McMaster Nuclear Reactor

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

Annual Compliance Monitoring and Operational Performance 2020

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 2020.

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, bio-chemistry 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 79.8% with no major unplanned outages taking place during the year.

There was one Reportable Event at MNR in 2020.

There were no lost time injuries, near misses or major safety findings in 2020.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2020.

Early in 2020, Nuclear Operations and Facilities instituted a Business Continuity Plan for the reactor in response to the pandemic. The plan was successfully implemented and managed throughout the rest of 2020. Routine operation and medical isotope production (essential service) continued normally throughout the rest of 2020.

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.

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. 2020 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 was one reportable incident in 2020. In July, the reactor was operated for approximately 8 hours with one of its trips impaired. During the period, no condition existed which would have required actuation of the trip. Several other redundant trips were available and in-service during the duration of the impairment. A root cause investigation was completed for the event and a corrective action plan was initiated.

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

Facility Operation

Reactor operation proceeded normally throughout 2020. Overall performance continues to be good. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

There were twenty-three (23) unscheduled shutdowns in 2020. The largest factor affecting the unplanned shutdowns remains hydro fluctuations. Overall performance continues to be good. There was no evidence of any trends or changes.

There were no significant issues with equipment or systems during 2020. Minor repairs and replacements were performed as required. There was no evidence of any trends or significant changes.

The reactor was operated at power during 2020 for a total of 3,535 hours, for a total energy output of 10,328 megawatt-hours. At year-end MNR had been operated for 212,908 hours for a life-time energy output of 619,648 megawatt-hours. Reactor availability, defined for MNR as the percentage of operating hours relative to available hours, was 79.8%. **Figure 1.3-1** shows reactor operation and power output at MNR over the past ten years.

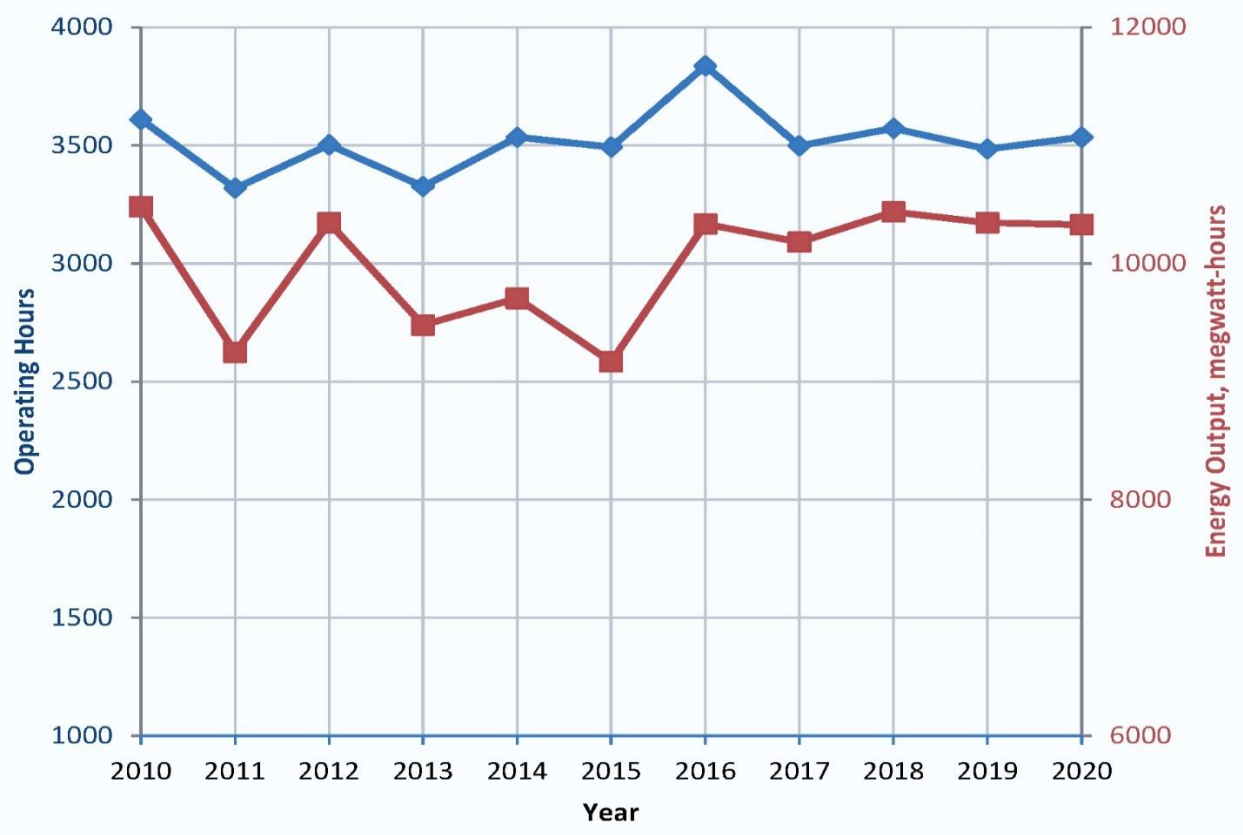


Figure 1.3-1 Reactor Operating Hours and Power Output

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.

A new Fission Products Monitor completed its commissioning and was placed in service in 2020.

The reactor's demineralization facility underwent several upgrades during the year with new pumps and motors installed, a new high efficiency filter added as well piping modifications to simplify the system.

The MNR containment structure; including exterior building surfaces and roofing systems was completely refurbished in 2020. The multi-million-dollar, 9-month project was successfully completed and is a significant investment in the facility's infrastructure.

A paperless surveillance monitoring system was put into service in 2020 after an extended commissioning exercise. The system provides an enhancement to efficiency and robustness for routine operations.

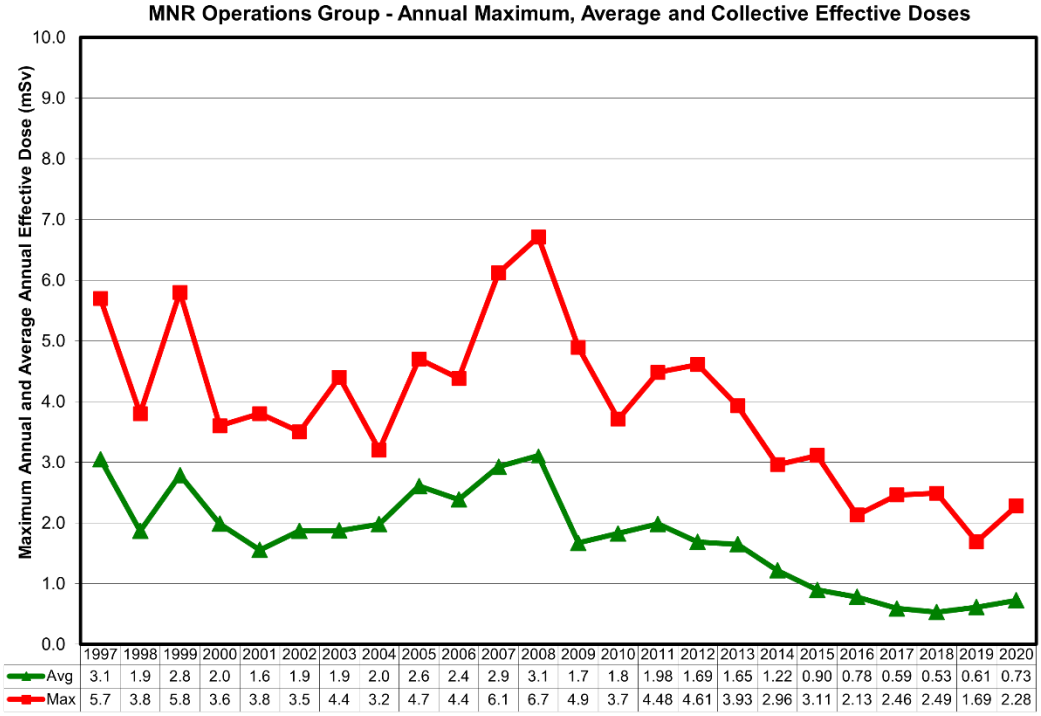
Radiation Protection

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, and this was the case for one Health Physics staff member in 2020. All other personnel associated with the operation of the facility receive annual effective doses of less than 1 mSv.

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 2020 occupational exposures for the group are presented in **Table 2.3.1-1**.

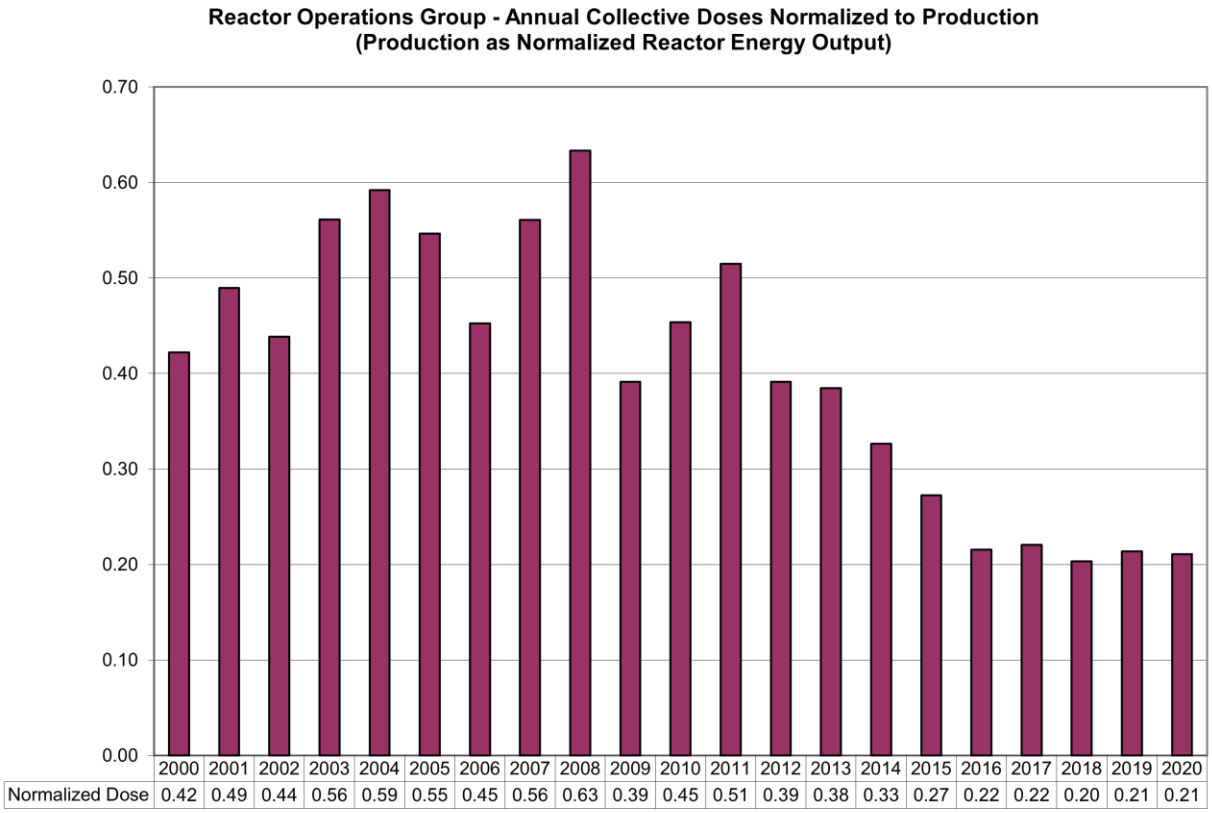


	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Avg	3.1	1.9	2.8	2.0	1.6	1.9	1.9	2.0	2.6	2.4	2.9	3.1	1.7	1.8	1.98	1.69	1.65	1.22	0.90	0.78	0.59	0.53	0.61	0.73
Max	5.7	3.8	5.8	3.6	3.8	3.5	4.4	3.2	4.7	4.4	6.1	6.7	4.9	3.7	4.48	4.61	3.93	2.96	3.11	2.13	2.46	2.49	1.69	2.28

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 2020, the goal was 0.3

person mSv per unit relative output. The result for 2020 was 0.21 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-2**. A generally improving trend in this performance is evident.

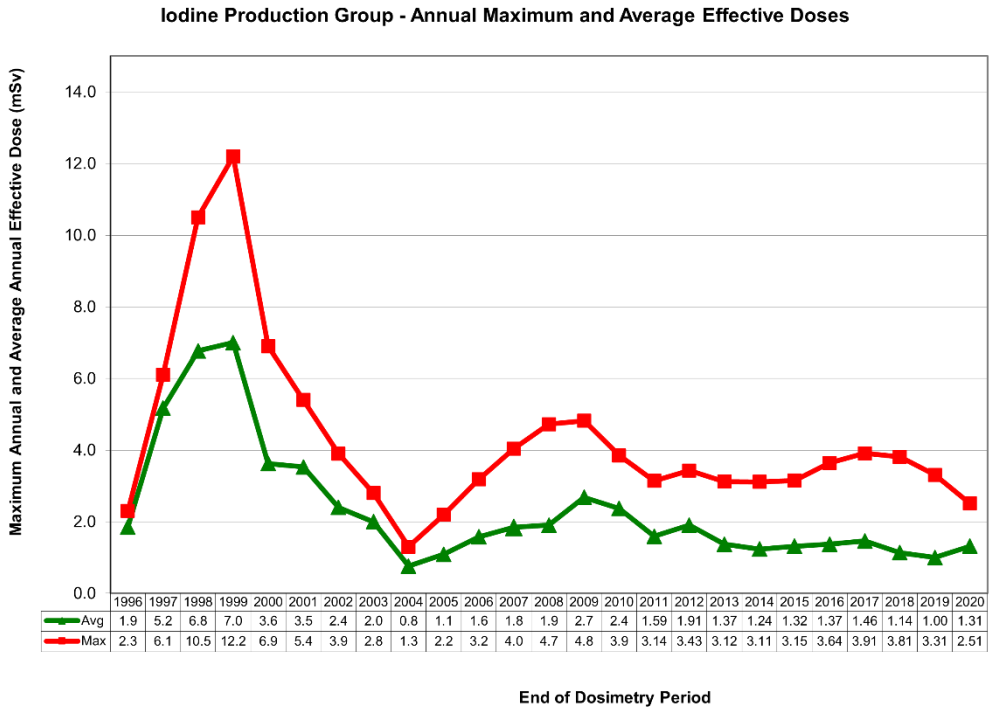


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Normalized Dose	0.42	0.49	0.44	0.56	0.59	0.55	0.45	0.56	0.63	0.39	0.45	0.51	0.39	0.38	0.33	0.27	0.22	0.22	0.20	0.21	0.21

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 2020 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
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
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

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 2020, the goal was 0.25 person mSv per unit relative output. The result for 2020 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 2020 value among the lowest historical values for the facility.

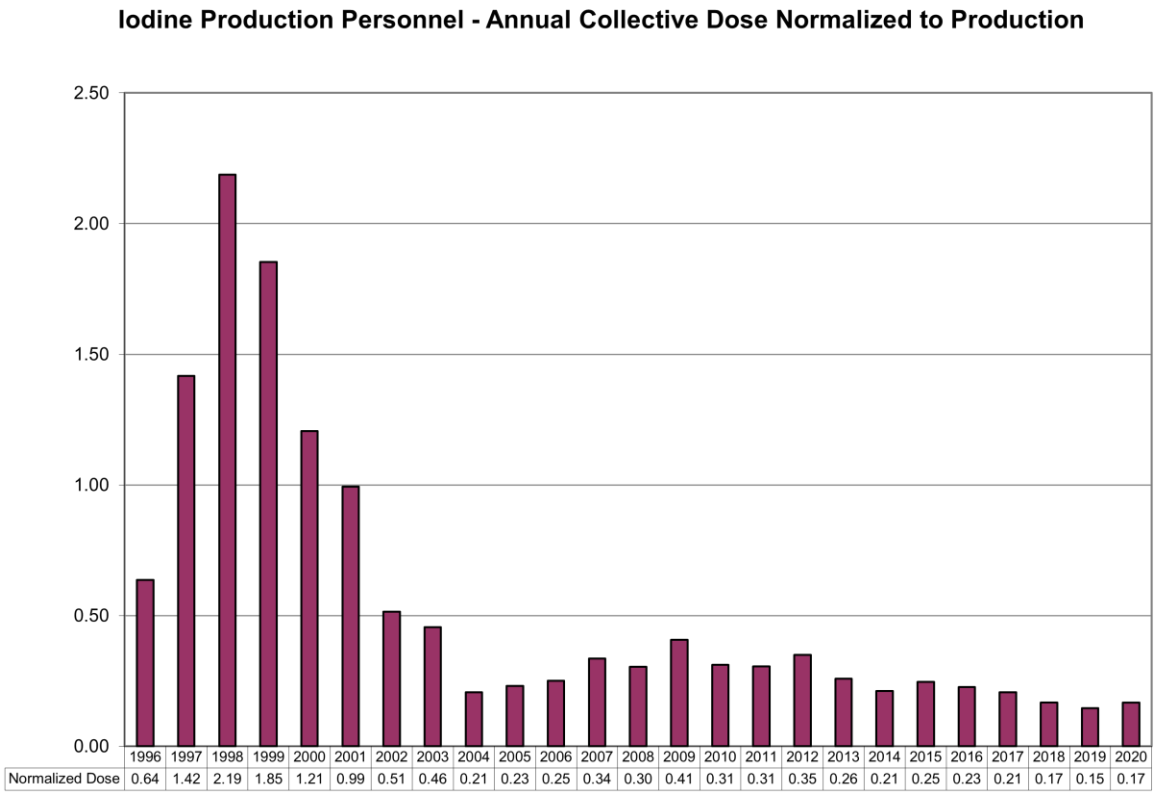
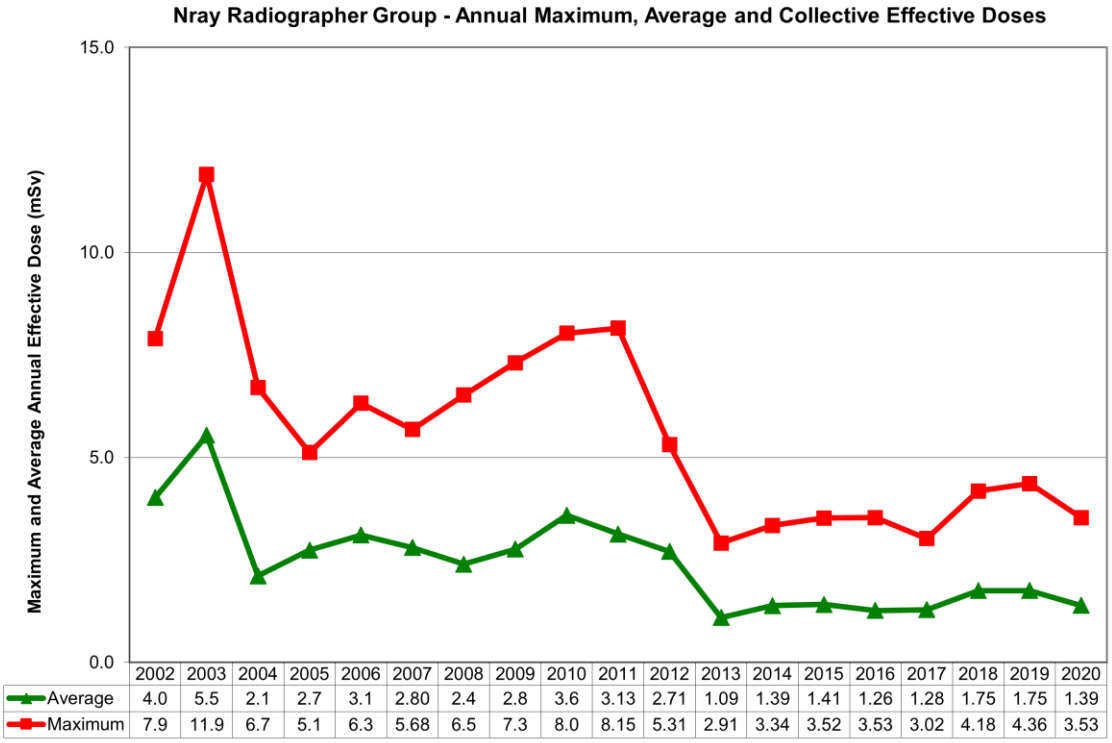


Figure 2.3.1-4

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 2020 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
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
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

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 2020, the goal was 0.20 person mSv per unit relative output. The result for 2020 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.

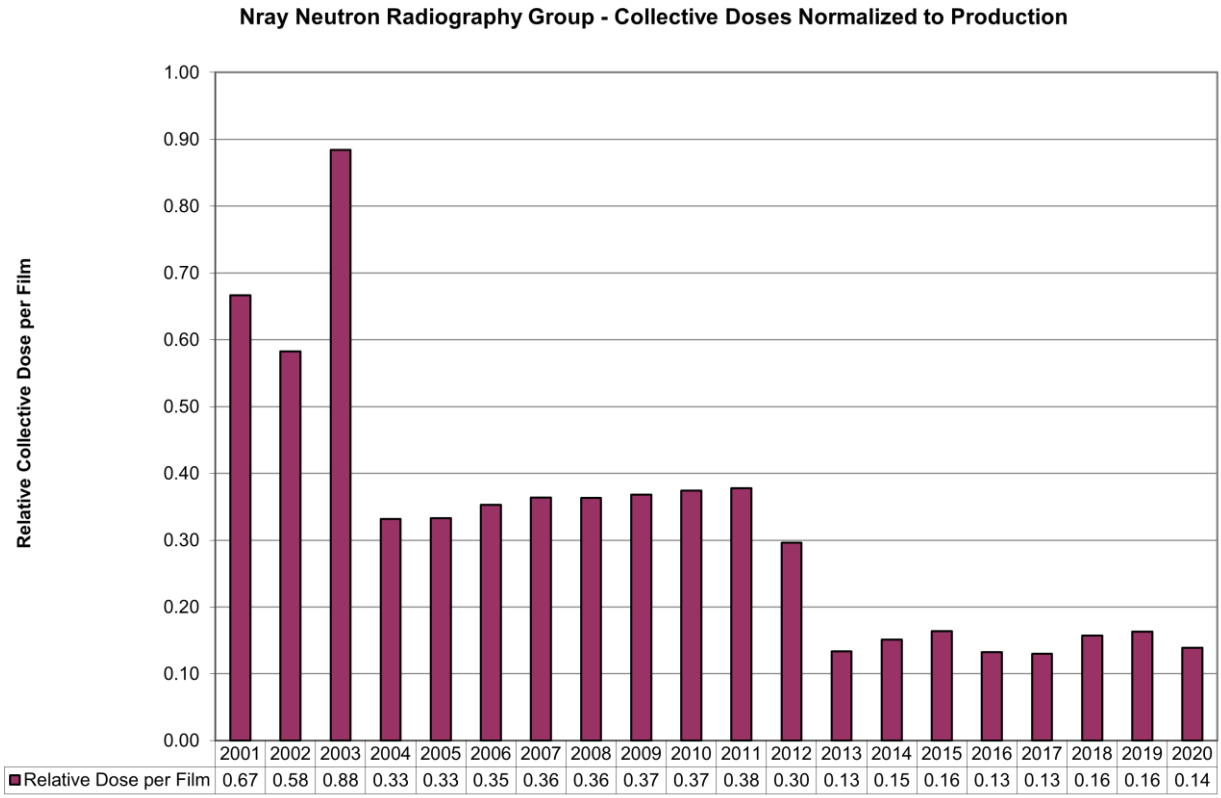


Figure 2.3.1-6

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 0.97 mSv during 2020. 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 2020.

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. While slightly higher than the previous year, the value for 2020 is among the lowest collective dose result in the recent operating history of the facility, despite generally higher utilization.

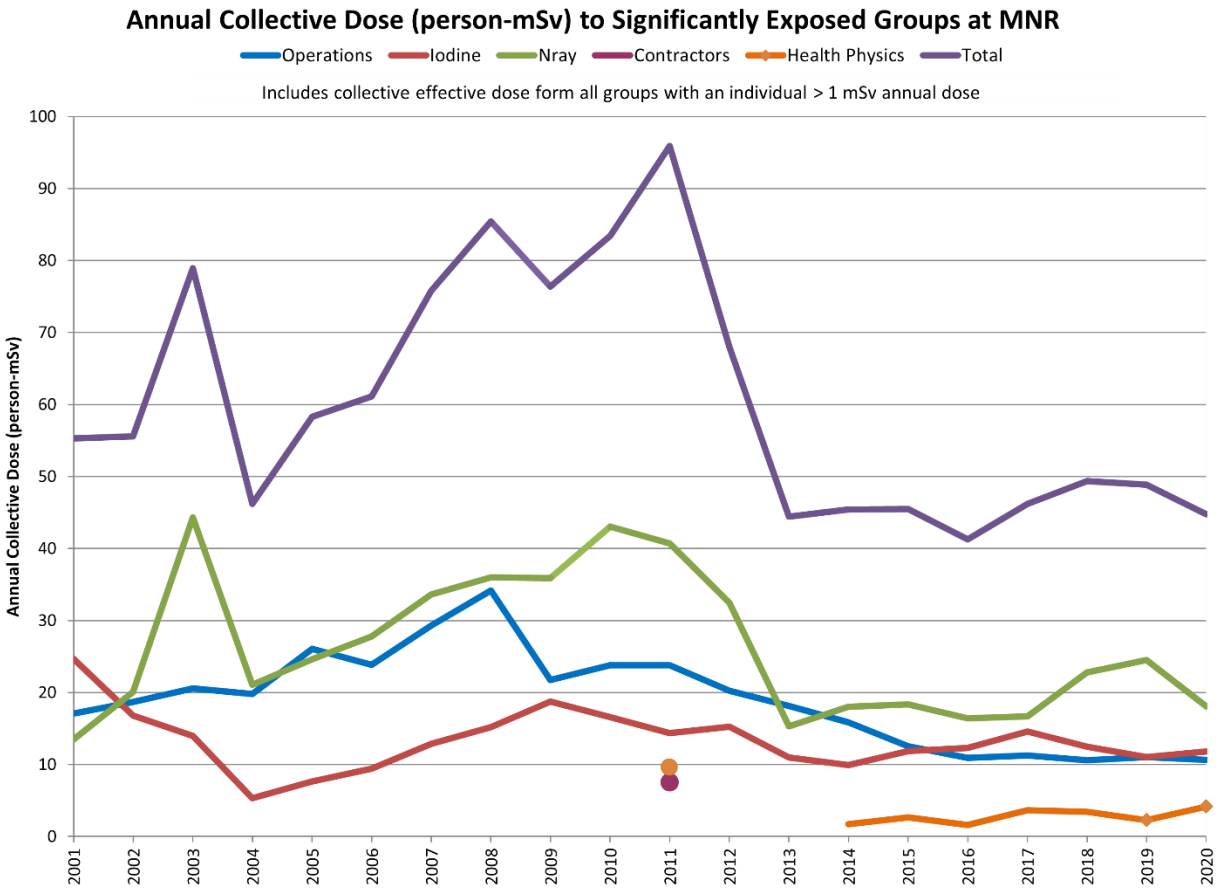


Figure 2.3.1-7

Significant Radiological Incidents

During 2020:

- 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 2020 goals were met or exceeded.

During 2020, the committee met virtually on several occasions. Workplace inspections continued though out 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 2020.

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 – 2020

Annual Average Concentration: 6.9×10^{-3} Bq m^{-3}
Maximum Weekly Average Concentration: 6.2×10^{-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	%
3.6×10^{5}	5.0×10^{8}	0.07	6.2×10^{4}	9.0×10^{6}	0.7

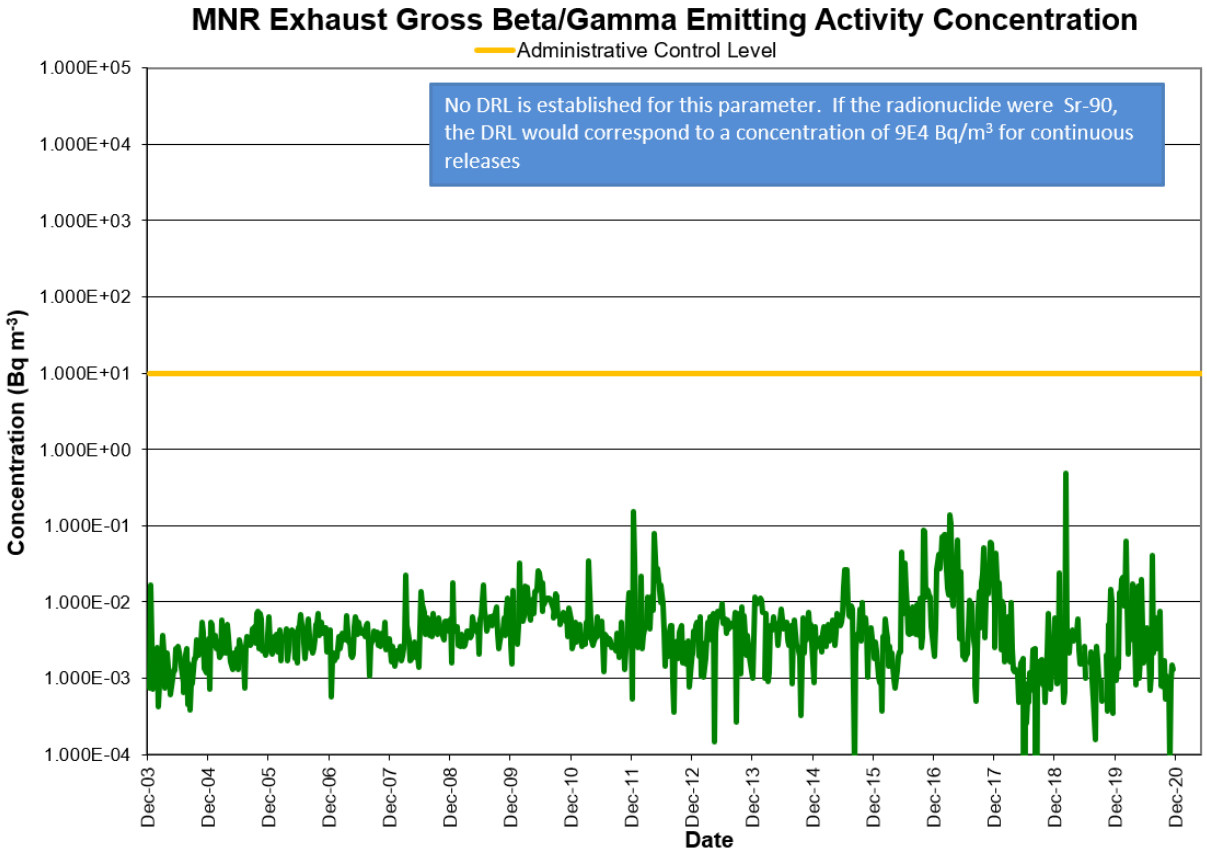


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2020

Annual Average Concentration: 2.6 Bq m^{-3}
Maximum Weekly Average Concentration: 6.7 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	%
1.3×10^{8}	1.0×10^{10}	9.4×10^{12}	0.001	6.7×10^{6}	2.0×10^{8}	1.8×10^{11}	0.005

Boundary Dose = 0.013 micro-Sv (NRB Occupants)

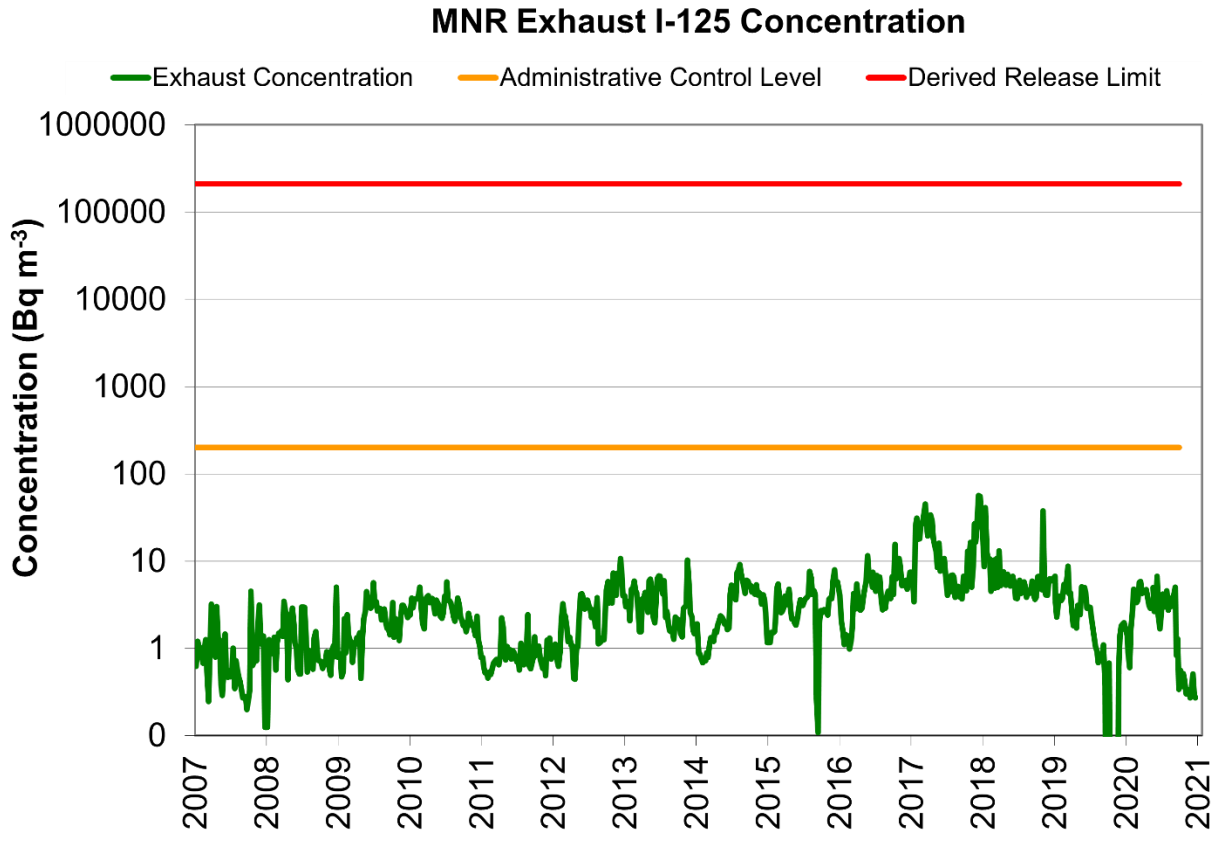


Figure 2.3.3-2

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 – 2020

Annual Average Concentration: 3.3×10^{4} Bq m^{-3}
Maximum Weekly Average Concentration: 7.1×10^{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	%
6.9×10^{11}	1.6×10^{13}	1.3×10^{15}	0.05	2.9×10^{10}	3.1×10^{11}	2.5×10^{13}	0.1

Boundary Dose = 0.7 micro-Sv (infant permanently at point of maximum ground level concentration)

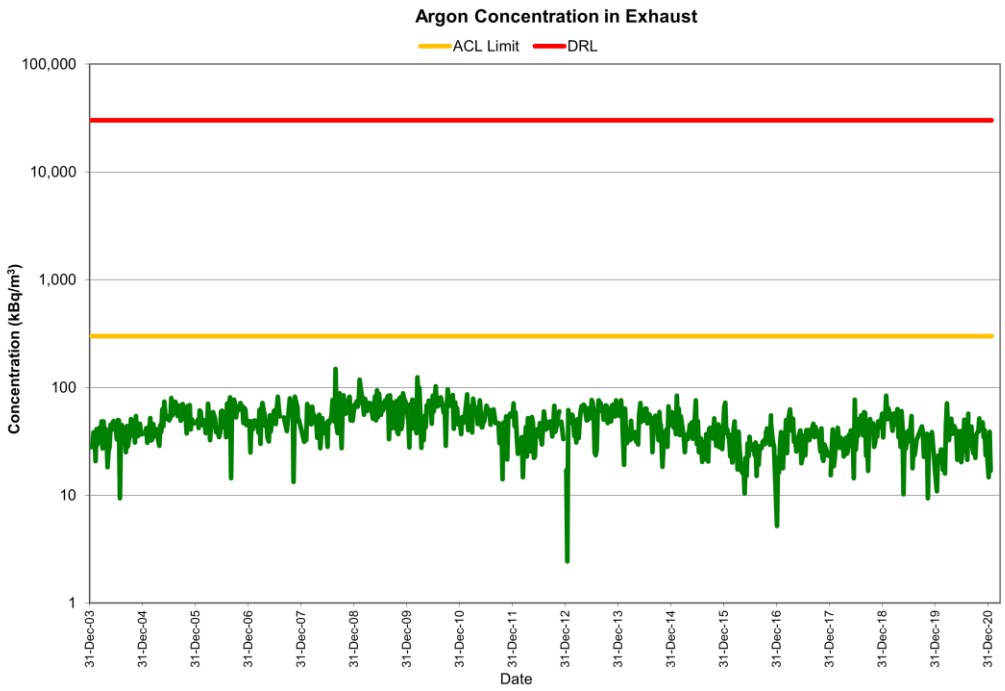


Figure 2.3.3-3

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. The 2020 value for ^{125}I is presented in **Table 2.3.3-2** and the value for ^{41}Ar is presented in **Table 2.3.3-3.** Historical values are presented in **Figure 2.3.3-4**. Increase beginning with the 2014 value for I-125 is the result of a change in the calculated dilution factors with updated weather data, not the result of increased emissions.

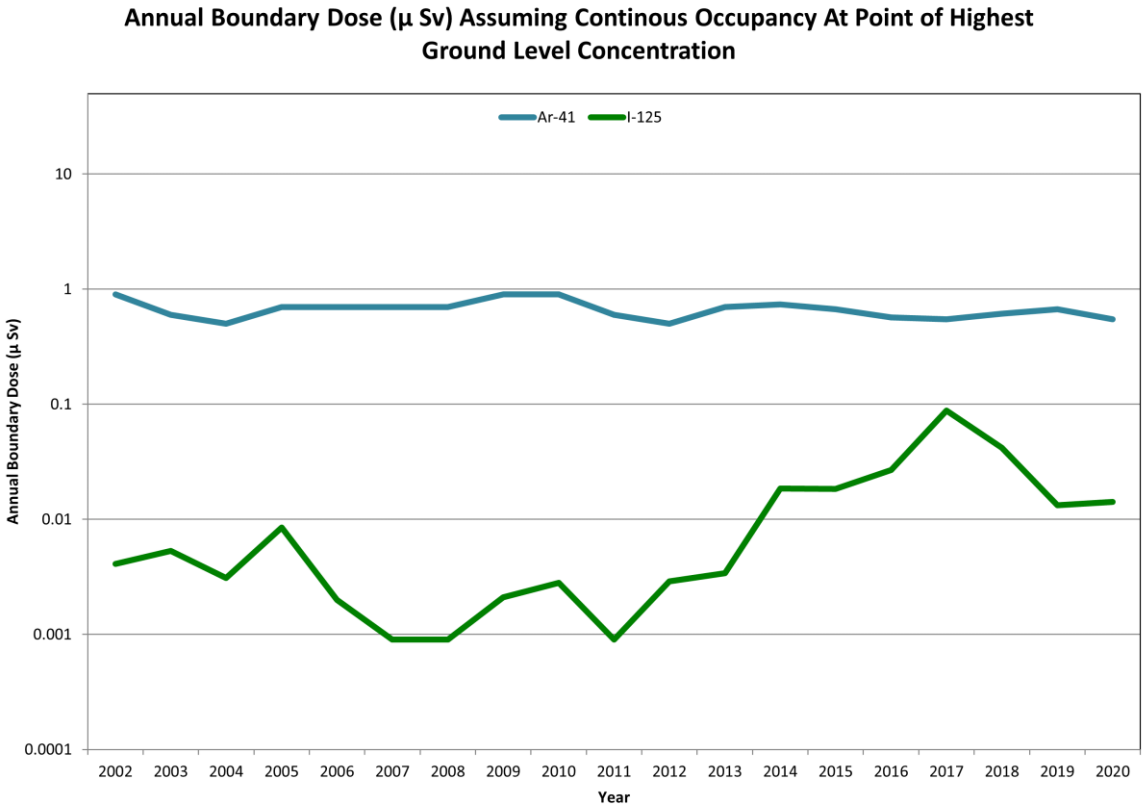


Figure 2.3.3-4

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 2020. 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 2020.

No trends of concern are evident in any of the effluent monitoring data and there is no indication that releases from the facility pose an unreasonable hazard to members of the public.

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 windowless proportional 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 2020 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.

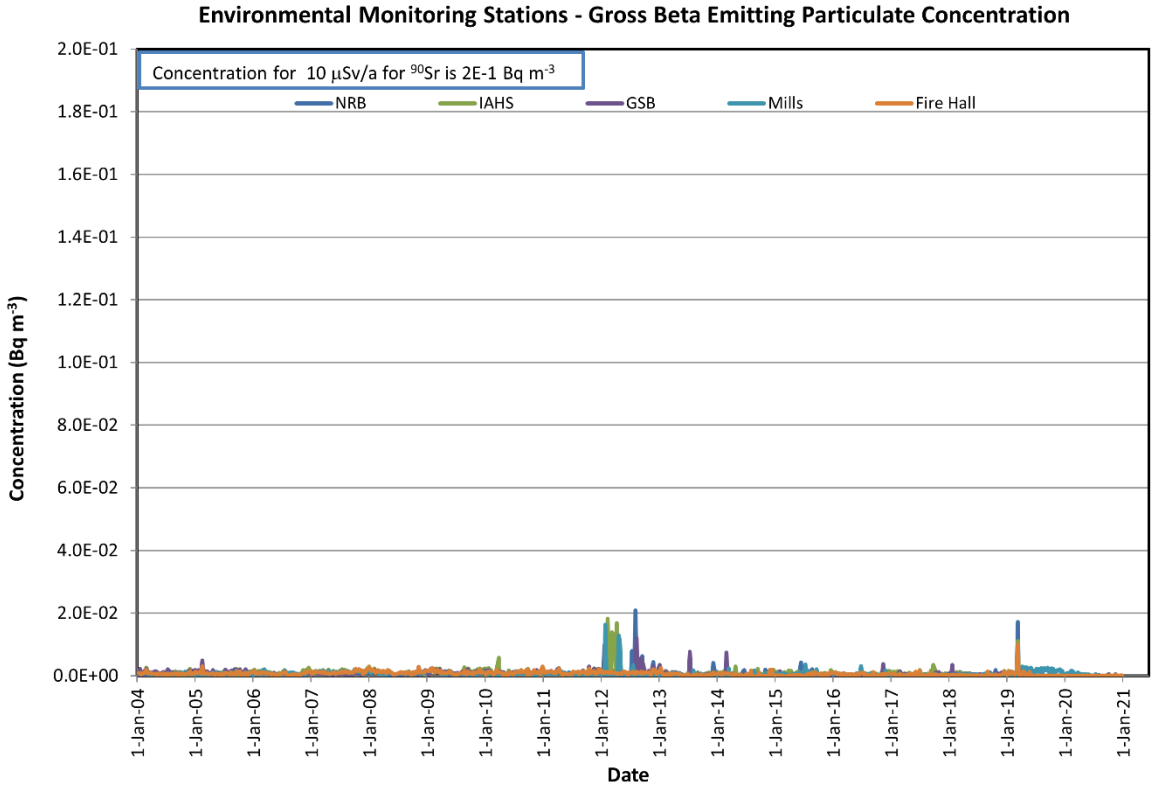


Figure 2.3.3-6

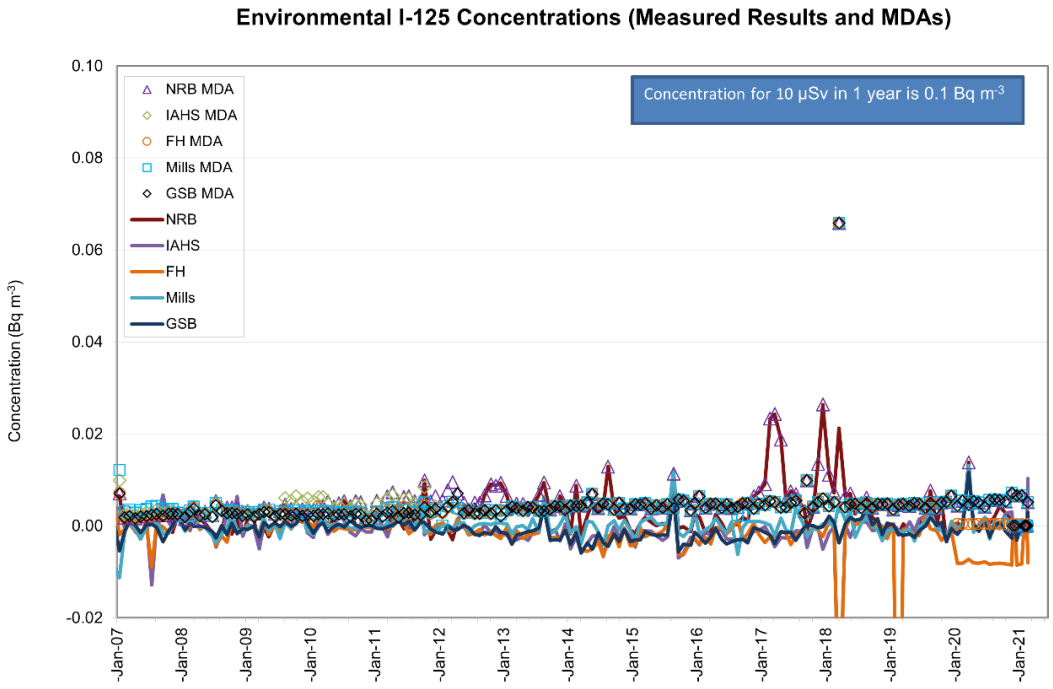


Figure 2.3.3-7

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 2020.

Several corrective actions were implemented as a result of findings from the large-scale Type D emergency exercise that was conducted in September 2019. Actions included updating and improving position specific binders, purchasing of additional communications equipment, relocating potassium iodide (KI) pills to the Emergency Control Centre, and purchasing new high range gamma meters.

CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely and effectively in 2020 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 through out 2020.

There was one Reportable Event at MNR in 2020.

There were no lost time injuries, near misses or major safety findings in 2020.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2020.

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.