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Update from CNSC Staff

Mise à jour du personnel de la CCSN

Update on the guideline for uranium in ambient air and groundwater

Mise à jour au sujet de la recommandation pour l’uranium dans l’air ambiant et dans les eaux souterraines

Action item from December 12-13, 2018 Commission Meeting (#18712)

Mesure de suivi de la réunion de la Commission des 12-13 décembre 2018 (#18712)

Commission Meeting

Réunion de la Commission

May 15, 2019

Le 15 mai 2019

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To / A	Marc Leblanc Commission Secretary c.c: P. Elder, K. Sauvé, H. Tadros, G. Frappier
From / De	Michael Rinker Director General Directorate of Environmental and Radiation Protection and Assessment

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Subject / Objet: **RIB Action # 18712 - Environmental Quality Guidelines/Criteria of Uranium in Groundwater and Ambient Air and Briefing Note to President on Bq/Year versus Bq•MeV**

This memo is to provide closure of Secretariat RIB Action # 18712.

CONTEXT

On December 13th, 2018, Commission Members requested CNSC staff to provide them with a memo on Canadian environmental quality guidelines/criteria of uranium in groundwater and ambient air at the Commission Meeting on *Regulatory Oversight Report for Uranium and Nuclear Substance Processing Facilities in Canada: 2017*. In addition, staff were asked for an explanation for the similarities of the federal drinking water quality guideline for uranium of 0.02 mg/L and the Ontario Ministry of Environment, Conservation and Parks (MECP) ambient air quality criteria of 0.03 $\mu g/m^3$.

The purpose of this memo is to provide a technical briefing to Commission Members on environmental quality guidelines/criteria of uranium in groundwater and ambient air based on a detailed literature review by CNSC staff.

Previous to the December 2018 request, in the November 2018 Commission Meeting, Commission Members requested more information on Derived Release Limit (DRL) units with regard to Bq/Year versus Bq•MeV. The purpose of this request was to clarify the differences between units and how they are derived and implemented. In 2013, the Commission raised a similar matter, which was addressed by the attached Briefing Note for the President: *Update on the Derived Release Limits (DRL) Units: Bq/Year versus Bq•MeV* in the appendix of this memo.

DISCUSSION

1.0 Environmental Quality Guideline of Uranium in Groundwater

CNSC considers both the radiological and toxicity impacts of uranium. There are no environmental quality guidelines or criteria for uranium in groundwater regulated at the federal or provincial level across Canada. However, in 1999 Health Canada developed a drinking water quality guideline for uranium of 0.02 mg/L on a toxicological health basis and listed it as a maximum acceptable concentration [1]. Uranium is both a radioactive isotope and a toxic chemical, although the specific radioactivity of uranium is very low. This means that, for a given mass of uranium, the dose imparted by its radioactivity is quite small compared to the toxic effects caused in exposed individuals. CNSC staff are currently using this guideline as a referenced environmental quality level in groundwater when reviewing a human health risk assessment and conducting environmental compliance verification.

2.0 Environmental Quality Criteria of Uranium in Ambient Air

There are no environmental quality guidelines or criteria for uranium in ambient air at the federal regulatory level. However, at the provincial regulatory level the Ontario MECP [2] has developed Ambient Air Quality Criteria (AAQCs) for uranium on a toxicological health basis (listed in Table 1 below). An AAQC is a desirable concentration of a contaminant in air and is used to assess general air quality resulting from all sources of a contaminant to air. AAQCs are used most commonly in environmental assessments, special studies using ambient air monitoring data, assessment of general air quality in a community, and annual reporting on air quality across the province. AAQCs are set with different averaging times appropriate for the effect they are intended to protect against. The effects considered may be health, odour, vegetation, soiling, visibility, corrosion or other effects.

CNSC staff have adopted the AAQC value of 0.03 $\mu g/m^3$ for uranium and uranium compounds in Total Suspended Particulates (TSP) for conducting ambient air quality assessment, human health risk assessment and the Independent Environmental Monitoring Program. In Table 1, the AAQC values are also shown for uranium in particulate matter (PM) with an aerodynamic diameter ≤10 µm (PM_{10}) which are the most conservative values.

Table 1 Ambient Air Quality Criteria (AAQCs) for uranium (U) and uranium compounds

Contaminant	AAQC ($\mu g/m^3$)	Averaging Time	Limiting Effect
Uranium and uranium compounds	0.03 (U in PM_{10})	Annual	Health
	0.06 (U in TSP)	Annual	Health
	0.15 (U in PM_{10})	24 hours	Health
	0.3 (U in TSP)	24 hours	Health

CONCLUSION

HSECD staff conclude that there is no direct relationship between the drinking water quality guideline for uranium of 0.02 mg/L and the Ontario MECP air quality criteria for uranium of 0.03 $\mu g/m^3$. Both were developed on a toxicological health basis; however, they are representative of two different environmental media (ambient air and groundwater).

REFERENCES

[1] Health Canada, Guidelines for Canadian Drinking Water Quality, Summary Table, 2017.

[2] Ontario Ministry of Environment, Conservation and Parks, Ontario's Ambient Air Quality Criteria, PIBS # 6570e01, April 2012.

APPENDIX

BRIEFING NOTE FOR THE PRESIDENT

Update on the Derived Release Limits (DRL) Units: Bq/Year versus Bq•MeV

1.0- Background

At the August 2013 Commission Meeting, it was requested to clarify differences between, units in Bq/year and Bq•MeV, for noble gas Derived Release Limits. The purpose of this briefing note is to provide information on how these units are derived and used. The following presents calculation procedures for both units Bq/year and Bq•MeV.

Note – added in 2019 by CNSC staff: Noble gas radionuclides (Xe, Kr, Ar) are gamma energy emitters with chemical inert and do not interact with the human body. In terms of dose calculation for each individual noble gas radionuclide or for a noble gas radionuclides mixture, there is air immersion exposure pathway only, i.e. no inhalation exposure pathway, so it can be simplified to measure gamma energy by a gamma ray detector for stack monitoring which can be readily calibrated to record the release rate as Bq•MeV per unit volume (m^3) per unit time for a noble gas mixture.

2-0 Definition of the Derived Release Limits

The Derived Release Limit (DRL) is the release rate that would cause an individual of the most highly exposed group to receive and be committed to a dose equal to the regulatory annual dose limit due to release of the radionuclide to air or surface water during normal operation of a nuclear facility over the period of a calendar year. The DRL is derived using mathematical equations that describe the transfer of radioactive materials through the environment to humans.

3.0- Calculation

DRLs are calculated independently for releases to air and to surface water. For any source, radionuclide, and representative person, the DRL is obtained by dividing the doses per unit release (X_1/X_0) into the relevant dose limit. For the purposes of DRL calculation, X_0 can be arbitrarily set at 1 $Bq \cdot s^{-1}$, which leads to DRLs that also have units of $Bq \cdot s^{-1}$. These may be multiplied by $3.154 X 10^7$ $s \cdot a^{-1}$ to obtain the DRL in $Bq \cdot a^{-1}$.

DRLs for releases ($Bq \cdot s^{-1}$ or $Bq.a^{-1}$), are calculated as follows [1]:

Releases to Air:

$$\text{DRL} = \frac{\text{annual dose limit } (Sv \cdot a^{-1})}{[X_1/X_0(\text{air})]\ (Sv \cdot s^{-1} \cdot Bq^{-1} \cdot s)} \quad [1]$$

where: X_1/X_0 (air): The dose per unit release to air.

Releases to water:

$$\text{DRL} = \frac{\text{annual dose limit } (Sv \cdot a^{-1})}{[X_1/X_0(\text{water})]\ (Sv \cdot s^{-1} \cdot Bq^{-1} \cdot s)} \quad [2]$$

where: X_1/X_0 (water): The dose per unit release to surface water.

All the DRLs for radionuclide releases for air and water are calculated and have units of $Bq \cdot s^{-1}$, except for noble gas that have units of either $Bq \cdot s^{-1}$ or $Bq \cdot MeV \cdot s^{-1}$. Section 3 provides both calculation procedures for noble gas.

4.0- DRLs for Noble gas

DRLs for noble gas may be calculated for each individual noble gas radionuclide released or for a noble gas mixture.

4.1- Individual noble gas

DRLs for each noble gas radionuclide (e.g., Xe, Kr, Ar) are calculated using the transfer parameter for each gas provided in Table 1 below. The DRL are obtained in $Bq \cdot a^{-1}$.

Calculation methodology

Individual noble gas: Argon-41

For a noble gas the only exposure is air immersion. Effective dose per unit release is calculated as follows:

$$X_1/X_0(air) = P_0 \cdot P_1$$

Where:

P_0 : The transfer parameter P_0 from source to air at the receptor location ($3.0E\text{-}07\ s \cdot m^{-3}$) can be obtained using default parameters from CSA N288.1-2008 [1].

P_1 : Transfer parameter P_1 for an individual noble gas can be obtained from Table 1.

Step 1:

For the adult receptor, the transfer parameters P_0 and P_1 have the following default values:

$$P_0 = 3.0E\text{-}07\ s \cdot m^{-3}$$

$$P_1 = 1.16E\text{-}06\ Sv \cdot a^{-1}/Bq \cdot m^{-3}$$

Step 2:

The adult effective dose per Bq/s release is as follows:

$$\begin{aligned} X_1/X_0(air) &= P_0 \cdot P_1 \\ &= 3.0E\text{-}07\ s \cdot m^{-3} \cdot 1.16E\text{-}06\ Sv \cdot a^{-1}/Bq \cdot m^{-3} \\ &= 3.48E\text{-}13\ Sv \cdot a^{-1} \cdot Bq^{-1} \cdot s \end{aligned}$$

Step 3:

The DRL for noble gas releases to air ($Bq \cdot s^{-1}$) are obtained using equation 1 and are calculated as follows:

$$DRL = \frac{\text{annual dose limit } (Sv \bullet a^{-1})}{[X_1/X_0(air)]\ (Sv \bullet s^{-1} \bullet Bq^{-1} \bullet s)}$$

$$= 0.001\ Sv \bullet a^{-1} / 3.48E\text{-}13\ Sv \bullet a^{-1} \bullet Bq^{-1} \bullet s$$
$$= 2.87E\text{+}09\ Bq \bullet s^{-1}$$

This is just to show the calculation steps. The DRLs of releases to air and water are calculated using Integrated Model for Probabilistic Assessment of Contaminant Transport (IMPACT version 5.4.0) software used by licensees to calculate their DRLs.

4.2- Noble gas mixture

Rather than considering dose coefficients given in the table below for each radionuclide, DRL may be based on the gross gamma energy component of the noble gas mixture, expressed in units of Bq•MeV. Stack monitors can be readily calibrated to record Bq•MeV• m^{-3} for compliance monitoring of the release rate of the mixture.

Measurements of noble gas mixture

Noble gas stack monitors are designed specifically to measure energy absorption per unit volume per unit time, and can be calibrated in terms of Bq•MeV•m^{-3}.

To monitor noble gas releases, air is pulled from stack or duct through isokinetic intake nozzles and flow meter, through glass fiber particulate pre-filter, (and optional filter zeolite or charcoal prefilter for airborne iodine), into a shielded measurement chamber, then out through the pump and back to the stack. Within the shielded detection chamber is a scintillation photo-multiplier detector that detects gammas emitted by the Noble Gas.

Output from the scintillation detector is sorted into three groups, based on the energy of the gamma rays detected. Each energy window is adjustable. The typical settings are:

- Low Energy: Xe^{133}, 0.035 to 0.100 MeV
- Mid Energy: Xe^{135}, 0.100 to 0.400 MeV
- High Energy: Xe^{135m}, 0.400 to 4.0 MeV

The noble gas stack monitor (Model # CAM -3XG) description is attached to this Briefing note.

Calculation methodology

Noble gas mixture (e.g. Xe, Ar, Kr)

As mentioned above, for a noble gas mixture, the stack monitor can be readily calibrated to record Bq•MeV• m^{-3}.

Step 1:

For the adult receptor, the transfer parameters have the following default values:

$P_0 = 3.0E\text{-}07\ s \cdot m^{-3}$

$P_1 = 9.36E\text{-}07\ (Sv \cdot a^{-1})/(Bq \cdot MeV \cdot m^{-3})$

Where:

P_0 : The transfer parameter P_0 from source to air at the receptor location can be obtained using default parameters from CSA N288.1-2008 [1].

P_1 : The transfer parameter P_1 for a noble gas mixture can be obtained using default parameters from CSA N288.1-2008 [1].

Step 2:

The adult effective dose per Bq/s release is as follows:

$$X_1/X_0(air) = P_0 \cdot P_1$$
$$= 3.0E\text{-}07\ s \cdot m^{-3} \cdot 9.36E\text{-}07\ (Sv \cdot a^{-1})/(Bq \cdot MeV \cdot m^{-3})$$
$$= 2.81E\text{-}13\ Sv \cdot a^{-1} \cdot Bq^{-1} \cdot MeV^{-1} \cdot s$$

Step 3:

The DRL for noble gas mixture releases to air ($Bq \cdot s^{-1}$) are obtained using equation 1 and are calculated as follows:

$$DRL = \frac{\text{annual dose limit } (Sv \cdot a^{-1})}{[X_1/X_0(air)]\ (Sv \cdot s^{-1} \cdot Bq^{-1} \cdot s)}$$

$$= 0.001\ Sv \cdot a^{-1} / 2.81E\text{-}13\ Sv \cdot a^{-1} \cdot Bq^{-1} \cdot MeV^{-1} \cdot s$$
$$= 3.56E+09\ Bq \cdot MeV \cdot s^{-1}$$

The unit used for noble gas, that is Bq•MeV / year or week, is consistent with the CSA standard N288.1-08. The licensee can monitor noble gas for compliance in units of Bq•MeV.

Table 1: Transfer parameter P_1 for an individual noble gas ($Sv \cdot a^{-1}/Bq \cdot m^{-3}$)

	Effective dose coefficients		**Skin dose coefficient**
Noble Gas	**Adults and children**	**Infants**	**All age groups**
Ar-41	1.16E-06	1.51E-06	3.19E-06
Kr-85	4.83E-09	6.28E-09	4.17E-07
Kr-87	7.44E-07	9.67E-07	4.32E-06
Kr-88	1.84E-06	2.39E-06	4.26E-06
Xe-125	2.03E-07	2.64E-07	4.71E-07
Xe-131m	7.02E-09	9.13E-09	1.52E-07
Xe-133	2.63E-08	3.42E-08	1.57E-07
Xe-135	2.10E-07	2.73E-07	9.85E-07
Xe-138	1.04E-06	1.35E-06	3.38E-06

References

[1]-CSA N288.1-2008 – Guideline for calculating derived release limits for radioactive material in airborne and liquid effluents for normal operation of nuclear facilities

Prepared by: Mike *Jones, Environmental Program Officer*
Reviewed by: *Said Hamlat, Director, ECLSD*
Approved by: *Patsy Thompson, Director General, DERPA*
Date: *September 9, 2013*