McMaster Nuclear Reactor

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

Annual Compliance Monitoring and Operational Performance 2018

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 2018.

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, radio-chemistry, 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 79.6% with no major unplanned outages taking place during the year.

There were no lost time injuries, near misses or major safety findings in 2018.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2018.

As part of MNR's outreach program more than 2000 visitors toured through the facility in 2018. Many visitors were students from local high schools and universities who were given the unique experience of seeing the "blue glow" of an operating reactor core and an introduction to nuclear sciences.

Major activities scheduled for 2019 will include further commissioning of beam line for the McMaster Intense Positron Beam Facility (MIPBF) and instrument installation support for the McMaster University Small Angle Neutron Scattering (SANS) facility. As Canada's largest research reactor, a continued increase in support is expected by researchers and by the radiopharmaceutical industry.

INTRODUCTION

General Introduction

McMaster Nuclear Reactor (MNR) is operated by McMaster University for research, education and commercial service. 2018 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 checkout 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 2018, resulting from an alpha uptake to a worker which was initially believed to have approached or exceeded an ACL for the facility. Final dosimetry concluded that the actual uptake was radiologically insignificant, however given the potential for a larger uptake a root cause investigation was completed for the event and a resulting corrective action plan was implemented to prevent recurrence. (Note: this event was reported under the Consolidated Licence for the University as the work leading to the contamination was performed under that licence).

Throughout the year MNR continued to play a significant role in the leadership of neutron based science and medical isotope production within Canada.

Facility Operation

Reactor operation proceeded normally throughout 2018. Overall performance continues to be good. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

There were twenty-four (24) unscheduled shutdowns in 2018, up from 2017. The largest factor affecting the increase was the number of hydro fluctuations experienced in 2018 versus 2017. 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 2018. Minor repairs and replacements were performed as required. There was no evidence of any trends or significant changes.

Two planned outages were taken in 2018. The first, at the beginning of January, to install prompt gamma beam line components and to complete some annual maintenance activities and the second, complete in early July, to perform NDE work on the primary water systems and to complete maintenance on two Ion Chamber housings.

The reactor was operated at power during 2018 for a total of 3,572 hours, for a total energy output of 10,438 megawatt-hours. At year-end MNR had been operated for 205,890 hours for a life-time energy output of 599,302 megawatt-hours. Reactor availability, defined for MNR as the percentage of operating hours relative to available hours, was 79.6%. **Figure 1.3-1** shows reactor operation and power output at MNR over the past ten years.

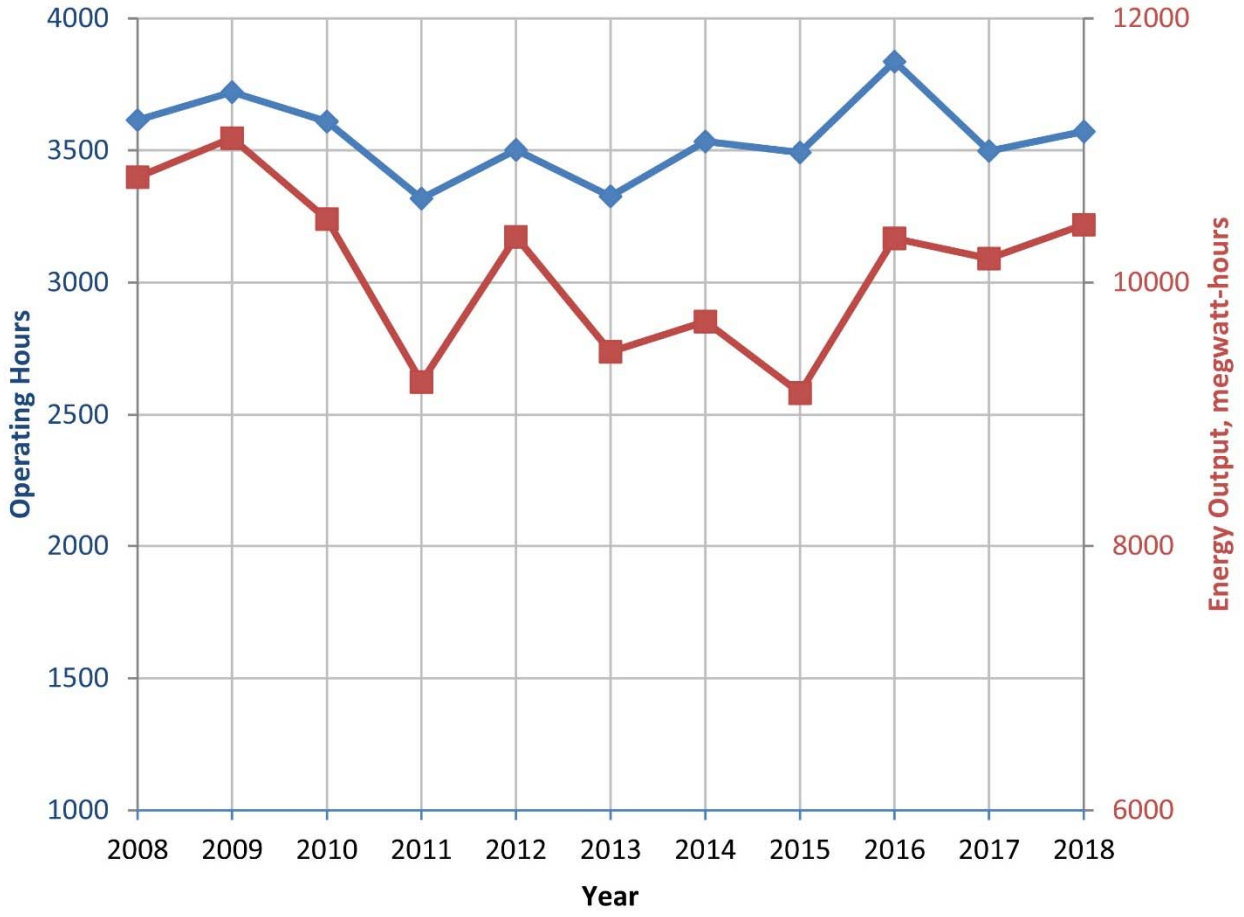


Figure 1.3-1 Reactor Operating Hours and Power Output

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 installed in 2017 continued its performance testing throughout 2018.

A new state of the art exhaust monitoring system was physically installed and continued its performance testing throughout 2018.

A project was initiated to implement electronic reading sheets to allow for expanded data monitoring and analysis capabilities.

Additional paperless recorders were installed to enhance monitoring capabilities of the facility.

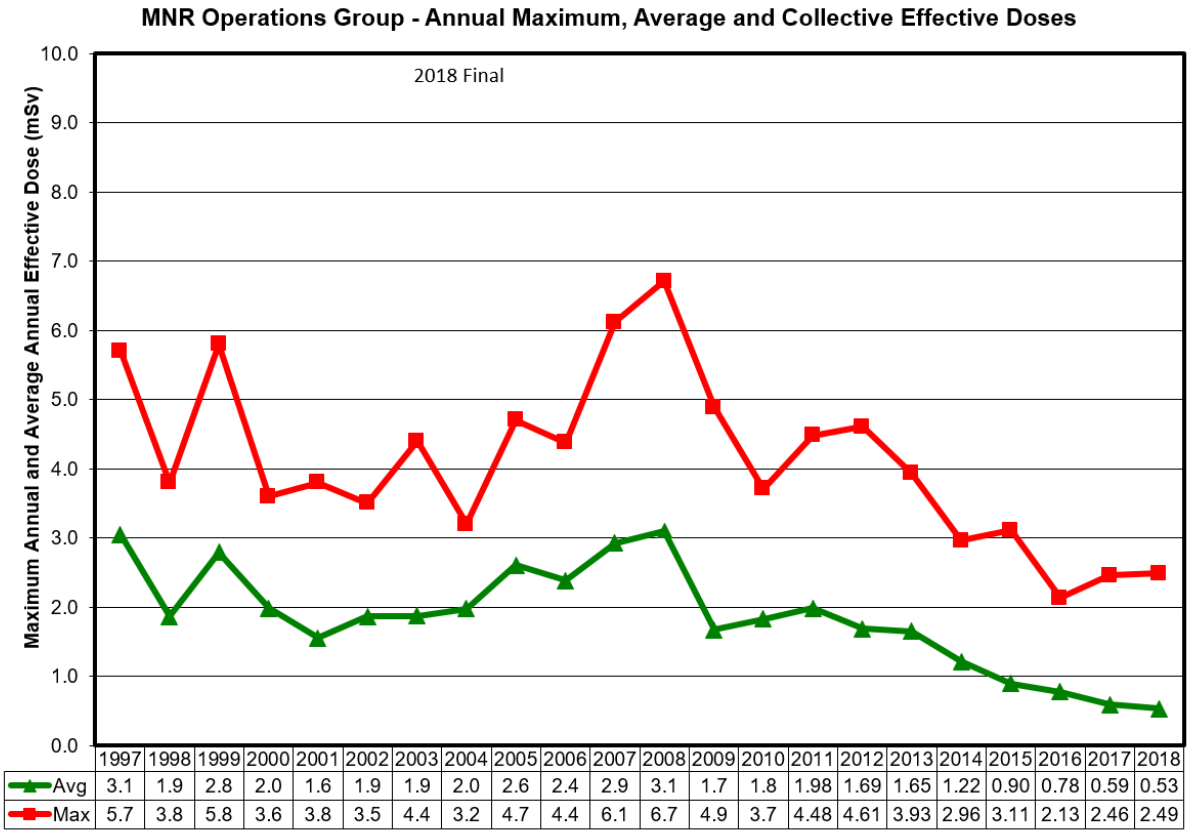
Radiation Protection

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 two Health Physics staff members in 2018. All other personnel associated with the operation of the facility receive annual effective doses of less than 1 mSv.

Operations Personnel

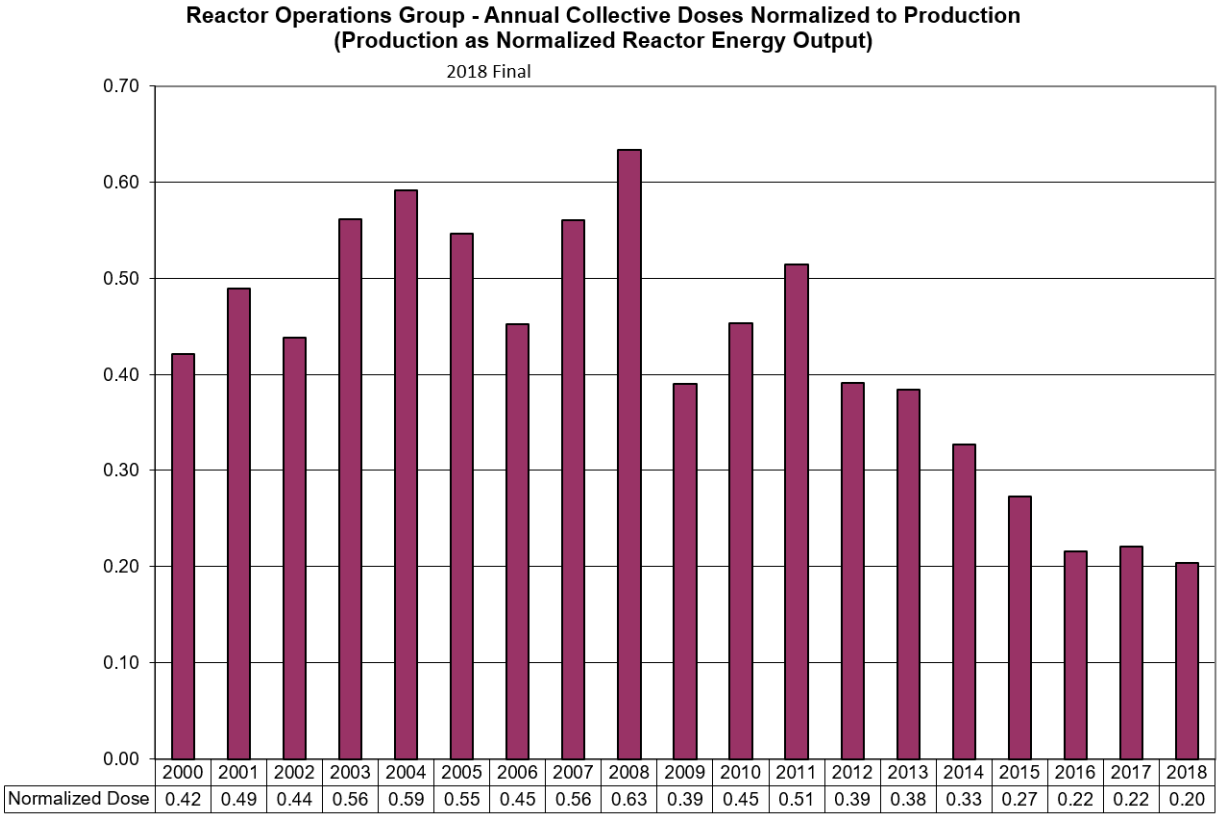
Operations Personnel comprise the Director of Nuclear Operations and Facilities, the Manager, Reactor Operations, Reactor Supervisors, Reactor Operators, and Assistant Reactor Operators. Student Operators are also included in this group.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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
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

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 2018, the goal was 0.40 person mSv per unit relative output. The result for 2018 was 0.20 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-2**. A generally improving trend in this performance is evident.



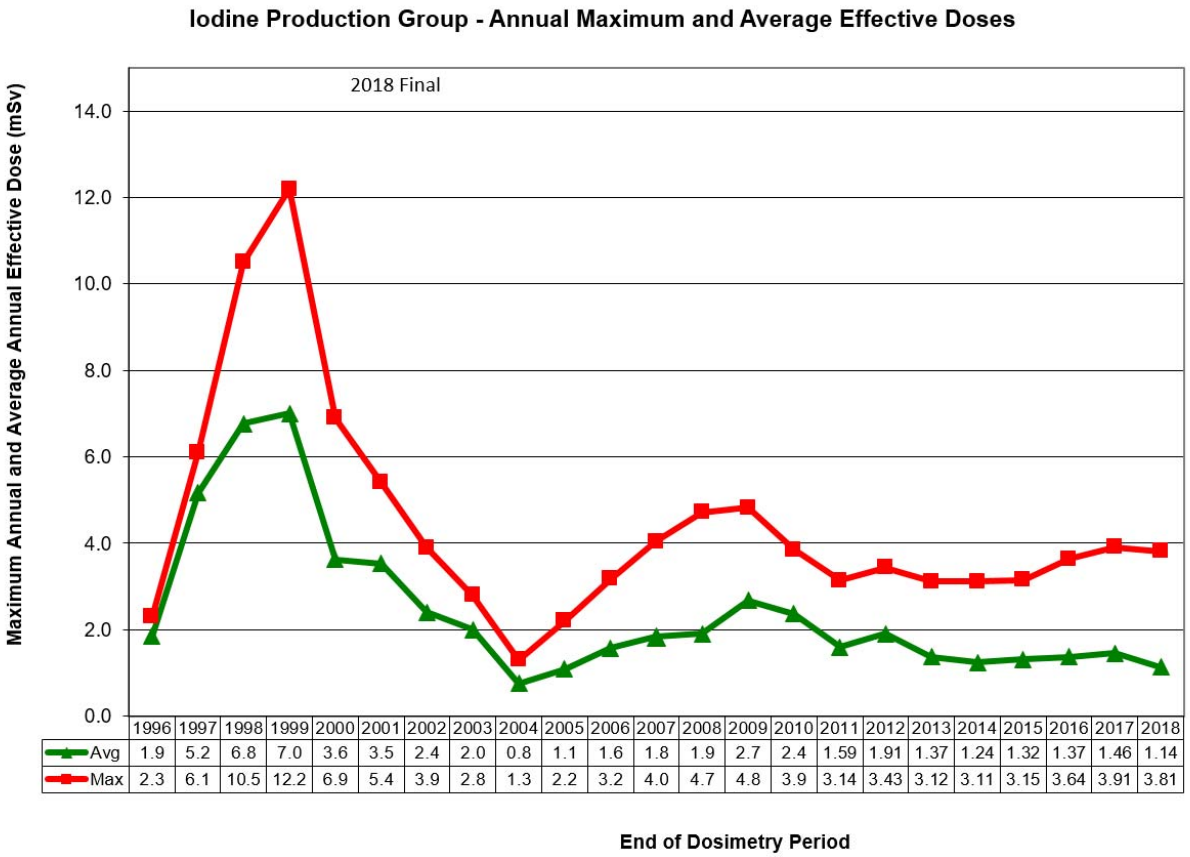
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Normalized Dose	0.42	0.49	0.44	0.56	0.59	0.55	0.45	0.56	0.63	0.39	0.45	0.51	0.39	0.38	0.33	0.27	0.22	0.22	0.20

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 2018 occupational exposures for the group are presented in **Table 2.3.1-1**.

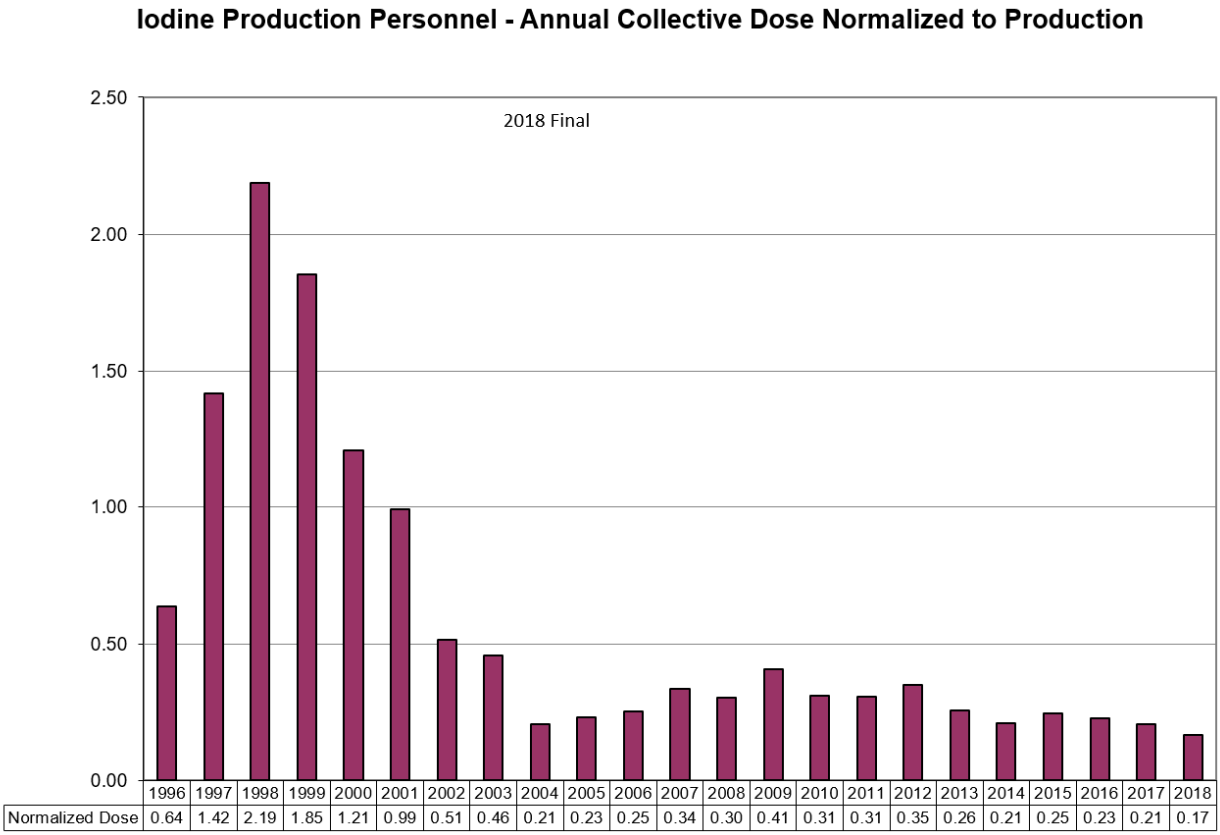
The historical values of the annual average and maximum dose for this group are presented in **Figure 2.3.1-3**. No trends of concern are indicated by the data. The average, maximum and collective effective doses are all well within the recent operating experience for the facility.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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
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

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 2018, the goal was 0.32 person mSv per unit relative output. The result for 2018 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 2018 value representing the lowest historical value ever.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Normalized Dose	0.64	1.42	2.19	1.85	1.21	0.99	0.51	0.46	0.21	0.23	0.25	0.34	0.30	0.41	0.31	0.31	0.35	0.26	0.21	0.25	0.23	0.21	0.17

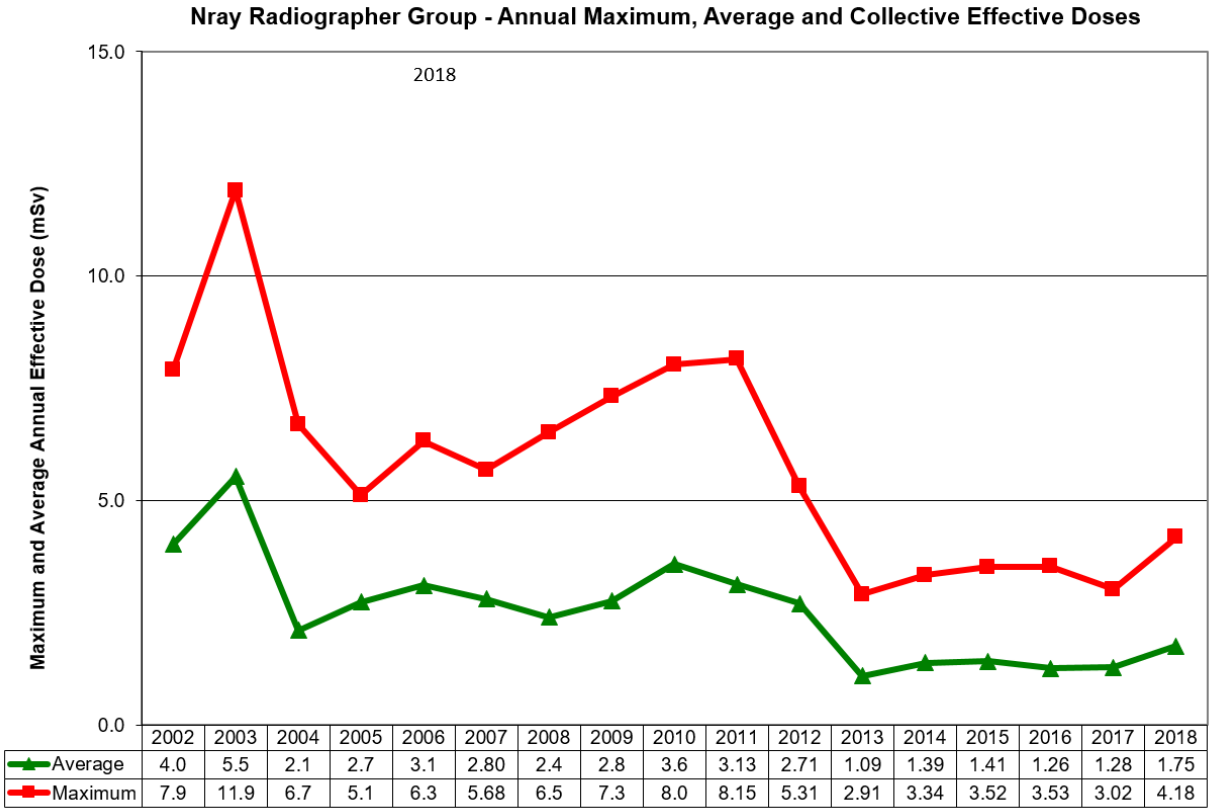
Figure 2.3.1-4

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 2018 occupational exposures for the group are presented in **Table 2.3.1-3**.

As in previous years, the only contribution to effective dose was external deep dose (Hp(10)). There is no indication of any significant internal exposures from extensive facility air and surface contamination monitoring or from personnel contamination monitoring.

A comparison of the maximum dose of each type with the facility Administrative Control Levels (ACLs) and Regulatory Limits is presented in **Table 2.3.1-4**. No doses exceeded the corresponding ACL or Regulatory Limit in 2018.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
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
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

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 2018, the goal was 0.20 person mSv per unit relative output. The result for 2018 was 0.16 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-6**. Performance continues to be excellent, near historically low values.

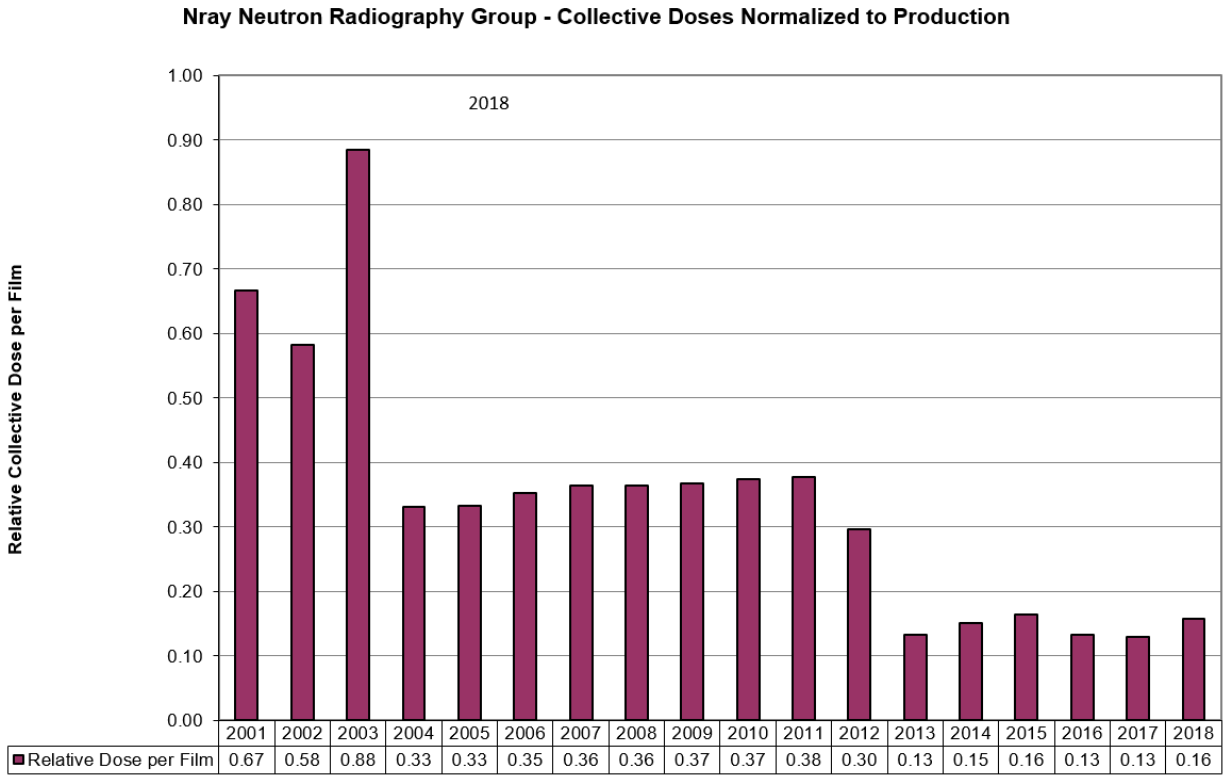


Figure 2.3.1-6

Health Physics

Two Health Physics Department staff members, DL and CM, received an annual effective dose of 1.50 mSv and 1.10 respectively, during 2018. The dose was accumulated gradually through the year on various tasks in the Reactor Building and other McMaster facilities. The majority of the dose was associated with the preparation, characterization and shipping of waste. Additional dose was accumulated during support of radiological work plans.

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 2018 is among the lowest collective dose result in the recent operating history of the facility, despite generally higher utilization.

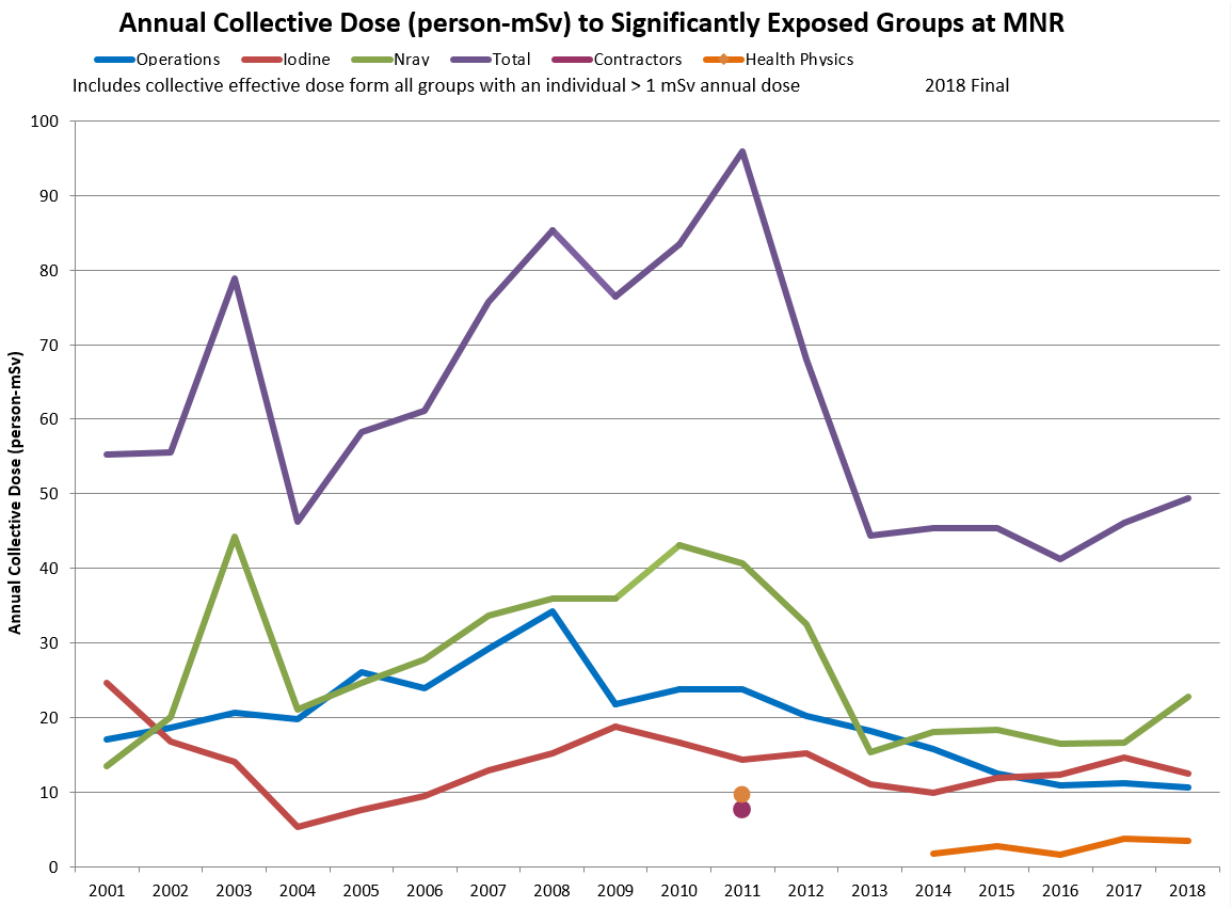


Figure 2.3.1-7

Significant Radiological Incidents

During 2018:

- 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 2018 goals were met or exceeded.

During 2018, the committee met on 9 occasions. 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 2018.

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 – 2018

Annual Average Concentration:	3.6×10^{-3} Bq m^{-3}
Maximum Weekly Average Concentration:	4.3×10^{-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	%
1.9×10^{5}	5.0×10^{8}	0.04	4.2×10^{4}	9.0×10^{6}	0.5

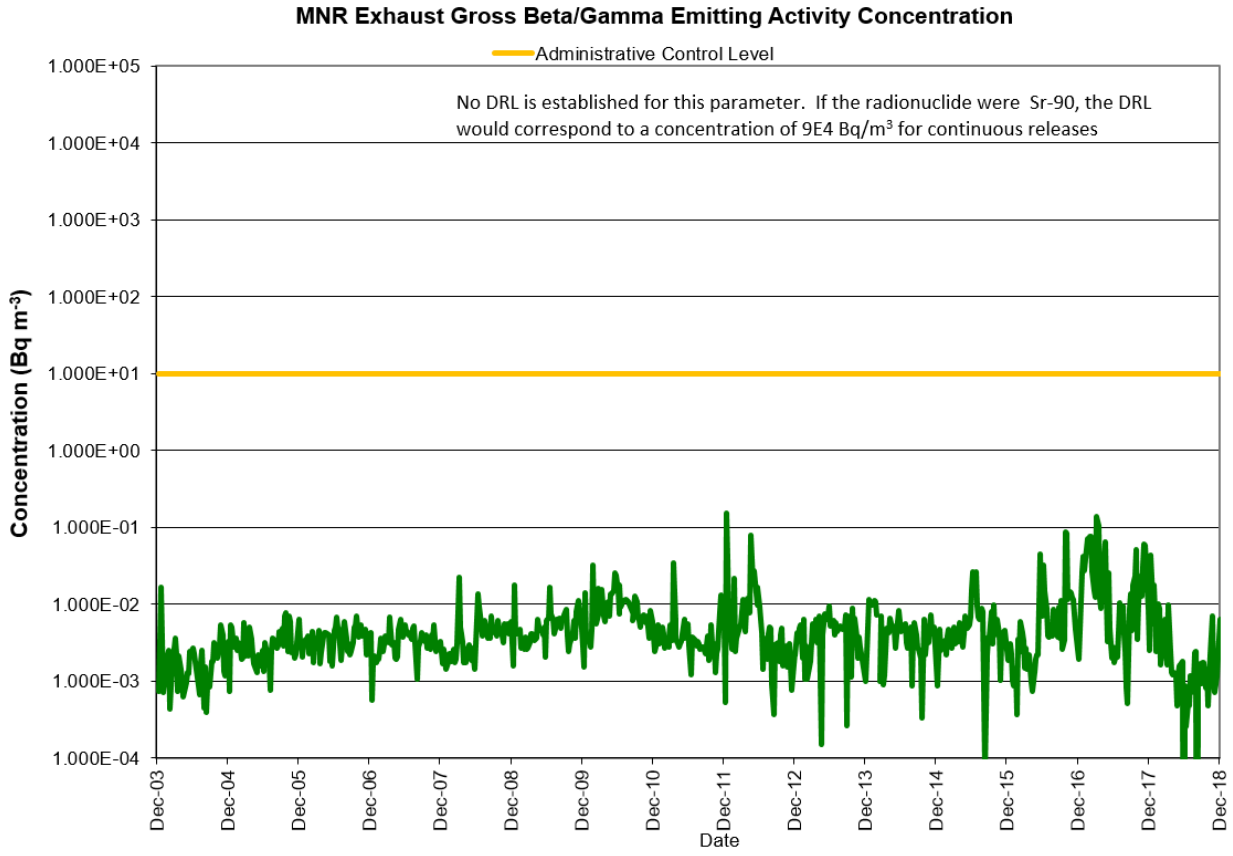


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2018

Annual Average Concentration:	7.6 Bq m^{-3}
Maximum Weekly Average Concentration:	40.9 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	%
4.0×10^{8}	1.0×10^{10}	9.4×10^{12}	0.004	4.1×10^{7}	2.0×10^{8}	1.8×10^{11}	0.02

Boundary Dose = 0.042 micro-Sv (NRB Occupants)

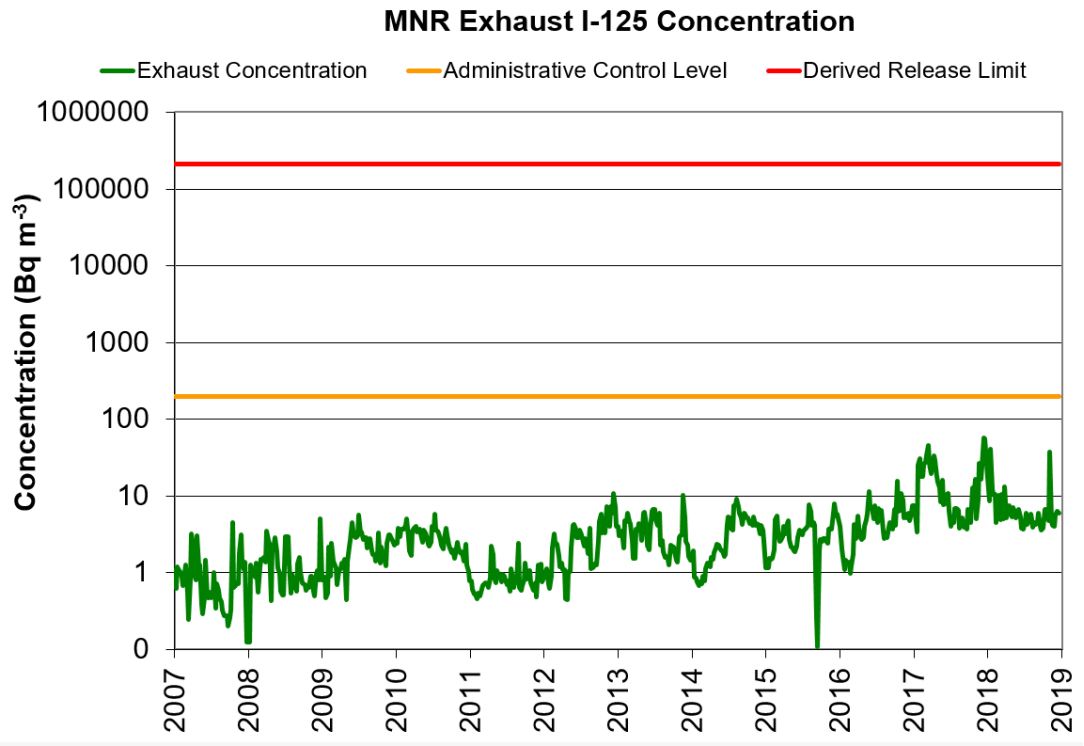


Figure 2.3.3-2

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 – 2018

Annual Average Concentration: 3.6×10^{4} Bq m^{-3}
Maximum Weekly Average Concentration: 7.7×10^{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	%
7.7×10^{11}	1.6×10^{13}	1.3×10^{15}	0.06	3.1×10^{10}	3.1×10^{11}	2.5×10^{13}	0.1

Boundary Dose = 0.6 micro-Sv (infant permanently at point of maximum ground level concentration)

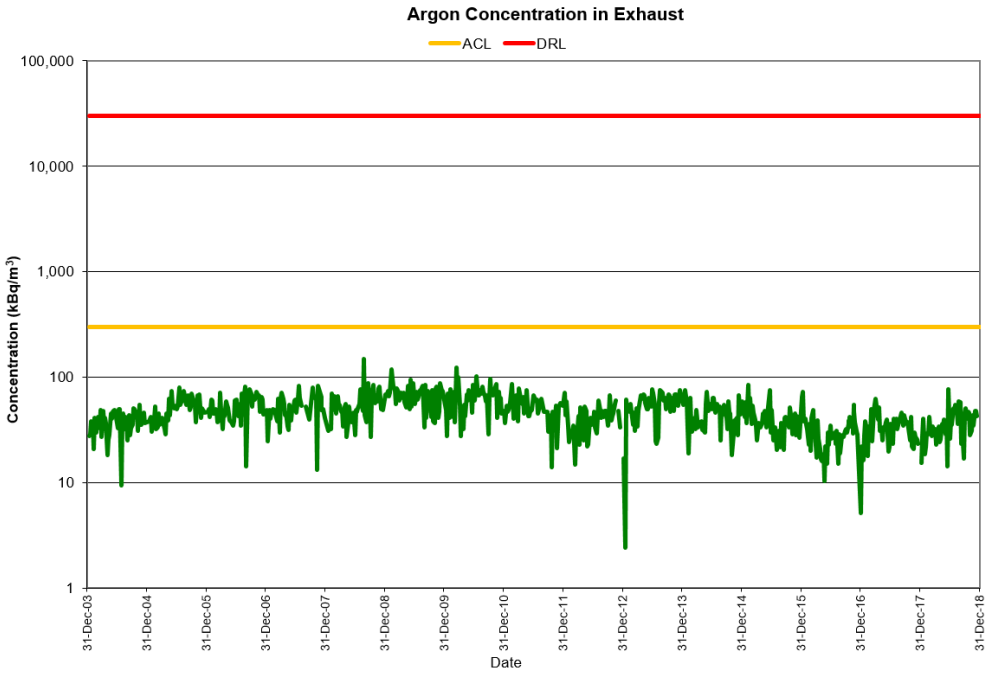


Figure 2.3.3-3

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 2018 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.

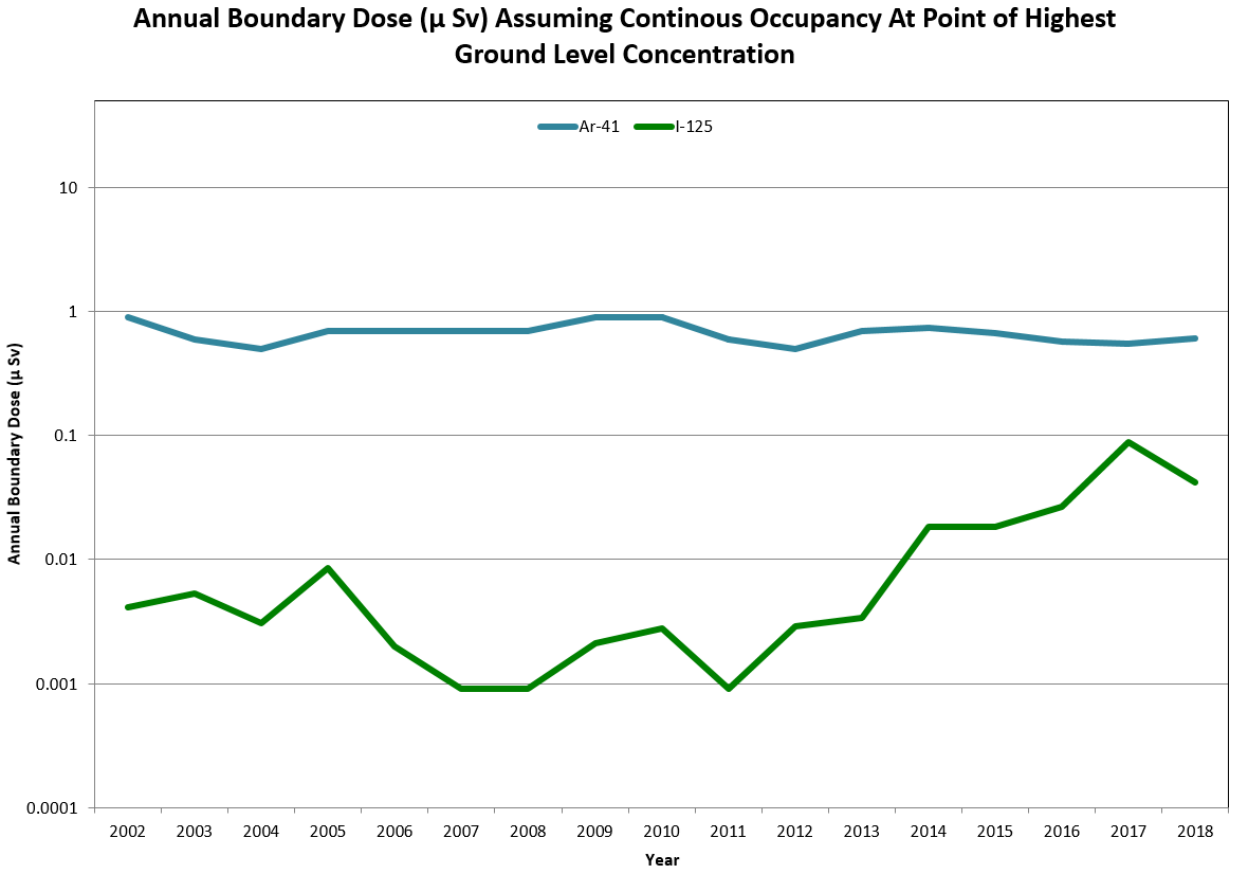


Figure 2.3.3-4

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 2018. 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. There is no indication of any breakthrough to this system in 2018.

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**.

There were higher than normal, although not radiologically significant, activities detected on some environmental particulate samples during 2018. These values are intermittent and show no apparent trend. 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.

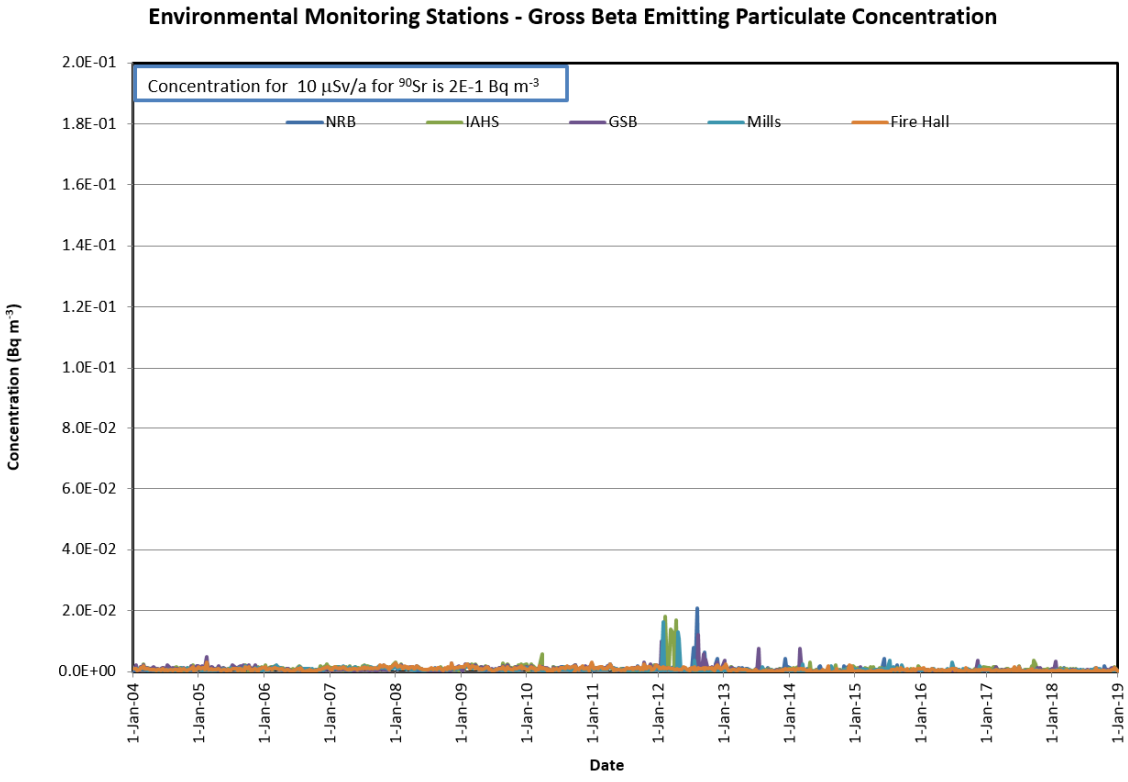


Figure 2.3.3-6

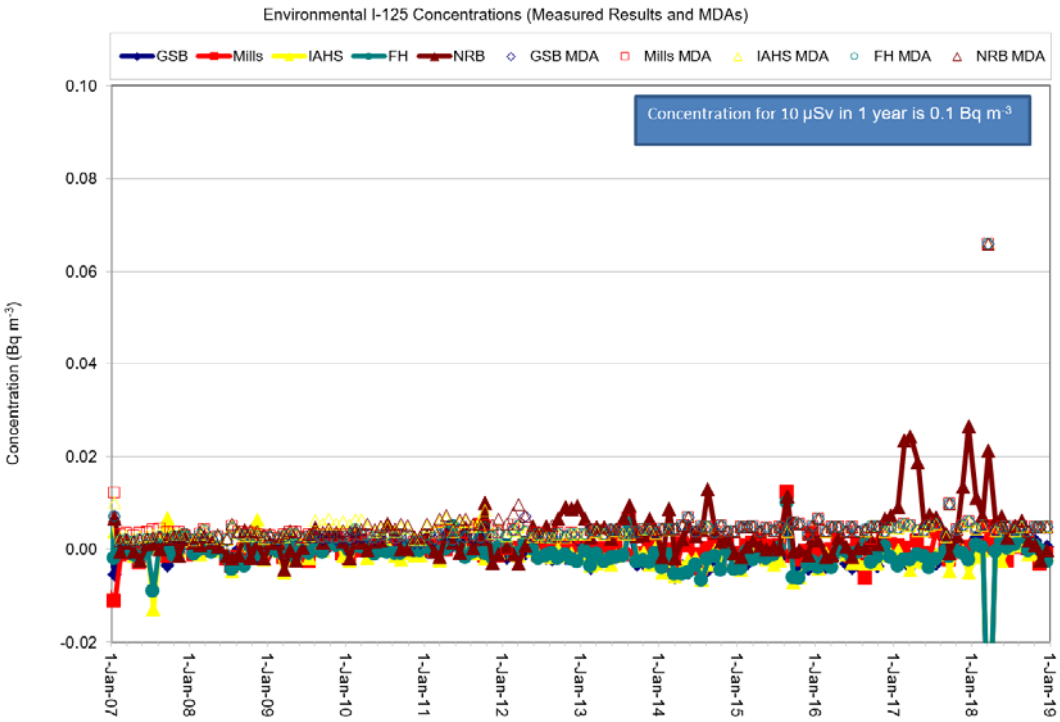


Figure 2.3.3-7

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 December 2018. Another annual review of the Type D emergency procedures with University, City and Provincial emergency responders was held in December 2018. An evaluation and walk-through of the Access Control Point in support of the Type D procedure was held in April 2018.

CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely and effectively in 2018 and continued to support the educational and research goals of McMaster University.

There were no lost time injuries, near misses or major safety findings in 2018.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2018.

Major projects planned for 2019 include the continued commissioning of the MIPBF at MNR, the installation and initial commissioning of the SANS instrumentation.

Expanded support for Canadian researchers, students and industries displaced by the closure of NRU is provided by MNR to its best ability given the realities of self-funding constraints.