The Tritium Tempest in a Teapot

Problem Summary

The trouble with tritium is there *is* no trouble with tritium.

James Conca

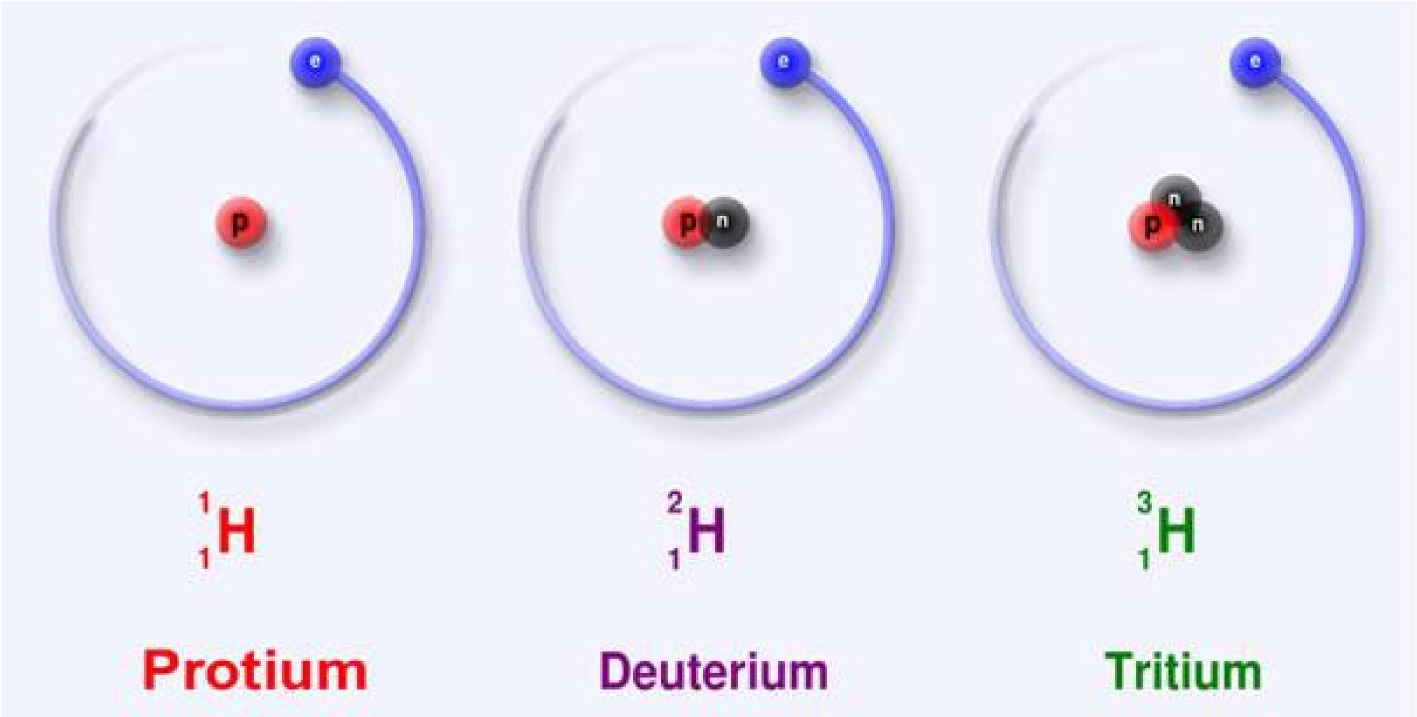
Fukushima Tritiated Water Tanks

Fukushima Tritiated Water Controversy

The Real Problem: There are many people who are very angry with the decision to dump tritiated water from the Fukushima accident into the Pacific Ocean.

- There are those who know it's not a genuine health concern, but spread false information to advance an anti-nuclear agenda.
- There are many more who uncritically repeat the disinformation.
- There are the masses who become frightened because they willingly believe what they are told.

Isotopes of Hydrogen



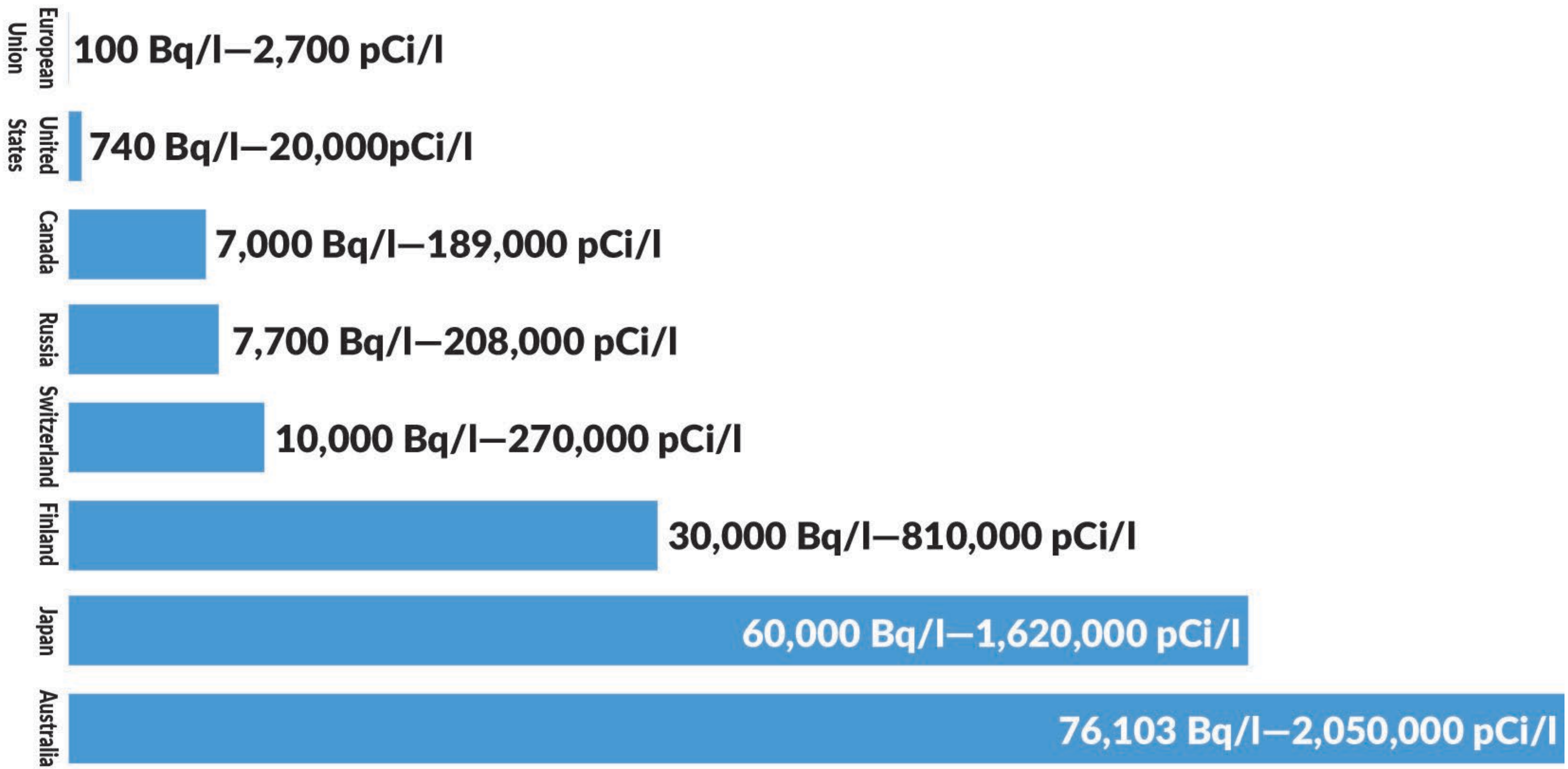
Tritium Production

- Levels of tritium generated in normal industrial processes are harmless
- More tritium created continuously in Earth's upper atmosphere from neutron activation of nitrogen (N-14 + neutron → C-12 + H-3) than produced by commercial nuclear reactors
- Reactor-generated tritium reacts with oxygen in reactor cooling water to produce HTO (tritiated water)

Natural Tritium in Environment

- Natural tritium (H-3) in waters of the Earth present at concentrations that range from 0.185 to 0.925 Becquerel per liter (Bq/L) of water.[1]
- Tritium so harmless that maximum regulatory limits in drinking water range from low of 100 Bq/L (European Union) to high of 76,000 Bq/L (Australia)[2]

Tritium in Drinking Water Regulatory Limits



Tritium Biological Facts

- Tritium has weakest radioactivity of any radionuclide, with beta particle energy of 18.6 keV
- Low-energy beta particle has extremely limited range in biological material (< 10 µm), depositing energy primarily through inelastic collisions with atomic electrons of cellular matter[1]

Tritium Biological Facts (cont.)

- While tritium radiological half-life is 12.3 years, biological half-life only about 10 days
  - Thermodynamically prefers to exist as water (HTO)[1]
  - Roughly 60% of body weight is water; 5 tritium atoms per 10^{18} hydrogen atoms[2] → ≈ 1.7×10^{-14} gram tritium in human body
  - No observed tritium concentration in biological material
  - 55% excreted in urine, 29% through skin, 12% in exhaled air
  - Tritium radioactivity in human body about 59 Becquerels per liter,[2] well below EU regulatory limit for drinking water

Biological Tritium in Perspective

To put tritium “concern” in proper perspective, consider two radionuclides that present internal radiation exposures that aren’t health concerns – carbon-14 (C-14) and potassium-40 (K-40)

- Like tritium, C-14 and K-40 radioactively decay by beta particle emission (K-40 also emits gamma-ray)
- C-14 plentiful in human body because we are carbon-based life forms
- K-40 found everywhere in human environment

Biological Tritium in Perspective (cont.)

- Carbon-14 emits beta particle with energy of 157 keV (greater than 8 times energy of tritium beta)
- Carbon ≈ 23% of body weight; one carbon-14 atom for every trillion carbon atoms[1] → ≈ 1.6×10^{-8} gram carbon-14 in human body (one million times mass of tritium)
- Beta particle range in biological material about 300 µm[(2)] (greater than 30 times range of tritium beta)
- Biological half-life is 40 days, with primary excretion pathways being feces and exhalation
- Carbon-14 presents no biological hazard to humans

Biological Tritium in Perspective (cont.)

- Potassium-40 emits beta particle with energy of 1330 keV (greater than 70 times energy of tritium beta) as well as 1461 keV gamma-ray
- Potassium-40 most common radioisotope in human body
- Potassium ≈ 0.18% of body weight;[1] potassium-40 ≈ 0.0117% of potassium[2] → ≈ 0.015 gram potassium-40 in human body (one trillion times mass of tritium)
- Average biological half-life is ≈ 16 days,[3] excreted from human body primarily through urine
- Potassium-40 contained in food we eat and presents no biological hazard to humans

Natural Radioactivity in Food

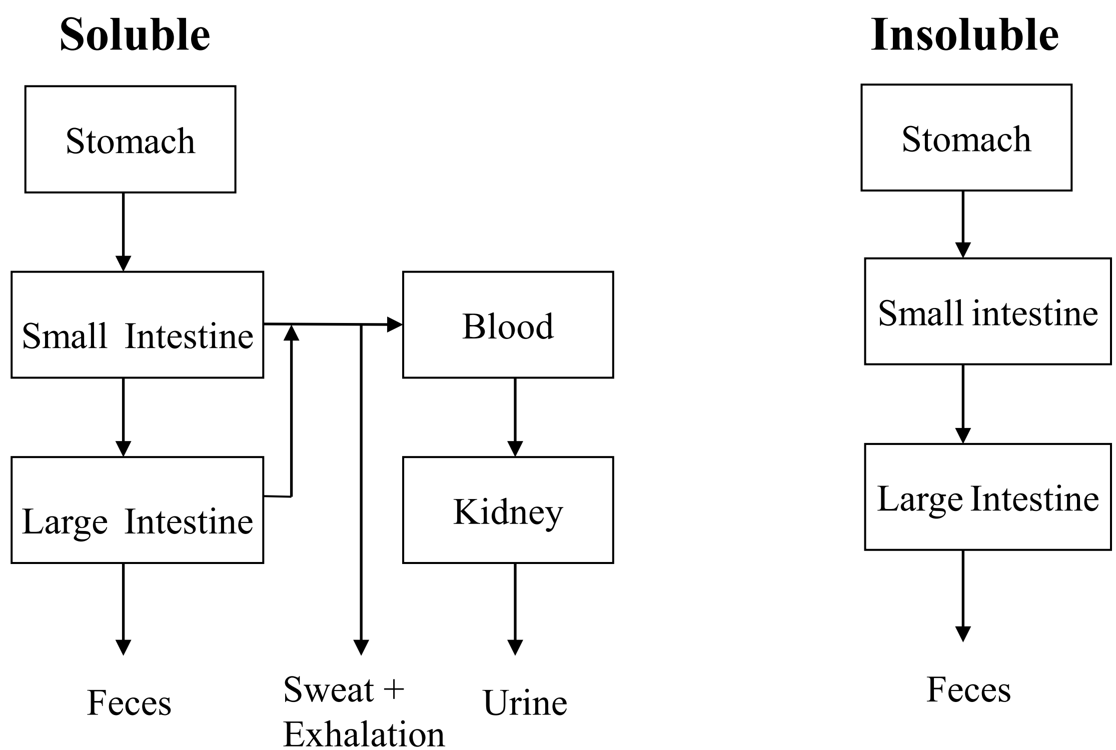
Food	^{40}K (β,γ) pCi/kg	^{226}Ra (α) pCi/kg
Brazil Nuts	5600	1000-7000
Lima Bean	4640	2-5
Banana	3520	1
White Potato	3400	1-2.5
Carrot	3400	0.6-2
Red Meat	3000	0.5
Low-sodium Salt	3000	---
Beer	390	---
Drinking Water	---	0-0.17

GI Absorption of Radionuclides

Isotope	Radiation	Half-life	GI Absorption
Hydrogen-3 (Tritium)	β	12.3 years	100%*
Carbon-14	β	5730 years	> 90%[1]
Potassium-40	β,γ	1.26×10^9 years	90%[2]
Strontium-89	β	50.5 days	30%
Strontium-90/Yttrium-90	β	28.8 years	30%
Iodine-131	β,γ	8 days	100%
Cesium-137	β,γ	30 years	100%

* Tritiated water can also be absorbed through the skin

Biological Radionuclide Excretion Pathways



Radioactive Elements in Human Body

Radioactive Isotope	Half Life (years)	Isotope Mass in the Body (grams)	Element Mass in the Body (grams)	Activity within the Body (Disintegrations/sec)
Potassium-40	1.26×10^{9}	0.0165	140	4,340
Carbon-14	5,730	1.6×10^{-8}	16,000	3,080
Rubidium-87	4.9×10^{10}	0.19	0.7	600
Lead-210	22.3	5.4×10^{-10}	0.12	15
Tritium (H-3)	12.43	2×10^{-14}	7,000	7
Uranium-238	4.46×10^{9}	1×10^{-4}	1×10^{-4}	3 - 5
Radium-228	5.76	4.6×10^{-14}	3.6×10^{-11}	5
Radium-226	1,620	3.6×10^{-11}	3.6×10^{-11}	3

Source: http://www.rerowland.com/BodyActivity.htm

Tritium Releases to Environment

- Routine authorized releases of tritiated water from U.S. nuclear power plants closely monitored by nuclear utilities and reported to Nuclear Regulatory Commission (release information available on NRC website)
- Abnormal releases from nuclear power plants always evaluated by NRC
  - Offsite releases never found to be high enough to adversely affect public health and safety

Tritium Releases to Environment (cont.)

- Millions of gallons of slightly tritiated water released to oceans, large lakes, and large rivers from world's commercial nuclear power plants every year
  - Has been occurring for decades in accordance with globally accepted nuclear safety standards
  - No observed adverse effects on environment or humans

Annual Discharge of Tritium from Nuclear Facilities							
Location	Nuclear Facility	Closest waters	Liquid (TBq)	Steam (TBq)	Total (TBq)	Total (mg)	Year
United Kingdom	Heysham nuclear power station B	Irish Sea	396	2.1	398	1,115	2019
United Kingdom	Sellafield reprocessing facility	Irish Sea	423	56	479	1,342	2019
Romania	Cernavodă Nuclear Power Plant Unit 1	Black Sea	140	152	292	872	2018
France	La Hague reprocessing plant	English Channel	11,400	60	11,460	32,100	2018
South Korea	Wolseong Nuclear Power Plant and others	Sea of Japan	211	154	365	1,022	2020
Taiwan	Maanshan Nuclear Power Plant	Luzon Strait	35	9.4	44	123	2015
China	Fuqing Nuclear Power Plant	Taiwan Strait	52	0.8	52	146	2020
China	Sanmen Nuclear Power Station	East China Sea	20	0.4	20	56	2020
Canada	Bruce Nuclear Generating Station A, B	Great Lakes	756	994	1,750	4,901	2018
Canada	Darlington Nuclear Generating Station	Great Lakes	220	210	430	1,204	2018
Canada	Pickering Nuclear Generating Station Units 1-4	Great Lakes	140	300	440	1,232	2015
United States	Diablo Canyon Power Plant Units1, 2	Pacific Ocean	82	2.7	84	235	2019

Tritium Releases to Environment (cont.)

- Fukushima Tritiated Water Task Force 2016 Report identified 760 TBq of tritium (≈ 2.1 grams or 14 mL of HTO) contained in 860,000 m^3 of onsite stored water
- Tritiated water to be diluted with seawater to 1500 Bq/L before ocean discharge via 1 km long undersea tunnel[1,2]
  - —One-fortieth concentration allowed by Japanese drinking water safety standards
  - —One-seventh WHO guideline for drinking water
- Final tritium concentration about 2.3×10^{-6} Bq/L following 10-year discharge to North Pacific Ocean[3] – absolutely no health concern to aquatic life or humans

The Burning Question

- Whereas both carbon-14 and potassium-40 body burdens are much greater than the tritium body burden,
- Whereas both carbon-14 and potassium-40 emit higher energy beta particles than tritium (potassium-40 also emits high energy gamma-ray),
- Whereas we don’t worry about radiological health effects from carbon-14 or potassium-40,
- Why do we get all bent out of shape over discharging tritium below drinking water standards to the ocean?

The Sad Answer

As with other nuclear issues, tritium is a political problem, not a real problem.