McMaster Nuclear Reactor

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

Annual Compliance Monitoring and Operational Performance 2016

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 2016.

MNR continued to support the educational and research goals of the University throughout the year specifically in the areas of nuclear 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 82% with no major unplanned outages taking place during the year.

There were no Reportable Events at MNR in 2016.

There were no lost time injuries, near misses or major safety findings in 2016.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2016.

As part of MNR's outreach program more than 2000 visitors toured through the facility in 2016. 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 2017 will include commissioning of beam line for the McMaster Intense Positron Beam Facility (MIPBF) and construction support for the McMaster University Small Angle Neutron Scattering (SANS) facility.

1.0 INTRODUCTION

1.1 General Introduction

McMaster Nuclear Reactor (MNR) is operated by McMaster University for research, education and commercial service. 2016 was a typical year in terms of operation.

The reactor was operated between 2.5 and 3.0 MW to accommodate 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.

For a six week period starting on October 17th the reactor was operated on a 24-5 operating schedule to assess a continuous operating cycle for the facility. The continuous operating cycle was successfully completed on November 26th.

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 2016.

1.2 Facility Operation

Reactor operation proceeded normally throughout 2016. Overall performance continues to be good. There were no significant unscheduled outages as a result of equipment performance or maintenance issues.

There were no significant issues with equipment or systems during 2016. Minor repairs and replacements were performed as required. There was no evidence of any trends or significant changes.

From October 17th through November the 26th the reactor was operated twenty-four hours a day five days a week to assess a continuous operating cycle at the facility. The assessment was successfully completed without incident.

The reactor was operated at power during 2016 for a total of 3,837 hours, for a total energy output of 10,335 megawatt-hours. At year-end MNR had been operated for 198,821 hours for a life-time energy output of 578,672 megawatt-hours. Reactor availability, defined for MNR as the percentage of operating hours relative to available hours, was 82%. **Figure 1.3-1** shows reactor operation and power output at MNR over the past ten years.

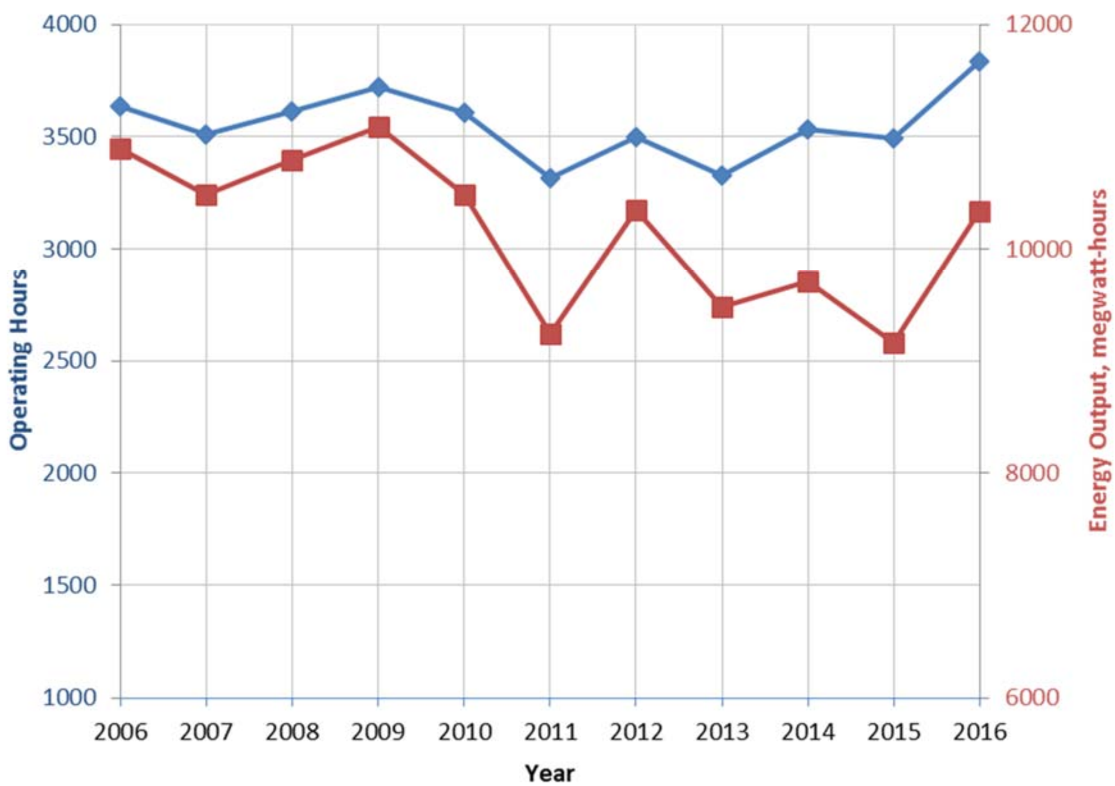


Figure 1.3-1 Reactor Availability and Power Output

Work was completed on the cooling water towers (motor and fan replacements) as part of the campus wide noise abatement program.

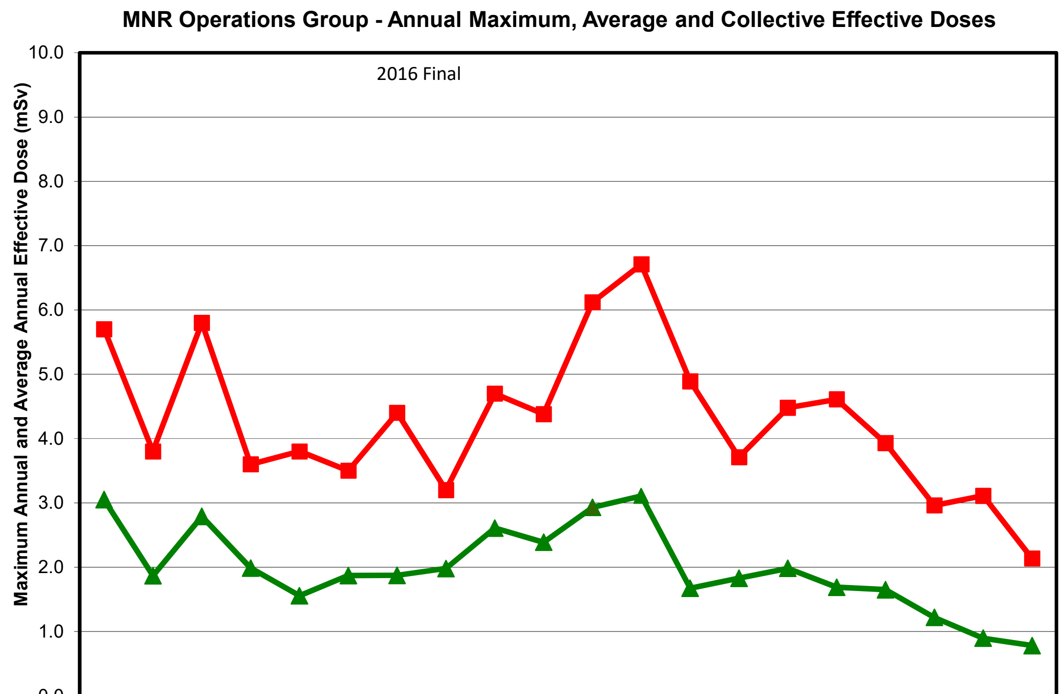
2.3.1 Radiation Protection

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 2016. 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 2016 occupational exposures for the group are presented in **Figure 2.3.1-1**.



	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
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
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	2.14

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 2016, the goal was 0.40 person mSv per unit relative output. The result for 2016 was 0.22 person mSv per unit relative output. The goal was achieved. The recent annual values of this quantity are shown in **Figure 2.3.1-2**. A generally improving trend in this performance is evident.

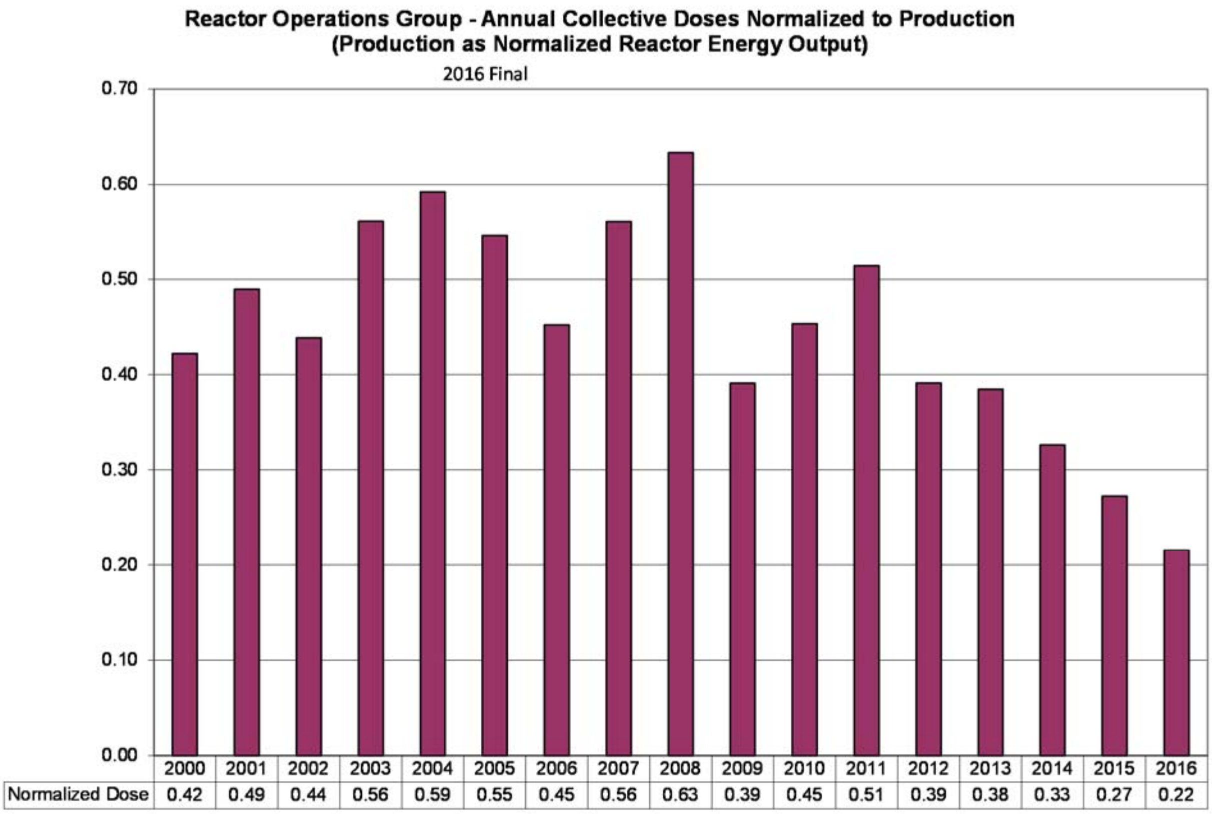
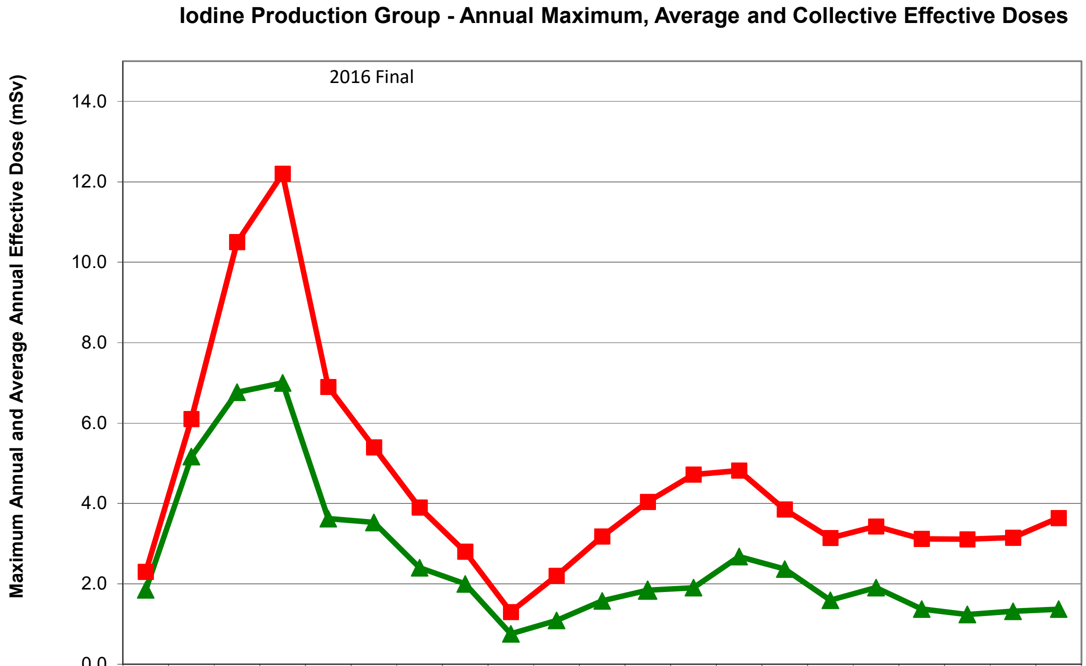


Figure 2.3.1- 2

Iodine Production Personnel

Iodine Production Personnel comprise the Production Manager, Production Technologist, the Manager of Laboratory Services and Production Assistants.

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.



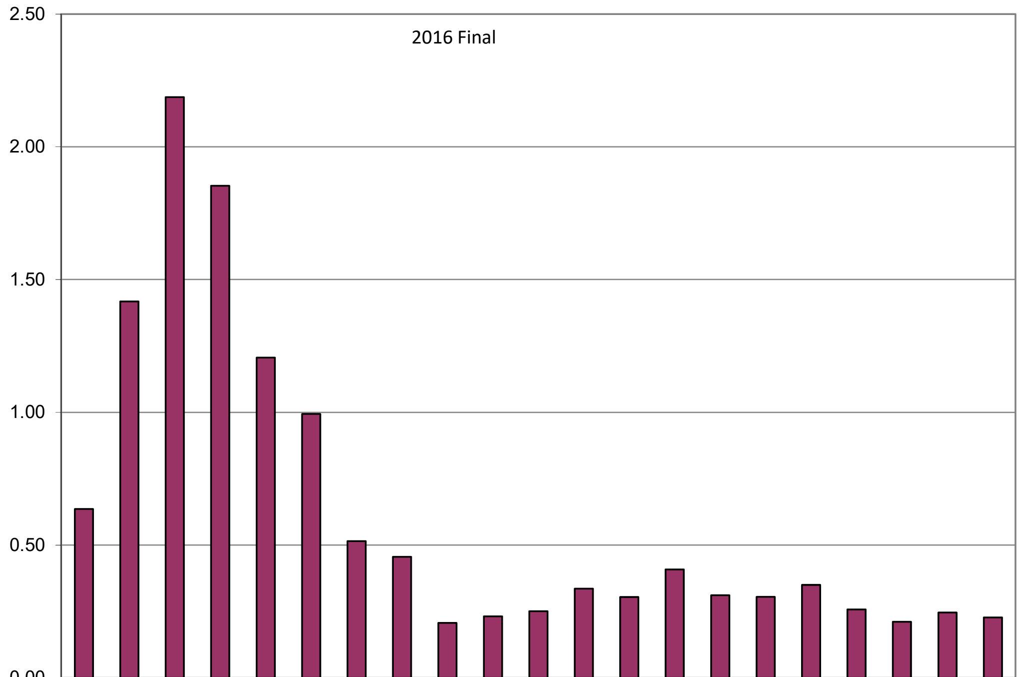
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Average	1.9	5.2	6.8	7.0	3.6	3.5	2.4	2.0	0.8	1.1	1.6	1.8	1.9	2.7	2.4	1.59	1.91	1.37	1.24	1.32	1.37
Maximum	2.3	6.1	10.5	12.2	6.9	5.4	3.9	2.8	1.3	2.2	3.2	4.0	4.7	4.8	3.9	3.14	3.43	3.12	3.11	3.15	3.64

End of Dosimetry Period

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 2016, the goal was 0.32 person mSv per unit relative output. The result for 2016 was 0.23 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, close to the historical minimum, is evident.

Iodine Production Personnel - Annual Collective Dose Normalized to Production



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

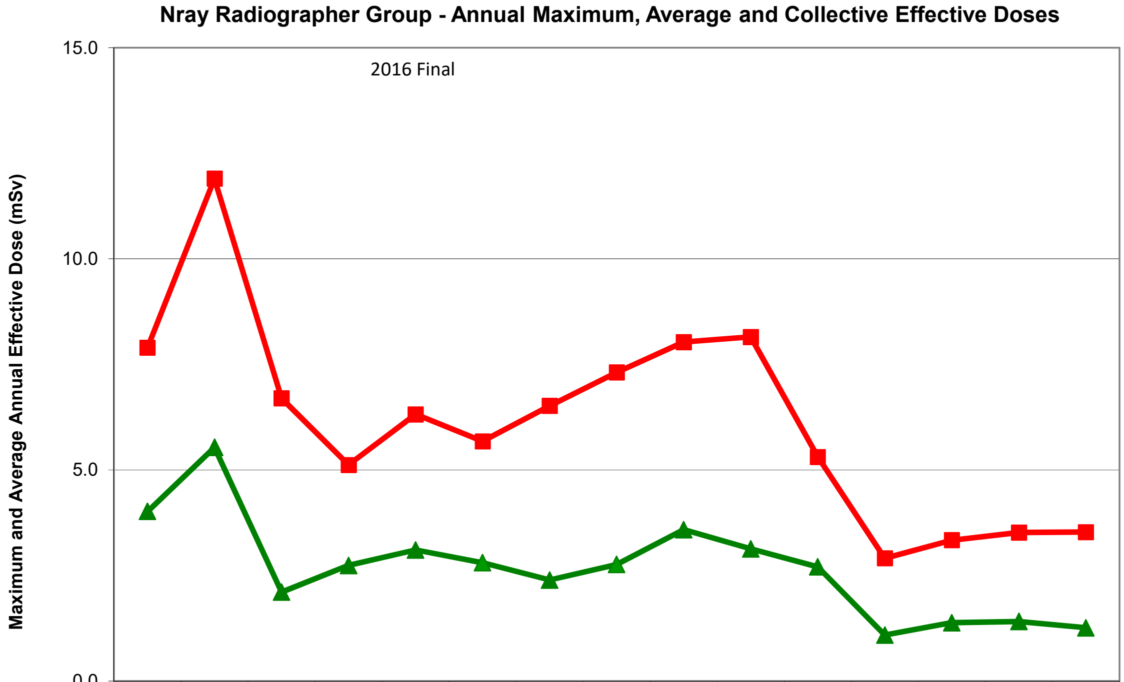
Figure 2.3.1-4

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.

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.

The historical values of the annual average and maximum dose for this group are presented in Figure 2.3.1-5. 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.



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

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 2016, the goal was 0.20 person mSv per unit relative output. The result for 2016 was 0.13 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.

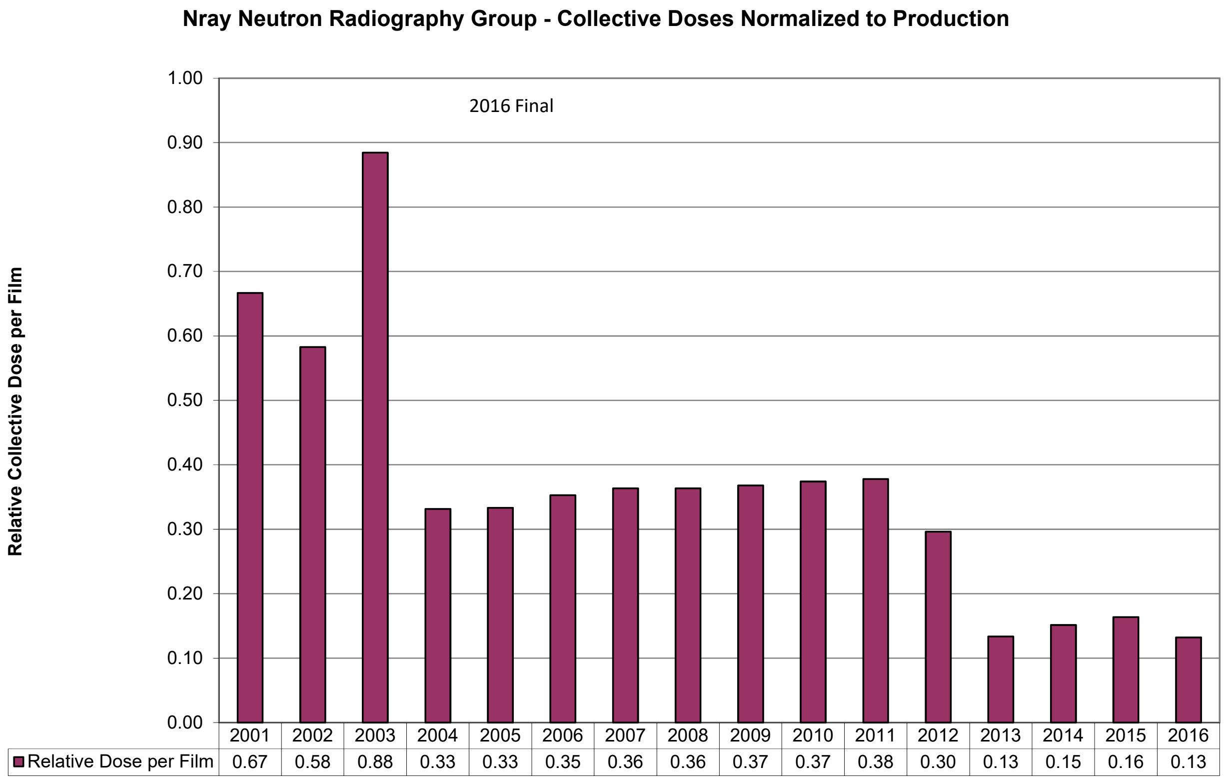


Figure 2.3.1-6

Health Physics

One Health Physics Department staff member received an annual effective dose of 1.58 mSv during 2016. 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 a spent resin waste shipment. That work began in 2015 and carried over into 2016. A second shipment was prepared at the end of 2016 and carried over into 2017.

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 2016 is the lowest experienced in the recent operating history of the facility, despite generally higher utilization.

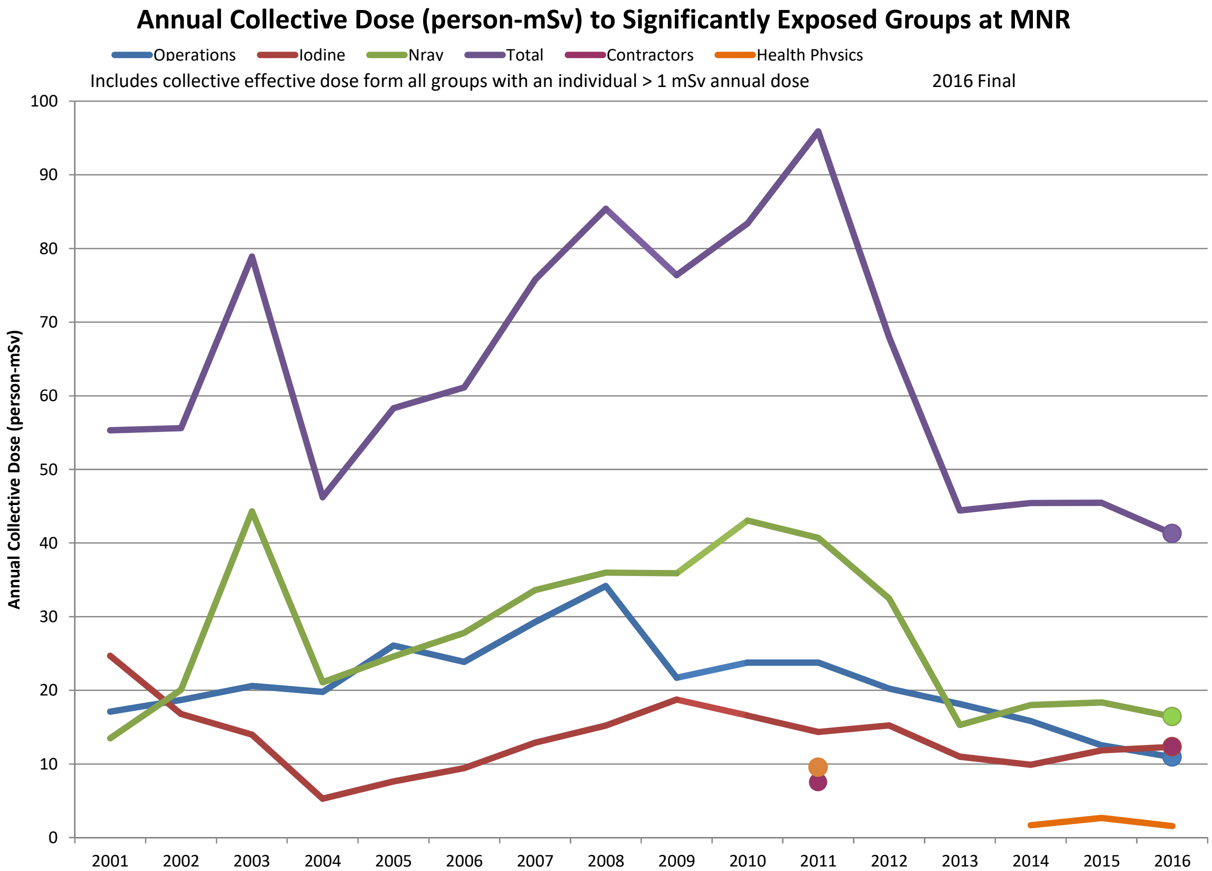


Figure 2.3.1-7

Significant Radiological Incidents

During 2016:

- 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.

2.3.2 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 2016 goals were met or exceeded.

During 2016, the committee met on approximately ten 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 2016.

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

2.3.3 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 – 2016

Annual Average Concentration: 9.5×10^{-3} Bq m^{-3}

Maximum Weekly Average Concentration: 8.8×10^{-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	%
5.0×10^5	5.0×10^8	0.1	8.8×10^4	9.0×10^6	1.0

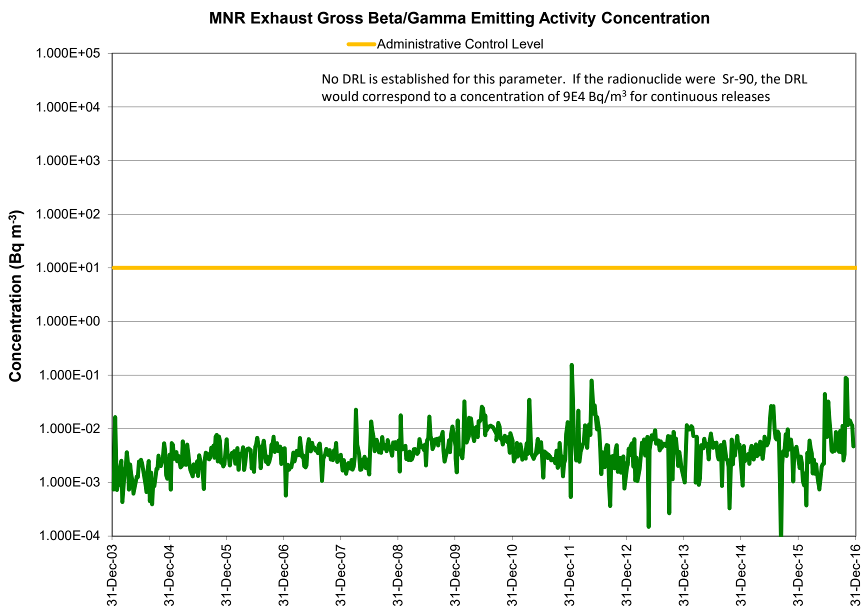


Figure 2.3.3- 1

Table 2.3.3- 2: Comparison of I-125 Concentrations with Applicable Limits – 2016

Annual Average Concentration: 4.8 Bq m^{-3}
Maximum Weekly Average Concentration: 15.5 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	%
2.5×10^{8}	1.0×10^{10}	9.4×10^{12}	0.003	1.6×10^{7}	2.0×10^{8}	1.8×10^{11}	0.01

Boundary Dose = 0.027 micro-Sv (NRB Occupants)

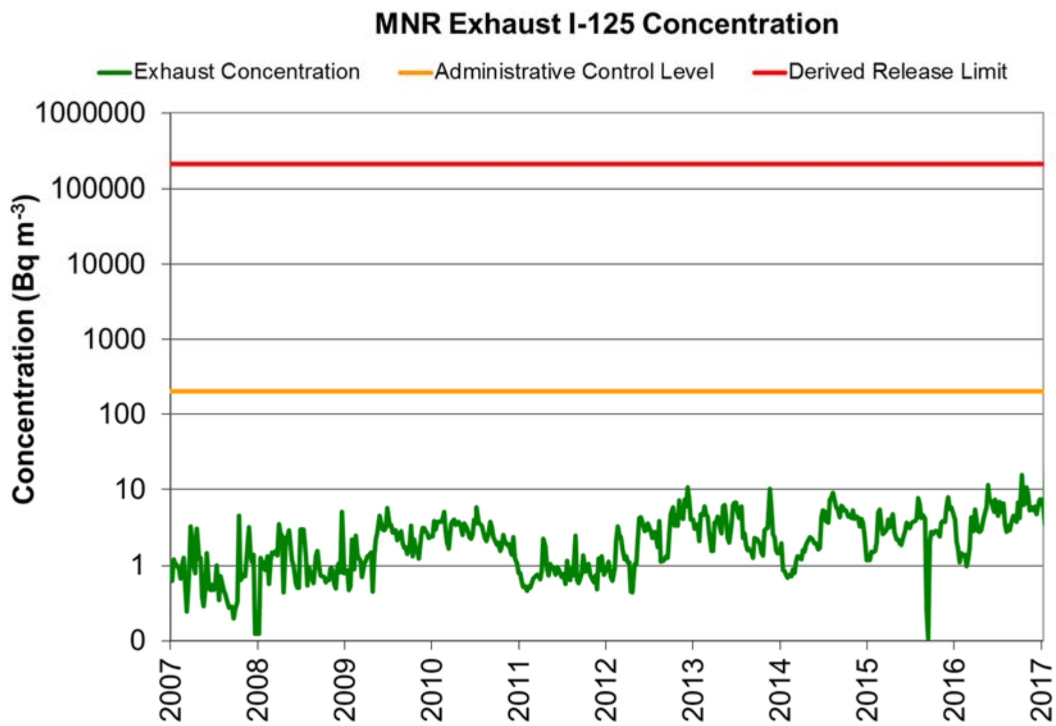


Figure 2.3.3-2

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 – 2016

Annual Average Concentration: 5.16×10^3 Bq m^{-3}
Maximum Weekly Average Concentration: 15.6×10^3 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	%
7.1×10^{11}	1.6×10^{13}	1.3×10^{15}	0.05	3.2×10^{10}	3.1×10^{11}	2.5×10^{13}	0.2

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

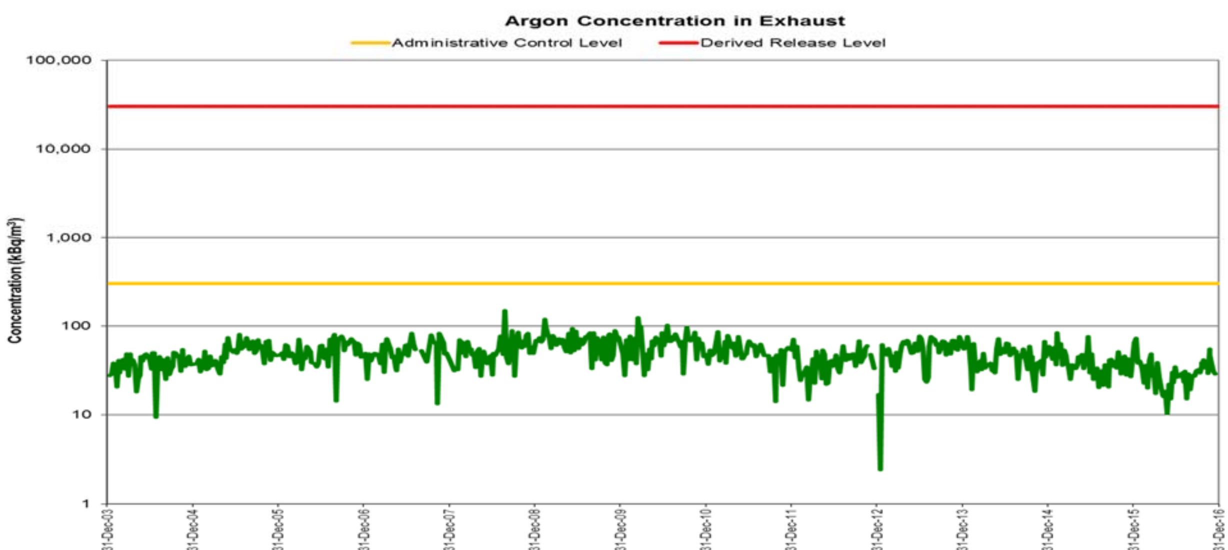


Figure 2.3.3-3

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 2016 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.

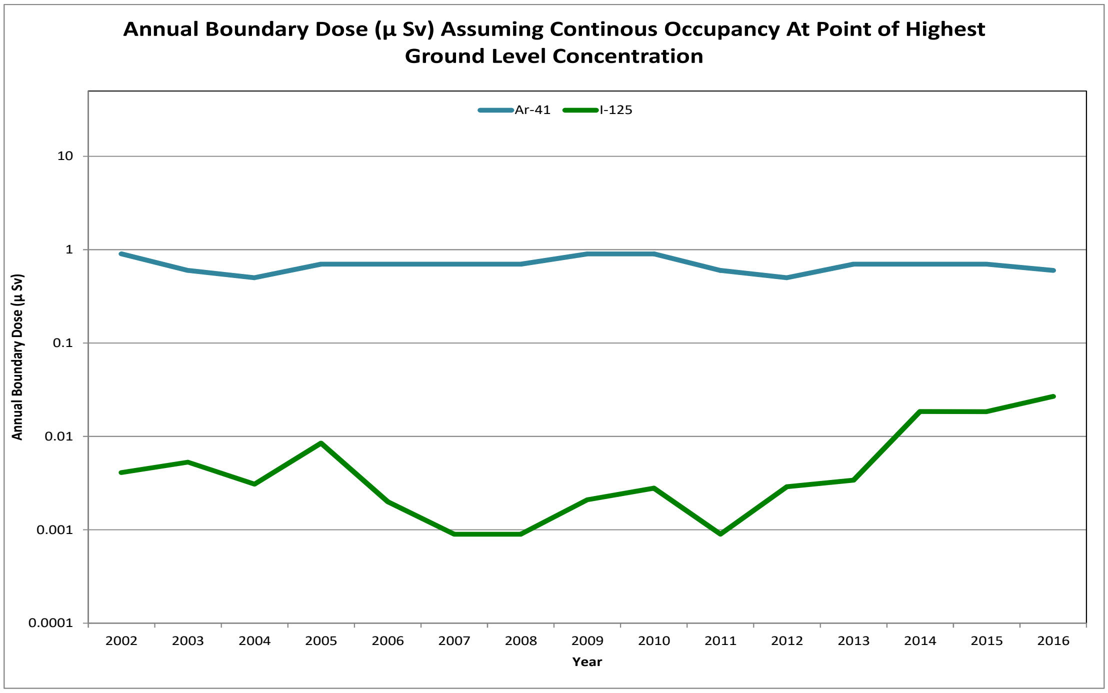


Figure 2.3.3-4

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 2016. 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 2016.

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 2012. There was no apparent continuation of the trend in the three following years. The lack of any correlation with concentrations at the sampling point at the Nuclear Research Building air intake (a point very close to the MNR exhaust and in the predominant wind direction) indicates that the activity is likely attributable to a source other than MNR. 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.

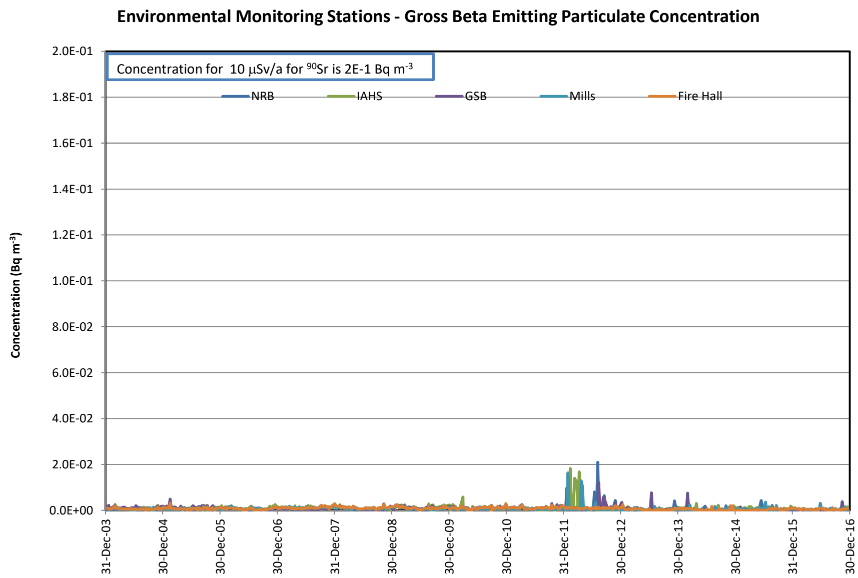


Figure 2.3.3-6

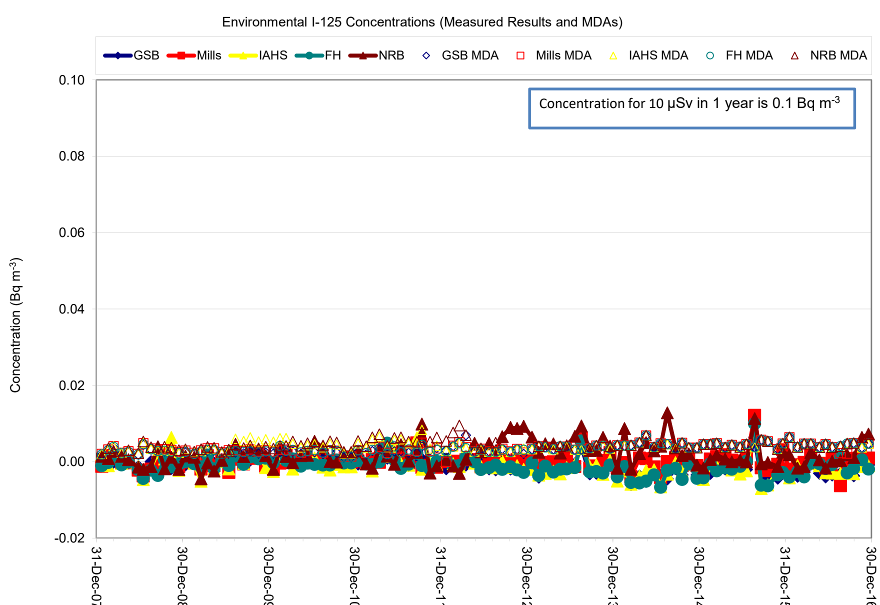


Figure 2.3.3-7

2.3.4 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 March 2016.

4.0 CONCLUDING REMARKS

The McMaster Nuclear Reactor (MNR) was operated safely, securely and effectively in 2016 and continued to support the educational and research goals of McMaster University.

No Reportable Events occurred at MNR in 2016.

There were no lost time injuries, near misses or major safety findings in 2016.

Doses to workers and releases to the environment remained ALARA throughout the year. Specific radiological and environmental safety goals were met or exceeded in 2016.

Major projects planned for 2017include the installation of the MIPBF at MNR, the construction of the SANS and the associate guide hall.

The impact of the closure of NRU on the MNR's mission will be extensively evaluated during the upcoming year.