TRITIUM HEALTH RISK ASSESSMENT IN HEAVY-WATER REACTOR DEPLOYMENT: DOCUMENTED DEFICIENCIES IN THE CNSC REGULATORY FRAMEWORK AND IMPLICATIONS FOR MONARK LICENSING

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1.. Background

Canada's investment of $304 million in the MONARK next-generation CANDU reactor design, announced March 2025, positions heavy-water reactor technology as a cornerstone of Canada's decarbonisation strategy [1]. The MONARK design retains the Canadian Deuterium Uranium (CANDU) heavy-water moderation system, which is the highest tritium-producing civilian reactor design in commercial operation. Tritium output from CANDU reactors is characteristically one to two orders of magnitude greater than pressurised-water reactors of equivalent thermal output [2].

The Canadian Nuclear Safety Commission (CNSC) regulates tritium releases and sets health-based limits under the authority of the Nuclear Safety and Control Act. As Canada moves toward MONARK deployment, including proposed siting in Alberta (Peace River), the adequacy of the CNSC's tritium health risk assessment framework warrants rigorous independent scrutiny. This paper identifies six documented inconsistencies between the CNSC's public-facing tritium communications and the CNSC's own peer-reviewed technical literature, examines their regulatory significance, and proposes a corrected framework for MONARK licensing.

2.. The CNSC Tritium Assessment Framework and Its Internal Contradictions

The CNSC's primary public statement on tritium health effects is its Tritium Fact Sheet, available at nuclearsafety.gc.ca. The CNSC's primary technical reference is INFO-0799, Health Effects of Tritium, a peer-reviewed technical report published by CNSC staff. A comparative analysis of these two documents reveals six inconsistencies material to the assessment of health risk from CANDU-derived tritium.

2.1 Relative Biological Effectiveness

The public Tritium Fact Sheet describes tritium's beta radiation as "relatively weak." INFO-0799 reports that tritium's relative biological effectiveness (RBE) has been experimentally measured at 1.4 times that of X-rays and 2.2 times that of gamma radiation for certain endpoints [3]. The CNSC uses a radiation weighting factor (wR) of 1.0 for tritium in all regulatory dose calculations, consistent with the International Commission on Radiological Protection (ICRP) framework. INFO-0799 acknowledges that a wR of 2.2 "would best reflect radiation risk for tritium" [3]. Every dose calculation used to establish that tritium releases are "below limits" therefore systematically underestimates biological risk by a factor of 2.2.

2.2 Fetal Dosimetry

The public Tritium Fact Sheet states that tritium is released in "extremely large quantities" from CANDU reactors but characterises the resulting doses as safe. INFO-0799 documents that fetal

dose from tritiated water (HTO) is double the adult dose at any environmental concentration, owing to differential body water content and metabolic rate in fetal tissue [3]. This differential is not reflected in the public dose assessments used to characterise the safety of routine CANDU releases.

2.3 Organically Bound Tritium and Fetal Oocyte Incorporation

The public Tritium Fact Sheet does not mention organically bound tritium (OBT), the form in which tritium becomes incorporated into biological molecules. INFO-0799 documents that OBT incorporates into DNA, including fetal oocyte DNA, which is the specific biological substrate of most concern for intergenerational mutagenesis and childhood cancer induction [3]. OBT has a biological half-life estimated at 40 days in adults, but some researchers estimate up to 500 days in certain tissues, with implications for long-term dose accumulation not reflected in regulatory models [4].

2.4 The Pickering Study Characterisation

The CNSC's health studies page states that the Pickering tritium study "has confirmed that tritium is not associated with an increased risk of radiation-sensitive cancers" [5]. INFO-0799 and the study itself (Wanigaratne et al., 2013) note that the study was powered to detect only very large differences in risk, achieving adequate statistical power for large effects but not the modest elevations of biological concern [3, 6]. The study also found a statistically significant doubling of female childhood cancer incidence (SIR = 1.99, 95% CI: 1.08–3.38), attributed by the authors to multiple comparisons [6]. Use of the word "confirmed" for a study with acknowledged power limitations and a positive signal finding is not scientifically defensible.

2.5 The ODWAC Recommendation

The Ontario Drinking Water Advisory Committee (ODWAC) recommended in 2009 a 350-fold reduction in Canada's tritium drinking water guideline, from 7,000 Bq/L to 20 Bq/L, on the grounds that the existing guideline was insufficiently protective for the developing fetus [7]. INFO-0799 acknowledges this recommendation. The CNSC has neither refuted the scientific basis of the ODWAC recommendation nor implemented it in seventeen years. The current guideline of 7,000 Bq/L remains in force.

2.6 Biokinetic Model Validation

INFO-0799 acknowledges that the biokinetic models used to derive dose estimates for tritium have not been validated for fetal tissue specifically, and that the model parameters (biological half-life, tissue distribution, OBT formation rates) carry substantial uncertainty [3]. The public Tritium Fact Sheet presents dose estimates without qualification regarding this acknowledged uncertainty.

3.. Regulatory Significance for MONARK Licensing

The MONARK design, as a next-generation CANDU, will operate with heavy-water moderation and will produce tritium at characteristically CANDU-scale emissions. The six inconsistencies documented above are not minor definitional disputes. They represent structural failures in the risk assessment framework that will form the evidentiary foundation of any MONARK licensing proceeding.

The most at-risk population for CANDU tritium exposure is the developing fetus in the residential perimeter of the facility. The current regulatory framework: (a) applies a biological weighting factor that INFO-0799 acknowledges underestimates risk by a factor of 2.2; (b) uses whole-body average dosimetry rather than fetal tissue-specific dosimetry despite documented fetal dose differential; (c) does not model OBT incorporation into fetal oocyte DNA despite this being the biologically relevant endpoint; and (d) maintains a drinking water guideline that the CNSC's own advisory process recommended reducing 350-fold in 2009.

The consequence is that tritium health risk for the most vulnerable subpopulation may be underestimated in the existing framework by a compound factor. The precise magnitude depends on site-specific OBT formation rates, local population diet and lifestyle (particularly consumption of locally grown food, which accumulates OBT), and the proportion of pregnant women in the near-facility residential population — none of which are currently assessed as pre-licensing conditions.

Proposed siting of MONARK or CANDU-derived facilities in regions such as northern Alberta introduces additional complexity. The Peace River region has documented elevated baseline cancer incidence of unknown etiology, and its population relies partly on locally grown food from agricultural land potentially within the tritium dispersion perimeter. The region also carries a legacy of aromatic hydrocarbon contamination from bitumen operations. Radiation science (BEIR VII) establishes that ionising radiation acts as a cancer initiator, and chemical carcinogens — including aromatic hydrocarbons — act as promoters in the initiation-promotion sequence [8]. Mixture interaction in this specific setting has not been assessed.

4.. Proposed Framework Corrections for MONARK Licensing

Four corrections are proposed as pre-licensing conditions for any MONARK deployment:

First, tritium dose assessments should be calculated using both wR = 1.0 and wR = 2.2, with the results of both calculations disclosed in all public-facing licensing documents, and the CNSC should provide a documented technical rationale for its choice of weighting factor.

Second, fetal tissue-specific dosimetric modelling should be required, separate from whole-body average dosimetry, with explicit disclosure of the fetal dose differential and its implications for near-facility pregnant populations.

Third, OBT formation modelling should be incorporated into the environmental pathway assessment, including modelling of OBT accumulation in locally grown food within the tritium dispersion perimeter, with results disclosed as a pre-licensing condition.

Fourth, the CNSC should either implement the ODWAC 2009 recommendation of 20 Bq/L as the tritium drinking water guideline or publish a technical refutation of the ODWAC analysis. A regulatory advisory recommendation cannot stand unrebutted and unimplemented for seventeen years and simultaneously serve as the scientific foundation for a major deployment licensing proceeding.

5.. Conclusion

MONARK represents a substantial national investment in a tritium-producing reactor design. The CNSC's tritium risk assessment framework contains six documented inconsistencies

between its public communications and its own technical literature. These inconsistencies are not resolved by asserting that doses are below current regulatory limits, because the adequacy of those limits is precisely what is in question. The four framework corrections proposed here are technically implementable within the MONARK design timeline and are consistent with the CNSC's statutory mandate under section 9 of the Nuclear Safety and Control Act to disseminate scientific, technical, and regulatory information. Resolution of these inconsistencies before MONARK licensing proceedings commence would strengthen, not weaken, the credibility of the Canadian nuclear regulatory system.

6.. References

[1] Natural Resources Canada, "Canada Invests in the Next Generation of Canadian-Made, Clean, Affordable Nuclear Energy," NRCan press release, March 6, 2025.

[2] Ontario Clean Air Alliance Research, "Ontario Nuclear's Tritium Problem," 2016.

[3] Canadian Nuclear Safety Commission, Health Effects of Tritium, INFO-0799, CNSC, Ottawa, 2010.

[4] C. Vakil and L. Harvey, "Letter to the Editor re Wanigaratne et al. (2013)," Chronic Diseases and Injuries in Canada, Vol. 34, No. 2-3, 2014.

[5] Canadian Nuclear Safety Commission, "Health Studies," cnsc-ccsn.gc.ca, accessed March 2026.

[6] S. Wanigaratne, E. Holowaty, H. Jiang et al., "Estimating cancer risk in relation to tritium exposure from routine operation of a nuclear-generating station in Pickering, Ontario," Chronic Diseases and Injuries in Canada, Vol. 33, No. 4, 2013, pp. 247-256.

[7] Ontario Drinking Water Advisory Committee, Advice on Ontario's Drinking Water Quality Standard for Tritium, ODWAC, Toronto, 2009.

[8] National Research Council, Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2, National Academies Press, Washington, D.C., 2006.