Human Health and the Biological Effects of Low Dose Tritium in Drinking Water

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BELLE - April 26, 2011

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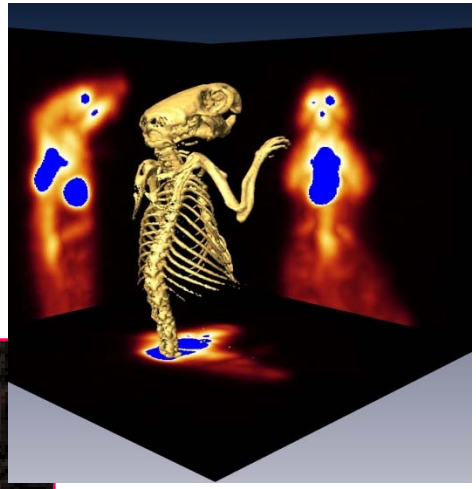
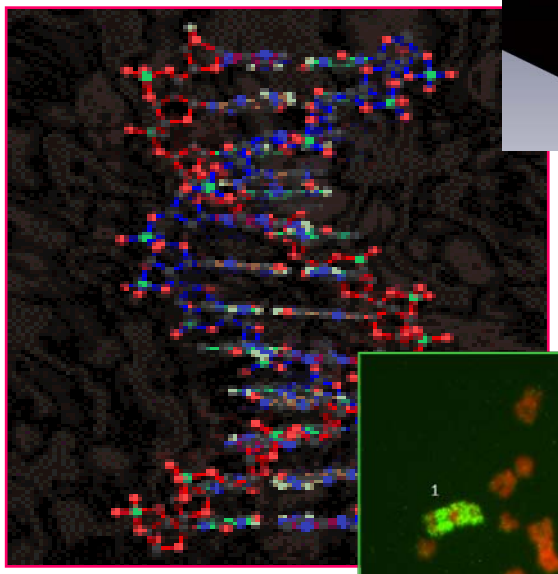
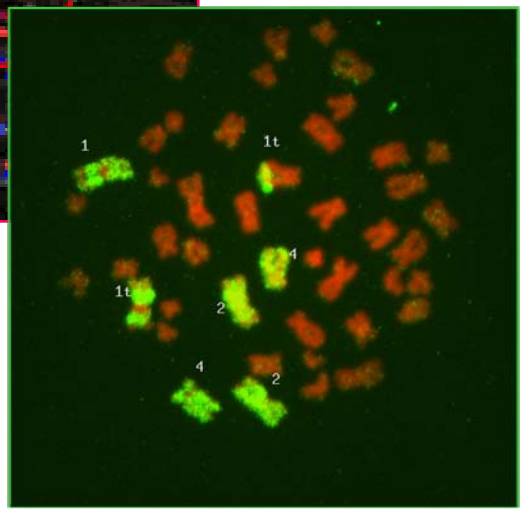
McMaster Focus of Research



Understanding Risk Mechanisms



Relative Risk - Genetics vs Environment



Biological Dosimetry Detecting Risk

Bruce A

Ontario + 50% Nuclear
(BP 20%)
8 CANDU Reactors (2 Refurbs)
4000 Employees

Bruce B

Bruce Power™

WELCOME

Human Health and the Biological Effects of Tritium in Drinking Water

Prudent Policy through Science – Addressing the ODWAC New Recommendation
August 26 and 27, 2010

Co-Chairs: Dr. Douglas R. Boreham, Ph.D. and *Dr. William Morgan, Ph.D., D.Sc.*

Outline

- Why does the Ontario government believe a new recommendation is required for tritium?
- What is tritium and how does it affect humans?
- Who will the new recommendation protect?
- How much will it cost?
- What do the experts say?
- What where the conclusions of the symposium?

History

On February 21, 2007, the Minister of the Environment requested that Ontario Drinking Water Advisory Council (ODWAC) review and provide advice on the current Ontario Drinking Water Quality Standard for Tritium of 7,000 becquerels per Litre (Bq/L), in response to a request from the City of Toronto's Medical Officer of Health.

History

ODWAC was also requested at that time to take into consideration the 1994 report entitled “A Standard for Tritium” prepared by the former Ontario Advisory Committee on Environmental Standards (ACES), which recommended a Standard of 100 Bq/L, to be further reduced to 20 Bq/L after 5 years.

History

Subsequent to this request, on June 12, 2007, the Minister of the Environment also asked that the Council take into account a report entitled "Tritium Hazard Report: Pollution and Radiation Risks from Canadian Nuclear Facilities" released by Greenpeace Canada, and authored by Dr. Ian Fairlie of the UK.

Report and Advice on the Ontario Drinking Water Quality Standard for Tritium

Prepared for the Honourable John Gerretsen
Ontario Minister of the Environment

By the Ontario Drinking Water Advisory Council

May 21, 2009

ODWAC
Ontario Drinking Water Advisory Council

The Ontario Drinking Water Advisory Council, known formally as the Advisory Council on Drinking Water Quality and Testing Standards, is an Agency of the Government of Ontario

Ontario
Advisory Council on Drinking Water Quality and Testing Standards
Le Conseil consultatif sur les normes de qualité et d'analyse de l'eau potable

www.odwac.gov.on.ca

ODWAC
Ontario Drinking Water Advisory Council

Recommendation

1) 20 Bq/L relates to health effects from long term, chronic exposure over a life time of exposure of 70 years;

What does 20 Bq/L (Dose) mean?

7000 Bq/L (7000 decays per second/L) x 2L x 365 days = 0.1 mSv/year

20 Bq/L x 2L x 365 days = 0.0003 mSv/year

70 years = 0.02 mSv total dose

ODWAC
Ontario Drinking Water Advisory Council

Recommendations

2) 20 Bq/L is within the range of variations considered by the council (7 Bq/L to 109 Bq/L), for a 10^{-6} risk level;

What are the assumptions?

- Based on Linear No Threshold Assumption
- Dose is Additive
- Risk is Additive
- Risk is fixed and can not be modified
- Individuals are the same wrt to risk

ODWAC Recommendations

3) 20 Bq/L, based on a running annual average, is achievable in drinking water, without significant cost to the nuclear power industry, according to the Canadian Nuclear Association.

What is the cost?

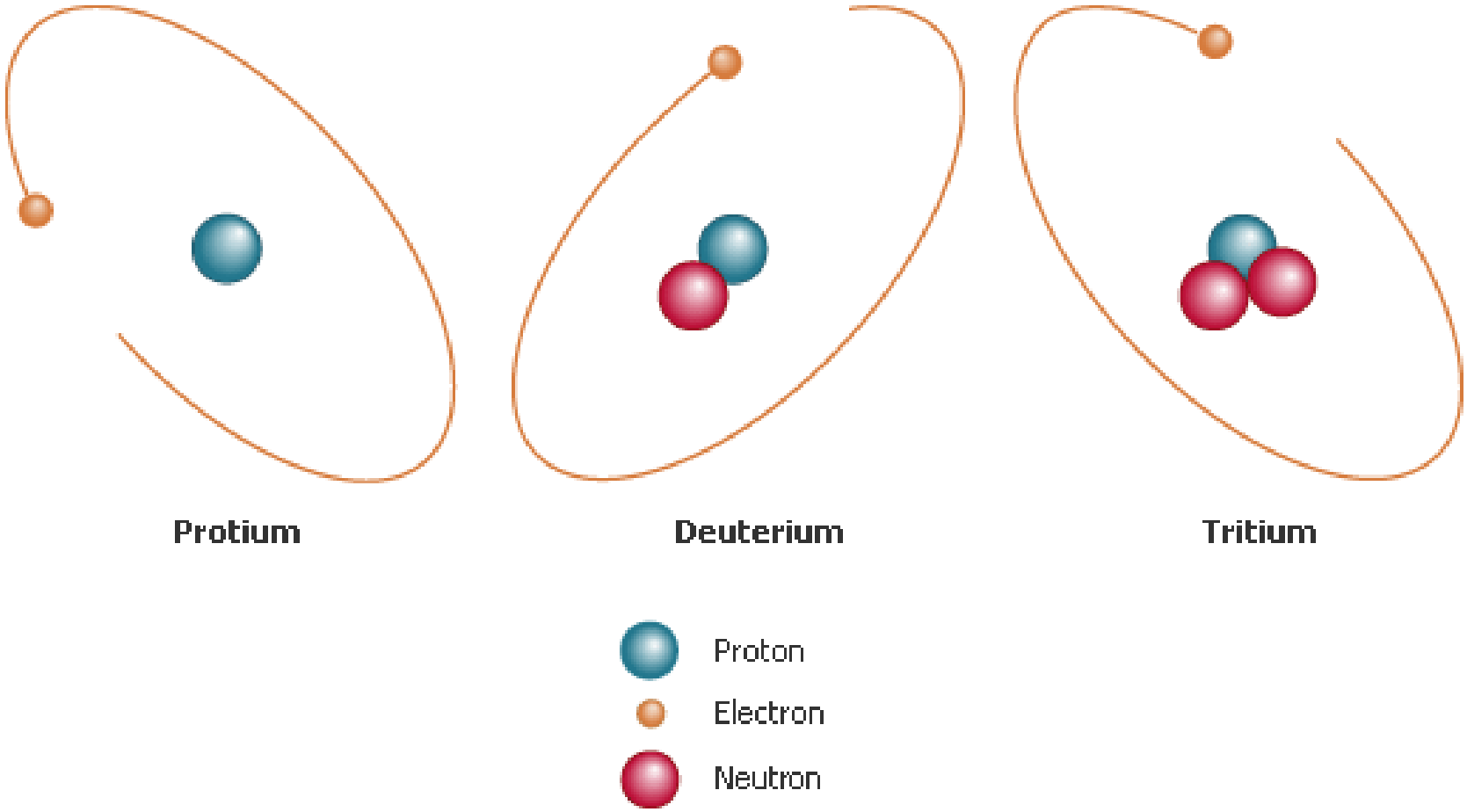
What is the cost to industry?
What is the cost to the public (consumer)?
What is the benefit for the cost?

What the is Tritium and where does it come from?

Natural Tritium

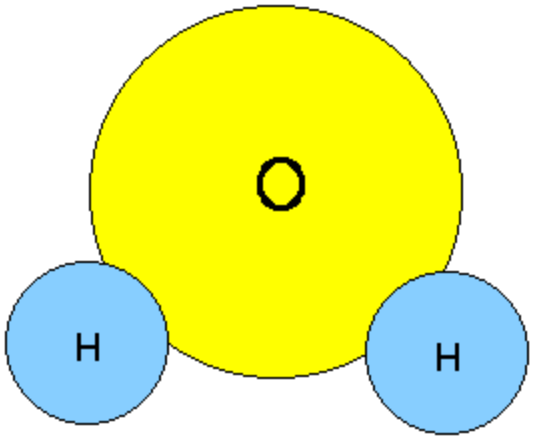
Manmade Tritium
- Bombs
- Fission

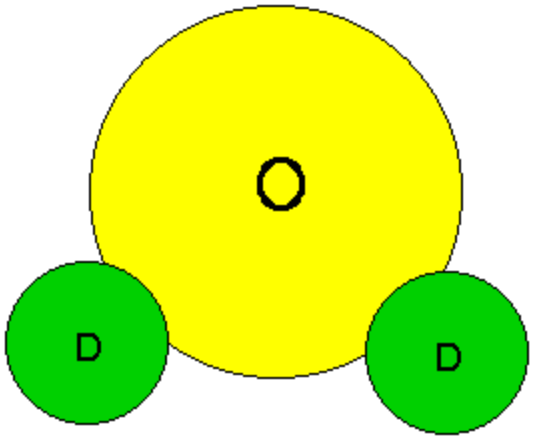
Tritium

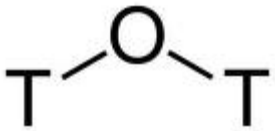


Tritium is also made by Cosmic Radiation (5 Bq/L).

0.015% of hydrogen atoms are deuterium





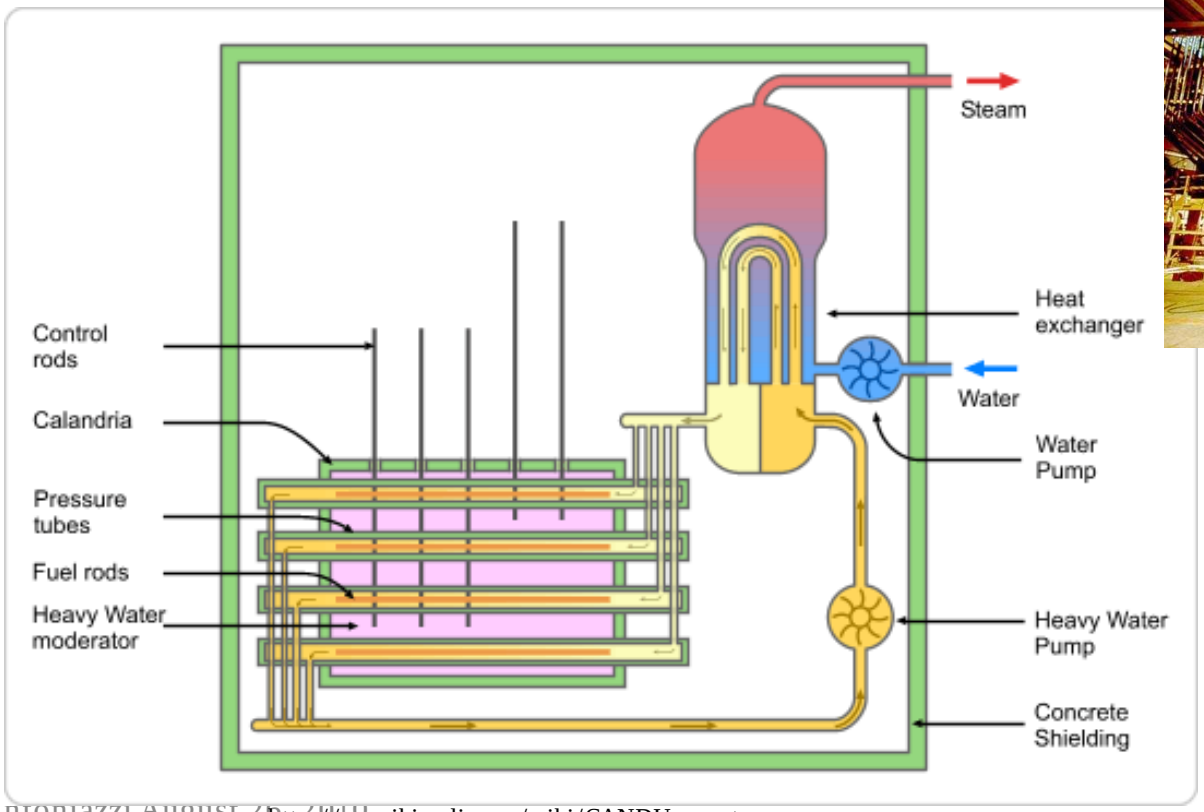


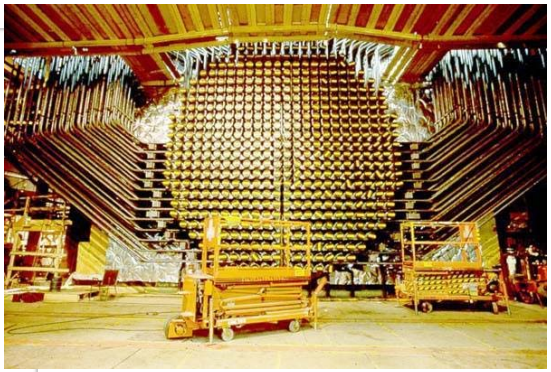
Tritiated Water


DOUG
BOREHAM
Environment
EP 41474
EP 41244
EP 41037

Basic CANDU Operation

- CANDU's (CANadian Deuterium Uranium) reactors use heavy water in the primary heat transport system (the coolant) and as a moderator of the nuclear reaction





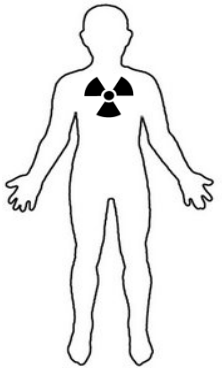
http://en.wikipedia.org/wiki/CANDU_reactor

What is Bq/L and Dose

70,000 Bq/L = 1.0 mSv per year = 1 mammogram

7000 Bq/L = 0.1 mSv per year = Standard X-ray

70 Bq/L = 0.001 mSv = Human (7000 Bq)



20 Bq/L = 0.0003 mSv = 3 minutes flying

Ramsar Iran: 200-700 mSv/yr

The latest exclusion zone in Japan 20 mSv/year

Geographic location	Annual dose (mSv)
Guarapari Beach, Brazil	Up to 790
Ramsar, Iran	Up to 700
SW France	Up to 88
Kerala Beach, India	Up to 35
Ataxa Beach	Up to 25
Sweden	Up to 18
U.S. Rocky Mountain States	6–12
Evacuated Land near Chernobyl	6
World Average	2.4
U.S. Gulf States	0.8–1.2

What is Bq/L (beta Emitters)

Water

Tritium – Naturally 1-7 Bq/L

Banana Smoothie

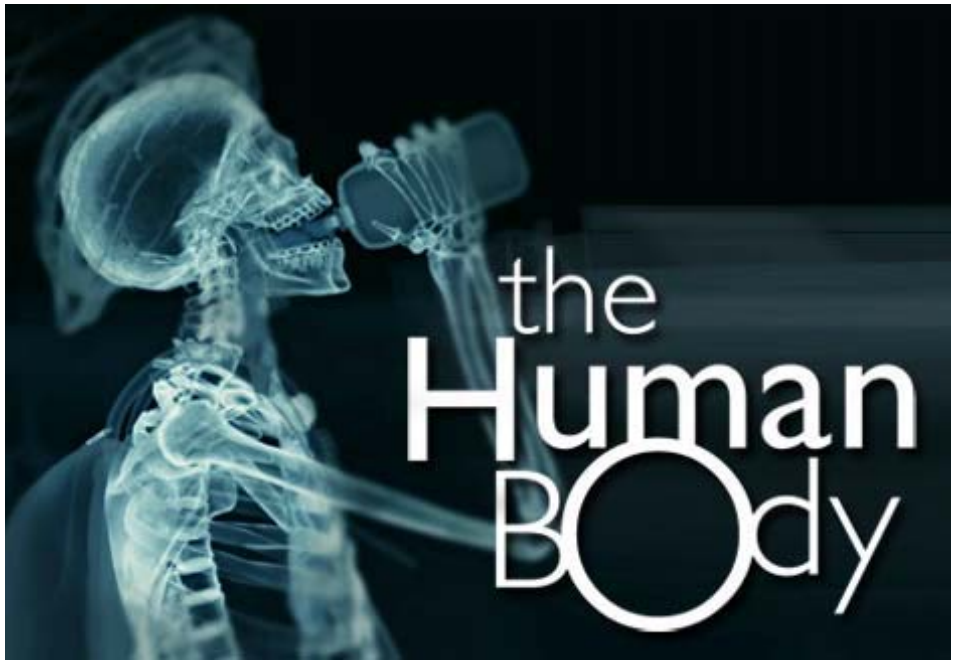
Potassium – 40 100-150 Bq/L

Veggie Shake

Carbon – 14 200-300 Bq/L

Natural Radioactivity in Your Body

- **Uranium**
- **Thorium**
- **Potassium-40**
- **Radium**
- **Carbon-14**
- **Tritium**
- **Polonium**



Uranium alpha particles 45,000 decays/day
Potassium-40 beta particles 300 million decays/day
Carbon-14 beta particles 150 million decays/day

Bq is a decay per second

Fukushima 0.5 -1 Bq I-131

Potassium Iodide (KI)

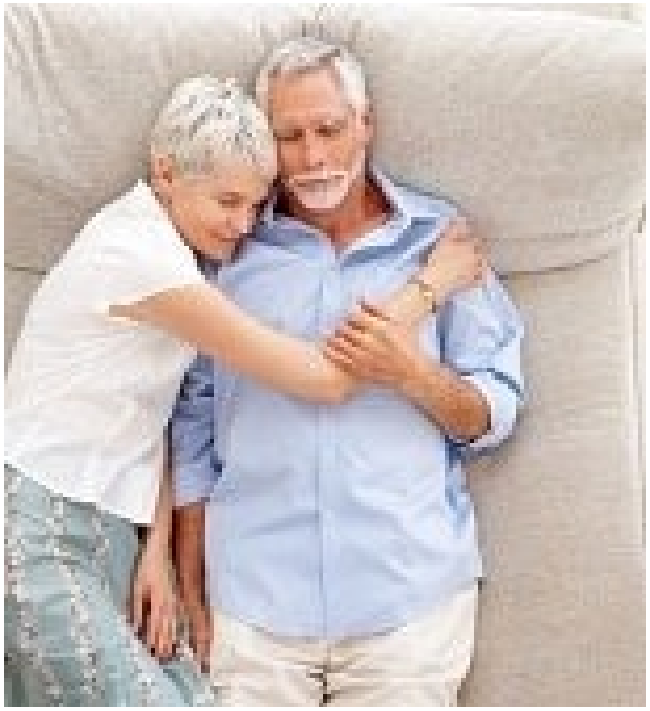
130 mg (250 mg is a therapeutic dose)

Iodine Possible Teratogen

10 Bq Potassium-40 to protect against 0.5 -1 Bq I-131

Sleeping next to someone most nights of a year results in a radiation dose about the same as drinking 20 Bq/L tritium after 70 years.

0.02 mSv/a



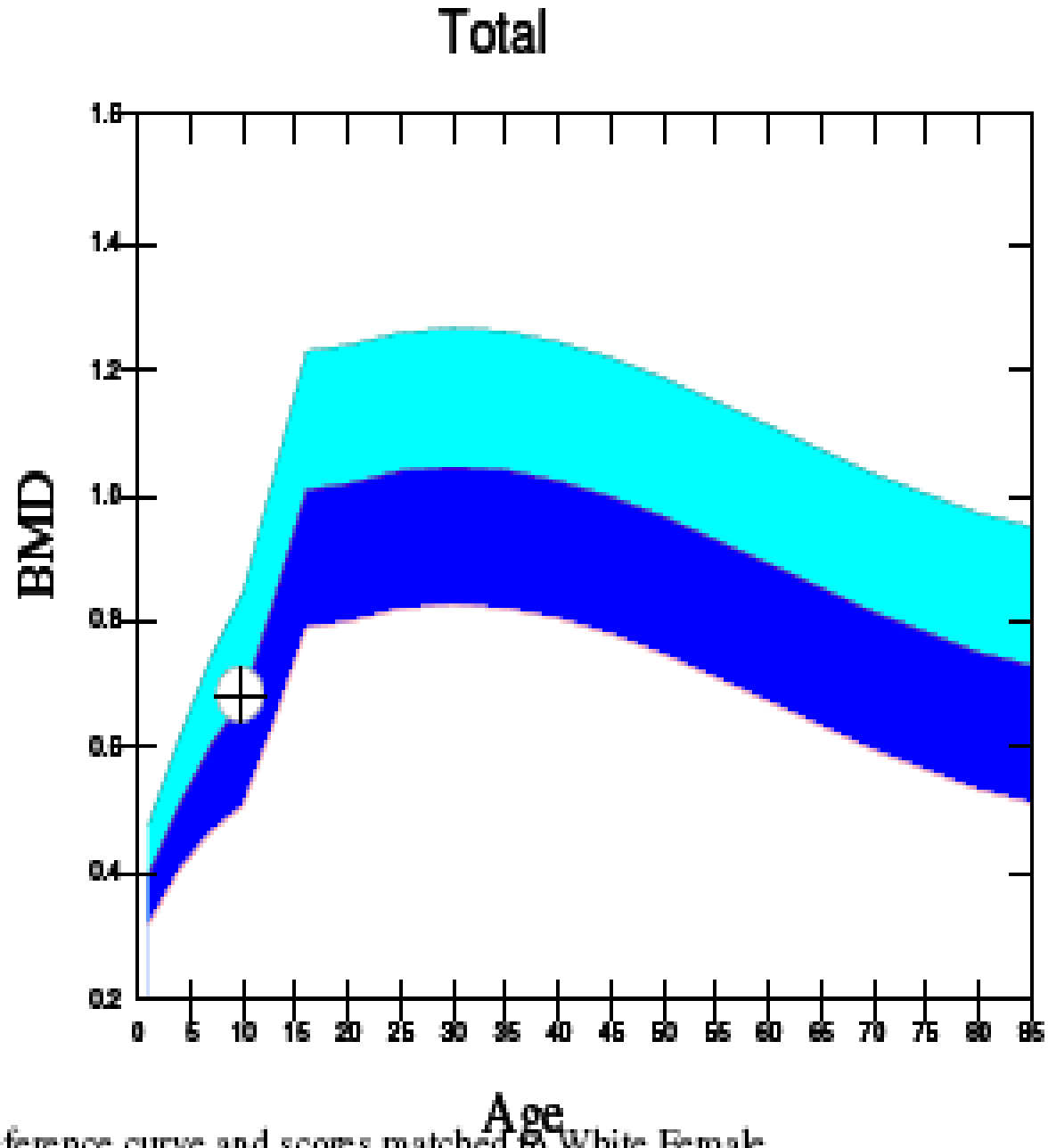
Potassium-40

Tritium (T-3)

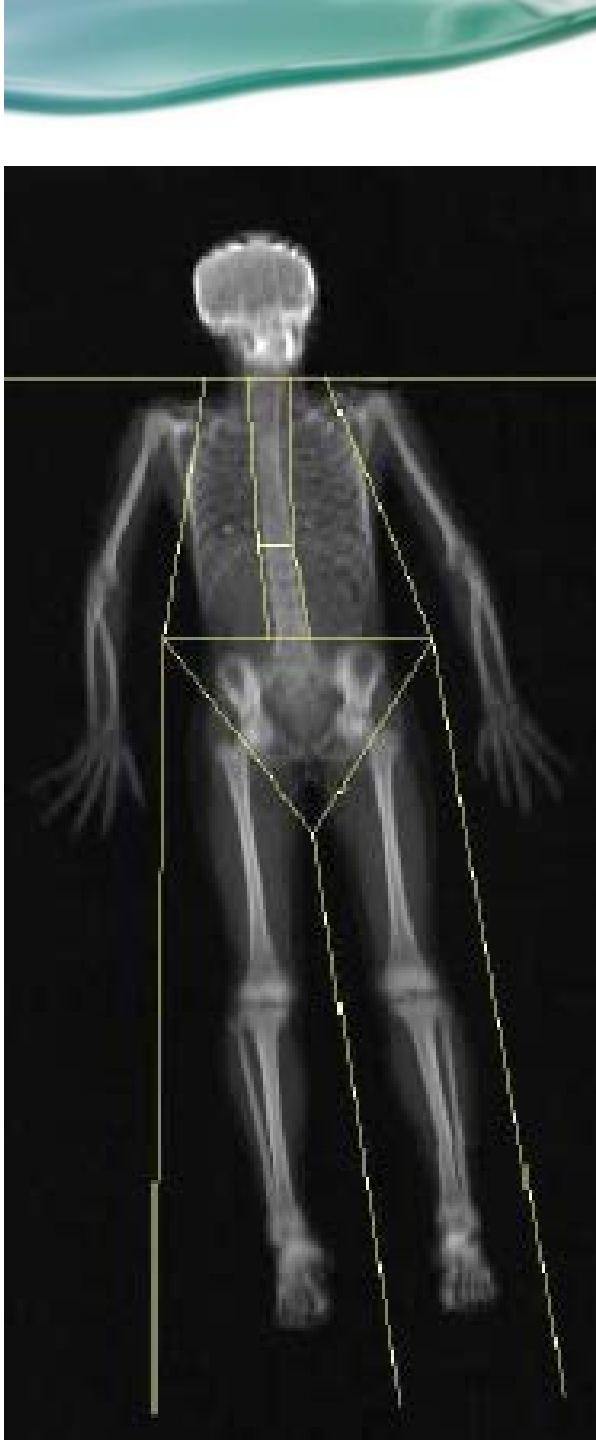
20 Bq/L x 2 L/day x 365 days

1 in a million cancer risk?

Dual X-Ray Absorption
February 6, 2008

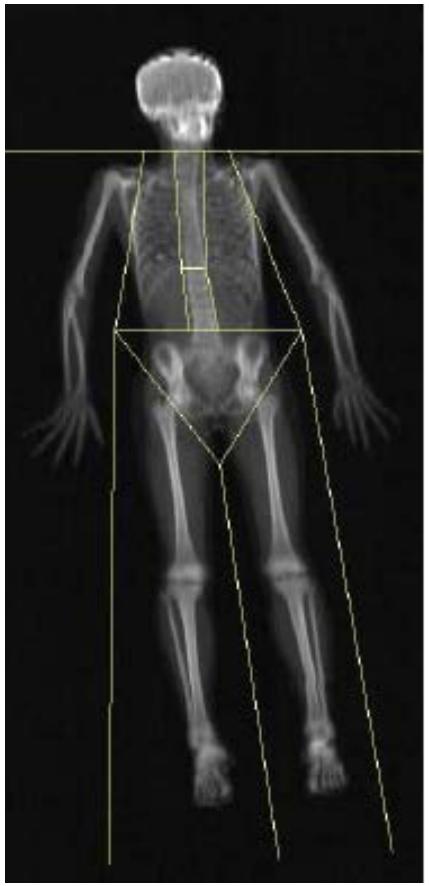


Reference curve and scores matched to White Female



Comparing Dose (Risk?)

Bone Density X-ray



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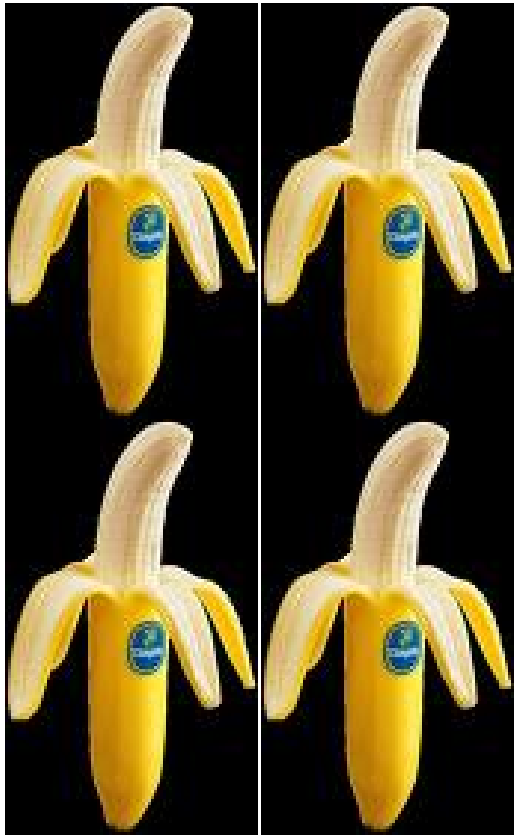
Potassium-40

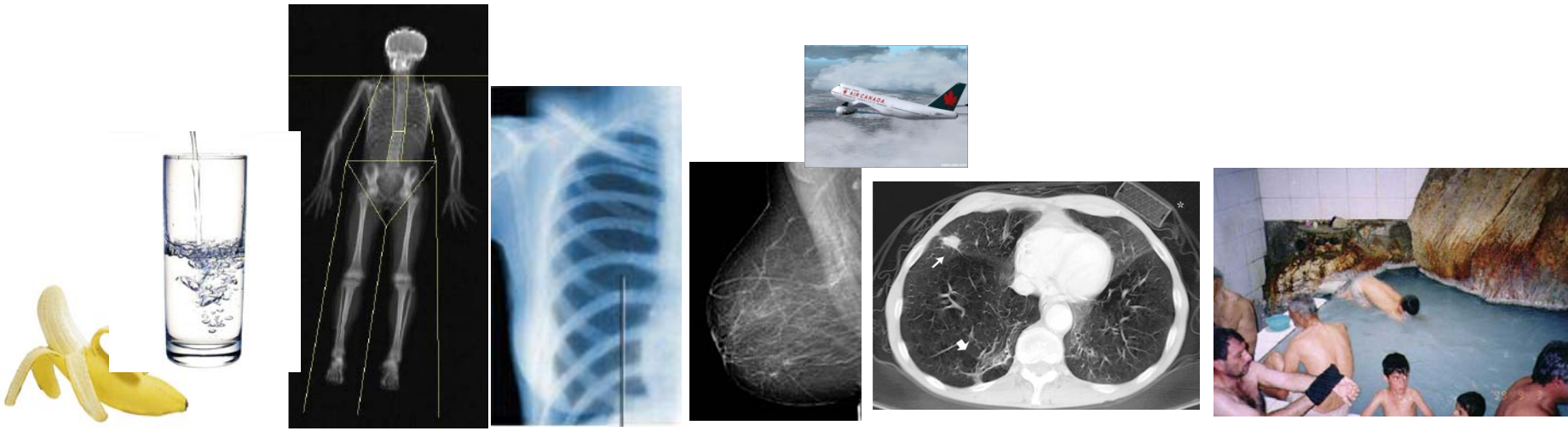


0.0004 mSv

6 feet in elevation per year = 20 Bq/year

A change in six feet of elevation increases my child's risk of getting cancer by 1 in a million over 70 years?

Tony Brooks

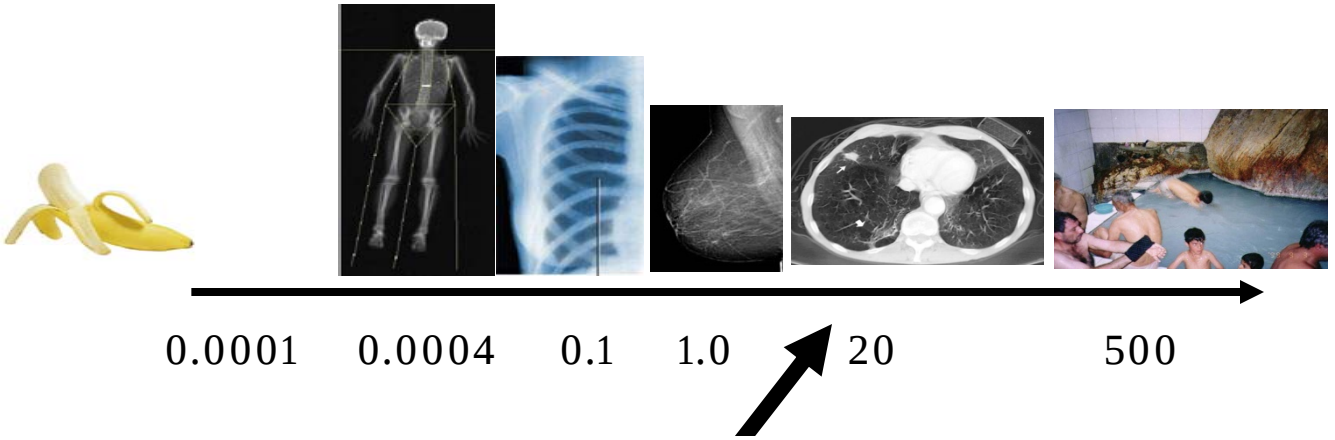


0.0001 0.0004 0.1 1.0 10 500

Dose (mSv/yr)

20 Bq/L (2L/day x 365 days = 0.0003 mSv)

Dose (mSv/yr)



CT Scans May Reduce Rather than Increase the Risk of Cancer

Bobby R. Scott, Ph.D.
Charles L. Sanders, Ph.D.
Ron E. J. Mitchel, Ph.D.
Douglas R. Boreham, Ph.D.

ABSTRACT

Extrapolating from data on atomic bomb survivors on the basis of the linear no-threshold (LNT) model as applied to radiation exposure, a recent paper concludes that within a few decades 1.5–2 percent of all cancers in the U.S. population could be caused by current rates of use of computed tomography (CT). This paper ignores the other war-related exposures of the Japanese population, which would be expected to shift the dose-response relationship for cancer induction to the left. Moreover, the LNT model is shown to fail in four tests involving low-dose radiation exposures. Considering the available information, we conclude

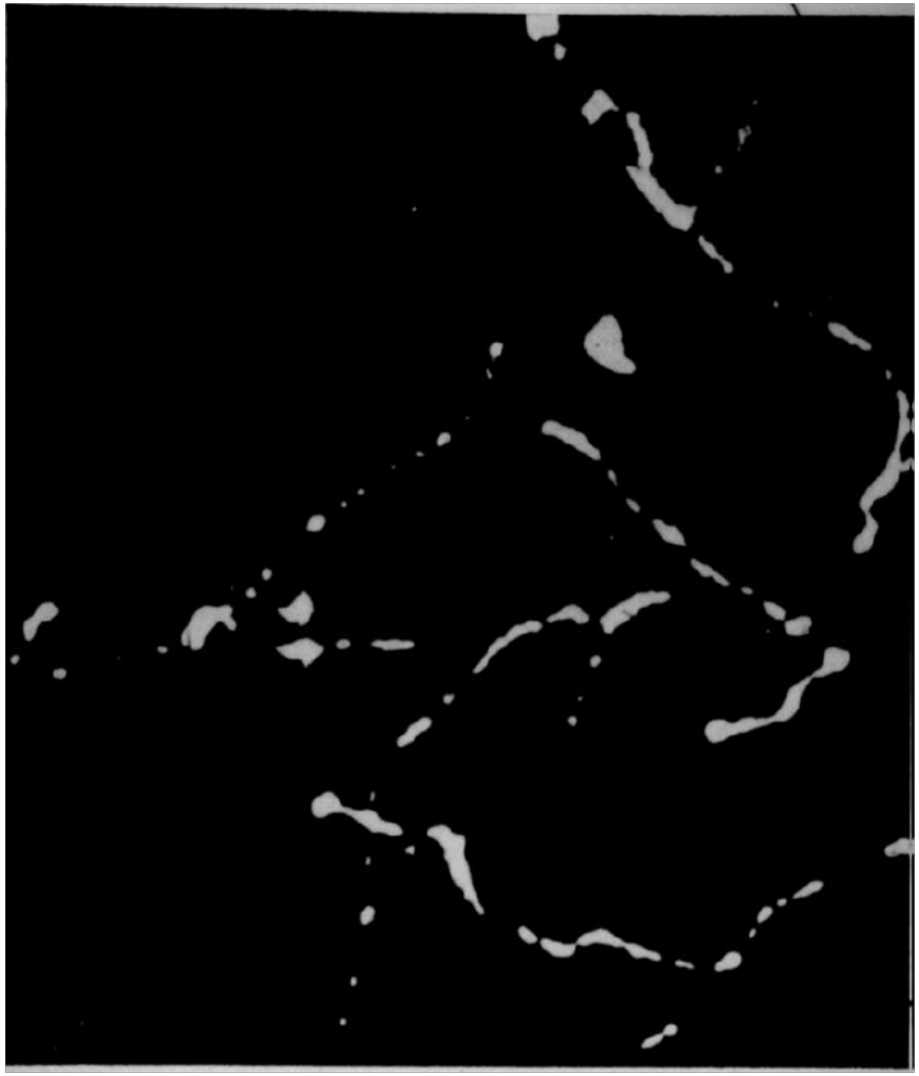
defenses. This effect has been called radiation activated natural protection (ANP).[2] Radiation ANP includes selective removal of aberrant cells (e.g., precancerous cells) via apoptosis and stimulated immunity against cancer cells. Thus, radiation ANP can prevent some cancers (sporadic and hereditary) that would otherwise occur in the absence of radiation exposure.[3]

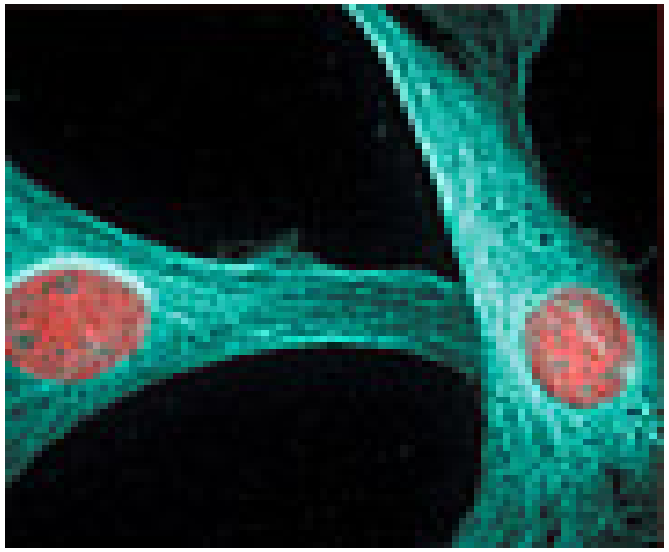
Recent papers by Bauer[4] and by Portess et al.[5] describe how low-dose radiation activates the selective removal of precancerous cells via apoptosis. The selective removal is mediated via intercellular signaling involving reactive oxygen and nitrogen species and specific cytokines (e.g., transforming growth factor ß).

Numerous papers have been published related to low-dose radiation stimulating immunity against cancer cells.[6-8] Because of radiation ANP, low doses and low dose-rates of x-rays and gamma rays can actually reduce rather than increase cancer occurrences.[3] Conversely, high radiation doses suppress immunity and inhibit

Journal of American Physicians and Surgeons Volume 13 Number 1 Spring 2008

Radiation Tracks and Biological Cells





At low dose the density of radiation ‘tracks’ is low; some cells are ‘hit’ and others are not.

The radiation energy deposited in any individual cell is a random variable and covers a range that depends on the radiation type.

What are the Event Frequencies for Tritium

The average dose per hit for a spherical volume 5μm in diameter (approximate diameter of a mammalian cell nucleus) from the experiments of Ellet and Braby

$$\delta = 11.2 \text{ mGy}$$

$$F_1 = [1-e^{-D/\delta}]$$

For a tritium concentration of 20Bq/L the committed dose is 0.286 μGy and therefore the fraction of exposed cells with hit nuclei is:-

2.5 per 100,000 cells

Tony Waker

Let's Compare with K-40

The average dose per hit for a spherical volume 5μm in diameter can be approximated by experimental data for heavily filtered 250 kVp x-rays, again from the experiments of Ellet and Braby

$$\delta = 8.33 \text{ mGy}$$

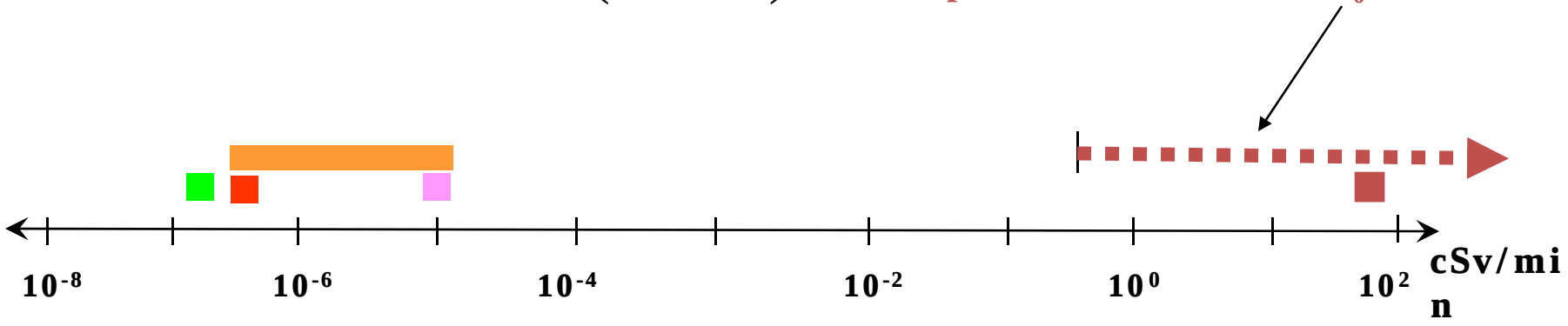
From natural levels of K in the human body the annual dose to soft tissue from K-40 is calculated to be 180μGy (Argonne National Laboratory) therefore the fraction of exposed cells with nuclei hit at least once annually is:-

2 per 100 cells

Tony Waker

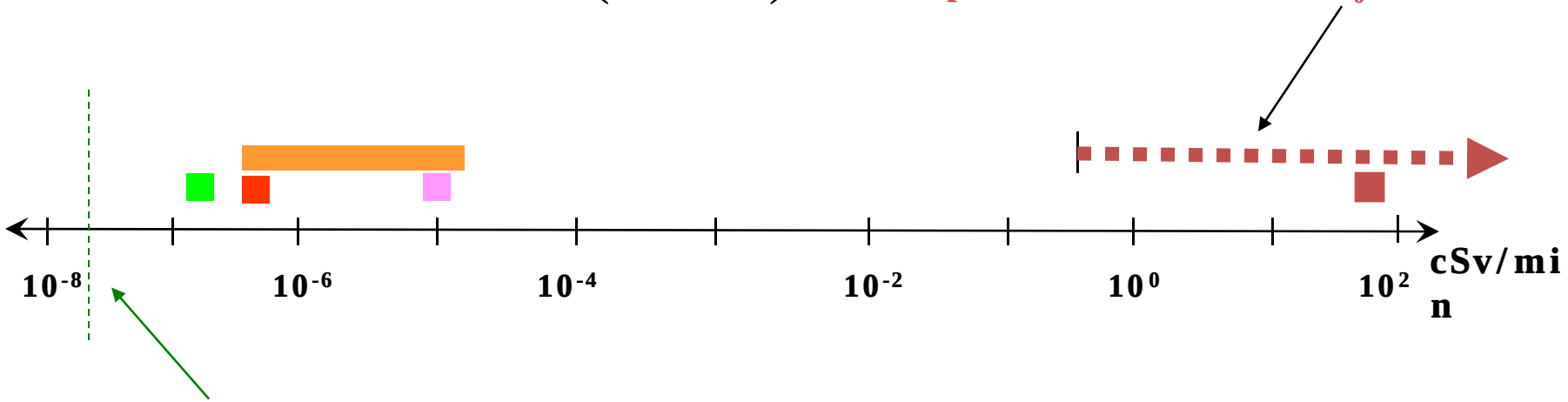
Logarithmic Scale of Dose-Rate

- World background rate (avg): **[4.9 10^{-7} cSv/min]**
- High background regions **[> 30 x world average]**
- Occupational exposure
  - Nuclear power worker **[2.3 x 10^{-7} cSv/min during working year]**
- Airline travel **[10^{-5} cSv/min at 40,000 ft]**
- Diagnostic radiology procedures **[~ 10 - 100 cSv/min for short times]**
- A-bomb irradiations (< 1 min) **Depends on distance from G_0**



Logarithmic Scale of Dose-Rate

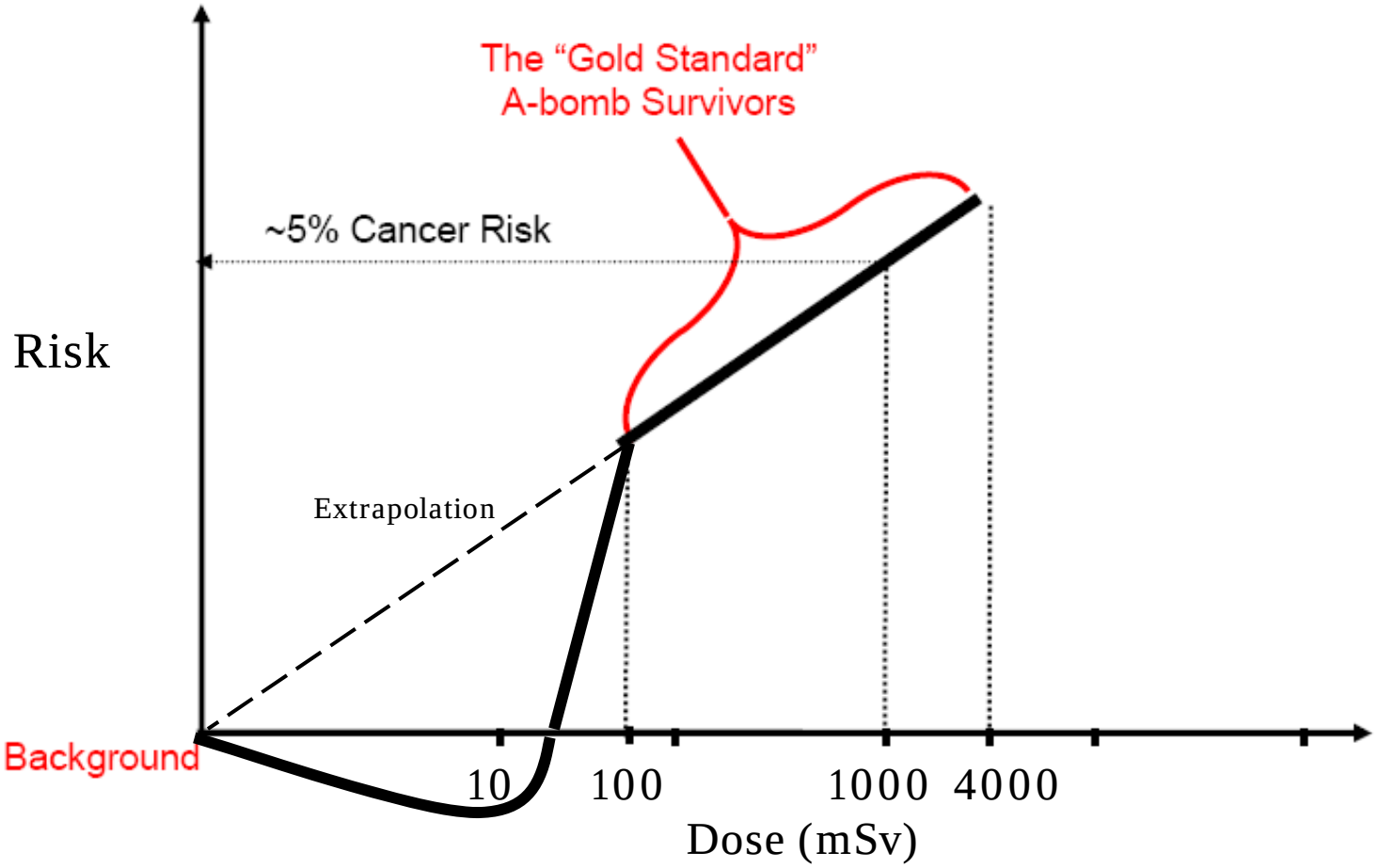
- World background rate (avg): **[5.7 10^{-7} cSv/min]**
- High background regions **[> 30 x world average]**
- Occupational exposure
  - Nuclear power worker **[2.3 x 10^{-7} cSv/min during working year]**
- Airline travel **[10^{-5} cSv/min at 40,000 ft]**
- Diagnostic radiology procedures **[~ 10 - 100 cSv/min for short times]**
- A-bomb irradiations (< 1 min) **Depends on distance from G_0**



- Tritium (7000 Bq/L)

May 2006 “Phoenix - Out of the Ashes and Into the Atomic Age”

Linear No-Threshold Hypothesis



Courtesy of W. F. Morgan

Canadian Radiation Protection Association

“The Ontario Drinking Water Advisory Council has recently recommended to the Ontario Minister of the Environment that the Ontario drinking water quality standard for the radionuclide tritium be lowered by a factor of 350. The recommendation has not been prompted by a finding of an increase in the risk associated with the ionizing radiation from tritium but from the reliance on the methodology recommended by the US National Academy of Sciences (NAS) for the assessment of risks due to exposure to carcinogenic chemicals. The NAS risk assessment methodology is not generally applied to ionizing radiation nor is it generally applied to situations where exposure is dominated by naturally occurring sources, as is the case with ionizing radiation.”

Symposium Conclusions

There was no new scientific evidence reported to support the recommendation that a new regulatory limit for tritium in drinking water is required to protect people or improve human health.

The carcinogenic potential of very low dose radiation exposure from tritium at a concentration of 20 Bq/L was considered insignificant. Much higher levels of exposure to humans, caused by natural radioactivity in the environment, have not been shown to be deleterious.

Radiation is not a chemical carcinogen and treating it as a non-threshold chemical carcinogen results in a significant overestimation of cancer risk.

Current radiation protection regulations are being appropriately applied and are effective at protecting human health.

Symposium Conclusions (Cont.)

Levels of tritium released from nuclear power plants are already close to the minimum achievable level.

The Canadian Radiation Protection Association does not support the new recommendation, because it is not supported by science.

The Canadian Nuclear Association does not support the new recommendation because it is not scientifically based and the industry already protects the environment and humans by keeping tritium emissions as low as reasonably achievable.

There is growing evidence to suggest that the LNT model for risk estimation is inadequate and that low dose radiation induces cellular responses that are different than detrimental effects observed at high doses.

Overall, the new recommendation does not seem to be justified based on scientific evidence.

Conclusions

The current regulation (7000 Bq/L – 0.1 mSv/yr) has a ten times safety factor already, based on solid scientific data (70,000 Bq/L = 1 mSv/yr).

If we adopt the recommendation our credibility is at risk and the recommendation will cause a ripple effect on public perception about radiation and its safety.

Dose-Response, 9:6–31, 2011
Formerly Nonlinearity in Biology, Toxicology, and Medicine

ISSN: 1559-3258
DOI: 10.2203/dose-response.10-048.Boreham

International Dose-Response Society

HUMAN HEALTH AND THE BIOLOGICAL EFFECTS OF TRITIUM IN DRINKING WATER: PRUDENT POLICY THROUGH SCIENCE – ADDRESSING THE ODWAC NEW RECOMMENDATION

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□ Tritium is a radioactive form of hydrogen and is a by-product of energy production in Canadian Deuterium Uranium (CANDU) reactors. The release of this radioisotope into the environment is carefully managed at CANDU facilities in order to minimize radiation exposure to the public. However, under some circumstances, small accidental releases to the environment can occur. The radiation doses to humans and non-human biota from these releases are low and orders of magnitude less than doses received from naturally occurring radioisotopes or from manmade activities, such as medical imaging and air travel. There is however a renewed interest in the biological consequences of low dose tritium exposures and a new limit for tritium levels in Ontario drinking water has been proposed. The Ontario Drinking Water Advisory Council (ODWAC) issued a formal report in May 2009 in response to a request by the Minister of the Environment, concluding that the Ontario Drinking Water Quality Standard for tritium should be revised from the current 7,000 Bq/L level to a new, lower 20 Bq/L level. In response to this recommendation, an international scientific symposium was held at McMaster University to address the issues surrounding this change in direction and the validity of a new policy. Scientists, regulators, government officials, and industrial stakeholders were present to discuss the potential health risks associated with low level radiation exposure from tritium. The regulatory, economic, and social implications of the new proposed limit were also considered.

F. E. A. R.

- F: Forget
- E: Everything
- A: And
- R: Run!

thestar.com

Port Hope is sitting on a carcinogenic time bomb that residents can only escape by moving out of town, a renowned doctor and anti-nuclear activist warns.
(Helen Caldecott)