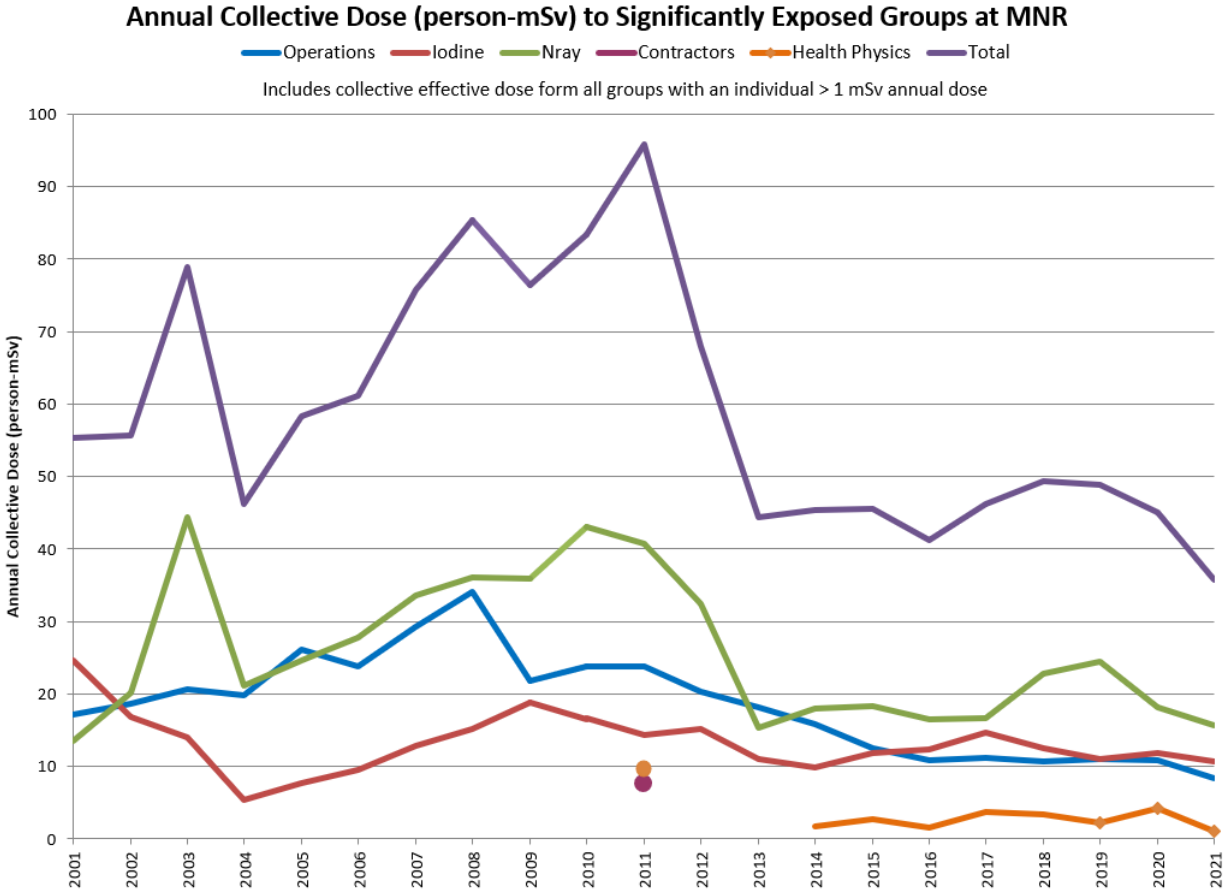


Figure 2.3.1-7

Significant Radiological Incidents

During 2021:

- 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.

In addition to the local safety committee inspections, various building safety inspections are routinely conducted by reactor management.

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 2021 goals were met or exceeded.

During 2021, 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, no incident reports of injuries with first aid and no incident reports for hazardous conditions related to the Reactor Building in 2021.

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) and Regulatory Limits 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 – 2021

Annual Average Concentration: 1.9×10^{-3} Bq m^{-3}
Maximum Weekly Average Concentration: 4.7×10^{-3} 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	%
1.0×10^{5}	5.0×10^{8}	0.02	4.7×10^{4}	9.0×10^{6}	0.05

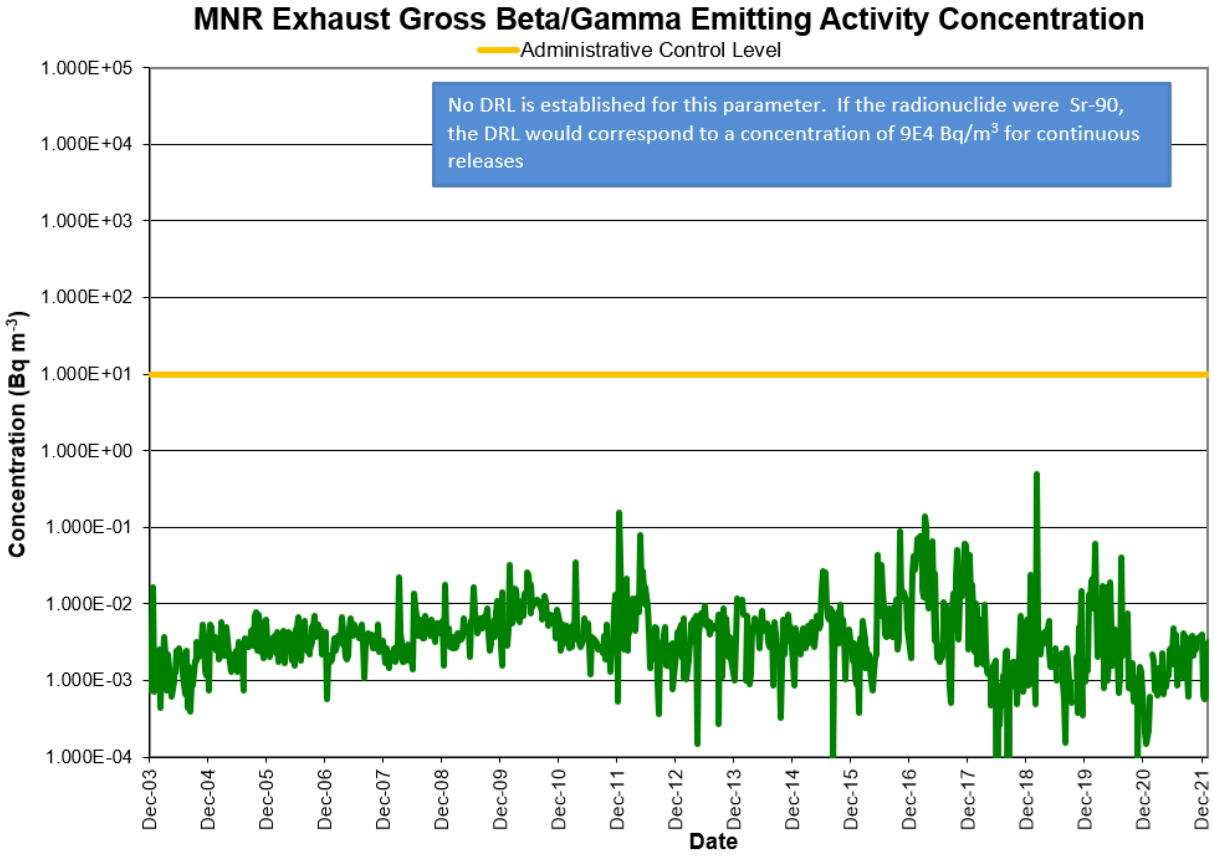


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2021

Annual Average Concentration: 0.5 Bq m^{-3}
Maximum Weekly Average Concentration: 2.8 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	%
2.8×10^{7}	1.0×10^{10}	9.4×10^{12}	0.0003	2.8×10^{6}	2.0×10^{8}	1.8×10^{11}	0.0015

Boundary Dose = 0.003 micro-Sv (NRB Occupants)

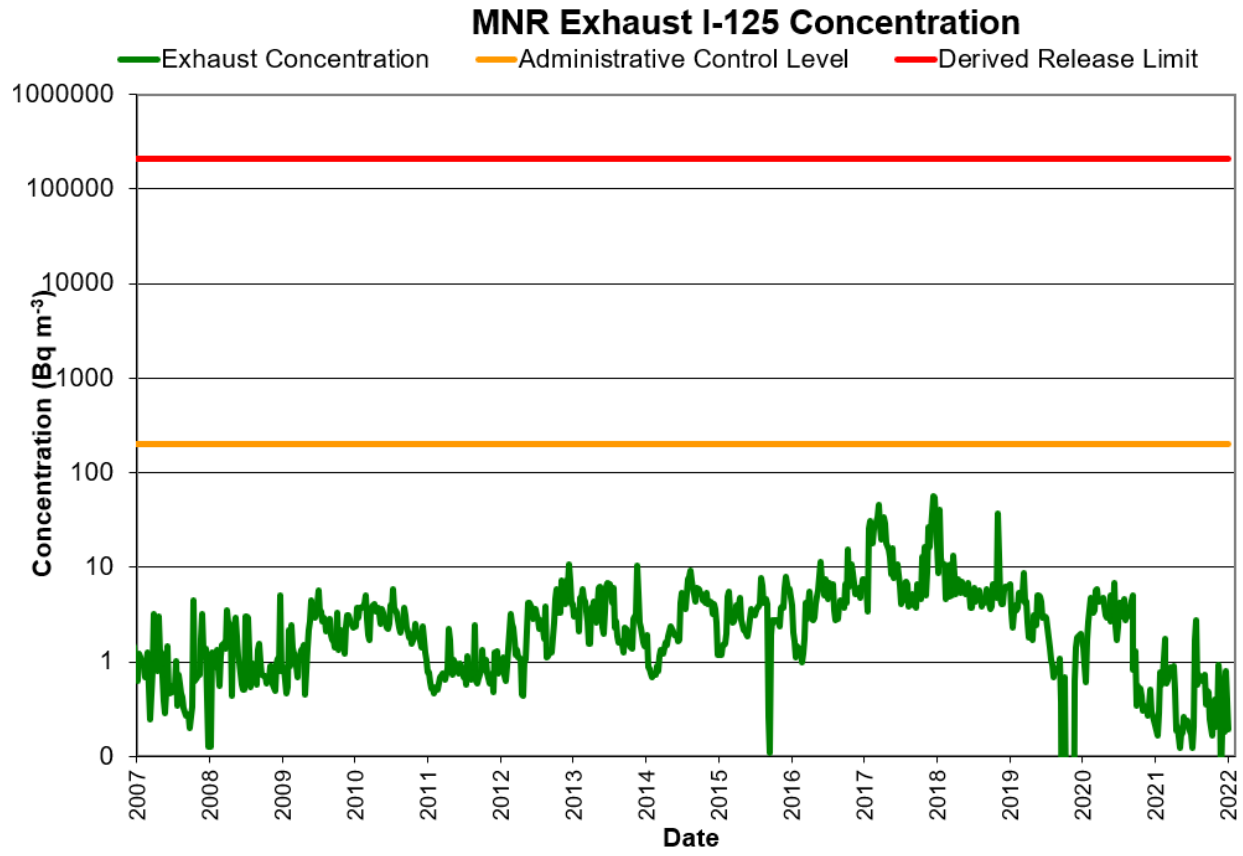


Figure 2.3.3-2

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**.

Table 2.3.3-3: Comparison of Ar-41 Concentrations with Applicable Limits – 2021

Annual Average Concentration:	3.1×10^{4} Bq m^{-3}
Maximum Weekly Average Concentration:	5.3×10^{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	%
6.3×10^{11}	1.6×10^{13}	1.3×10^{15}	0.05	2.1×10^{10}	3.1×10^{11}	2.5×10^{13}	0.1

Boundary Dose = 0.5 micro-Sv (infant permanently at point of maximum ground level concentration)

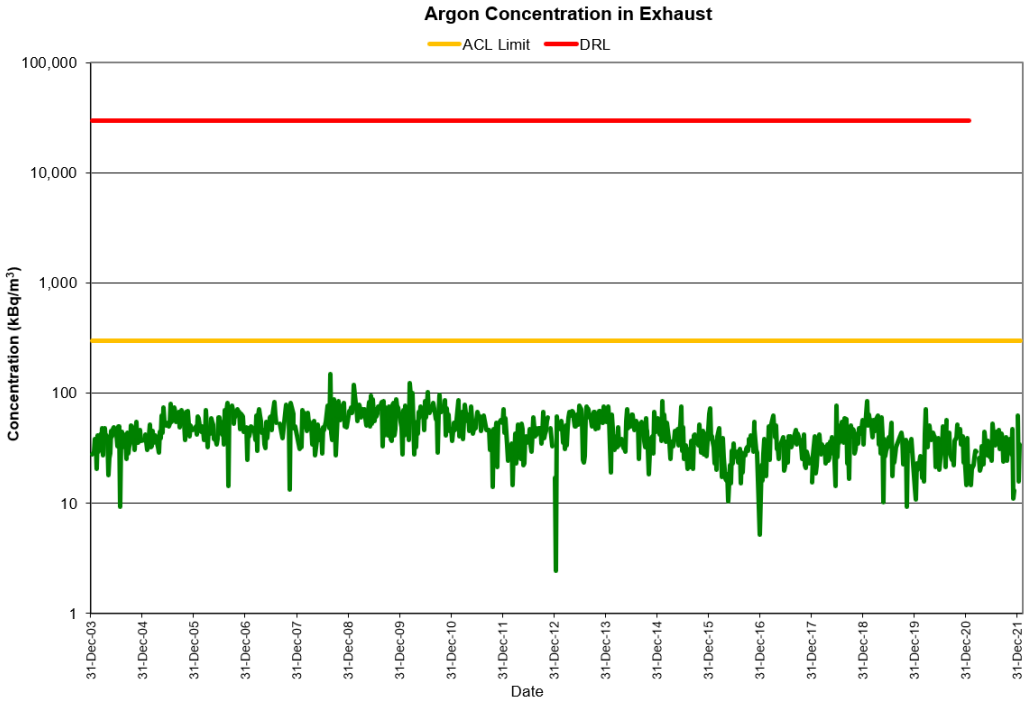


Figure 2.3.3-3

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. Historical values are presented in **Figure 2.3.3-4**.

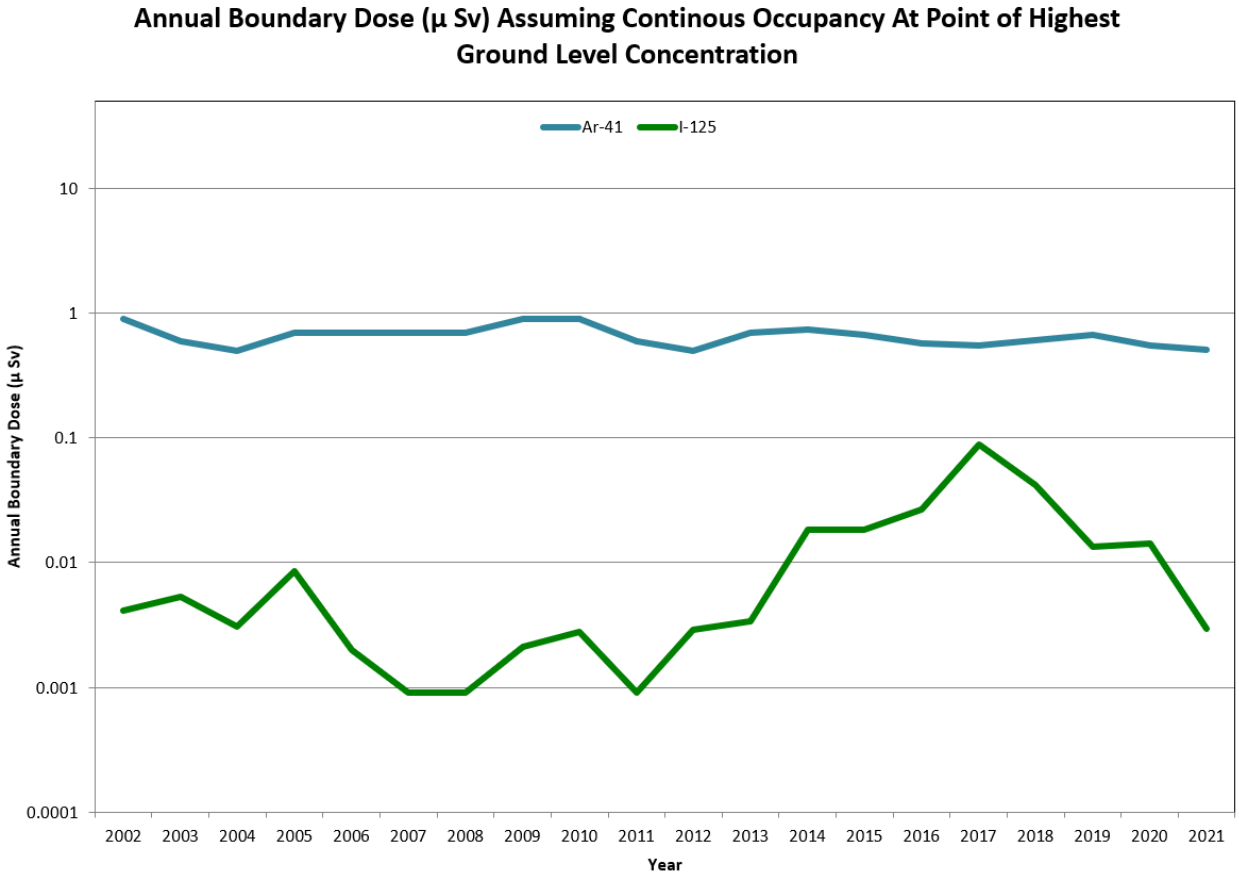


Figure 2.3.3-4

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 2021. Liquid waste continues to be captured and processed or evaporated in the facility. The most recent 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 2021.

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 in order 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 2021 are tabulated in **Table 2.3.3-4** and **Table 2.3.3-5.**

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.

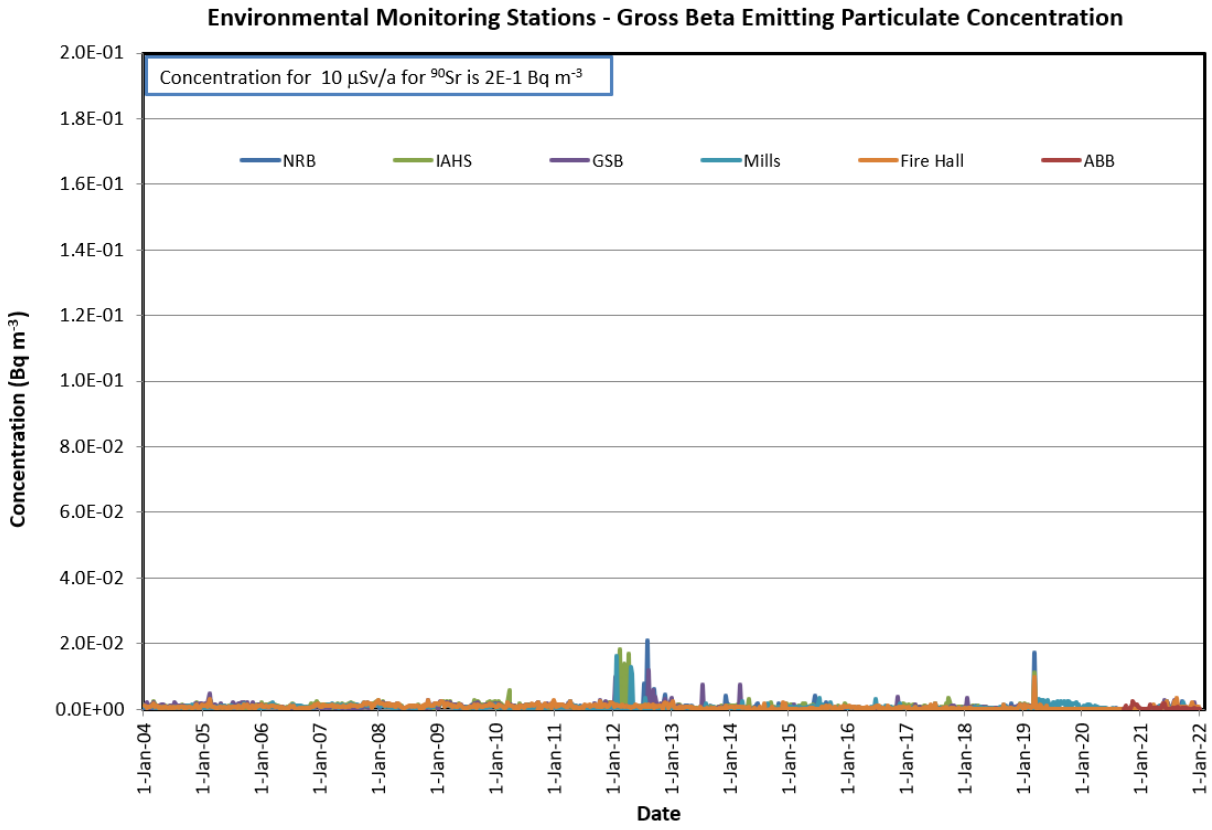


Figure 2.3.3-6

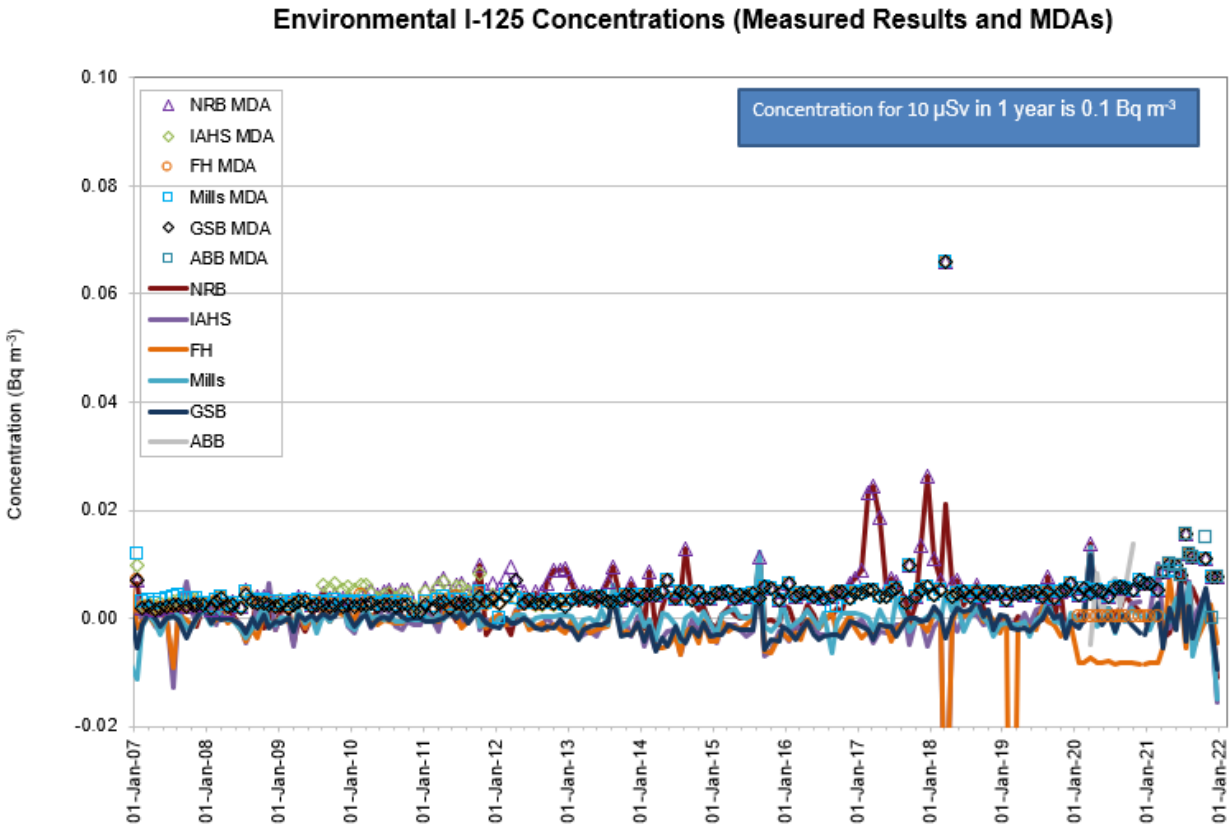


Figure 2.3.3-7

Emergency Management and Response

Emergency Preparedness Program

The annual review of the Type D emergency procedures with University, City and Provincial emergency responders was held in February 2021.

On June 18, 2021, McMaster held a hybrid in-person and virtual Type B Emergency Preparedness Drill at the McMaster Nuclear Reactor. The drill involved more than 65 individuals from internal and external agencies, including Hamilton Fire Services and the Canadian Nuclear Safety Commission. The drill scenario involved a simulated fire in the MNR pump room and incorporated Operations, Health Physics, Administration, and other group responses at each stage of the virtual drill. Following the virtual component, MNR Operations staff received instruction from Hamilton Fire Services on the selection and use of fire extinguishers. Under the supervision of Hamilton Fire Services, MNR Operations staff took turns putting out a real fire with a fire extinguisher.

CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely, and effectively in 2021 and continued to support the educational and research goals of McMaster University.

Despite the many challenges presented by the pandemic, the reactor continued to operate normally supporting the needs of Researchers and providing life-saving medical isotopes throughout 2021.

There were no Reportable Events at MNR in 2021.

There were no lost time injuries, near misses or major safety findings in 2021.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2021.

Major projects planned for 2022 include:

1) the 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 2022.
4) installation of the unused Greek Research Reactor Fuel.
5) accelerated support for the deployment of SMR technologies.

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 anticipated over the next five years.