Health Effects of Tritium

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These comments are submitted to the Canadian Nuclear Safety Commission (CNSC) at the invitation of the Citizens of Renfrew County and on behalf of the International Institute of Concern for Public Health, in Toronto, with respect to the re-licensing of the SRB Technologies, Inc. in Pembroke, Ontario.

My Doctorate Degree is in Biometrics, and I have worked in Environmental Epidemiology for about 40 years, with a specialty in low dose ionizing radiation. I was one of the Founding Members of the International Institute of Concern for Public Health in Toronto and served as its President between 1984 and 2000. Since my retirement, I have served as advisor/consultant to projects of the Institute. I am also currently a member of the International Science Oversight Committee of the Association of Organic Consumers, USA, and a member of the Board of Regents of the International Association for Humanitarian Medicine, Geneva, Switzerland.

I have directly studied the health effects of ionizing radiation at low dose levels. Therefore I do not rely on extrapolations from high dose and fast dose rate. I disagree with many scientists and nuclear regulators who conduct such unreliable and outdated extrapolations.

Since about 1990 the international radiation research community has fortunately begun to considered low dose health effects in a more direct manner. We no longer guess at a suitable extrapolation from high doses and high dose rates down to the lower doses that are more frequent in radiation protection practice. Many scientists now conducting direct low dose research have been surprised to discover such effects as genomic instability, the bystander effect, an increase in Relative Biological Effect (RBE) at low dose, mini-satellite damage and non-homogeneous distribution of radionuclides, especially for internal exposures, which significantly effect absorbed dose estimates at low levels of exposure.

I have long disputed Canada's reliance on the recommendations of the International Commission on Radiological Protection (ICRP), a self-appointed and self-perpetuating non-governmental organization (NGO) that does not accommodate peer review. ICRP dosimetry for internal exposure to ionizing radiation has been challenged by the European Committee on Radiation Risk (ECRR) [Ref 1]. This critique of ICRP methodology for estimating internal radiation dose has been affirmed by NATO [Ref. 2] and the French Radiation Protection Agency [Ref. 3]. At present there is no generally accepted alternative method, and each radionuclide must be considered separately.

In my testimony, I conservatively reject many assumptions apparently underlying and supporting the announced new plans of SRBT ostensibly reducing the levels of local tritium pollution and increasing region-wide pollution by dispersing tritium in the Ottawa River.

Although not sufficiently well articulated publicly, a zero Health Based Goal for tritium in water is the only acceptable goal for regulation from a public health stand point. Along with CCRC, I believe that transportation industry signs can be competitively illuminated without incorporation of tritium. I would also argue that tritium should no longer be released into the Ottawa River.

The proponent must amply demonstrate to CNSC that Canadian Citizens of the Ottawa Valley benefit from their risky tritium handling and proposed disposal method. Failing such rigorous demonstration, we urge the CNSC to withdraw license privileges from SRBT.

In consequence:

1. I reject the ICRP methodology for calculating the internal absorbed dose from inhaled, ingested and skin-absorbed tritium. My assessment of dose also takes into consideration: a category of organic bound tritium (OBT) which has been consistently ignored by ICRP, namely exchangeable OBT. The biological half-life of carbon-bound (or fixed) OBT is significantly underestimated in ICRP methodology. This longer exposure time will increase the estimated deposit of energy in tissue by a factor of three. See APPENDIX I.
2. The proportion of OTB in the human body after long term (at least 15 years in Pembroke) exposure to OBT is also underestimated. Chronic exposure to tritiated water (HTO) in food will cause an increase in the exchangeable fraction of OBT to approximately the same proportion as HTO. The non-homogeneous distribution of the two OBT components in the body will mean higher localized absorbed doses, each at least four times higher than the average dose for uniform spread of HTO. This will increase the estimate of energy deposit generally by another factor of three. See APPENDIX I
3. There needs to be a correction of the relative biological effectiveness (RBE) of tritium, based on a consensus of scientific research, by a factor of two to three. ICRP has rejected this position. These points are discussed in APPENDIX I.
4. I will also examine the distribution of risk of fatal cancers in the exposed population and demonstrate that the Canadian accepted ICRP methodology is biased against women and children who will bear the burden of the risks.
5. I will examine the non-fatal cancers and non-cancer effects of tritium that will be experienced by Canadians although these are not addressed by the ICRP. There is ample evidence that these effects occur. I reject ICRP's assumption that ordinary people care only for the fatal cancer effects.

PART I: CALCULATING THE DOSE TO HUMANS FROM TRITIUM

ICRP methodology assumes that exposure to tritiated gas released from the stack of a facility like SRBT will quickly react with oxygen in the air, forming tritiated water (HTO). This water can pollute the air, water and food web becoming internal to the body

through inhalation, ingestion and absorption through the skin. ICRP assumes tritium is distributed homogeneously in the whole body and passes through the body quickly, with a half-life of 12 days, emitting a low energy beta radiation. ICRP assumes about 3% will be bound to the carbon atoms in DNA (fixed OBT), with a biological half-life of about 40 days. Taken together, ICRP assumes that the RBE (relative biological effectiveness) of internally deposited tritium will be about one when compared for cell killing with 200 kVp X-ray or 137 cesium.

This methodology neglects several facts about tritium and about radiation in general:

- The radiation dose depends on both the strength of the source, and the length of time one is exposed to that source. This is intuitively true. If one thinks of sitting in the sun, the person avoids, if possible, the heat of mid-day, and generally limits his or her time spent sun-bathing.
- The organic bound tritium (OBT) fraction of tritiated water (HTO) actually has two components, The first is exchangeable (easily reacts with other chemicals in the internal environment) and binds with oxygen, sulfur, phosphorus or nitrogen atoms, to form amino acids, proteins, sugars, starches, lipids, and cell structural material. It is this fraction of the tritium which has a biological half-life of 40 days. This component is sometimes called the OBT 1 component. The second more fixed component, the OBT 2, binds with the carbon atoms of the DNA. This OBT 2 has a biological half-life of about 550 days. The OBT 1 component is increased when the food supply contains OBT, as one would expect in an area subjected as Pembroke was to excessive tritium pollution for fifteen years. The expanded definition of OBT will increase the estimate of energy deposited in tissue by about a factor of three, i.e. a mGy dose estimate of one mGy per year, using ICRP methodology, is 3 mGy per year when the compartments of OBT and the extended time of OBT 1 and 2 exposure are considered. Details and references for this calculation are given in APPENDIX I.
- It has also been demonstrated by scientists that the dose from both the OBT 1 and OBT 2 components are localized, and not homogeneous, as is assumed by the ICRP methodology. Localized absorbed doses may be up to four times greater than is the dose from HTO. With 15 years of pollution with tritium from SRBT, the HTO and OBT 1 proportions in the body would be expected to equalize, giving the following internal distribution of tritium: HTO 47.5%; OBT 1, 47.5% ; and OBT 2, 3%. This would increase the estimate of energy deposited in tissue by at least another factor of three for non-homogeneity, to about nine, i.e. the mGy dose of 1 mGy per year, according to ICRP can be corrected to 9 mGy per year. This is discussed in APPENDIX I.
- In calculating the mSv dose from a mGy dose of tritium, scientists and professional committees generally agree that an RBE (relative biological effectiveness factor) of two to three is needed. Counter to this, ICRP recommends using one as the nearest order of magnitude of ten to the true number. Professionals would make the conversion of nine mGy energy deposit in tissue by tritium into an effective dose equivalent of 18 to 27 mSv, roughly equivalent to 20 mSv, that of a 1 mGy dose from an alpha particle. Discussed in detail in APPENDIX I.

I conclude that the internal chronic dose from tritiated water to the Canadian public resulting from 1 mGy/year absorbed dose according to ICRP methodology and Canadian practice, should be conservatively corrected by professionals to about 20 mSv/year effective dose equivalent. The proclaimed maximum dose to the public from man-made radioactivity is 1 mSv/year. Therefore all tritium maximum permissible limits based on a maximum 1 mSv dose need to be divided by 20 in order to meet regulatory limits. The maximum permissible dose of tritium would change from 7000 to 350 Bq per liter of water.

As noted above, regulatory limits are risk vs benefit trade offs, which replace the Health Based Limit of zero when there is over riding benefit from the activity. This proposal does not seem to warrant an exemption.

The proposal of SRB, as I understand it, is in the future, to collect the HTO which falls on its roof into gutters. It can be directed to the Municipal sewer and thence to the Ottawa River. This proposal has many flaws:

- The proposal will do nothing to assist or compensate the people of Pembroke for their environmental and human pollution from the last fifteen years of over-exposure to radiation.
- It neglects the real damage to the ecosystem of the Ottawa River and to those drinking or consuming fish from its already radiologically polluted waters. There is no water treatment plant capable of separating tritiated water from normal water, and the Ottawa River already receives radionuclides from the licensed burial trenches at the Chalk River facility.

PART II: DISTRIBUTION OF RISK IN THE PEMBROKE POPULATION:

There are many uncertainties associated with the nominal risk of fatal cancer associated with an effective dose of ionizing radiation. Based on ICRP 60 [Ref.4], the nominal risk is 5 fatal cancers over a lifetime per 100 Person Sv dose [Ref. 5]. The ICRP nominal risk includes an assumption and correction factor. Since the dose is low (under about 100 mSv) and dose-rate of delivery is slow, a DDRF (dose, dose- rate reduction factor) of two has been incorporated into the estimate. This DDRF has no support from in vivo human scientific research, and will be discarded later, but for now, we will consider the spread of this risk among a normally distributed population by age in a typical North American community.

According to data from the Atomic Bomb Studies, radiation risk (i.e. the probability of contracting a fatal cancer due to the radiation over a life-time of 70 years) is distributed as follows by age at time of a homogeneously distributed exposure to 100 Person Sv dose of ionizing radiation:

0 to 10 years:	7.5
10 to 20 years:	7.2
20 to 30 years:	5.4

30 to 40 years:	3.1
40 to 50 years	3.3
50 to 60 years	3.5
60 to 70 years	3.0
70 to 80 years:	1.9
80+ years	0.9

The average nominal risk per 100 mSv, weighted for a stationary population having U.S. age structure and mortality rates is 4.4 or about 5. [Ref. 6]. Obviously, the major damage from this common dose will go disproportionately to those under 20 years of age. Youth are not only more vulnerable because of an underdeveloped immune system, but also because of their long expected life-span after exposure. We also know that for all age groups over 20 years, because of women's high risk breast and uterine tissue, the nominal risk over-estimates the risk for adult men and under-estimates the risk for adult women [Ref. 7].

Regulations based on the weighted average dose to the population, will systematically underestimate damage to children and women, and be "conservative" only for adult men. Clearly Canadian regulations do not protect the part of the population at highest risk, demonstrating that CNSC accepts ICRP recommendations without question!

In 2000, the Lawrence Livermore Nuclear Laboratory, U.S. Department of Energy, prepared a Health Consultation on "Tritium Releases and Potential Offsite Exposures" [Ref. 8] 11 March 2002. They recommend using a nominal risk coefficient for the adult population, 5 per 100 Person Sv, and a risk of 8 per 100 Person Sv for a child. This may afford a partial remedy.

Removing the DDRF, these nominal risks would increase to 10 per 100 Person Sv for adults and 16 per 100 Person Sv for children. See APPENDIX II for discussion of the DDRF.

PART III: RISKS OTHER THAN FATAL CANCER DUE TO TRITIUM EXPOSURE:

The embryos are even more susceptible to damage from tritium than are young children. Commerford et al. [Ref. 9] have stated that the cells most at risk from tritium would be those dividing at the time of exposure, and which afterwards have a long life-span. This is a good description of oocytes (precursor cells for the ovum), the embryo and nerve cells. Tritium easily crosses the placenta. The concern for spontaneous abortions, stillbirths, congenital malformations and diseases was raised by Dr. Edward Radford in 1978 testimony before the Select Committee on Hydro Matters, Provincial Government of Ontario, [Ref. 10]. His concerns have not yet been addressed by regulation or legislation.

ICRP recognizes as "detriments" only severe genetic effects in live-born offspring, and in many real cases such as miscarriage and still birth the offspring is not live-born, hence

not counted. Teratogenic effects, such as congenital malformations or diseases, are not, strictly speaking, genetic effects, so these also are not counted. Childhood asthma would not be considered by ICRP as a "severe" genetic effect, so it is not counted. These eliminations run counter to Canada's traditional support of the Rights of the Child!

T. Straume [Ref 11, 12] estimated that the teratogenic risks for tritium, ignored by ICRP, were six-fold higher than the risks of fatal cancers, i.e. about a risk of 30 per 100 Person Sv for the fetus, when the population risk of fatal cancer is assumed to be 5 per 100 Person Sv.

Since no comprehensive health assessment in Pembroke has ever been undertaken, it is difficult to document those health effects which have already occurred there. I strongly recommend that Health Canada begin to conduct higher level studies than those based merely on Statistic Canada's data. Information from a matched case-control study of a small community is much more exact than is geographical data based on Statistics Canada information, especially for small rural communities.

Basing risk on fatal cancers alone does not mean that other radiation related health effects will not occur. The non-fatal non-skin cancers associated with the fatal cancer risk are about half as large, and the non-fatal skin cancer risks are about equal. If one multiplies the fatal cancer risk by 2.5, the total cancer risk including non-fatal skin cancer, can be estimated as 12.5 per 100 Person Sv or 24 per 10 mSv when the DDRF is removed. Melanoma skin cancer is included in the fatal cancer risk. Severe genetic effects add another factor equal to one, making the total 13.5 per 100 Person Sv with the DDRF, and which could be doubled to 27 per 100 Person Sv if one rejects on scientific ground the DDRF used by ICRP. This is discussed in APPENDIX II. ICRP also assumes that the public is unconcerned about non-fatal cancers and reproductive problems. Most Canadians recognize that non-fatal cancers and loss of an offspring place an often unbearable burden of suffering on patients, families and our Health Care system.

In addition, with tritium exposure one can assume that people will suffer chronic illnesses due to nonfunctional enzymes, hormones and other proteins due to disruption by tritium atoms. Tritium spontaneously disintegrates into a helium atom, with a recoil excitation which disrupts the chemical bonds. These disruptions when reproduced cause chronic diseases such as allergies or hormonal dysfunction.

The risk of fatal cancers can be thought of as one of the most serious but also most rare health effects. Regulators must be aware of all of the effects, which will be serious for the victim and society. It is the role of the regulators to protect the public health, not to protect the right of corporations to pollute up to industry established non-health based levels. Industry based regulations have ordinarily proven too lenient! Tritium is not the exception!

Canadian experience strengthens the case that the health detriment of tritium has been underestimated, as demonstrated in the following studies:

- A study by McArthur noted a correlation between tritium releases from Pickering Nuclear Station (PNS) and a later increase in the number of fatal birth defects and neonatal deaths in the area around the plant between 1978 and 1985 [Ref. 13].
- Down's Syndrome was found to be increased by 80% in Pickering (observed 24; expected 12.9 cases) and by 46% at Ajak (observed 14, expected 9.6), a town further from the (PNS). This report by the AECB (Atomic Energy Control Board) also found an association between the high tritium releases from PNS and central nervous system anomalies in births at Pickering [Ref. 14].
- The IARC (International Agency for Research on Cancer) study of Nuclear Workers found that radiation related cancer rates of Canadian nuclear workers are higher than that of other nuclear workers receiving the same radiation dose. The study on which this was based, done by Lydia Zablotska, J.P. Ashmore and the Radiation Protection Bureau of Health Canada [Ref. 15] tested the results with and without tritium exposure (with ICRP calculations) and were unable to account for the difference. They failed to consider a significant under-estimation of the effects of tritium exposure as the possible cause. The IARC study was a summary of the experience of 400,000 workers at 531 nuclear reactors internationally.
- The AECB study of child leukemia deaths found the rate increased by a factor of 1.4 for locally born children after the Bruce Nuclear Reactor Station opened.[Ref. 16, 17]

It is my professional opinion that the SRBT proposal, far from restoring environmental healthfulness to Pembroke and the Ottawa Valley, will spread the tritium further and do nothing to help the Pembroke population which has suffered tritium pollution for fifteen years. The quality of life in the lush Ottawa Valley, source of food for farms, wild-life and people, will be seriously compromised, probably beyond full restoration by Nature.

Canadian citizens are capable of setting their own radiation protection standards based on their own high regard for health and the environment, independently of the recommendations of the ICRP.

Dilution has never been, and will never be the solution for pollution!

References:

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4. International Commission on Radiological Protection No 60, 1990.
5. Note: the Person Sievert dose is the number of persons exposed times the sum of the doses, in Sieverts, received by each person.
6. Based on U.S. National Academy of Science BEIR V 1990.

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