# BUILT ON THE WRONG PEOPLE: FOUR UNVALIDATED EXTRAPOLATION STEPS IN THE LNT DOSE MODEL AS APPLIED TO CHRONIC INTERNAL EMITTER EXPOSURE FROM CANDU REACTORS

Independent Anonymous Researcher

## 1.. Background

Every safety determination made by the Canadian Nuclear Safety Commission (CNSC) regarding routine releases from CANDU reactors rests on a risk estimate derived from the Linear No-Threshold (LNT) model as calibrated primarily on the Life Span Study (LSS) of Japanese atomic bomb survivors. The CNSC applies this model to calculate the incremental cancer risk to populations in the vicinity of CANDU facilities from routine tritium and other radionuclide releases, and uses the resulting risk estimates to conclude that routine releases do not pose an unreasonable health risk.

This paper does not contest the LNT model as a general framework for radiation protection. It identifies four specific respects in which the population, exposure conditions, and biological endpoints of the LSS calibration dataset differ structurally from the population, exposure conditions, and biological endpoints relevant to CANDU routine releases — and four corresponding respects in which the extrapolation from the calibration dataset to the CANDU context has not been validated. Each extrapolation step introduces uncertainty that compounds multiplicatively. The CNSC's own technical literature acknowledges each of these gaps individually. The paper argues that acknowledging them individually while presenting compounded risk estimates as though the extrapolation were validated is the central scientific credibility problem in CANDU routine release health assessment.

## 2.. The calibration dataset and its characteristics

The LSS cohort comprises approximately 120,000 Japanese survivors of the Hiroshima and Nagasaki bombings, monitored since 1950 [1]. Its defining characteristics are: acute (single-event) exposure; external whole-body gamma and neutron irradiation; adult and older-child population at time of exposure; doses in the range of tens to thousands of millisieverts; and a Japanese demographic and genetic background. The LNT model extrapolated from this dataset is used to estimate cancer risk at doses orders of magnitude lower than the calibration range, for populations that differ from the LSS cohort in every relevant characteristic.

CANDU routine tritium releases create: chronic (continuous lifetime) exposure; internal emitter exposure via inhalation, ingestion, and skin absorption; fetal tissue as the primary biological endpoint of concern; doses in the range of microsieverts per year; and a Canadian demographic including pregnant women and fetuses whose biological sensitivity to tritium is documented to differ substantially from the adult whole-body average used in LSS calibration.

## 3.. Four unvalidated extrapolation steps

| Step | LSS calibration | CANDU routine releases | Validation status |
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| 1 | Acute single exposure | Chronic lifetime exposure | Not validated for tritium |
| 2 | External whole-body gamma | Internal emitter: OBT in fetal DNA | wR=1 used; wR=2.2 acknowledged [2] |
| 3 | Adult/older child population | Fetal tissue primary endpoint | Biokinetic models not validated [2] |
| 4 | High dose (>100 mSv) range | Micro-dose (<0.01 mSv/yr) range | Below LSS statistical resolution |

### 3.1 Step 1: Acute to chronic exposure

The LSS cohort received a single acute exposure event. CANDU routine tritium releases produce continuous low-level exposure throughout the lifetime of a near-facility resident, beginning in utero. The radiobiological relationship between acute and chronic low-dose-rate exposure is not equivalent at the cellular level: DNA repair mechanisms operate differently under chronic low-dose conditions, and the dose-rate effectiveness factor (DREF) introduced to account for this difference carries substantial uncertainty at the dose rates relevant to CANDU routine releases [3]. CNSC dose calculations apply the LNT model without disclosing the DREF assumption or its uncertainty range.

### 3.2 Step 2: External to internal emitter — the tritium weighting problem

The LSS calibration is based on external gamma and neutron irradiation delivering a relatively uniform whole-body dose. Tritium, as an internal emitter, incorporates into organically bound tritium (OBT) and becomes part of DNA structure, including in fetal oocytes — the specific cellular substrate for intergenerational mutagenesis and childhood cancer induction [2]. CNSC technical report INFO-0799 acknowledges that the radiation weighting factor wR = 2.2 “would best reflect radiation risk for tritium” but applies wR = 1.0 in all regulatory dose calculations [2]. The LSS calibration, conducted with external radiation, provides no basis for the wR = 1.0 assignment for internal OBT exposure. The biological mechanism — DNA incorporation rather than traverse — is categorically different.

### 3.3 Step 3: Adult to fetal tissue endpoint

The LSS cohort was predominantly adult at the time of exposure. The primary population of concern for CANDU routine tritium releases is the developing fetus of pregnant residents within the tritium dispersion perimeter. CNSC INFO-0799 documents that fetal dose from tritiated water is double the adult dose at any environmental concentration, owing to differential body water content and metabolic rate [2]. It further acknowledges that the biokinetic models used to derive dose estimates have not been validated for fetal tissue and that the model parameters carry substantial uncertainty for this subpopulation [2]. An extrapolation from an adult-calibrated model to a fetal tissue endpoint, using unvalidated biokinetic parameters, does not produce a validated fetal risk estimate. It produces an extrapolation whose uncertainty bounds have not been quantified.

> The most at-risk subpopulation for CANDU tritium exposure is the developing fetus. The dose model is calibrated on adult atomic bomb survivors. The extrapolation between these two populations has not been validated. This is not disputed — it is documented in INFO-0799.

### 3.4 Step 4: High-dose to micro-dose extrapolation

The LSS dataset provides statistically reliable risk estimates at doses above approximately 100 mSv — the lower bound of its statistical resolution. CANDU routine releases produce annual doses to near-facility residents in the range of 0.001–0.01 mSv/year — four to five orders of magnitude below the reliable calibration range. The LNT model assumes linearity through this range by extrapolation. BEIR VII (2006) supports this extrapolation as a precautionary framework [3]. But the CNSC presents dose estimates in this range with apparent precision — specific decimal-place risk figures — without disclosing that these figures are extrapolations four to five orders of magnitude beyond the range in which they were empirically derived.

### 4.. Compound uncertainty

Each of the four extrapolation steps introduces a multiplicative uncertainty factor. The CNSC does not present compound uncertainty bounds in its routine release dose assessments. A regulatory dose estimate that compounds four unvalidated extrapolations without disclosing the resulting uncertainty range is not a point estimate of risk. It is a lower-bound assumption presented as a measurement.

The direction of each uncertainty is not symmetric. For each of the four steps, the unvalidated assumption produces a risk estimate that is lower than the risk estimate that would result from validation:

wR = 1.0 rather than 2.2 underestimates internal emitter risk. Whole-body average rather than fetal tissue dosimetry underestimates fetal risk. Unvalidated biokinetic parameters for fetal tissue carry unquantified uncertainty with no demonstrated lower bound. Acute-to-chronic extrapolation at micro-dose rates, in the absence of a validated DREF, carries unquantified uncertainty in both directions but with a biological plausibility argument for higher effectiveness at chronic low doses.

The consequence is that every CNSC dose estimate for CANDU routine tritium releases is most likely a lower bound on actual biological risk for the most sensitive subpopulation, not a central estimate. The confidence interval around that lower bound has not been calculated or disclosed.

**Four unvalidated extrapolations. All in the same direction. None of the uncertainty disclosed.**

The CNSC's dose estimates for CANDU routine releases are lower bounds presented as measurements.

## 5.. Proposed disclosure requirements

Three disclosure requirements are proposed for CNSC dose assessments supporting CANDU routine release safety determinations.

First, every dose assessment should identify which of the four extrapolation steps it employs, disclose the validation status of each step for the specific population and exposure pathway being assessed, and present a compound uncertainty range rather than a single point estimate.

Second, dose assessments for near-facility populations should present separate calculations for: (a) the adult whole-body average population; and (b) the fetal population, using both the validated adult biokinetic parameters and the acknowledged uncertainty range for unvalidated fetal parameters, with both wR = 1.0 and wR = 2.2 applied.

Third, the CNSC should commission validation studies for the fetal biokinetic tritium model before MONARK or any CANDU-derived facility enters the licensing phase. INFO-0799 identified this validation as a research requirement in 2010. It remains unaddressed sixteen years later. A major national investment in CANDU technology cannot responsibly proceed on the basis of a risk model that the CNSC's own scientists identified as unvalidated for the most at-risk subpopulation more than a decade before deployment.

## 6.. Conclusion

The LNT model is a defensible precautionary framework for radiation protection. What is not defensible is applying a model calibrated on acute, external, adult, high-dose exposure to a chronic, internal, fetal, micro-dose exposure pathway — across four unvalidated extrapolation steps — and presenting the result as a validated safety determination. The CNSC's own published technical literature documents each of these extrapolation gaps individually. The contribution of this paper is to place them side by side and ask: when four unvalidated extrapolations are compounded, all in the direction of underestimation, and the resulting lower-bound estimate is presented as a central estimate of risk to the most sensitive subpopulation, has a safety determination been made? Or has a lower-bound assumption been labelled one?

## 7.. References

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

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

[6] International Commission on Radiological Protection, The 2007 Recommendations of the ICRP, ICRP Publication 103, Annals of the ICRP, Vol. 37, 2007.