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SUPPLEMENTAL/COMPLÉMENTAIRE

CMD: 20-H2.D

Date signed/Signé le : 28 OCTOBER 2020

Reference CMD/CMD de référence : 20-H2

A Licence Renewal

Un renouvellement de permis

BWXT Nuclear Energy Canada Inc.

BWXT Nuclear Energy Canada Inc.

CNSC staff response to Commission's Notice of Continuation of public Hearing

Réponse du personnel de la CCSN à l'avis de poursuite de l'audience publique de la Commission

Conducted on:

March 2-6, 2020

Tenue du :

2-6 mars 2020

Submitted by:

CNSC Staff

Soumise par :

Le personnel de la CCSN

e-Doc 6285249 (WORD)
e-Doc 6382204 (PDF)

Summary

On April 6, 2020 subsequent to the BWXT Commission Hearing, the Commission directed CNSC staff to carry out expedited soil resampling for beryllium of properties adjacent to BWXT's Peterborough facility, with a special focus on the property where the Prince of Wales Elementary School is located. The Commission also directs CNSC staff to carry out an analysis of the results with the aims of clarifying the risk that the increasing beryllium levels may present to the health and safety of the public and the environment, and potentially identifying the reasons for the increase and the source of the beryllium.

Due to the ongoing COVID-19 pandemic and the need for heightened health and safety protocols, CNSC staff requested a two-month extension to complete the resampling and analyses. The CNSC President, as a panel of the Commission on procedural matters, approved the request to submit this supplemental CMD on or before October 30, 2020.

Résumé

Le 6 avril 2020, à la suite de l'audience de la Commission sur BWXT, la Commission a demandé au personnel de la CCSN de procéder à un rééchantillonnage accéléré des sols pour vérifier la présence de béryllium dans les propriétés adjacentes à l'installation de BWXT à Peterborough, en mettant particulièrement l'accent sur la propriété où se trouve l'école primaire Prince of Wales. La Commission a également demandé au personnel de la CCSN d'analyser les résultats afin de mieux définir le risque que représentent les concentrations accrues de béryllium pour la santé et la sécurité du public et pour l'environnement et, dans la mesure du possible, de déterminer pourquoi les concentrations ont augmenté et quelle est la source du béryllium.

En raison de la pandémie de COVID-19 qui se poursuit et de la nécessité d'appliquer des protocoles plus rigoureux pour assurer la santé et la sécurité, le personnel de la CCSN a demandé d'avoir deux mois de plus pour procéder au rééchantillonnage et aux analyses. La présidente, en tant que formation de la Commission pour les questions de procédure, a approuvé la demande visant à soumettre ce CMD supplémentaire au plus tard le 30 octobre 2020.

Signed/signé le

28 October 2020

Murthy, Kavita

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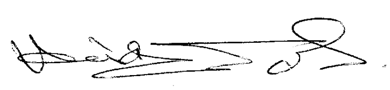
28 October 2020



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EXECUTIVE SUMMARY

BWXT Nuclear Energy Canada Inc. (BWXT) currently holds licence FFOL-3620.01/2020 [1], which expires December 31, 2020. In 2018, BWXT applied to renew the licence for a period of 10 years to continue operations of the Toronto and Peterborough facilities with a request to allow pelleting operations, currently conducted at the Toronto facility, to be conducted at the Peterborough facility.

The Canadian Nuclear Safety Commission (CNSC) conducted a public hearing March 2 to 6, 2020. During the hearing the Commission considered BWXT's renewal application along with 248 interventions. Several interventions expressed concerns over the levels of beryllium in soil near the Peterborough facility observed during the CNSC's Independent Environmental Monitoring Program (IEMP) sampling campaigns in 2014, 2018 and 2019.

On April 6, 2020, the Commission directed CNSC staff to carry out expedited soil resampling for beryllium on properties adjacent to BWXT's Peterborough facility, with a special focus on the Prince of Wales Public School. The Commission also directed CNSC staff to analyze the results to clarify the risk that the beryllium levels could present to the health and safety of the public and the environment, to identify any potential reasons for the apparent increases in beryllium in soil, and to identify the source(s) of the beryllium. Due to the COVID-19 pandemic and the need for heightened health and safety protocols, CNSC staff requested a two-month extension to complete the resampling and analyses. The CNSC President, as a panel of the Commission on procedural matters, approved this request to submit this supplemental CMD on or before October 30, 2020.

This CMD provides the results of the July 2020 soil resampling for beryllium of properties adjacent to BWXT's Peterborough facility, with a special focus on the Prince of Wales Public School. It also includes an analysis of the results with the aims of clarifying the risk that the beryllium levels may present to the health and safety of the public and the environment.

CNSC staff also provide additional information regarding the suitability of the results that were derived using both total and partial digestion methods to measure beryllium concentrations in soil samples as well as the impact of analytical uncertainties on the interpretation of soil data collected in 2014-2020 using total digestion method. In addition, CNSC staff used the partial digestion method in 2020 to allow for alignment with federal and provincial analytical methodologies.

All concentrations of beryllium in soil detected by partial digestion are in the range of natural background in Ontario (up to 2.5 mg/kg) and below the most restrictive Canadian Council of Ministers of the Environment (CCME) soil quality guideline for the protection of environmental and human health (4 mg/kg). Therefore, CNSC staff continue to confirm that there is no risk to the environment and to human health at the Prince of Wales Public School and on other properties adjacent to BWXT's Peterborough facility.

CNSC staff conclude that there is no evidence that the BWXT facility emissions have affected soil quality in Peterborough, as concentrations of beryllium measured using partial digestion near the BWXT facility are in the range of natural background in Ontario and do not appear to increase over time.

Accumulation of soil concentrations occurs when deposition of contaminants from the air is not compensated by removal processes from the surface soil horizons. In general, removal processes are very slow and depend on site-specific conditions. Due to these slow processes, it can be impossible to detect statistically significant changes in soil concentrations from year to year when low levels of beryllium are released to the air. In the case of BWXT, CNSC staff reviewed the soil resampling results and found that the values of total beryllium measured in 2014 to 2020 are not statistically different. Therefore, these data cannot be used to support any conclusions on potential trends of beryllium levels in soil.

Should the BWXT licence be renewed, future sampling campaigns will include engagement with the public, municipal officials and Indigenous communities. This engagement will aim to address concerns that have been raised.

Referenced documents in this CMD are available to the public upon request, unless identified as confidential or proprietary. CNSC staff have included web hyperlinks to facilitate information sharing where available.

1 OVERVIEW

1.1 Background

BWXT Nuclear Energy Canada Inc. (BWXT) operates two Class IB nuclear facilities to manufacture nuclear reactor fuel bundles under a single nuclear fuel facility operating licence, FFOL-3620.01/2020 [1]. In November 2018, BWXT submitted an application to the Canadian Nuclear Safety Commission (CNSC) for the renewal of its licence, with a request for authorization to conduct pelleting operations at the Peterborough facility [2].

The CNSC conducted a public hearing March 2 to 6, 2020, where the Commission considered BWXT's renewal application and 248 interventions from the public, Indigenous groups and provincial and municipal government officials. Many interventions expressed concerns over the levels of beryllium in soil near the Peterborough facility observed during the CNSC's Independent Environmental Monitoring Program (IEMP) sampling campaigns in 2014, 2018 and 2019. Although beryllium concentrations in soil were in the range of natural background for Ontario and below existing soil quality guidelines for the protection of environmental and human health, intervenors expressed concern regarding the concentration measured in 2019 at the Prince of Wales Public School. This sample was higher than previous years and intervenors were concerned about a potential increasing trend in beryllium levels in the soil.

On April 6, 2020, after their initial deliberations subsequent to the hearing, the Commission directed CNSC staff [11] to carry out expedited soil resampling for beryllium at properties adjacent to BWXT's Peterborough facility, with a special focus on Prince of Wales Public School. The Commission also directed CNSC staff to analyze the results with the aims of clarifying the risk that the beryllium levels may present to the health and safety of the public and the environment, and to identify potential reasons for the apparent increase and the source(s) of the beryllium. Due to the COVID-19 pandemic the Commission approved a two month request from CNSC staff to submit the supplemental CMD on or before October 30, 2020 [28].

2 MATTERS UNDER CONSIDERATION

2.1 Background Concentrations and Guidelines for Beryllium

2.1.1 Beryllium in Soil

Beryllium is one of the lightest metals that occurs naturally in the environment and is present in a variety of materials including rocks, coal, oil, soil and volcanic dust. Natural sources of beryllium released to the atmosphere, such as windblown dust and volcanic particles, are estimated to account for 5.2 tonnes per year, or 2.6% of worldwide total emissions [27]. The most important source of beryllium exposure comes from human activities (i.e. anthropogenic sources), such as the burning of coal, fuel oil and petroleum-based products.

Beryllium emissions are also produced by foundries, ceramic plants, incinerators, municipal waste combustors, and open-burning waste disposal sites. Beryllium is used at the BWXT facility in Peterborough during the nuclear fuel bundle manufacturing process, which results in extremely low atmospheric emissions of beryllium from the facility [10].

Particulate releases of beryllium to the atmosphere can be transported to the soil by dry and wet deposition. Dry deposition of larger particles is the result of gravitational settling. For smaller particles, deposition rates are controlled by diffusion processes. The rates of dry deposition are influenced mainly by particle size distribution, chemical form, and air turbulence. Wet deposition occurs when a chemical substance is washed out of the atmosphere by rain or snow, and the rate of this deposition is dependent on particle size and solubility.

Beryllium deposited onto soil can be washed into surface water or dissolved (leached) into groundwater. Sorption mechanisms (the physical and/or chemical process by which one substance becomes attached to another) are usually strong enough to prevent significant amounts of substances from leaching from surface soil to groundwater. The leaching potential is dependent upon soil properties (such as pH, oxidation-reduction potential, soil porosity, etc.) and substance solubility. Soils containing clay are more likely to retain emitted contaminants than soils composed of silt and sand.

Accumulation of soil concentrations occurs when deposition of contaminants from the air is not compensated by removal processes from the surface soil horizons. In general, removal processes are very slow and depend on site-specific conditions. Due to these slow processes, it can be impossible to detect statistically significant changes in soil concentrations from year to year when low levels of beryllium are released to the air.

In general, soil concentrations of beryllium are low. Soils reflect the composition of parent material. Common rocks and minerals contain from less than 1 to about 10 milligram (mg) of beryllium per kilogram (kg), whereas mineralized areas can contain several thousand mg/kg [5]. In Canada, the mean beryllium concentration in soil was determined to be 0.75 mg/kg for the range from 0.25 to 16 mg/kg [5]. In Ontario, beryllium soil concentrations appear to be similar to those from the rest of Canada despite slightly lower mean values for urban and rural parkland (0.52 mg/kg and 0.47 mg/kg, respectively) that were calculated by the Ontario Ministry of Environment in 1993 [5]. A study of natural soil, reported at 1318 locations throughout the USA contained from less than 1 to 15 mg/kg of beryllium, averaging approximately 1 mg/kg [3]. Agricultural soils in the USA contained less than 1 to 7 mg beryllium per kg of soil and averaged 0.6 mg/kg [4]. There are also areas, such as Italy, with high natural background levels of beryllium (up to 300 mg/kg) due to volcanic events [5].

2.1.2 Guidelines and Standards for Beryllium

The Ontario Ministry of the Environment, Conservation and Parks (MECP) has established a standard for the typical range of background concentrations for many substances in soils not contaminated by industrial sources. This standard is based on partial digestion methodology to measure only the environmentally available portion of potential contaminants. For beryllium the upper limit[1] of typical background is 2.5 mg/kg for agricultural and residential land uses [7].

The Canadian Council of Ministers of the Environment (CCME) has established Canadian Soil Quality Guidelines (SQG) for the protection of environmental and human health (http://ceqg-rcqe.ccme.ca/en/index.html). The guidelines specify environmental levels of toxic substances or other parameters that are recommended to protect and maintain wildlife and/or the specified human uses of water, sediment, and soil. The CCME SQG were developed with a particular focus on remediation of contaminated sites and are based on partial digestion analytical methodology.

Both environmental and human health SQG were developed for four land uses: agricultural, residential/parkland, commercial, and industrial. The CCME recommends that the lowest value generated by the two approaches (i.e., environmental and human health) for each of the four land uses is used as the SQG. The most recent CCME SQG for beryllium were published in 2015. The SQG for the protection of environmental health is 4 mg/kg and for the protection of human health is 75 mg/kg [5]. There are five primary ways people are exposed to beryllium (air, water, soil, food and consumer

[1] Upper limit of typical background is referring to the highest value in the range of typical soil concentrations not subjected to the influence from known sources of pollution. For example in Ontario measured natural soil concentrations range up to 2.5 mg/kg for beryllium at the 98% confidence level (two standard deviations). Thus 2.5 mg/kg is the upper limit of these natural soil concentrations [7, 8].

products). The CCME SQG are developed assuming 20% of tolerable daily intake[2] since oral ingestion of soil is the major contributor to the total exposure.

The most restrictive CCME human health SQG for residential/parkland land use (75 mg/kg) is based on an assessment of non-cancer risk to a critical receptor (young children) from direct contact exposure to beryllium in soil through oral ingestion and skin contact. This guideline is very conservative given that the absolute (100%) absorption of beryllium into the gastrointestinal tract was assumed. Most studies indicate that orally ingested beryllium compounds pass through the gastrointestinal tract unabsorbed [5]. This adds additional conservatism to the SQG.

The CCME SQG for the protection of environmental health (4 mg/kg) was set in 2015 using the interim remediation criteria for soils in Ontario. The 4 mg/kg guideline is considered generally protective of human and environmental health at contaminated sites [25]. CNSC staff use both the MECP soil standards and the CCME SQG when assessing soil concentrations of potential contaminants observed near nuclear facilities in Ontario. The MECP soil standards are an indication that concentrations that exceed these levels may be the result of contamination from a pollution source such as emissions from the operations of a nearby nuclear facility.

The Ontario Ambient Air Quality Criteria (AAQC) for airborne releases of beryllium are used by the CNSC and MECP to assess risk to members of the public from airborne releases of beryllium from the BWXT facility. The AAQC for beryllium was developed based on a 24 hour averaging time period. The criteria is derived with conservative assumptions of exposure where the limiting effect is health and is designed to protect the most sensitive human receptor. The AAQC for beryllium is 0.01 $\mu g/m^3$ and CNSC staff have verified that the releases reported in the Annual Compliance Monitoring Report for the BWXT facility in Peterborough are well below this level [26]. The maximum concentration of beryllium during the current licensing period was 0.009 $\mu g/m^3$ [26].

2.1.3 Ontario Ministry of Environment Beryllium Study in Peterborough

In 2005, the Ontario Ministry of the Environment (presently MECP) completed a phytotoxicology survey in the vicinity of the BWXT Peterborough facility (formerly General Electric) [8]. The survey assessed whether potential emissions of beryllium and beryllium compounds from the Peterborough facility operations resulted in elevated concentrations of beryllium in soil and vegetation on residential and public properties, specifically those near the nuclear fuel fabrication and assembly building. The survey included two soil sampling locations at the Prince of Wales Public School. Most of the beryllium concentration data for soil samples were below or at the analytical detection limit (0.5 mg/kg) and up to 0.7 mg/kg. The study concluded that if beryllium emissions occurred at the Peterborough facility they were of insufficient magnitude to have a measurable impact on the soil or vegetation assessed.

[2] Tolerable daily intake refers to the daily amount of a chemical that has been assessed safe for people on a long-term basis (i.e.: their lifetime).

2.2 Ecological and Human Health Risks of Beryllium

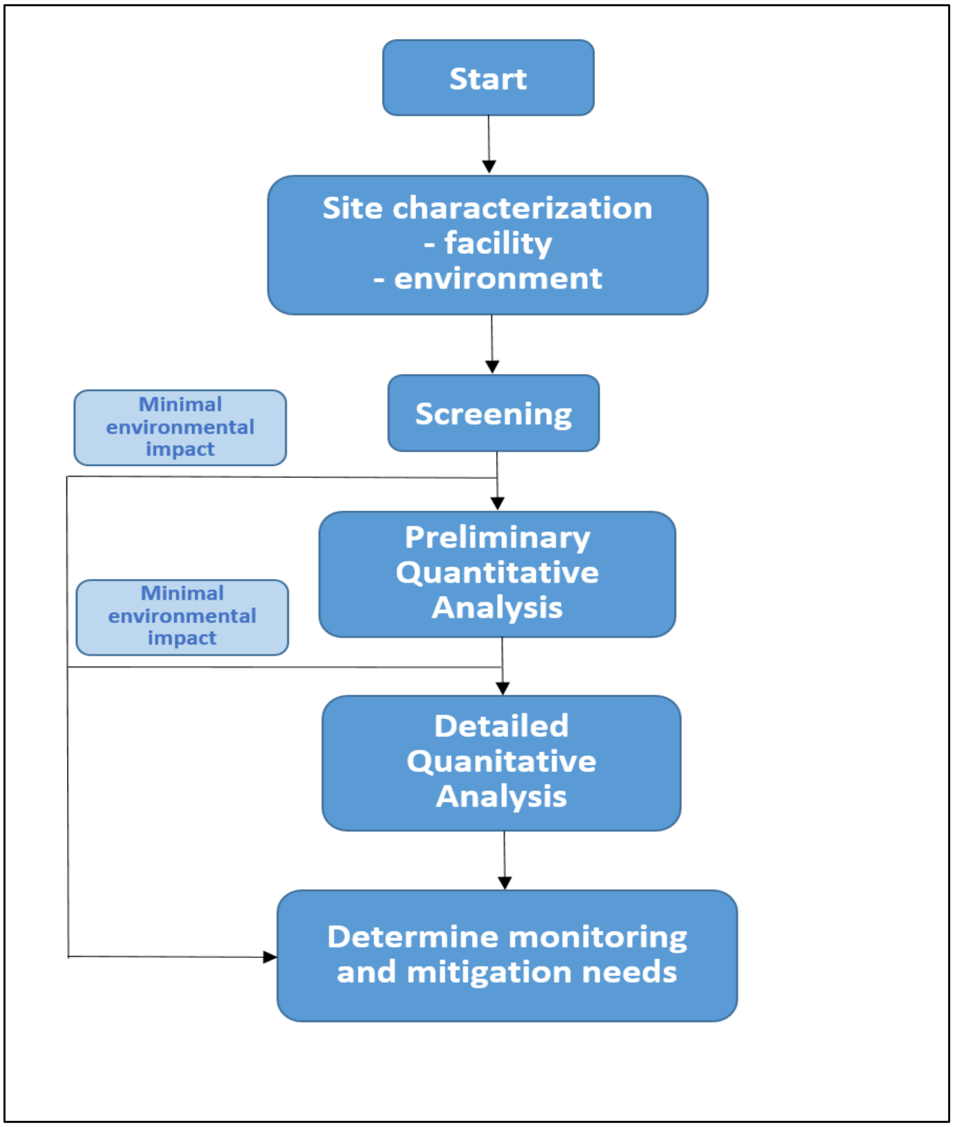
An Environmental Risk Assessment (ERA) of a nuclear facility is performed by the licensee or applicant and reviewed by CNSC staff to ensure compliance with CSA N288.6 *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills* [9]. An ERA is a systematic process that identifies, quantifies and characterizes the risk posed by contaminants (nuclear or hazardous substances) and physical stressors on biological receptors (human and non-human biota), including the magnitude, extent and reversibility of the potential effects associated with a facility [9]. Within an ERA, human and ecological receptors are addressed through a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment respectively.

An ERA follows a tiered approach (Figure 1) starting from a broad evaluation using protective generic parameters and a high degree of conservatism (screening level risk assessment) and advancing towards more precise analysis involving site-specific parameters and less conservatism (preliminary quantitative risk assessment and detailed quantitative risk assessment).

Within the context of a tiered approach to ERA, a screening level risk assessment represents the less detailed lower tier and serves as the most conservative and broadest form of risk assessment. CSA N288.6 *Environmental risk assessment at Class I nuclear facilities and uranium mines and mills* [9] indicates that the screening level risk assessment is focused on problem formulation which should identify relevant contaminants, receptors, exposure pathways and screening criteria. Then screening level risk assessment should determine if contaminant concentrations exceed the screening criteria and, therefore if a preliminary quantitative risk assessment is required.

The CNSC completed an independent screening level risk assessment of the CNSC IEMP soil data from the BWXT facility in Peterborough using the most conservative background MECP soil standards and residential/parkland CCME SQG as the screening criteria. Given that no concentrations of beryllium exceeded these benchmarks in 2014, 2018 and 2019, no further assessment was needed at a higher tier, preliminary or detailed quantitative risk assessment [6 & 9].

Figure 1: Tiered options for Environmental Risk Assessments (ERA)



The preliminary detailed quantitative risk assessment and potentially a detailed quantitative risk assessment would be needed if the beryllium soil concentrations exceeded the CCME SQG of 4 mg/kg for ecological receptors and 75 mg/kg for human receptors. A preliminary quantitative risk assessment would produce preliminary estimates of exposure and risk for each receptor at relevant locations using measured and/or modeled concentrations and generic parameter values. A detailed quantitative risk assessment is a further refinement including a more detailed exposure assessment, risk characterization and supplementary studies, to address data gaps or verify potential effects.

From an inhalation pathways perspective, due to the low concentrations of beryllium (less than 0.009 µg/m^3) emitted from the BWXT Peterborough facility, there are no additional precautions necessary for the public. As part of the BWXT ERA [24] that was accepted by CNSC staff, a screening level risk assessment was completed for beryllium air emissions with maximum concentrations well below screening criteria (i.e., AAQC). As such, no further assessment was needed at a higher tier.

BWXT's current licence [1] stipulates a value of 0.05 µg/m^3 as the occupational exposure limit for workers to control hazards associated with beryllium particulates present in the air. Workers at BWXT are protected from beryllium exposure through a combination of engineering and management/process controls. These include, but are not limited to, the use of work processes, facility design (e.g. brazing room ventilation), air quality monitoring, and the use of personal protective equipment (e.g. self-contained breathing apparatus with approved filters) to eliminate or reduce occupational exposure of workers to beryllium.

2.3 Potential Source of Beryllium in Soil near BWXT-Peterborough

2.3.1 Beryllium Source Emissions

BWXT is required to submit air effluent monitoring results annually to both the CNSC and MECP. CNSC staff reviewed BWXT's air effluent monitoring results at the beryllium points of discharge (stacks) for the Peterborough facility from 2013-2019. BWXT takes these measurements directly at the stacks. MECP developed the AAQC for beryllium in 2012 and thus BWXT began reporting the emissions to MECP and CNSC in 2013 as shown in Table 1. Annually, BWXT is required to have an accredited third party verify measurements taken at the beryllium stacks. The third party results are reviewed by CNSC staff during inspections and the results indicate the stacks are operating as designed. In addition, the stack is monitored continuously and checked daily [26]. CNSC inspectors verify the data collected and inspect the stack during regular compliance activities. The data reported by BWXT is compared to Ontario's AAQC for beryllium which is based on the point of impingement[3] in the receiving environment.

Beryllium air concentrations measured at the stacks are below Ontario's AAQC for beryllium of 0.01 µg/m^3 prior to any dilution (i.e., mixing in the atmospheric environment beyond the end of stack). As can be seen from Table 1, the average and maximum concentrations reported by BWXT are well below Ontario's AAQC.

[3] Point of impingement is the point at which a contaminant contacts the ground or a building at any point in the natural environment that is not on the same property as the source of the contaminant and as defined by section 2 of O. Reg. 419/05.

Table 1: Annual airborne beryllium concentrations (μg/m^3)

Year	Average Beryllium Concentration at the stacks	Maximum Beryllium Concentration at the stacks	Ontario's AAQC - Beryllium
2013	0.0001	0.0069	0.01
2014	0.0005	0.0045	
2015	≤ 0.001	0.009	
2016	≤0.0005	0.002	
2017	≤0.0005	0.001	
2018	≤0.0005	0.001	
2019	≤0.0005	0.001	

In the regional area, other than the BWXT facility, beryllium emissions are reported by an industrial facility located approximately 5 kilometers north of BWXT's facility in Peterborough (based on the Ontario Environmental Activity and Sector Registry). The maximum reported beryllium concentration from this facility at the point of impingement in the environment was 7.92E-07 μg/m^3. This concentration is well below Ontario's AAQC for beryllium (0.01 μg/m^3) and is significantly below BWXT's current emissions. The contributions of beryllium to soil from this facility would be negligible.

To investigate the plausibility of BWXT being the source of beryllium concentrations in soil CNSC staff completed a hypothetical calculation (Appendix A) to determine how much airborne beryllium would have to be emitted to account for the change in beryllium concentrations in soil found by the CNSC's IEMP between 2018 and 2019. CNSC staff conclude that based on the calculation results, beryllium emissions from BWXT's Peterborough operations are at a level that could not result in the change in beryllium soil concentrations.

2.4 Resampling for Beryllium and Data Interpretation

2.4.1 Soil Sampling Campaign Design

In response to the Commission's Notice of Continuation, CNSC staff repeated soil sampling on July 20 and 21, 2020 at the nine locations around BWXT's Peterborough facility that were sampled in previous years, including the Prince of Wales Public School. The additional samples consisted of a 3x3 grid centered on the original sampling point (GP05) in the school yard as shown in Appendix B Figure B.1. Within the grid pattern, nine soil samples were collected at a distance of five meters apart. Each soil sample was a composite sample comprised of five soil plugs (0-5 cm) as shown in Appendix B Figure B.2. CNSC staff collected a total of 17 composite samples in the vicinity of the BWXT Peterborough facility (16 samples) and a reference (background) location (1 sample) as seen in Appendix B Table B.1 and Figures B.3-B.4.

2.4.2 Sampling and Lab Analysis Methodology

For the purpose of this CMD, CNSC staff completed a thorough review of the IEMP methodology used in the field. The CNSC's sampling techniques have improved over the years resulting in different sampling procedures being used in 2014 compared to 2018, 2019 and 2020. In 2014, soil was sampled using a shovel, whereas in 2018, 2019 and 2020, a core sampler was used. These changes may have contributed to the relatively low concentrations of total beryllium reported in 2014 compared to the other years.

The samples collected in July 2020 were analyzed at the CNSC Laboratory using the same methodology as in 2014, 2018 and 2019 (microwave-assisted total digestion, adapted from method EPA 3052 [16], followed by ICP-MS analysis of the digests, according to EPA 6020B [17]). By using a potent acid mixture, the total digestion method involves total decomposition of the investigated sample, thus giving both environmentally available and environmentally inaccessible portions of elements. The concentrations of elements determined upon total digestion of soil are very conservative values, useful for geological studies and forensic work.

In 2020, the soil samples were also analyzed by microwave-assisted partial digestion, using adapted method EPA 3051A [18], followed by ICP-MS analysis, according to EPA 6020B [17].

Partial digestion results in lower beryllium concentrations due to the inability of the partial digestion to fully digest siliceous materials and zircons within the soil matrix. This is well known and documented in several peer reviewed articles [19 - 22]. Beryllium contained in siliceous and zircon matrices is not considered bio available. Given that environmentally available portion of an element is determined by partial digestion, this method is used for environmental monitoring and allows a direct comparison to the MECP soil standard which is based on this analytical method.

When interpreting results for beryllium in soil, CNSC staff use the CCME SQG for the protection of environmental and human health, which are based on the environmentally available concentrations obtained by partial digestion. These guidelines are used by the CNSC to determine if soil concentrations of potential contaminants observed near nuclear facilities may present a risk to the environment and public health. For the 2014, 2018 and 2019 IEMP campaigns, the CNSC had selected a more conservative total digestion method. The total digestion results were compared to the CCME SQG despite these guidelines being based on partial digestion. Although this was a conservative approach taken by the CNSC, the results come from different analytical methods and it may have been misleading to make this comparison. Based on analysis of the soil samples in 2020, the environmentally available fraction of beryllium can range from 22 to 57% of the total content. As the CCME SQG is used to limit the health and environmental effects of exposure to toxic elements, the partial digestion method was used in 2020 to allow for a direct comparison with the guidelines.

The CNSC's laboratory methods have continuously improved since the inception of the IEMP. In general, the sensitivity of the method for beryllium determination is low, which results in higher uncertainty values in comparison with some other elements (i.e. uranium). To reduce this measurement uncertainty, in 2020 a new standard reference material with certified concentration of beryllium was introduced.

The practice has been to not report uncertainties in the IEMP summary on the CNSC website but uncertainties have always been included in analysis documentation. During the March 2020 Commission proceedings [10], CNSC staff presented uncertainties as plus/minus one standard deviation (i.e. at 68% confidence level). As part of the review completed in response to the Commission's Notice of Continuation, specifically to address the apparent trend of increasing beryllium in soil, CNSC staff have reported uncertainties in this CMD as plus/minus two standard deviations (i.e. at 95% confidence level) as this is considered common practice for the interpretation and analysis of soil data. For example, this was the case in MECP's 2005 survey of beryllium in Peterborough soil [8]. The upper limit of natural background for beryllium in Ontario (2.5 mg/kg) was derived from the Ontario Typical Range values which are equivalent to the arithmetic mean plus two standard deviations of the suitable background dataset [7]. Using two standard deviations the results for total beryllium had an 80% uncertainty in 2014, 50% uncertainty in 2018, and less than 20% uncertainty in 2019 and 2020.

2.4.3 Soil Sampling Results and Data Interpretation

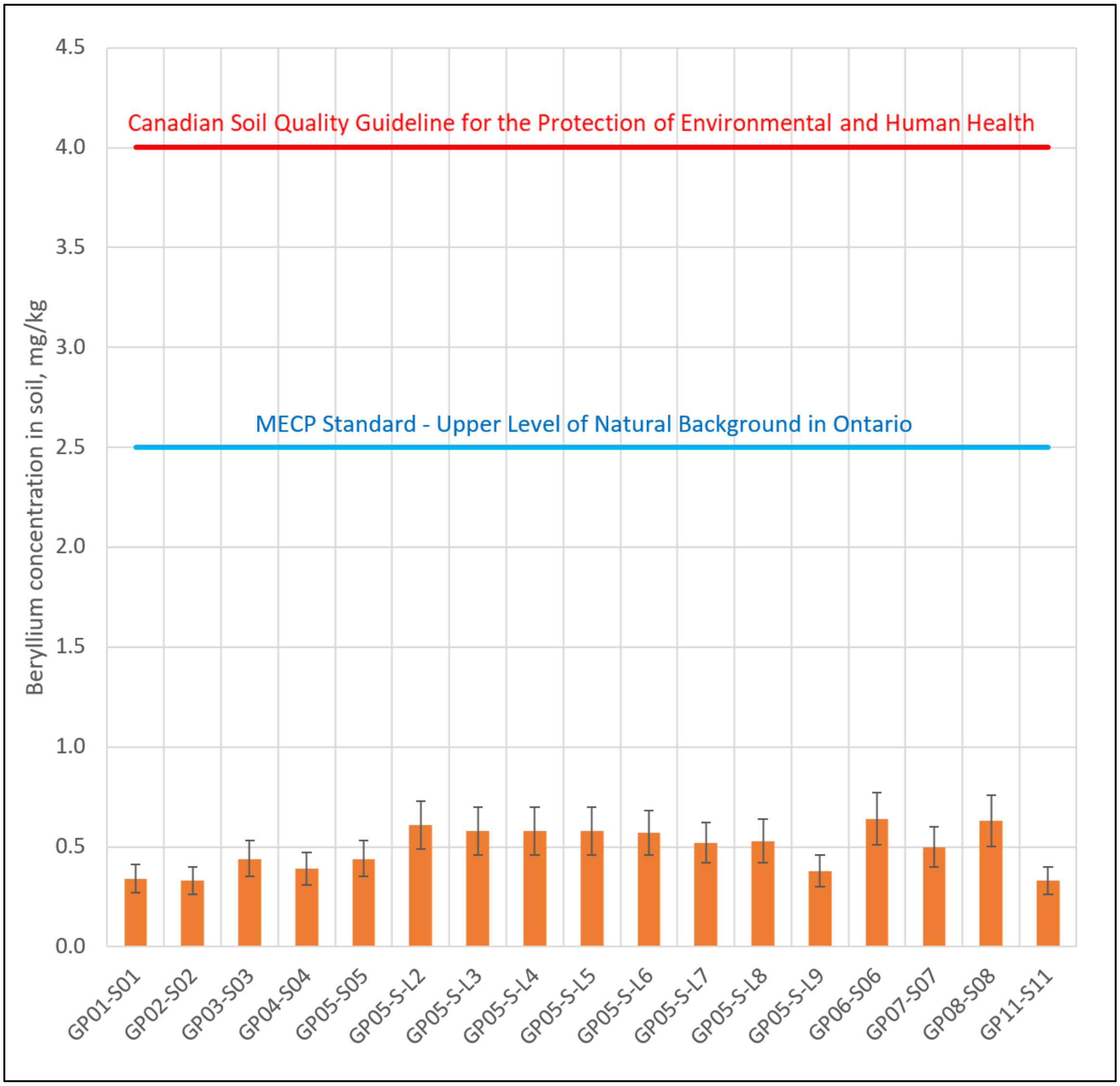
All soil samples collected in July 2020 were analyzed using both partial and total digestion. Implementing the partial digestion analytical method allows for a direct comparison to the respective federal and provincial soil quality guidelines and standards which are based on partial digestion. Although there are no soil quality standards or guidelines for beryllium measured using total digestion, this analytical method was repeated in 2020 to compare to the CNSC results observed in previous years.

2.4.3.1 Partial Digestion Results

Environmentally available concentrations of beryllium derived by partial digestion of soil samples in 2020 were compared to respective federal and provincial soil quality guidelines and standards (which are developed based on partial digestion). Figure 2 demonstrates that the concentrations of beryllium measured using partial digestion with the respective uncertainties are significantly below both the MECP upper limit of natural background in Ontario (2.5 mg/kg) [7], and the most restrictive CCME SQG (4 mg/kg) [5]. They are also below the CCME human health SQG (75 mg/kg) [5] and the MECP environmental and human health guidelines for beryllium which uses the 4 mg/kg as its most restrictive level [23]. The maximum value observed in 2020 (0.64±0.13 mg/kg) is 6 times lower than the most restrictive CCME SQG for the protection of environmental and human health (4 mg/kg) and 117 times lower than the CCME human health guideline (75 mg/kg).

Furthermore, the partial digestion data observed in 2020 align with the results of the survey conducted in 2005 by the Ontario Ministry of the Environment in the vicinity of the BWXT Peterborough facility [8] (see section 2.1.3). For example, the measured beryllium concentrations were up to 0.7 mg/kg and 0.64±0.13 mg/kg in 2005 and 2020 respectively. Therefore, the soil concentrations of beryllium measured using partial digestion near the BWXT facility in 2020 are very low and do not appear to increase over time. CNSC staff confirm there is no evidence that the BWXT facility emissions have affected soil quality in Peterborough.

Figure 2: Beryllium soil concentrations (partial digestion, mg/kg) measured in Peterborough during the 2020 CNSC sampling campaign (uncertainties shown at two standard deviations). Sampling stations GP05-S05 to GP05-S-L9 are located in the Prince of Wales Public School Yard while the reference location is GP11-S11.



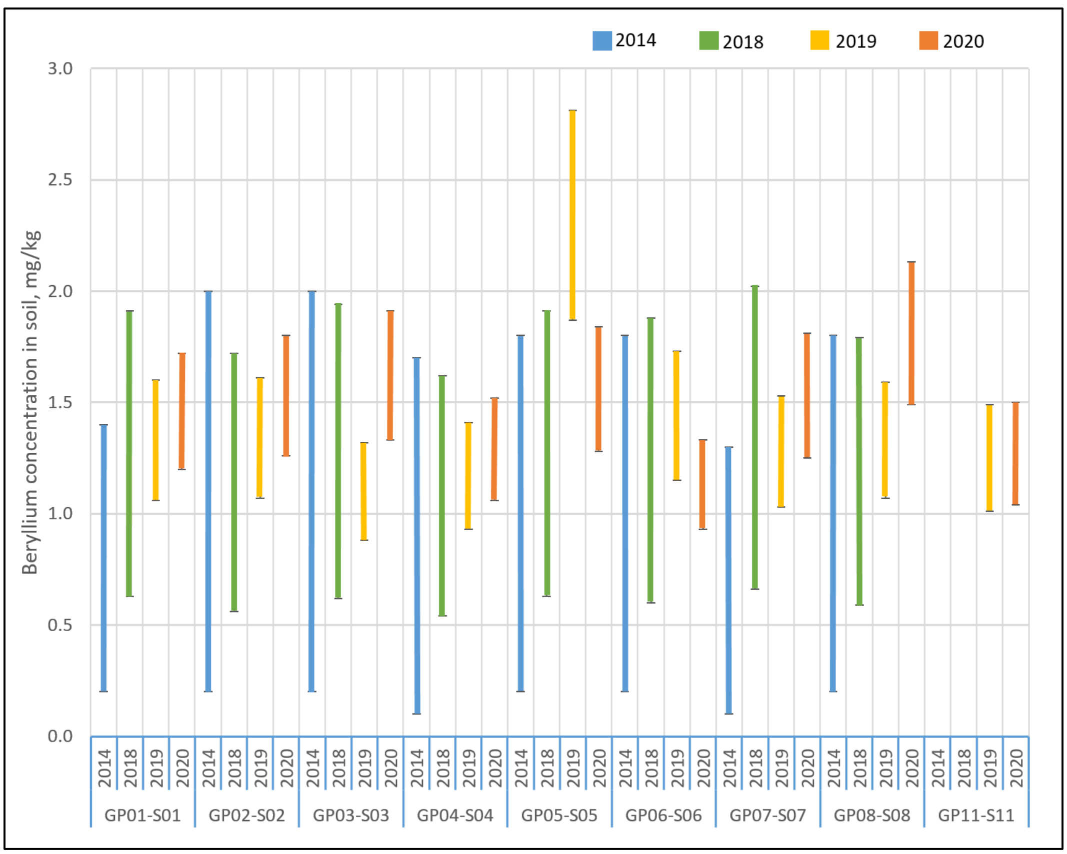
Prior to the 2020 expedited resampling, the CNSC used total digestion to determine beryllium concentrations in soil. Although at the March proceedings [10] the total digestion results were compared to the soil standards and guidelines (which are based on partial digestion) this was a conservative approach since the yield of partial digestion can only be lower or equal to the yield of total digestion (see section 2.4.2).

As a result of the analysis conducted, CNSC staff will use the partial digestion for future lab analyses of soil samples for the substances for which soil quality guidelines are available. This will allow direct comparison to the MECP background soil standard in Ontario and the respective CCME SQG.

2.4.3.2 Total Digestion Results

Figure 3 provides the concentrations (in mg/kg) of beryllium derived by total digestion of soil samples in 2014, 2018, 2019 and 2020 from 9 sampling locations around the BWXT facility. The results are provided using uncertainties at 95% confidence level (two standard deviations). All soil sample results are within normal background variations, including the 2019 soil sample result from the Prince of Wales Public School sampling location (sample GP05-S05).

Figure 3: Impact of measurement uncertainties shown as two standard deviations on beryllium soil concentrations (total digestion, mg/kg) detected during all CNSC sampling campaigns in Peterborough (2014-2020).



The total digestion data demonstrate that the high uncertainties in 2014 and 2018 (80% and 50% respectively) have significant impact on the interpretation of the 2014-2020 dataset. When available data on the measurement uncertainties are considered there is an overlap between the data range such as “mean plus/minus two standard deviations”. In such an instance, the measured concentrations of beryllium are not statistically different and, therefore, these data cannot be used to support any conclusions on potential trends of beryllium levels in soil.

Given that:

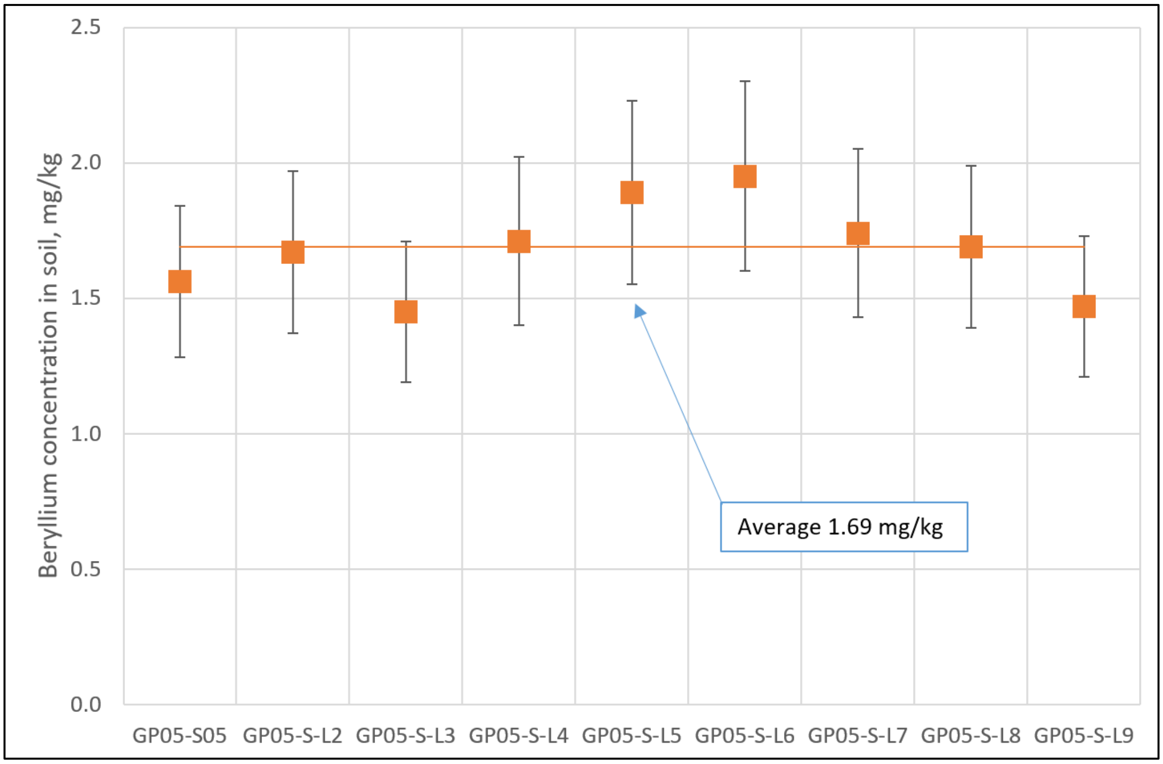
1. with the exception of the soil sampling technique used in 2014, similar sampling and analytical methodology was used in 2018, 2019 and 2020,
2. the total digestion results are comparably very low, and
3. partial digestion data are in the normal background range for Ontario and do not appear to increase over time,

CNSC staff are of the opinion that it is unlikely there is any significant upward trend of total beryllium in soil concentrations since 2014.

In 2019, the highest concentration of total beryllium in Peterborough soil (2.34±0.47 mg/kg) was observed at the Prince of Wales Public School sampling location (sample GP05-S05). This concentration, due to high measurement uncertainties observed in 2014 and 2018, is still within the range of other concentrations measured in Peterborough since 2014 and, therefore, this sample may represent the upper level of total beryllium concentrations in local soils.

Figure 4 demonstrates the total digestion results of beryllium measurements with the respective uncertainties observed at the original Prince of Wales Public School sampling location (GP05-S05) and the eight sampling locations added during the 2020 campaign.

Figure 4: Beryllium soil concentrations (total digestion, mg/kg) observed at the nine Prince of Wales Public School sampling locations in 2020.



The total beryllium concentrations observed at the Prince of Wales Public School in 2020 ranged between 1.45±0.26 to 1.95±0.35 mg/kg with an average value of 1.69 mg/kg. All these values are comparable to the concentration of 2.34±0.47 mg/kg observed in 2019 and in the range of other total digestion results measured in Peterborough in 2020.

CNSC staff will ensure that environmental sampling in the Peterborough area continues in order to verify that the levels of beryllium continue to remain very low and that there is no increasing trends in soil due to BWXT operations. Should the Commission decide to renew BWXT's licence, CNSC staff plan to conduct future sampling engaging with the public, municipal officials and Indigenous groups. CNSC staff will also continue working with these groups in future sampling campaigns in Peterborough to collaborate on the interpretation of the IEMP results.

It is also recognized that in the future, CNSC staff will have to better explain any changes in sampling and analytical techniques used during the IEMP. As laboratory methodologies and processes improve, CNSC staff will clearly communicate this with the Commission, the public and Indigenous Groups how and if these changes may impact any conclusions about past, current and future results.

3 Conclusions

3.1 Conclusion

The Commission directed CNSC staff to carry out expedited soil resampling for beryllium of properties adjacent to BWXT's Peterborough facility, with a special focus on the property where the Prince of Wales Elementary School is located. The Commission also directed CNSC staff to carry out an analysis of the results with the aims of clarifying the risk that the increasing beryllium levels may present to the health and safety of the public and the environment, and potentially identifying the reasons for the increase and the source of the beryllium.

The results of the expedited soil resampling affirms CNSC staff conclusions presented to the Commission in CMD 20-H2 during the March proceedings [10]. CNSC staff continue to conclude that there is no risk to the environment and to human health at the Prince of Wales Public School and on other properties adjacent to BWXT's Peterborough facility, since all concentrations of beryllium in soil measured by partial digestion method are in the range of natural background in Ontario (up to 2.5 mg/kg) and well below the CCME SQG for the protection of environmental and human health (4 mg/kg).

CNSC staff conclude that there is no evidence that the BWXT facility emissions have affected soil quality in Peterborough, as concentrations of beryllium measured near the BWXT facility by partial digestion are in the range of natural background in Ontario (up to 2.5 mg/kg) and do not appear to increase over time.

CNSC staff conclude that beryllium values measured by the total digestion of soil samples in 2014-2020 are not statistically different given the measurement uncertainties at 95% confidence level. Therefore, these data cannot be used to support any conclusions on potential trends of beryllium levels in soil.

Should the Commission decide to renew BWXT's licence, CNSC staff commit to conduct future sampling in consultation with the public, municipal officials and Indigenous groups. These results would be reported to the public, Indigenous Groups and the Commission through the CNSC website and Regulatory Oversight Reports.

ACRONYMS

AAQC	Ambient Air Quality Criteria
BWXT	BWXT Nuclear Energy Canada Inc.
CCME	Canadian Council of Ministers of the Environment
CMD	Commission Member Document
Cm	Centimeter
CNSC	Canadian Nuclear Safety Commission
CSA	Canadian Standards Association
ECA	Environmental Compliance Approval
ERA	Environmental Risk Assessment
HHRA	Human Health Risk Assessment
ICP-MS	Inductively coupled plasma mass spectrometry
IEMP	Independent Environmental Monitoring Program
Kg	Kilogram
M^3	Meters cubed
MECP	Ministry of the Environment, Conservation and Parks
mg	Milligram
NPRI	National Pollutant Release Inventory
SQG	Soil Quality Guidelines
µg	Micrograms

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APPENDIX A: BERYLLIUM MASS BALANCE CALCULATIONS

CNSC staff performed a mass balance calculation to determine the concentration and mass of airborne beryllium required to result in an increase of 1.07 mg/kg/year. The calculation focused on the school yard at Prince of Wales Public School, where beryllium concentrations in soil samples changed from 1.27 mg/kg in 2018 to 2.34 mg/kg in 2019.

The calculations are representative of a conservative estimation as additional parameters including wind direction and dispersion modeling were not considered. CNSC staff assumed that the prevailing wind direction was towards the Prince of Wales Public School at all times resulting in deposition at the school yard only. When calculating the beryllium deposition rates, the CNSC used soil bulk densities, particle deposition velocities, and depths. CNSC's calculation used the largest concentration change in soil samples at the school yard between 2018 and 2019 (1.07 mg/kg).

CNSC's calculations applied the soil loss constant of beryllium due to leaching. This takes into consideration the rate at which beryllium will presumably leach out of the soil. This was calculated by applying additional soil parameter values including the velocity of water percolation through soil, soil water content, and the soil-liquid equilibrium distribution coefficient. This approach was similarly implemented by a third-party consultant when modeling air and soil concentrations as part of the ERA for other fuel manufacturing facilities in Ontario [12]. Implementing this methodology and including these additional soil parameters allowed the CNSC to perform a comprehensive calculation.

The calculation methodology applies conservative assumptions when determining the concentration and mass of airborne beryllium. The calculations assume that air emissions are constantly released from BWXT stacks 365 days per year. Beryllium is transported to the soil from air deposition by gravitational settling, so CNSC staff assumed that atmospheric deposition is the only source of beryllium to the soil and the calculated beryllium air concentration is what is emitted from the stacks. The soil parameter values applied are outlined in Table A.1.

Beryllium is naturally removed from the soil by many mechanisms including leaching. The soil loss constant of beryllium from the soil due to leaching is calculated using Equation A.1. Beryllium soil concentrations from 2018 and 2019 at the Prince of Wales Public School and the soil parameters from Table 2 were inputted into Equation A.2 to obtain the beryllium deposition rate. The concentration of airborne beryllium was calculated using Equation A.3.

CNSC staff applied the measured stack flow rates and the air volume which passed through the beryllium stacks in 2018 and 2019. The average stack air volume Table A.2 was used to calculate the total mass of airborne beryllium as shown in Equation A.4.

CNSC staff calculated that the concentration of airborne beryllium required to increase soil concentrations by 1.07 mg/kg in soil over one year is 1.28 µg/m^3. This concentration is 42 times greater than BWXT's action level (0.03 µg/m^3) which applies directly at the stacks and would have triggered action level exceedances. This action level is based on continuous sampling on all three beryllium stacks with samples collected and measured on a weekly basis. Compliance verification activities conducted by CNSC staff verified that BWXT did not exceed its beryllium action level in 2018 or 2019. Furthermore, this concentration is 142 times greater than BWXT's maximum beryllium concentration emitted to the atmosphere over the current licensing period (0.009 µg/m^3). CNSC staff also determined that the mass of airborne beryllium required to result in an increase of 1.07 mg/kg in soil over one year is 133 g. The calculated mass is a conservative estimation as airborne beryllium concentrations emitted from the stacks would disperse outwards and into the environment based on a number of factors including the prevailing wind direction.

As noted during the March 2020 Commission proceedings, BWXT's Peterborough facility uses approximately 20 kg of beryllium annually. The majority is used directly into the product and approximately 15 mg of beryllium is released from the stacks annually [10]. This release is over 8000 times less than the mass of 133 g required to result in an increase of 1.07 mg/kg in soil over one year. Therefore, CNSC staff conclude that based on the calculation results, beryllium emissions from BWXT's Peterborough operations are at a level that could not result in the change in beryllium soil concentrations.

Equation A.1: Soil loss constant

$$k_{leaching} = \frac{V_w}{d_s\left[1+\left(\frac{\rho}{\Theta}K_{Di}\right)\right]} \times 365$$

$$K_{\text{leaching}} = 0.009114$$

where:

k_{leaching} = soil loss coefficeint due to leaching
V_{w} = veloity of water percolation downward through soil (cm/day)
d_{s} = soil sampling depth (cm)
p = soil bulk density (g/cm^3)
Θ = soil water content (mL/cm^3)
K_{D} = soil-liquid equilibrium distribution coefficient (mL/g)

Equation A.2: Beryllium deposition rate

$$C_{soil}(t) = \left(C_{soil}(t-1) + \frac{D(t)}{d_s \times \rho} \right) e^{-k}$$

D(t) = 5.12 µg/(cm^{2}year)

where:

C_{soil}(t) = soil concntration at time (t) (mg/kg)
k = soil loss coefficeint due to leaching (1/year)
D(t) = beryllium deposition rate (µg/(cm^{2}year)
d_s = soil sampling depth (cm)
p = soil bulk density (g/cm^3)

Equation A.3: Concentration of airborne beryllium

$$C_{air} = D(t) \times V_{dep}$$

$C_{air} = D(t) \times V_{dep}$$C_{air}$ = 5.12 µg/(cm^{2}year) ×× 0.25 cm/s
C_{air} = 1.28 µg/m^3

where:

D(t) = beryllium deposition rate (µg/(cm^2/year)
V_{dep} = particle depostion velocity (cm/s)
C_{air} = concentration of airbrone beryllium (µg/m^3)

Equation A.4: Mass of airborne beryllium

$$m_{air} = C_{air} \times V_{avg}$$

$m_{air}m_{air} = C_{air} \times V_{avg}m_{air}$ = 1.28 µg/m^3 ×× 10.35E+07 m^3

$m_{air}m_{air}$ = 133 g

where:

C_{air} = beryllium deposition rate (µg/(cm^2/year)
V_{avg} = averegae stack air volume form beryllium stacks
m_{air} = total mass of airbrone beryllium

Table A.1: Soil parameter values

Parameter	Value	Units	Reference
Velocity of water percolation through soil (V_w)	0.066	cm/day	CSA N288.1-14 [13]
Depth of soil zone of interest (d_s)	5.0	Cm	ASTM C998-05 [14]
Soil bulk density (*p*)	0.94	g/cm^3	CNSC IEMP [6]
Soil water content (Ɵ)	0.1354	mL/cm^3	SENES [12]
Soil-liquid equilibrium distribution coefficient (K_d)	76	mL/g	SENES [12]
Particle deposition velocity (V_{dep})	0.25	cm/s	US EPA [15]
Beryllium concentration in soil (C_{soil})	2.34 (2019) 1.27 (2018)	mg/kg	CNSC IEMP [6]

Table A.2: Estimated beryllium air stack volumes

Year	Beryllium Stacks			Total Stack Air Volume (V_{stack})	Average Stack Air Volume (V_{avg})
	North (m^3)	Acid (m^3)	South (m^3)		
2018	3.8E+07	2.6E+07	3.7E+07	10.1E+07	10.35E+07
2019	3.9E+07	2.6E+07	4.1E+07	10.6E+07	

APPENDIX B: JULY 2020, BERYLLIUM SOIL SAMPLING

Table B.1: 2020 beryllium soil sampling locations

Sample Code	Location	Latitude	Longitude	Sample Description	Rationale
GP11-S11	Emily Omemee Community Centre	44.31680	-78.56677	Soil (0-5 cm)	Reference location ~18 km west of the BWXT facility
GP07-S07	Victoria Park	44.307842	-78.318133	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is NW of the facility.
GP01-S01	R.A. Morrow Memorial Park	44.287474	-78.319528	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is SE of the facility along the main prevailing wind direction.
GP02-S02	Turner Park	44.29087	-78.3354	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is S of the facility
GP03-S03	Kinsmen Park	44.294736	-78.343218	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is W of the facility.
GP04-S04	Del Crary Park	44.295439	-78.317944	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is E of the facility along the main prevailing wind direction
GP06-S06	Residential Park	44.298273	-78.332654	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is N of the facility along the main prevailing wind direction.
GP08-S08	Bonnerworth Park	44.308177	-78.338756	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is NW of the facility.

GP05-S05	School Playground (Location 1)	44.29617	-78.3358	Soil (0-5 cm)	Airborne beryllium emissions are released from BWXT. Area is immediately W of the facility. Location is a key exposure receptor as it is within close proximity.
GP05-S-L2	School Playground (Location 2)	44.29613	-78.3357	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L3	School Playground (Location 3)	44.29612	-78.3357	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L4	School Playground (Location 4)	44.29608	-78.3358	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L5	School Playground (Location 5)	44.29615	-78.3359	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L6	School Playground (Location 6)	44.29618	-78.3359	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L7	School Playground (Location 7)	44.29619	-78.3358	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L8	School Playground (Location 8)	44.2962	-78.3358	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation
GP05-S-L9	School Playground (Location 9)	44.29616	-78.3357	Soil (0-5 cm)	Additional sampling location to address Commission's Notice of Continuation

Table B.2: Beryllium concentrations (mg/kg) in soil from 2014-2020

Sample ID Location	Total Digestion[1]				Partial Digestion[1]
	2014	2018	2019	2020	2020
GP01-S01	0.8±0.6	1.27±0.64	1.33±0.27	1.46±0.26	0.34±0.07
GP02-S02	1.1±0.9	1.14±0.58	1.34±0.27	1.53±0.27	0.33±0.07
GP03-S03	1.1±0.9	1.28±0.66	1.10±0.22	1.62±0.29	0.44±0.09
GP04-S04	0.9±0.8	1.08±0.54	1.17±0.24	1.29±0.23	0.39±0.08
GP05-S05	1.0±0.8	1.27±0.64	2.34±0.47	1.56±0.28	0.44±0.09
GP05-S-L2	-	-	-	1.67±0.30	0.61±0.12
GP05-S-L3	-	-	-	1.45±0.26	0.58±0.12
GP05-S-L4	-	-	-	1.71±0.31	0.58±0.12
GP05-S-L5	-	-	-	1.89±0.34	0.58±0.12
GP05-S-L6	-	-	-	1.95±0.35	0.57±0.11
GP05-S-L7	-	-	-	1.74±0.31	0.52±0.10
GP05-S-L8	-	-	-	1.69±0.30	0.53±0.11
GP05-S-L9	-	-	-	1.47±0.26	0.38±0.08
GP06-S06	1.0±0.8	1.24±0.64	1.44±0.29	1.13±0.20	0.64±0.13
GP07-S07	0.7±0.6	1.34±0.68	1.28±0.25	1.53±0.28	0.50±0.10
GP08-S08	1.0±0.8	1.19±0.60	1.33±0.26	1.81±0.32	0.63±0.13
GP11-S11	-	-	1.25±0.24	1.27±0.23	0.33±0.07

[1]Uncertainties are two standard deviations of measurement (95% confidence level)

Figure B.1: 3x3 sampling grid pattern

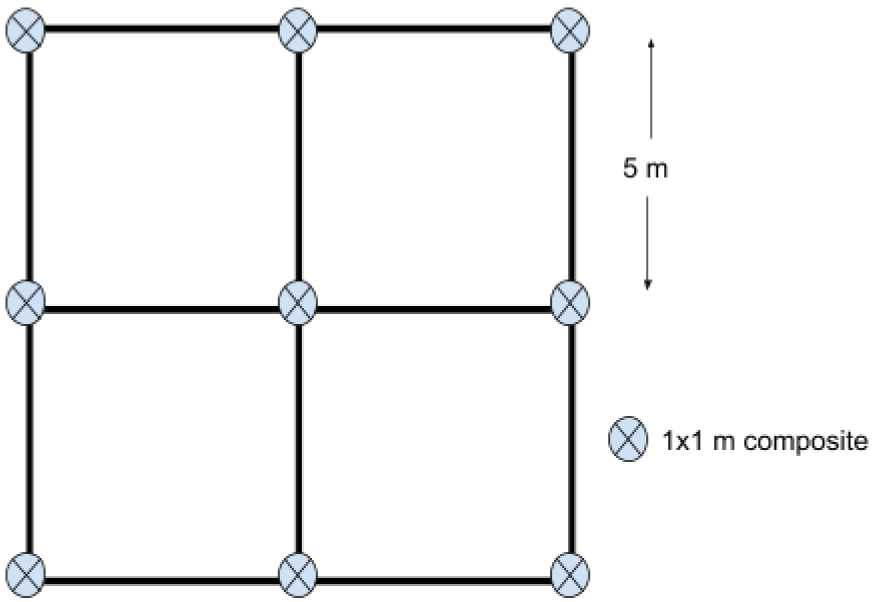


Figure B.2: 5-point composite sample

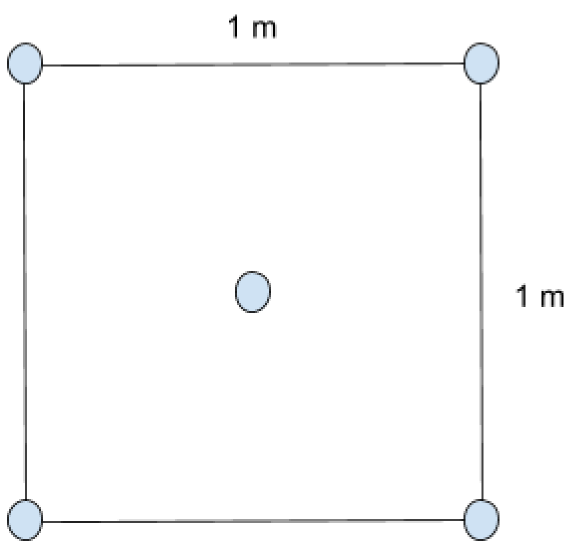
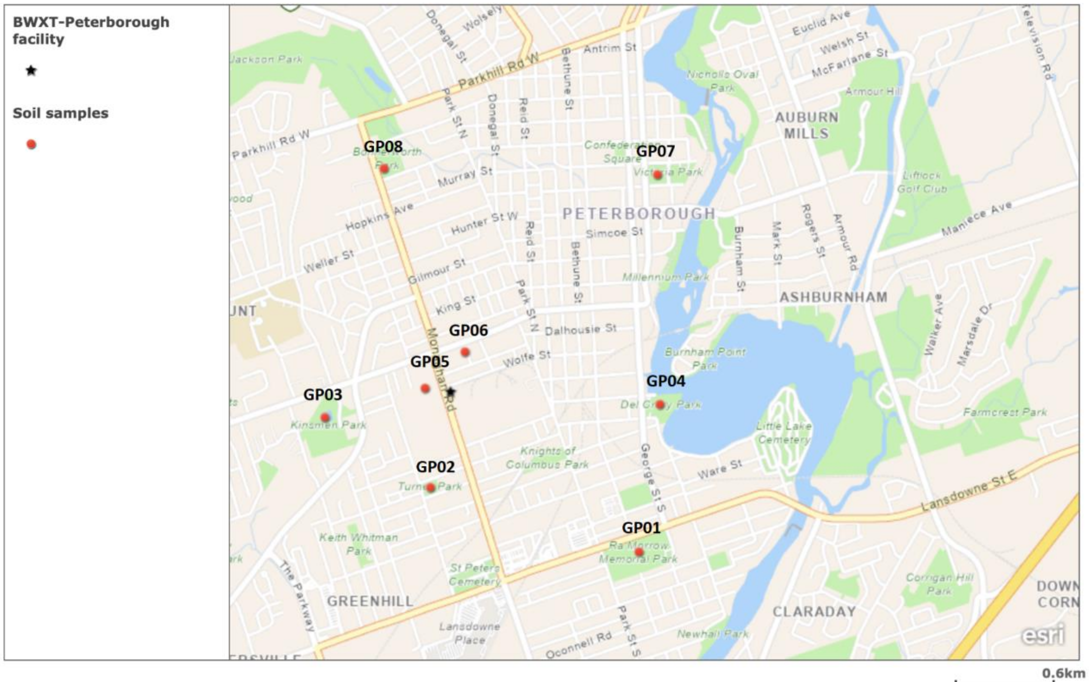
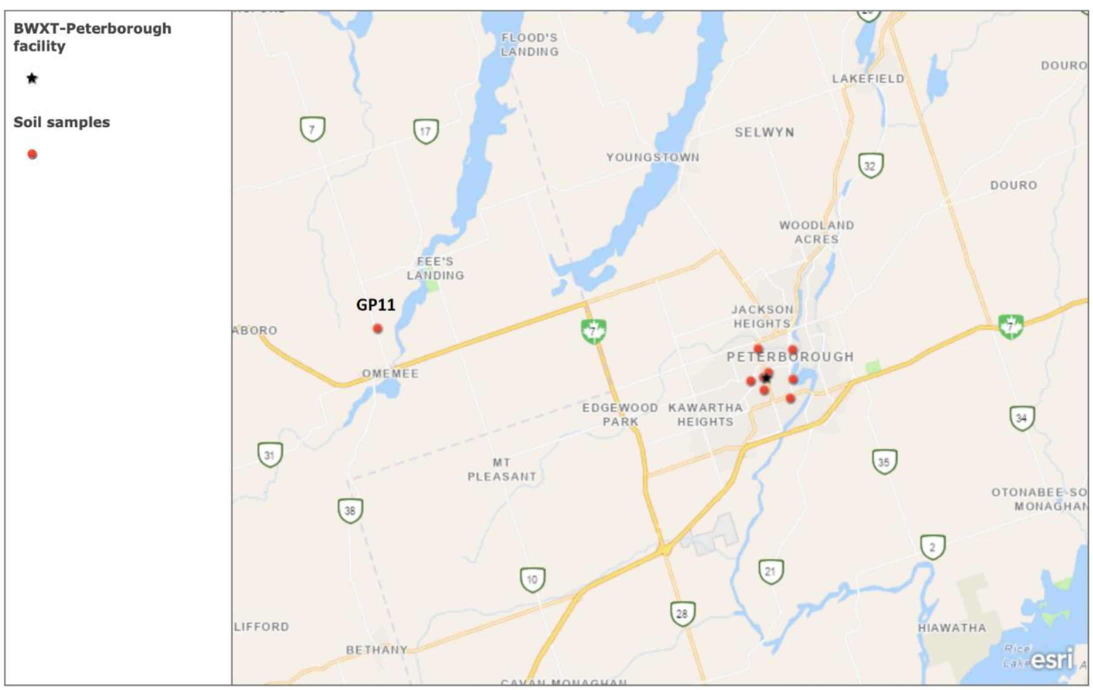


Figure B.3: 2020 soil sampling locations around BWXT Peterborough



Province of Ontario, Esri, HERE, Garmin, INCREMENT P, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, NRCan, Parks Canada

Figure B.4: 2020 soil sampling locations around BWXT Peterborough and reference location



Province of Ontario, Esri, HERE, Garmin, METI/NASA, USGS, EPA, NPS, USDA, NRCan, Parks Canada

Figure B.5: BWXT Peterborough and Prince of Wales Public School