Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

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SUPPLEMENTAL/COMPLÉMENTAIRE

CMD: 20-H2.E

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Reference CMD/CMD de référence : 20-H2.D

A Licence Renewal

Un renouvellement de permis

BWXT Nuclear Energy Canada Inc.

BWXT Nuclear Energy Canada Inc.

CNSC staff clarification on the beryllium calculations provided in CMD 20-H2.D

Précisions du personnel de la CCSN sur les calculs de béryllium fournis dans le CMD 20-H2.D

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BRIEFING NOTE FOR THE SECRETARIAT

To Marc Leblanc, Commission Secretary
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From Haidy Tadros,
Director General, Directorate of Environmental and Radiation Protection and Assessment

and

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Director General, Directorate of Nuclear Cycle and Facilities Regulation

Date December 7, 2020

Subject Clarification on the beryllium calculations provided in CMD 20-H2.D

OBJECTIVE

CNSC staff are providing information to the Commission to correct the typographical errors, calculation errors, and to provide clarity on the application of the units that were used in the equations in Appendix A of CMD 20-H2.D [1].

BACKGROUND

CNSC staff submitted CMD 20-H2.D [1] to the Secretariat in October 2020 in response to the Notice of Continuation issued in April 2020 [2] on the matter of BWXT Nuclear Energy Canada Inc's (BWXT) licence renewal application..

Following the submission of CMD 20-H2.D [1], the Commission secretariat requested CNSC staff provide clarity with regards to the beryllium equations and calculations in Appendix A of CMD 20-H2.D [1].

CNSC staff reviewed the calculations in Appendix A of CMD 20-H2.D [1] and are providing this briefing note to clarify the units used and correct the errors identified. CNSC staff sincerely apologize for these errors and any confusion this may have caused. The overall conclusions of CMD 20-H2.D [1] have not changed.

DISCUSSION

The objective of the calculations in Appendix A of CMD 20-H2.D [1] was to determine the hypothetical concentration and mass of airborne beryllium that would need to be emitted from the BWXT facility to result in the maximum increase of beryllium concentration in soil of 1.07 mg/kg observed at the school yard location over the span of one year (2018-2019).

In Table 1 of CMD 20-H2.D [1], CNSC staff provided the annual average and maximum beryllium concentration at the stacks. Beryllium stack monitoring is performed continuously where air filters are exchanged and analyzed weekly for beryllium concentrations. The annual maximum concentration of beryllium is the highest weekly sample result within the 52 weeks of measurements. The annual average concentration of beryllium is based on the average of all 52 weeks of measurements.

The accumulation of beryllium in soils due to atmospheric deposition can be used to estimate the concentration and mass of airborne beryllium. The beryllium soil concentrations resulting from air deposition depend on the deposition rate, the duration of deposition and natural mechanisms, such as leaching, which can remove contaminates from the topsoil (5 cm) horizon downwards. The loss of beryllium in soil due to leaching was calculated by applying several soil parameters including: the velocity of water percolation through soil, soil water content, and the soil-liquid equilibrium distribution coefficient. Please refer to Table 1 in the appendix to this briefing note for the soil parameter values used, the reference documents, and CNSC's rationale for selecting the values for these parameters.

Equations A.1 and A.2 in CMD 20-H2.D

The calculations for the beryllium soil loss constant due to leaching ($k_{leaching}$) and the beryllium deposition rate D(t) over the span of one year (2018-2019), are provided in Equation 1 and Equation 2 within the appendix to this briefing note. CNSC staff have reconciled the units and the results of these equations remain the same as the results from Equation A.1 and Equation A.2 in CMD 20-H2.D [1] respectively. The k_{leaching} parameter calculated in Equation 1 was carried over into Equation 2.

The reference document for these equations is the NCRP Report No.76 [3], issued by the United States National Council on Radiation Protection & Measurement (US NCRP) to assess contaminants released to the environment. In CMD 20-H2.D [1], CNSC staff referenced a third-party consultant that applied the equations from NCRP Report No.76 [3] to model air and soil concentrations for the ERA at a fuel manufacturing facility in Ontario [4].The equations in the NCRP Report No.76 [3] were embedded within the ERA [4], so CNSC staff are providing the Commission with the primary reference.

Equation A.3 in CMD 20-H2.D

CNSC staff noted that the double multiplication symbol (××) in Equation A.3 of CMD 20-H2.D [1] was a typographical error.

Furthermore, the concentration of airborne beryllium should have been calculated by **dividing** rather then multiplying the beryllium deposition rate D(t) by the particle deposition velocity (V_{dep}). In addition, the units for beryllium deposition rate D(t) and particle deposition velocity (V_{dep}) were not correctly converted in CMD 20-H2.D [1]. To address this, CNSC staff revised the V_{dep} parameter units (from cm/s to m/year) and the D(t) parameter units (from μg/cm^2 to μg/m^2), to reflect the units applied to the concentration of airborne beryllium (μg/m^3), and the deposition of beryllium over one year. Equation 3 in the appendix to this briefing note shows the recalculations and the revised beryllium concentration. The calculated mass of beryllium changed from 1.28 μg/m^3 in CMD 20-H2.D [1] to 0.65 μg/m^3 as shown in the appendix to this briefing note.

Equation A.4 in CMD 20-H2.D

The total mass of airborne beryllium (m_{air}) is calculated by multiplying the concentration of airborne beryllium (C_{air}) by the average volume of air (V_{avg}) passing through the beryllium stacks in 2018 and 2019. CNSC staff noted that the double multiplication of total mass of airborne beryllium (m_{air} m_{air}) and the double multiplication symbol (××) in Equation A.4 of CMD 20-H2.D [1] were typographical errors. The corrected equation and revised mass of beryllium are shown in Equation 4 in the appendix to this briefing note. The calculated mass of beryllium changed from 133 g in CMD 20-H2.D [1] to 67.34 g due to the change in the concentration of airborne beryllium (C_{air}) as shown in the appendix to this briefing note.

RESULTS

The measured values from CNSC's Independent Environmental Monitoring Program (IEMP) and the stack emissions reported by BWXT in CMD 20-H2.D [1] remain unchanged and were also considered in the calculations within this briefing note. As noted in the Discussion section above, CNSC staff have corrected the unit and typographical errors in equations A.3 and A.4 in CMD 20-H2.D, resulting in a revision to the calculated values.

Based on CNSC staff's revised calculations shown in Equations 3 and 4 of the appendix to this briefing note, the hypothetical concentration in air and mass of airborne beryllium changes from 1.28 $\mu g/m^3$ to 0.65 $\mu g/m^3$ and 133 g to 67.34 g, respectively. This means that, in order to see an annual increase in beryllium in soil of 1.07 mg/kg at the school yard location, BWXT would have had to release 67.34 g of beryllium from the stacks between 2018 and 2019 with a concentration in air of 0.65 $\mu g/m^3$. These hypothetical values are 72 times above BWXT's reported maximum concentration of beryllium in air (0.009 $\mu g/m^3$) and the corresponding estimated mass of airborne beryllium (0.93 g) released to the atmosphere over one year, respectively. The estimated mass of airborne beryllium (0.93 g) assumes the maximum concentration (0.009 $\mu g/m^3$) was released constantly from the beryllium stacks 365 days per year and considers the average stack air volume (V_{avg}) applied in Equation 4 in the appendix to this briefing note. This assumption is unrealistic and deliberately conservative to represent the maximum mass of beryllium released to the environment under normal operations.

CONCLUSION

CNSC staff confirm that the revised calculations do not change the conclusions within CMD 20-H2.D [1]. Although the hypothetical values are approximately half of what was reported in CMD 20-H2.D [1], the health and safety of people and the environment continues to remain protected based on CNSC staff's assessment of the beryllium levels. The revised calculations continue to demonstrate that beryllium emissions from BWXT's Peterborough operations are at a level that could not result in significant change to beryllium concentrations in soil.

REFERENCES

[1] Canadian Nuclear Safety Commission. 2020. CMD 20-H2.D *BWXT Nuclear Energy Canada Inc. CNSC staff response to Commission's Notice of Continuation of public Hearing*. October.

[2] Canadian Nuclear Safety Commission, Revised Notice of Continuation of Public Hearing, July 29, 2020. http://www.nuclearsafety.gc.ca/eng/the-commission/pdf/NoticeRev1-Continuation-BWXT-20-H2-e.pdf.

[3] United States National Council on Radiation Protection & Measurement (NCRP). 1984. *Radiological. Assessment: Predicting the Transport, Bioaccumulation, and Uptake by Man of Radionuclides Released to the Environment*. NCRP Report No. 76.

[4] Arcadis, 2016. Environmental Risk Assessment for the Cameco Fuel Manufacturing Facility. August 2016.

[5] Canadian Standards Association (CSA). 2014. *Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities.* N288.1-14. March.

[6] ASTM C998-05, Standard Practice for Sampling Surface Soil for Radionuclides, ASTM International, West Conshohocken, PA, 2005, www.astm.org.

[7] SENES Consultants Limited (SENES). 2008. FINAL – Soil Characterization and Evaluation Study at Port Hope. Project No. 34406-5. April.

[8] EPA. 1987. Health assessment document for beryllium. Prepared by Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, US Environmental Protection Agency, Research Triangle Park, NC for Office of Health and Environmental Assessment, Office of Research and Development.

[9] Canadian Nuclear Safety Commission. Independent Environmental Monitoring Program: BWXT Nuclear Energy Canada Inc. – Peterborough. http://www.nuclearsafety.gc.ca/eng/resources/maps-of-nuclear-facilities/iemp/bwxt-peterborough.cfm.

APPENDIX

Equation 1: Beryllium soil loss constant due to leaching

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

$$k_{leaching} = \frac{0.066 \text{ cm/day}}{5 \text{ cm } [1 + (\frac{0.94 \text{ g/cm3}}{0.1354 \text{ mL/cm3}} \times 76 \text{ mL/g})]} \times 365 \text{ days}$$

$$k_{\text{leaching}} = 0.009114/\text{yr}$$

where:

$k_{leaching}$ = soil loss constant due to leaching (1/yr) [represented as a value per year]
365 = conversion from days to year
V_w = velocity of water percolation downward through soil (cm/day)
d_s = soil sampling depth (cm)
ρ = soil bulk density (g/cm^3)
Θ = soil water content (mL/cm^3)
K_{Di} = soil-liquid equilibrium distribution coefficient (mL/g)

Equation 2: Beryllium deposition rate

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

$$2.34 \text{ µg/g} = [1.27 \text{ µg/g} + \frac{\text{D(t)}}{5\text{cm} \times 0.94 \text{ g/cm3}}]\ e^{(-0.009114)}$$

$$\text{D(t)} = 5.12 \frac{\text{µg}}{cm2yr}$$

where:

C_{soil}(t) = C_{soil}(2019) = soil concentration at time (t=2019) (mg/kg or µg/g)
C_{soil}(t-1) = C_{soil}(2018) = soil concentration at time (t-1=2018) (mg/kg or µg/g)
$k_{leaching}$ = soil loss coefficeint due to leaching (1/yr)
D(t) = beryllium deposition rate (µg/(cm^{2}yr))
d_s = soil sampling depth (cm)
ρ = soil bulk density (g/cm^3)

Equation 3: Concentration of airborne beryllium

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

$$C_{air} = 5.12\ \mu g/(cm^2 yr) \div 0.25\ cm/s$$

$$C_{air} = \frac{5.12\ \mu g}{cm2yr} \times \frac{1\ cm2}{0.0001\ m2} \times \frac{1\ s}{0.25\ cm} \times \frac{1\ cm}{0.01\ m} \times \frac{1\ yr}{31536000\ s}$$

$$C_{air} = 0.65\ \mu g/m^3$$

where:

D(t) = beryllium deposition rate (μg/(cm²yr))
V_{dep} = particle depostion velocity (cm/s)
C_{air} = concentration of airborne beryllium (μg/m³)

Equation 4: Mass of airborne beryllium

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

$$m_{air} = 0.65\ \mu g/m^3 \times 10.35E{+}07\ m^3 \times \frac{1e{-}6\ g}{1\ \mu g}$$

$$m_{air} = 67.34\ g$$

where:

C_{air} = concentration of airborne beryllium (μg/m³)
V_{avg} = average stack air volume from beryllium stacks (m³)
m_{air} = total mass of airborne beryllium (g)

Table 1: Soil parameter values

Parameter	Value	Units	Reference	Rationale
Velocity of water percolation through soil (V_w)	0.066	cm/day	CSA N288.1-14 [5]	Default value for southern Ontario soils
Depth of soil zone of interest (d_s)	5.0	cm	ASTM C998-05 [6]	Sampling depth of IEMP soil samples
Soil bulk density (*p*)	0.94	g/cm^3	CMD 20-H2.D [1]	Measured directly by CNSC staff
Soil water content (Θ)	0.1354	mL/cm^3	SENES [7]	Measured value representative of southern Ontario
Soil-liquid equilibrium distribution coefficient (K_{di})	76	mL/g	SENES [7]	Measured value representative of southern Ontario
Particle deposition velocity (V_{dep})	0.25	cm/s	US EPA [8]	Dry deposition velocity for beryllium particles over vegetation and soil surfaces
Beryllium concentration in soil (C_{soil})	2.34 (2019) 1.27 (2018)	mg/kg	CNSC IEMP [9]	Measured values from the 2018 and 2019 IEMP sampling campaigns