Tritium

Is the Current Ontario Drinking Water Standard for Tritium Acceptable?

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Ionizing Radiation

- Ionizing Radiation is known to be a complete carcinogen, one of few substances on Earth that can contribute to cancer in three ways:
  1. It can initiate cancer
  2. It can promote cancer
  3. It can accelerate many different cancers

Ionizing Radiation

- Dr. Rosalie Bertell:
  “Virtually every human tissue has been associated with radiation-induced cancer, but some appear to be more sensitive than others, including breast, thyroid, lung, colon, stomach, liver and skin.”

Tritium

- Tritium = H^3
- A form of hydrogen that emits beta radiation, it is a major radioactive pollutant from Canada's CANDU nuclear power reactors
- Unlike American reactors, the CANDU uses heavy water as a moderator and coolant. The moderator and heavy water coolant slows down the neutron release from the uranium fuel in the reactors, so that the chain reaction can take place

Tritium

- The active ingredient in heavy water is deuterium, another form of hydrogen. When the deuterium picks up a neutron, some of it is transformed into tritium
- As a reactor ages, the concentration of tritium increases

CANDU Reactor

- The CANDU reactor system produces 30 times as much tritium as the American light water reactor [1]
- It also normally releases over 20 times the amount of tritium to the environment (water and air) than a U.S. light water reactor. [1]
- This is a gigantic problem for Ontario Hydro, because tritium is extremely toxic. As little as one billionth of a gram can cause cancer if inhaled, ingested, or absorbed through the skin. One five-hundredth of a gram is fatal to an average person
- Ontario Hydro operates the Darlington tritium removal facility, there was a very lucrative market for it. It sells for $30 million per kilogram.
  (Source: Tritium Supply Considerations, February 2004)

1. UNSCEAR Sources and Effects of Ionizing Radiation. Report the the UN General Assembly, 1977

Human Health Effects

- Tritium:
  - Especially sensitive to the effects of tritium are rapidly growing cells such as foetal tissue and young girls' developing breasts, genetic materials and blood forming organs. Tritium can affect protein precursors that will make up the chromosomal strands in the DNA which can damage the DNA creating a mutational effect. The results of all these processes can result in cancers, miscarriages, birth defects, sterility, hypothyroid, etc., not only in those directly affected but also in their offspring and theirs.

Tritium Levels in Water

- 2-20 Bq/litre – In Durham Region
- A becquerel is the breakdown of one Tritium (H3O) molecule per second.
- The results of these tests are given in Becquerels per liter of water (Bq/l.). Thus 1 Bq/l. is the emission of 1 electron per liter of water per second.

The Petkau Effect

- Dr. Abram Petkau discovered that at 26 rads per minute (fast dose rate) it required a total dose of 3,500 rads to destroy a cell membrane. However, at 0.001 rad per minute (slow dose rate), it required only 0.7 rads to destroy the cell membrane. The mechanism at the slow dose rate is the production of free radicals of oxygen (O2 with a negative electrical charge) by the ionizing effect of the radiation.
- The sparsely distributed free radicals generated at the slow dose rate have a better probability of reaching and reacting with the cell wall than do the densely crowded free radicals produced by fast dose rates.
- This discovery was made by Dr. Abram Petkau at the Atomic Energy of Canada Ltd. Whiteshell Nuclear Research Establishment, in Manitoba, Canada in 1972!

BEIR 7 Report

The U.S. National Academies of Science 7th Biological Effects of Ionizing Radiation. 2005

- The International Agency for Research on Cancer 15 country study (includes Canada) “Cancer Risk Following Low Doses of Ionizing Radiation”
- This largest-ever study of nuclear industry workers concluded there is a 1-2% increase of deaths from cancer even at doses typically received by these workers. The study observed cancer rates were higher than ICRP standards would predict.

- Canada uses International Commission for Radiological Protection (ICRP) standards

BEIR 7 Report

The U.S. National Academies of Science 7th Biological Effects of Ionizing Radiation. 2005

- “There is no threshold or safe level of exposure to radiation.”
- The report also concluded that exposure to natural background radiation causes some cancers, and any additional exposure causes additional risks
- The BEIR 7 report also confirmed ionizing radiation causes other negative health effects, including heart disease and stroke

Recommendations

- Advisory Committee of Environmental Standards (ACES) 1994 to reduced Tritium in water from 7,000 Bq/L to 100 Bq/L then to 20 Bq/L within 5 years
- 1995 Report “Recommendations for the Primary Prevention of Cancer,” commissioned by Bob Rae’s NDP Government, recommended that the same methodology for chemical contaminants be applied to radioactive substances

Risk

- CNSC is still the “special regulator” for radioactive substances
- Ontario – and Canada as a whole – also have lax regulatory limits for radioactive materials compared to the more stringent standards imposed on carcinogenic chemicals. The chemical standards define an “acceptable risk” as one additional cancer for every million population

Risk

- “The acceptable risk” for tritium at 7,000 Bq/L is far higher at 340 excess fatal cancers per million people exposed or just under 1 in 3,000. Although the CNSC would never express the risk this way.

Dose coefficients, Individual and Collective for Acute HTO Intake (ICRP HTO model)

Adult male
Carbon $T_{1/2}$ of 40 d
1.8 x 10^{-11} Sv/Bq

Adult population
2.0 x 10^{-11} Sv/Bq

Adult female
Carbon $T_{1/2}$ of 51 d
2.2 x 10^{-11} Sv/Bq
(25% more than ICRP)

• For all radionuclide intakes female dose coefficients 21% higher than males due to 1 Bq being more concentrated in female's smaller mass

RB Richardson, DW Dunford & S-R Peterson, health Physics 81 302-312 (2001)

Dose coefficients, Individual and Collective for Unspecified organic (^3H) compounds (ICRP OBT model)

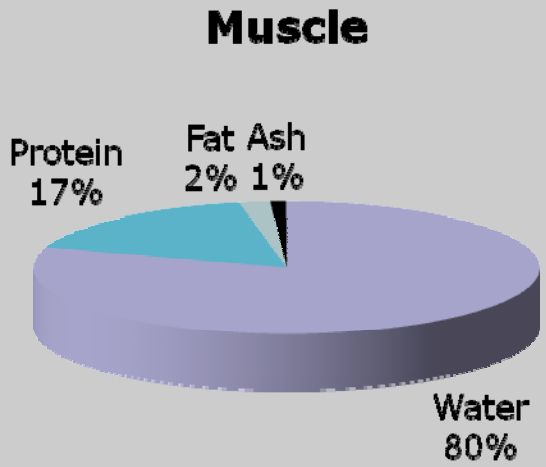
Adult male
Carbon $T_{1/2}$ of 40 d
4.2×10^{-11} Sv/Bq

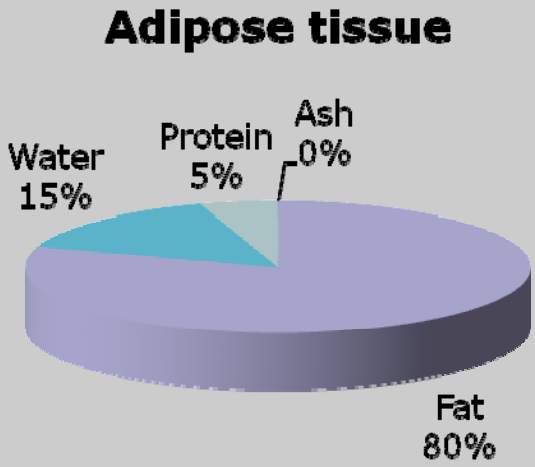
Adult population
5.2×10^{-11} Sv/Bq

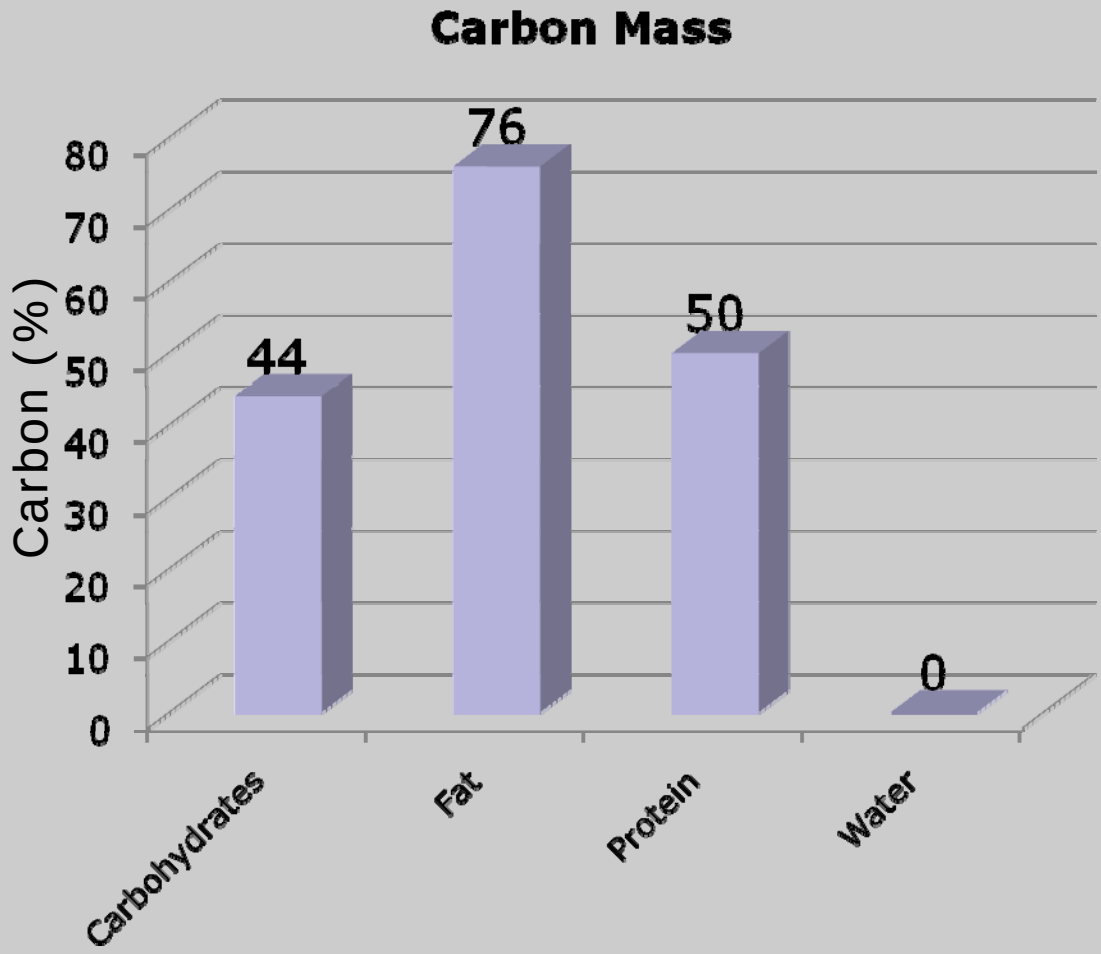
Adult female
Carbon $T_{1/2}$ of 51 d
6.2×10^{-11} Sv/Bq
(46% more than ICRP)

RB Richardson, DW Dunford & S-R Peterson, health Physics 81 302-312 (2001)

Carbon Content of Adipose Tissue and Muscle







Half-Time Retention of Carbon

Intake:
228 gC/day

Whole body pool:
29% Fat, 16.8 kgC

Intake:
303 gC/day

Whole body pool:
18% Fat, 16.8 kgC

$T_{1/2}$ = ln2 x 16.8 / 0.228 = **51 days**

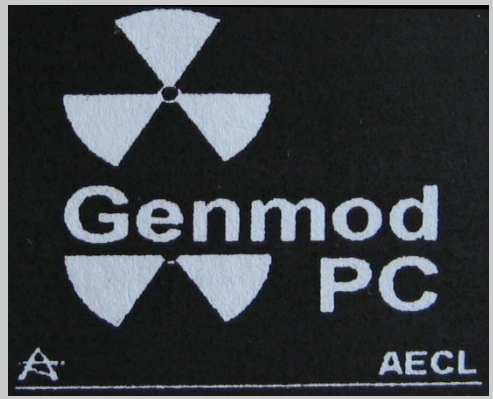
$T_{½}$ = ln2 x 16.8 / 0.303 = **38 days**

Reference man & woman's BMI ~ 23. Canadian patients, mean age 52y old. Average BMI is 29 (Balkau *et al*, 2007); therefore carbon $T_{1/2}$ are longer.

RB Richardson, DW Dunford & S-R Peterson, health Physics 81 302-312 (2001)

GenmodPC for Windows

RB Richardson, DW Dunford, SH Linauskas



- Dosimetric models (52 organs & tissues) based on current ICRP recommendations.
- 50 Elemental models (109 radionuclides), including C, **H**, Pb, Po, Pu, Ra & U.
- Custom-made models, e.g. HCNO (**H**ydrogen**C**…) for CNSC/COG.
- Adult male inhales/ingests/injects radionuclide.
- ICRP 66 Respiratory Tract model, GI Tract model.
- Estimates intake (Bq) from urine, feces, lung burdens…

Summary

- ICRP $^{3}H/^{14}C$ compound models have physiologically inconsistent features – most models not suitable for bioassay.
- HTO and OBT physiological HCNO model dose coefficients are ~ 20% or so greater than ICRP values.
- Adult female HTO and OBT dose coefficients are ~25% and 50% higher than those for males.
- There is a paucity of RBE studies for OBT.