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Oral Presentation

Written submission from Julian Aherne

Exposé oral

Mémoire de Julian Aherne

In the Matter of the

BWXT Nuclear Energy Canada Inc., Toronto and Peterborough Facilities

Application for the renewal of the licence for Toronto and Peterborough facilities

Commission Public Hearing

March 2 to 6, 2020

À l'égard de

BWXT Nuclear Energy Canada Inc., installations de Toronto et Peterborough

Demande de renouvellement du permis pour les installations de Toronto et Peterborough

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Du 2 au 6 mars 2020

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Intervention Submission | Julian Aherne

BWXT Licence Renewal Hearing (Reference 2020-H-01)
Date: February 3, 2020

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Summary of Recommendations

BWXT Nuclear Energy Canada Inc. (BWXT) has applied to renew its single Class 1B Fuel Facility Operating Licence 3620.01/2020. The licence application proposes the continued operations of both the Peterborough and Toronto facilities for a period of 10 years, from December 31, 2020 to December 2030. BWXT has also requested authorization to allow pelleting operations at the Peterborough facility. The environmental concentrations of hazardous substances, i.e., beryllium and uranium, released from the Peterborough facility are monitored only by the Canadian Nuclear Safety Commission (CNSC) under their Independent Environmental Monitoring Program (IEMP). Following review and analysis of the IEMP data, I recommend:

Recommendation 01. I recommend that the CNSC do not grant the BWXT licence renewal application. The statistically significant increase in the concentration of beryllium in surface soils observed in the IEMP data indicate that emissions from the BWXT facility in Peterborough may pose a risk to human health and the environment. This observation is inconsistent with the fundamental requirement that '*The Commission will only issue a licence if it is satisfied that the proposed nuclear facility or activity would pose no danger to the health, safety and security of persons and the environment*'.

Recommendation 02. I recommend that the CNSC require ambient environmental monitoring for all facilities located within residential areas; this will ensure that the public and the environment are protected from emissions from licenced facilities. Environmental monitoring programs provide additional (external) verification on facility emissions and provide the public with direct information on environmental quality.

Recommendation 03. The CNSC should require all licensee applicants to describe in detail their required (or proposed) environmental monitoring programs. The general public do not have access to documents by the Canadian Standards Association, e.g., CSA N288.4-10 0, as such, the public are excluded from commenting on the composition and completeness of environmental monitoring programs.

Recommendation 04. The CNSC need to ensure greater accuracy in the reporting of the IEMP results. The IEMP has its strength in the verification of the ongoing environmental monitoring activities by the licensee. In isolation, the IEMP data cannot independently verify that the public and the environment around licensed nuclear facilities are safe. The program uses a judgemental sampling design with a limited number of measurements, which does not support inferences of exposure to the general population or the environment.

Recommendation 05. The CNSC need to ensure greater thoroughness in the analysis and reporting of the IEMP results. Despite the limited sample size of the IEMP data, repeated (multi-year) sampling of soils at fixed locations can be used to support trend analysis, i.e., an assessment of environmental response to facility emissions. If trends are observed in the IEMP data, they should be reported and, where necessary, appropriate actions should be implemented; "*If soil analysis indicates rising levels, emissions have increased, and investigation must be made into the causes*" (BWXT 2018).

1. Independent Environmental Monitoring Program

BWXT Nuclear Energy Canada Inc. (BWXT) is licensed to operate a nuclear fuel fabrication facility in Peterborough, Ontario. The release of hazardous substances from the facility to the environment is controlled by BWXT in accordance with Canadian Nuclear Safety Commission's (CNSC) regulatory requirements. The current licence, FFOL-3620.00/2020, prescribes release limits for discharges of uranium and beryllium to water and air.

Under the current licence, BWXT is not required to implement an Environmental Monitoring Program (EMP) in Peterborough, i.e., they are not required to measure the concentrations of uranium and beryllium in the environment outside the facility boundary, as emissions discharged from the facility meet the required standards at the point of release, "*eliminating the need for additional ambient monitoring*" as noted by CNSC in their Commission Member Document (CNSC, 2019a).

The only program directly measuring concentrations of uranium and beryllium in the environment surrounding BWXT Peterborough is the CNSC's Independent Environmental Monitoring Program (IEMP). The CNSC implemented the IEMP to verify that the public and the environment around licensed nuclear facilities are safe. The IEMP involves taking samples from public areas around the facilities and measuring the amount of radiological (nuclear) and hazardous substances in those samples (CNSC, 2016).

There have been three IEMP sampling campaigns in Peterborough, carried out during 2014, 2018 and 2019. The concentrations of uranium and beryllium were measured in air, water, vegetation and soil samples collected during each campaign (all data are available online[1]). The air, water and vegetation samples are too few to support a reliable representative assessment of impacts to human health and environment or to assess environmental changes of uranium and beryllium. For example, the CNSC monitor ambient air concentrations of uranium and beryllium using a high-volume sampler deployed for only a short period on one day[2]. During 2014, one air sample was collected at one location in Peterborough, at four locations in 2018, and four locations in 2019 only. Given the limited sample size (limited number of samples) the data do not provide a representative estimate of exposure, e.g., one sample collected during a short period on one day during July 2014 is not representative of human and environmental exposure during the entire year of 2014. It is important to note, that the IEMP data may be used to verify the results of ambient monitoring by the licensee (i.e., evaluate by comparison); however, BWXT Peterborough is not required to directly monitor environmental concentrations, e.g., ambient air concentrations outside the facility boundary.

The IEMP soil monitoring provides the most useful data to assess the impacts of BWXT operations on human health and the environment in Peterborough. As noted by BWXT, airborne facility emissions impinge on the ground surface downwind of the release point. Accordingly, deposition of uranium and beryllium can be measured by analysing small samples of surface soil. "*If soil analysis indicates rising … levels, emissions have increased, and investigation must be made into the cause(s)*"; for

[1] URL: nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/bwxt-peterborough.cfm

[2] CNSC provide limited information on their field sampling protocols, this statement assumes that IEMP air samples are collected over a short duration rather than a 24-hour integrated sample.

further details see the Environmental Risk Assessment report prepared for BWXT by Arcadis Canada Inc. (BWXT, 2018). In Peterborough, soil sampling was carried out at eight fixed locations during each IEMP campaign (2014, 2018 and 2019). Despite the limited sample size, the repeated sampling (n = 3) at fixed monitoring locations provides greater statistical power to detect changes in the environment. It is important to note that surface soil (depth of 0–5 cm) is monitored as an indicator of uranium and beryllium long-term accumulation from atmospheric deposition rather than direct emissions to soil.

Following from the above, my analysis of the IEMP data primarily focused on soils (see Appendix A). This analysis indicates that: **(a) it is extremely likely beryllium concentrations in soils have significantly increased in response to emissions, (b) BWXT is very likely the source of the beryllium emissions, and (c) beryllium air concentrations during 2014 to 2019 were likely above the ambient air quality limits.**

1.1. Significant increase in the concentration of beryllium in soils

The IEMP data indicate a statistically significant increase ($p<0.05$[3]) in soil beryllium concentrations across the eight sampling sites between 2014 and 2019 (see Appendix B). On average there was an increase of 26% across the eight sites between 2014 and 2018, and a further increase of 12% between 2018 and 2019. The soil sampling site with the highest observed increase between 2014 and 2019 was the Prince of Wales Elementary School playground, which is located within 200 m from the BWXT facility boundary.

The median (rather than average) is a more robust measure of the mid-point of observed data, as it accounts for outliers (see Appendix B). The median concentration of beryllium in soils increased by 33% between 2014 and 2019. The observed increase in soil is inconsistent with CNSC's observation that '*Beryllium stack discharges to the environment from the Peterborough facility are considered to be negligible*' reported in their Environmental Protection Review (CNSC, 2019b). While a number of occupational exposures have been reported by BWXT[4], ambient air concentrations outside the facility are not monitored. The ambient air concentration measurements carried out by the CNSC under their IEMP, are too limited in number to provide a representative evaluation of the results of the soil data or the stack emissions.

It is important to note that the observed levels of beryllium in all soil samples were below the guideline thresholds, as reported by the CNSC staff in their Environmental Protection Review (CNSC, 2019b); however, the CNSC staff failed to report (or investigate) the statistically significant increase in the concentration of beryllium in surface soils.

[3] Strongly significant increase returned by parametric (paired t-test) or non-parametric (Wilcoxon-Mann-Whitney test) analysis, and strongly significant annual effect (using it in regression as continuous or ANOVA as categorical).

[4] "*In October 2017, CNSC staff conducted a compliance inspection in response to a beryllium occupational exposure limit exceedance event reported in August 2017 by BWXT as an EIR to the Commission in CMD 17-M53*" (CMD20-H2). "*In 2019, a personal air sample for an operator in the beryllium area was above the Occupational Exposure Limit. Subsequent investigation showed that the ventilation system needed adjustment and was upgraded to increase the capture efficiency which was effective*" (CMD20-H2.1).

Despite the small sample size, it is extremely likely that the statistically significant accumulation of beryllium in soils in Peterborough represents a true environmental change; "*If soil analysis indicates rising levels, emissions have increased, and investigation must be made into the cause*" (BWXT, 2018).

1.2. Little change in the concentration of uranium in soils

The IEMP data indicate little change in soil uranium concentrations across the eight sampling sites between 2014 and 2019 (see Appendix A and B). The average concentration of uranium in soils increased by 10% and the median concentration increased by 3% between 2014 and 2019 (not statistically significant). The observed levels of uranium in all soil samples during 2014, 2018 and 2019 were below the guideline thresholds.

1.3. Increase in beryllium concentration is not an artefact of soil sampling

In addition to the limited sample size, the interpretation of the soil data is influenced by a number of uncertainties. There is limited information on the field sampling protocol, and supplemental soil data such as bulk density, organic matter content, etc., are not available (online). As such, it may be argued that the observed increase is potentially related to an artefact of sampling; however, if the observed trend in beryllium was influenced by the soil sampling, then uranium concentrations would show the same increase.

There was a strong spatial correlation (R = 0.94[5]) between the concentration of beryllium and uranium in soils in 2014 (see Appendix C). The lowest concentrations were observed in soils closer to the Otonabee River, suggesting a common source, such as soil parent material or bedrock geology. By 2019, a weaker spatial correlation was observed (R =0.67) owing to the statistically significant increase in beryllium, which was not observed for uranium. This suggests a divergence in the relationship between uranium and beryllium in soils, potentially caused by an increase in emissions of beryllium since 2014.

1.4. BWXT is very likely the source of beryllium emissions

To evaluate if BWXT was the source of beryllium emissions, a preliminary wind sector analysis was carried out (see Appendix D). Using hourly meteorological data for 2018 (one full year of data), the frequency that wind blew from the facility to each individual sampling sites was calculated by summing up the number of hours during 2018 that wind blew from the BWXT beryllium emissions stack in the direction of each sampling site (see Appendix A). The accumulation of beryllium in soil at each site between 2014 and 2019 (estimated as 2019 beryllium concentration minus 2014 concentration) was strongly correlated (R = 0.79) with the cumulative frequency (hours) that wind blew from the BWXT beryllium emissions stack to each individual soil sampling site (see Appendix E).

This analysis suggests that the BWXT beryllium stack is very likely the source of beryllium leading to the accumulation in soils.

[5] Correlation is defined as a measure of the linear relationship between two quantitative variables, a correlation coefficient (R) of 1.0 indicates a perfect positive linear relationship (correlation).

1.5. Soil accumulation indicates an increase in uranium emissions

The accumulation of uranium in soils between 2014 and 2019 is strongly correlated (R = 0.84) with the accumulation of beryllium in soils during the same period (see Appendix E). Although a statistically significant increase in the concentration of uranium in soils was not observed, the relationship between the accumulation of beryllium and uranium suggests that atmospheric emissions of uranium from BWXT have also resulted in a small increase in uranium in soils. In 2019, the soil sites with the highest concentration of beryllium (GP05 and GP06; see Appendix D), had the second and third highest concentrations of uranium. Similarly, the lowest concentration of beryllium and uranium were both observed at site GP03, which was upwind from the BWXT facility (see Appendix D).

1.6. Air concentration of beryllium is likely above the ambient air quality limit

The accumulation of a contaminant, such as beryllium or uranium, in soils can be used to provide an approximate estimate of air concentration based on the assumption that the accumulation was caused by atmospheric deposition only. The median accumulation of beryllium and uranium in soils between 2014 and 2019 was estimated using the IEMP data (Appendix A). In combination with the depth of the surface soil samples collected by IEMP (5 cm) and average soil bulk density for urban soils (1 g/cm^3, Edmondson et al., 2011), the observed change (increase) in soil concentration was used to estimate the annual accumulated soil pool (see Appendix F). The air concentration required to drive the annual soil pool accumulation was estimated using literature data on the tendency of fine particles (beryllium oxide and uranium oxide) to settle from the atmosphere (see Appendix F). This assumes that dry deposition is the only atmospheric removal process.

The estimated air concentration of beryllium was predicted to be higher than the Ontario Ambient Air Quality Criteria limit of 0.01 µg/m^3 (MECC, 2013), and potentially higher than the Ontario 8-hour occupational exposure limit of 0.05 µg/m^3 (see Appendix F). In contrast, the estimated air concentration of uranium was not predicted to be higher than the Ontario Ambient Air Quality limit.

Recommendation 01: I recommend that the CNSC do not grant the BWXT licence renewal application. Under the current licence, it is extremely likely beryllium concentrations in soils have significantly increased in response to emissions. BWXT is very likely the source of the beryllium emissions, and air concentrations of beryllium during 2014 to 2019 were likely above ambient air quality limits. I note that '*The Commission will only issue a licence if it is satisfied that the proposed nuclear facility or activity would pose no danger to the health, safety and security of persons and the environment*'. I believe that the observations from the IEMP indicate that emissions from the BWXT facility in Peterborough under the current licence may pose a risk to human and environmental health. As such, it would be premature to engage in a licence renewal application.

2. Environmental Monitoring Program

Under the Nuclear Safety and Control Act (NSCA), licensees of nuclear facilities are required to implement an environmental monitoring program (EMP) to demonstrate that the public and the environment are protected from emissions related to the facility's nuclear activities (CNSC, 2016). The goals of an EMP are to "measure contaminants in environmental media surrounding the facility, determine the effects, if any, and to serve as a secondary support to emission monitoring programs to demonstrate the effectiveness of emission controls" (CNSC, 2019b). BWXT Peterborough is not

required to implement an EMP due to the negligible release amounts from the facility that meet the required (annual) standards at the point of release (CNSC, 2019a).

As noted above, the only program directly measuring concentrations of uranium and beryllium in the environment surrounding BWXT Peterborough is the CNSC's Independent Environmental Monitoring Program. The IEMP was designed to verify that the licensee's EMP data are within the range of the IEMP observations. It was not designed to replace the licensee's EMP, as such it suffers from a number of limitations, e.g., it has a low frequency of sampling, it employs a limited sample size, its judgemental sampling design is not representative of impacts to human and environmental health, and it does not support continuous ambient air monitoring. These limitations are particularly relevant to the current intervention; it took five years (three IEMP monitoring campaigns) and a licence renewal application to 'identify' the statistically significant increase in the concentration of beryllium in soils in the residential areas surrounding the BWXT facility in Peterborough.

Where a licensee is required to establish an EMP, the principal stipulation is that the design of the monitoring program conform to the Canadian Standards Association, i.e., CSA N288.4-10 0, Environmental Monitoring Programs at Class I Nuclear Facilities and Uranium Mines and Mills. The general public do not have access to documents by the Canadian Standards Association. As such, the public are excluded from commenting on the composition and completeness of environmental monitoring programs, e.g., the number and location of ambient air sampling sites, or the frequency, number and sampling design of soil monitoring sites. If the goal of an EMP is to protect human health and the environment, then the full design of the program should be transparent to the public.

Recommendation 02: I recommend that the CNSC require ambient environmental monitoring for all facilities located within residential areas.

Recommendation 03: I recommend that the CNSC require all licensee applicants to describe in detail their required (or proposed) environmental monitoring programs (and to engage the public on the network design).

3. Data Analysis and Reporting

The IEMP is a valuable program providing direct measurement of contaminant concentrations in the environment surrounding facilities associated with nuclear activities. The IEMP data is particularly important for Peterborough as it represents the only available environmental monitoring data. To date, reporting of the results from the IEMP have suffered from inaccurate statements, limited data analysis, and reporting of incorrect results without subsequent publication of a corrigendum.

There are numerous reports and headlines stating that "*Overall, the sampling results indicate that there are no expected health or environmental impacts*" (CNSC, 2016) or that there is "*No impact on human health, environment from BWXT plant in Peterborough*" (The Peterborough Examiner, April 2019). These statements are not supported by the IEMP sampling design. The IEMP employs a judgemental (or site-specific) sampling design focused on publicly accessible areas with a limited sample size, e.g., there were four air and two water sampling locations in 2018. A judgemental sampling design does not support conclusion regarding exposure or impacts to a population. The design can only be used to support conclusions directly related to the data, e.g., the four air samples

and two water samples collected on one day in 2014 did not exceed the guideline thresholds, as opposed to the incorrect statement 'there were no impacts to the environment'. In concert, the limited sample size (spatially and temporally) does not provide representative data.

The IEMP provides important independent data that can be used to "*verify that the public and the environment around licensed nuclear facilities are safe*" (CNSC, 2016). However, the data have not been used to their full capacity, rather they are poorly and partially analysed and reported. The data can and should play a greater role in the licence (renewal) application process.

The CNSC correctly identified in their Environmental Protection Review (EPR) report (CNSC, 2019b) that the levels of uranium and beryllium in all of soil samples from the 2014, 2018 and 2019 IEMP sampling campaigns at BWXT Peterborough were below available guidelines. An EPR is a science-based environmental technical assessment conducted by CNSC staff in accordance with its mandate under the Nuclear Safety and Control Act (NSCA), to ensure the protection of the environment and the health of persons. However, CNSC staff failed to report the statistically significant increase in beryllium in soils between 2014, 2018 and 2019 in their EPR. This observation is particularly relevant to the BWXT licence renewal application because "*If soil analysis indicates rising levels, emissions have increased, and investigation must be made into the cause*" (BWXT, 2018). In a university setting, this omission may be interpreted as academic dishonesty. The IEMP results should be used to their full extent to verify that the public and the environment near the BWXT Peterborough facility are protected.

The 2014 IEMP report (CNSC, 2016) concludes that '*The concentrations of uranium and beryllium in air and soil samples were all below available guidelines. Overall, the sampling results indicate that there are no expected health or environmental impacts*'. This conclusion suffers in two respects; firstly, as noted above, the judgemental sampling design does not support the statement '*the sampling results indicate that there are no expected health or environmental impacts*'. Secondly, the data for uranium in soils (n = 8) in the 2014 report (published during 2016; CNSC, 2016) were completely revised and reported online during 2020 (January 22, 2020) without the publication of a corrigendum or refence (amendment) to previous conclusions based on the initial published incorrect data. The revised concentrations for uranium in soils are less than 50% of their original published values (see Appendix G).

Recommendation 04: I recommend that the CNSC ensure greater accuracy in the reporting of the IEMP results, specifically with respect to the representativeness of the data.

Recommendation 05: I recommend that the CNSC ensure greater thoroughness in the reporting and data analysis of the IEMP results.

References

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Appendix A. Beryllium and uranium soil data

Table A1. Beryllium and uranium concentration in surface soils (0–5 cm) sampled during 2014, 2018 and 2019. The location (latitude and longitude) of each sampling site (n = 8), distance and direction from BWXT, and frequency (sum of hours) of wind blowing from BWXT to the soil sampling site during 2018 is also given. The average, median and the relative standard deviation (RSD)[¥] in percent is shown for each year. Data source: Canadian Nuclear Safety Commission[☼].

ID	Latitude	Longitude	Distance[‡]	Direction[†]	Frequency[§]	Beryllium (mg/kg dry weight)			Uranium (mg/kg dry weight)		
	decimal	degrees	m	degrees	hrs	2014	2018	2019	2014	2018	2019
GP01	44.28766	-78.31800	1575.8	135.0	710	0.8	1.27	1.33	1.2	1.38	1.42
GP02	44.29113	-78.33540	552.1	202.5	427	1.1	1.14	1.34	1.8	1.75	1.60
GP03	44.29569	-78.34239	673.1	270.0	377	1.1	1.28	1.10	1.6	1.63	1.21
GP04	44.29536	-78.31824	1253.6	90.0	747	0.9	1.08	1.17	1.5	1.44	1.60
GP05	44.29663	-78.33600	176.4	292.5	569	1.0	1.27	2.34	1.6	1.70	1.88
GP06	44.29827	-78.33265	275.5	22.6	581	1.0	1.24	1.44	1.5	1.65	1.97
GP07	44.30737	-78.31753	1821.8	45.0	1029	0.7	1.34	1.28	1.0	1.67	1.37
GP08	44.30804	-78.33816	1383.7	337.5	451	1.0	1.19	1.33	1.7	1.92	2.05
Average						0.95	1.23	1.42	1.49	1.64	1.64
Median						1.00	1.26	1.33	1.55	1.66	1.60
RSD (%)						14.89	6.89	27.40	17.76	10.36	18.52

[¥] Relative standard deviation (RSD) is used as a measure of spatial variation in soil chemistry between sampling sites.

[☼] Data source: nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/bwxt-peterborough.cfm

[‡] Distance estimated as straight-line distance (m) from the beryllium stack at BWXT Peterborough (location: 44.29598, -78.33395).

[†] Direction is estimated as the compass direction (degrees) from the BWXT beryllium stack to the soil sampling location.

[§] Frequency indicates the sum of hours that wind blew from the BWXT beryllium stack to the soil sampling location.

Appendix B. Box plots of beryllium and uranium in soils

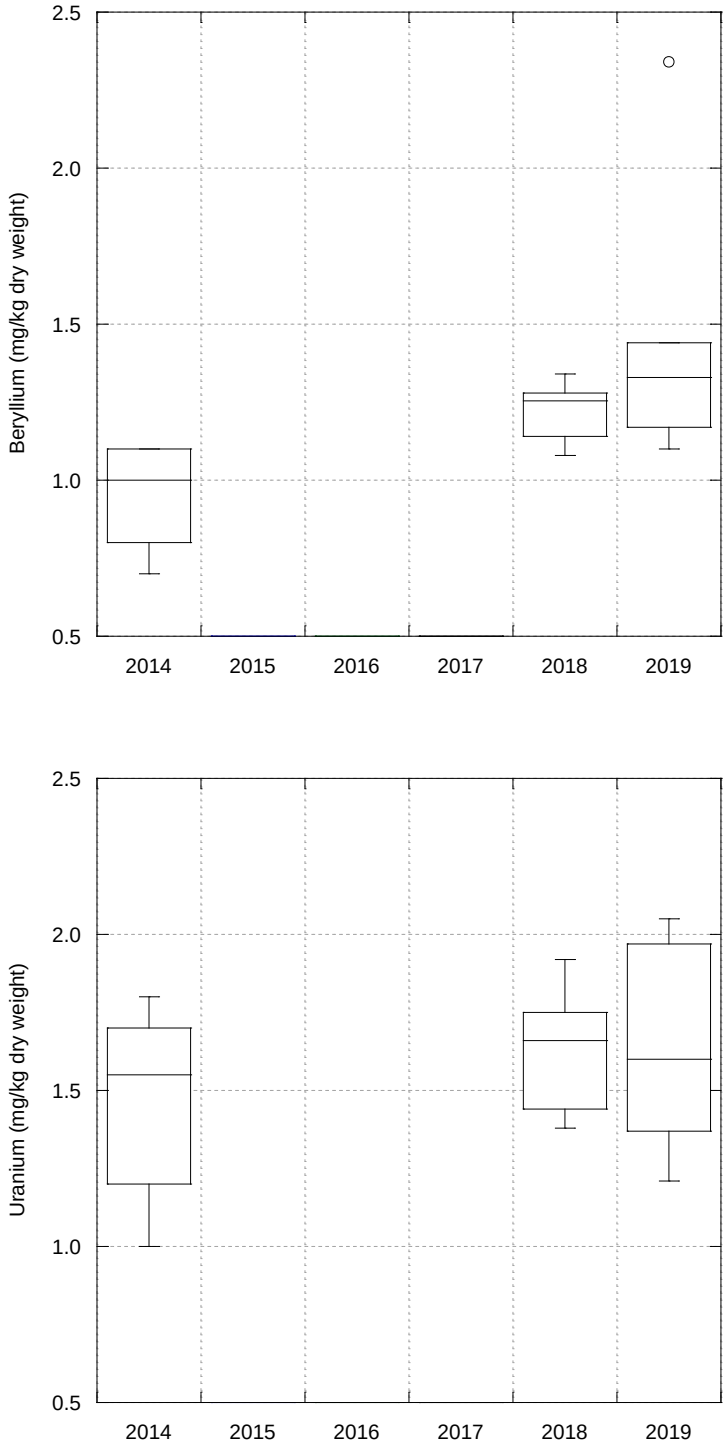

Figure B1. Box plots showing the distribution of beryllium (upper panel) and uranium (lower panel) concentrations (mg/kg dry weight) in soils (n = 8) sampled during 2014, 2018 and 2019 in Peterborough (see Table A1 for data values). The beryllium outlier (shown as an open circle) in 2019 is site GP05, which is located in the Prince of Wales School playground (see Figure D1). Data source: Canadian Nuclear Safety Commission.

Appendix C. Relationship between beryllium and uranium in soils

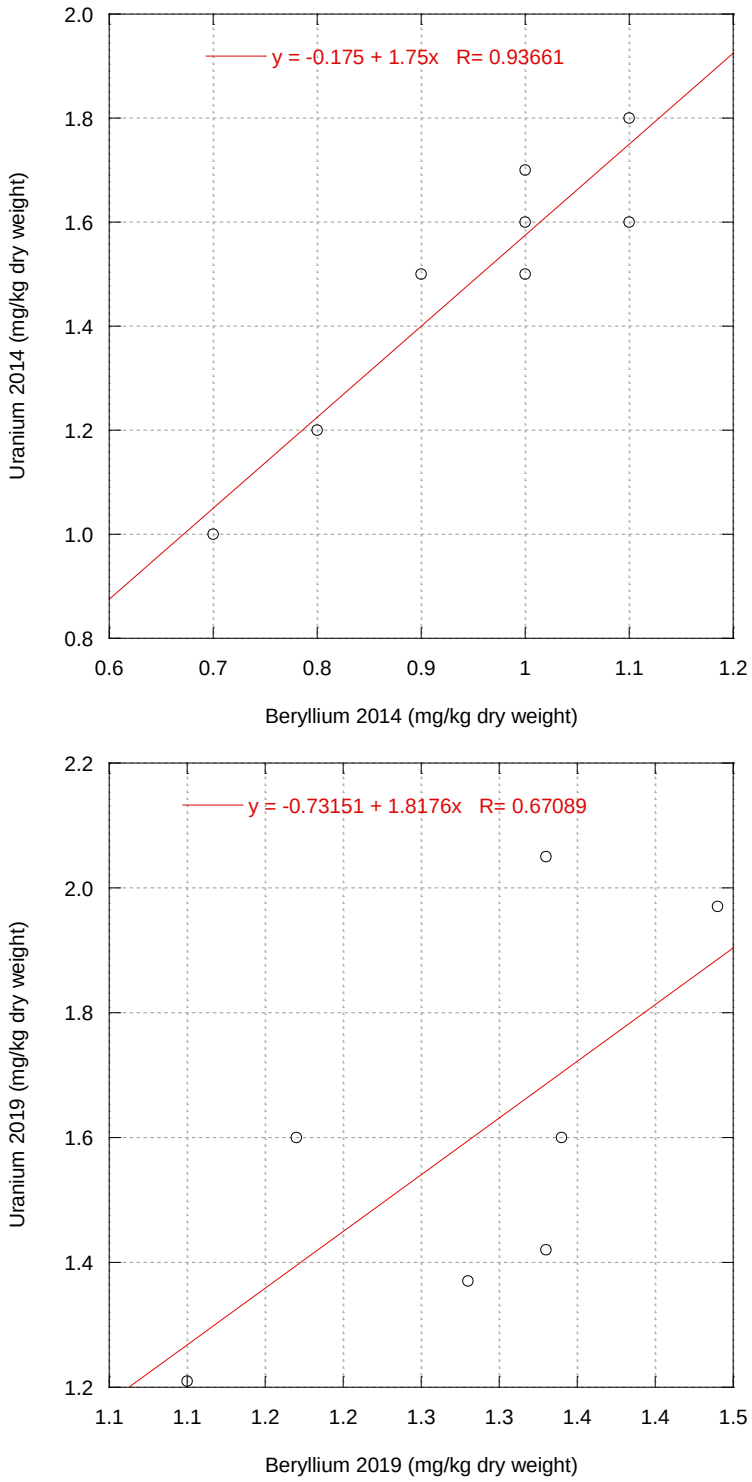

Figure C1. Scatter plot showing the relationship between the soil concentrations of beryllium and uranium (mg/kg dry weight) during 2014 (upper panel) and 2019 (lower panel) in Peterborough (see Table A1 for data). The relationship is quantified using the best-fit linear regression line (red); R is a statistical measure of how close the data fit the regression line (1.0 indicates a perfect fit). The outlier in 2019 (GP05) is excluded from the analysis (see Figure B1).

Appendix D. Location of soil sampling sites

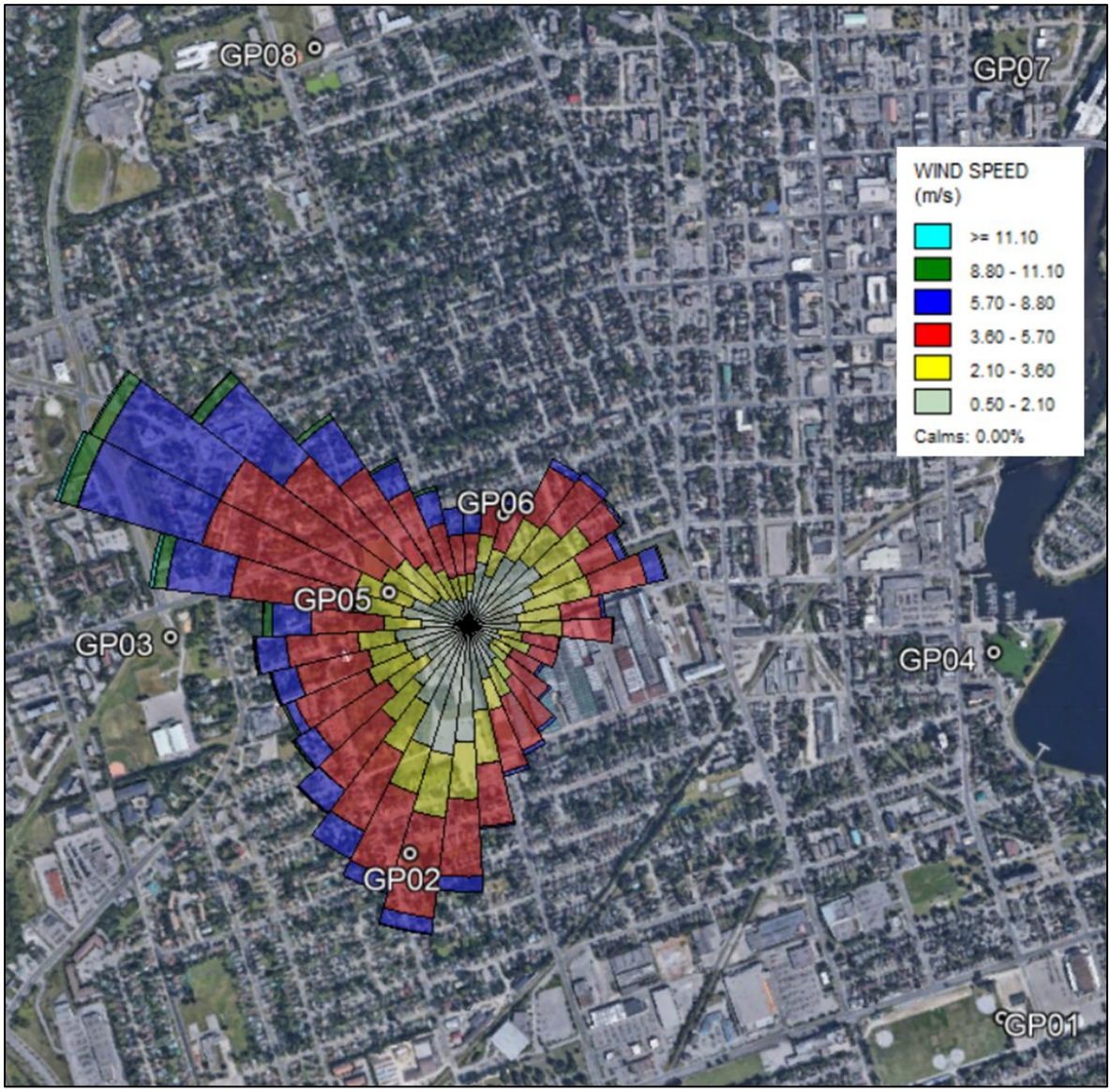

Figure D1. Map showing the location of the eight soil monitoring sites (GP01–GP08; see Table A1) sampled and analysed for beryllium and uranium by the Canadian Nuclear Safety Commission (Independent Environmental Monitoring Program) during 2014, 2018 and 2019. The wind rose (centred on BWXT) depicts the direction, frequency and speed of wind during 2018 using data from the Meteorological station at Peterborough Airport (Peterborough A 6166415 URL: climate.weather.gc.ca).

Appendix E. Accumulation of beryllium and uranium in soil

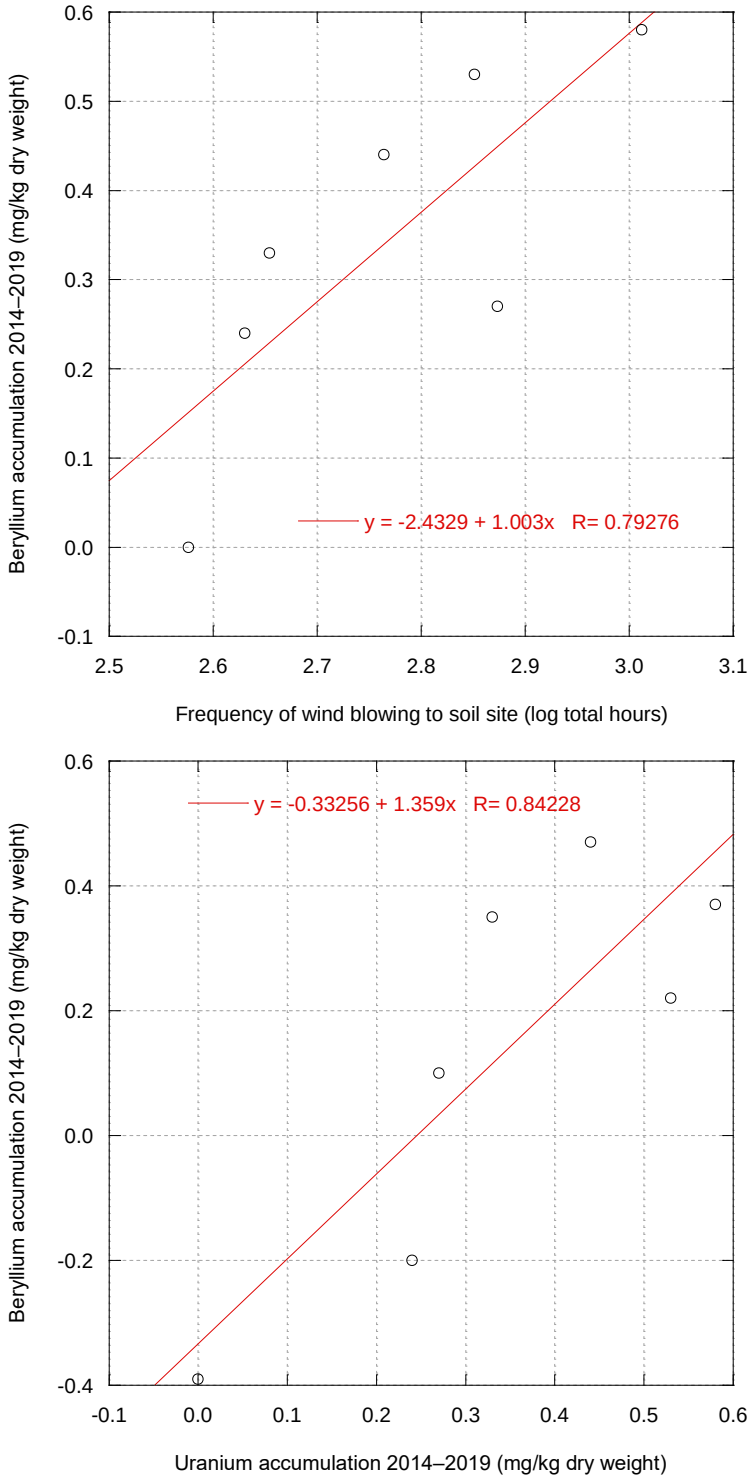

Figure E1. Scatter plot showing the relationship between the cumulative frequency of wind blowing to individual soil monitoring sites from the BWXT beryllium stack (total number of hours during 2018) and the accumulation of beryllium in soil (mg/kg dry weight) estimated as the difference between 2019 and 2014 (see Table A1 for data). The relationship between the accumulation of uranium against the accumulation of beryllium is also shown (lower panel). The outlier in 2019 (GP05) is excluded from the analysis (see Figure B1).

Appendix F. Estimated air concentrations of beryllium and uranium

The accumulation of atmospheric deposition of a contaminant in soils can be used to provide an approximate estimate of its air concentration. This calculation is based on a number of assumptions, e.g., that atmospheric deposition is the only source to soil, no losses have occurred (through soil erosion, uptake or leaching), atmospheric removal can be described by an annual deposition velocity, dry deposition is the only atmospheric removal process, etc. In addition, there a number of uncertainties, the representativeness of the soil observations, the use of literature values for soil bulk density and particle deposition velocity, etc. To account for data outliers, accumulation in soils was based on the difference in median soil concentration (2019 minus 2014). In addition, a low–high range was used for particle deposition velocity to accommodate uncertainty.

Table F1. Estimated ambient air concentrations (μg/m^3) of beryllium and uranium from the median concentration change (accumulation) in soils (n = 8) between 2014–2019 (see Table A1 for soil data).

	Beryllium	Uranium	Units
Soil concentration 2014 (median)[1]	1.00	1.55	mg/kg
Soil concentration 2019 (median)	1.33	1.60	mg/kg
Δ soil concentration (five-year)[2]	0.33	0.05	mg/kg
Δ soil concentration (annual)	0.066	0.01	mg/kg/year
Soil sampling depth	0.5	0.5	m
Soil bulk density (urban soils)[3]	1000	1000	kg/m^3
Soil pool (accumulation)[4]	3.3	0.5	mg/m^2/year
Particle deposition velocity (V_d)[5]	0.15–0.3	0.15–0.3	cm/s
Annual particle deposition velocity (V_d)	47304–94608	47304–94608	m/year
Estimated air concentration[6]	0.035–0.07	0.005–0.011	μg/m^3
Ambient air quality standard[7]	0.01	0.03	μg/m^3
Above air quality standard	Yes	No	

1. Soil concentration units are based on dry weight.
2. Δ or delta is the change between two periods, i.e., 2019 minus 2014.
3. Average bulk density for urban soils (1 g/cm^3) was taken from Edmondson et al. (2011).
4. Soil pool or accumulation was estimated as depth × bulk density × concentration.
5. Deposition velocity (V_d) is the tendency of a particles to deposition from the atmosphere; the range was taken from Zhang et al. (2013) and Zhang and He (2014).
6. Air concentration was estimated from the accumulated soil pool (mg/m^2/year) divided by annual particle deposition velocity (m/year) × 1000 (unit conversion).
7. Ontario's Ambient Air Quality (24-hour) Standards (MECC, 2013).

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Appendix G. Uranium in soils in 2014

Table G1. Reported uranium concentrations in soils (n = 8) sampled during 2014 by the Canadian Nuclear Safety Commission[¥].

ID	Sampling Location	Uranium 2014 (mg/kg dry weight)		
		Original	Revised[¥]	Difference (%)
GP01	R.A. Morrow Memorial Park	2.6	1.2	54
GP02	Turner Park	3.5	1.8	49
GP03	Kinsmen Park	4.7	1.6	66
GP04	Del Crary Park	2.8	1.5	46
GP05	Prince of Wales School Playground	3.5	1.6	54
GP06	Sherbrooke Street Park	3.5	1.5	57
GP07	Victoria Park	3.1	1.0	68
GP08	Bonnerworth Park	3.4	1.7	50
Average		3.4	1.5	
Median		3.5	1.6	
RSD (%)		24.1	14.2	

[¥] URL: nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/bwxt-peterborough.cfm

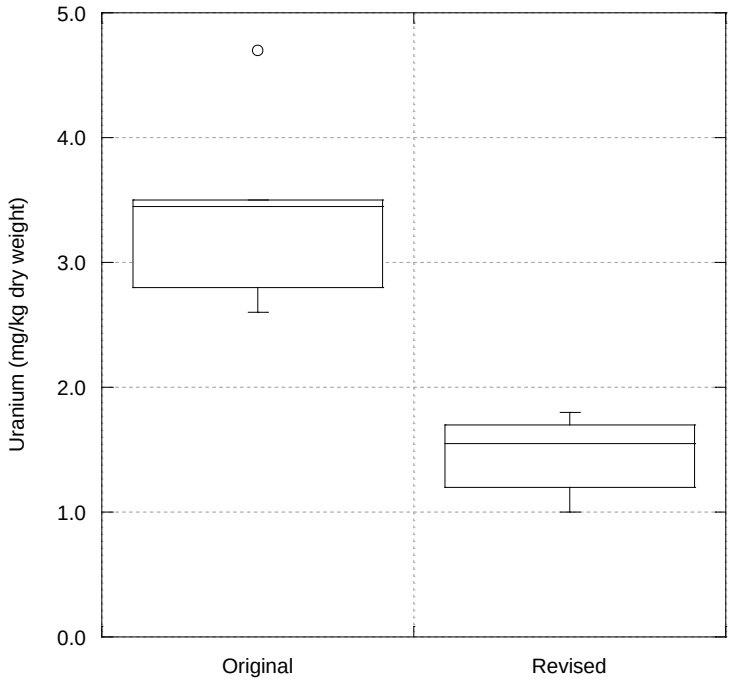

Figure F1. Box plot showing the uranium concentration (mg/kg dry weight) in the soils (n = 8) sampled during 2014; the original data reported by CNSC (2016) and the revised data (posted to the CNSC IEMP website on 22 January 2020) are both shown.

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