Tritium

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Citizen's Advisory Panel Meeting

Plymouth, MA

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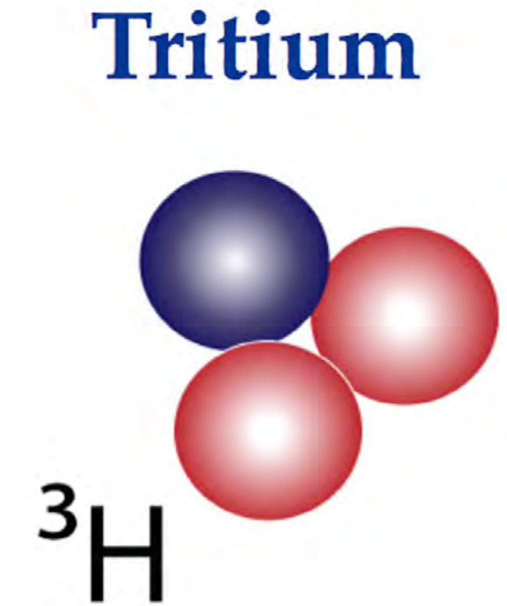
https://tricities.wsu.edu/parkerfoundation/

https://www.forbes.com/sites/jamesconca

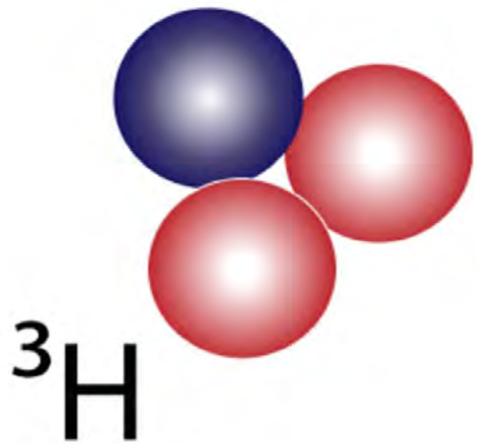


The Possibility of Discharging Tritiated Water into Cape Cod Bay

Holtec is evaluating discharging up to 1.1 million gallons of treated water, with residual tritium, from the shuttered Pilgrim Nuclear Station near Plymouth, Massachusetts into Cape Cod Bay

One scenario is mixing the water with 20x seawater and discharging slowly, no more than 40,000 gallons a day, as has been done routinely at nuclear power plants world-wide, including Pilgrim, with no adverse effects.

Tritium

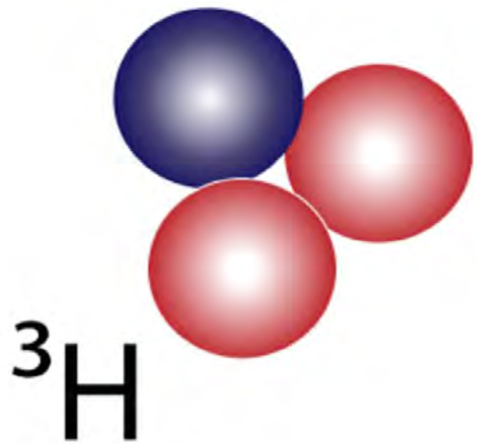


After 50 years of field and laboratory experiments, and environmental and biological monitoring, the scientific community has never observed any humans or organisms in the environment to have been harmed by ^{3}H at any level from any source

Only ^{3}H concentrated in laboratories, not even in nuclear reactors, can get ^{3}H levels high enough to cause harm. In the lab, to see any health effects at all, we have to enrich materials, water or food in ^{3}H almost a billion times above normal levels which takes large amounts of energy and advanced procedures. We then feed or inject it into an animal.

We do not need to do any more of these live animal tests.

Tritium



Units and Numbers

Units of radioactivity: (doesn't involve the organism)

Becquerel (Bq) – 1 nuclear disintegration per second

Curie (Ci) – 37 billion Bq

picoCurie (pCi) – 0.037 Bq

Units of dose: (involves the organism)

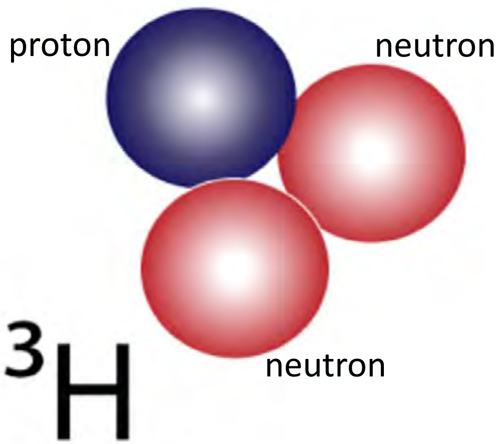
Sievert (Sv) – dose equivalent (normalized to rad type & organ)

rem - U.S. unit of dose equivalent (1 Sv = 100 rem)

Gray (Gy) – absorbed dose = 1 J/kg (100 rad)

Tritium

Weakest radioactivity of any radionuclide – 6 keV average



$^{1,2,3}H$ has the most unique chemistry and physics of any element or radionuclide. That's why we don't remove it from this water.

- Difficult for such a low-energy beta to get through the water, cell walls and other materials in between the radionuclide and any DNA, can't pass through dead skin layers. So only internal doses are possible.
- The energy mostly gets dispersed within the electron clouds of other molecules like H_2O through inelastic collisions and the Bremsstrahlung effect, turning kinetic energy into EM non-ionizing energy.

^{3}H half-lives are short (important for dose)

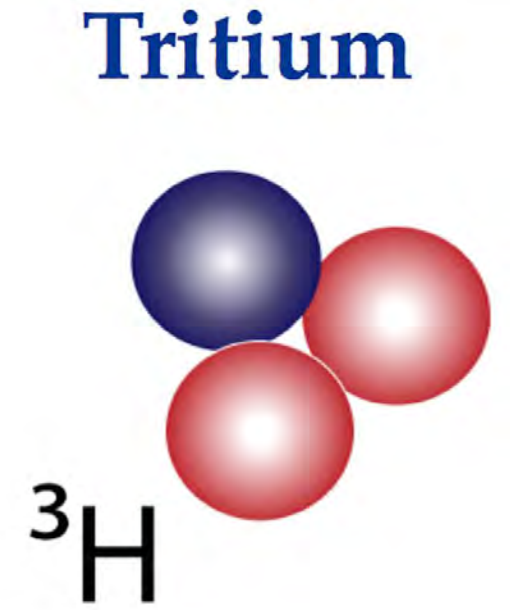
- Physical decay ½-life is just over 12 years
- Biological ½-lives are in days
  - Humans, just under 10 days
  - Fish, just over 2 days

^{3}H (HTO) thermodynamically prefers to be in water

- ^{3}H does not concentrate up the food chain
- ^{3}H dilutes up the food chain
- will not adversely affect the oysters, clams or fish in Cape Cod Bay

^{3}H (OBT) also thermodynamically prefers to be in water, but

- slightly slower to leave tissues
- no documented observation of concentration up the food chain



Tritium in the Environment

Natural (cosmogenic) tritium concentrations in seawater are about 0.7 Bq/l (our blood contains 250 Bq/l of radionuclides, 99% of which are ≥ 100 times more energetic than ^{3}H.

Natural (cosmogenic) tritium is continuously created in the upper atmosphere, mostly by

$$^{14}N + n \rightarrow {}^{3}H + {}^{12}C$$

forming *70,000,000,000,000,000 Bq (70 QBq; 2 x 10⁶ Ci)* of ^{3}H every year, which rains out into surface waters from which we end up drinking or fishing.

$^{1,2,3}H$ has the most unique chemistry and physics of any element or radionuclide. That's why we don't remove it from this water.

But there are *74,100,000,000,000,000,000,000 Bq (74 S_xBq)* of K-40, Rb-87 and many more higher-energy emitters already in the world's oceans. Fish are swimming in lots of radioactive material anyway, more than this Pilgrim water could ever effect.

For those of you who wear glow-in-the-dark wristwatches, you are carrying 925,000,000 Bq of tritium on your wrist. Medical and industrial applications in the U.S. use 1.45 x 10^{17} Bq/year (145,000,000,000,000,000) @ \$30,000/gram

The Issue As It Stands

Since there have been no documented health effects from ^3H levels outside of the laboratory, Nations have to guesstimate what maximum regulatory limits to set

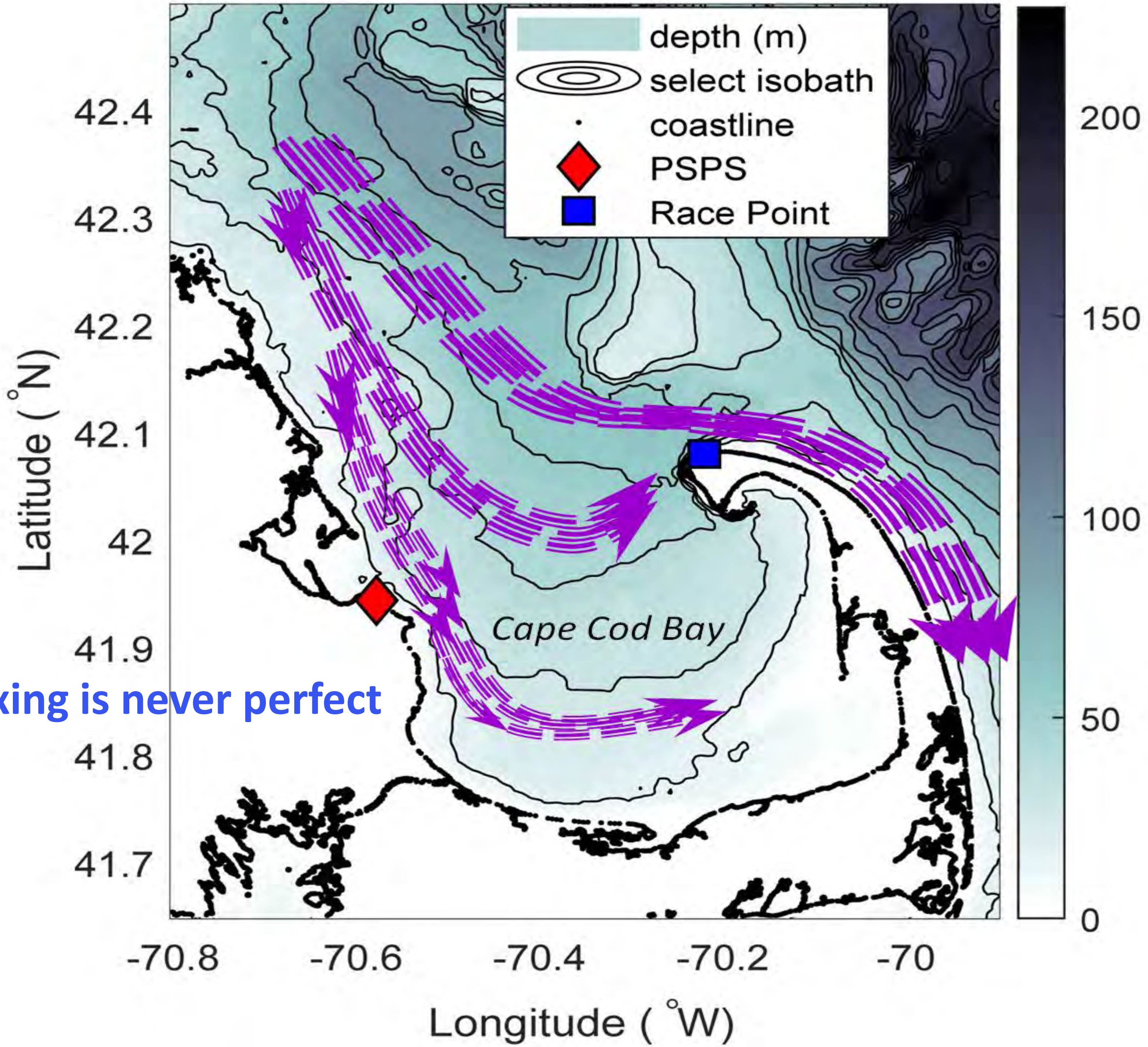
Tritium Drinking Water Limits By Country

Country	*Tritium Limit (Bq/liter)*	*(pCi/liter)*
European Union	100	2,700
United States	740	20,000
Canada	7,000	189,000
Russia	7,700	208,000
Switzerland	10,000	270,000
World Health Organization	10,000	270,000
Finland	30,000	810,000
Japan	60,000	1,620,000
Australia	76,103	2,050,000

What Happens After the Tritium Enters the Water?

Any dissolved constituent or chemical species in any packet of water that is in a concentration higher than the surrounding water will begin dispersing, or spreading out, to reach equilibrium, or steady-state, in order to smooth out any concentration differences.

Currents and wave action are very efficient in dispersing dissolved chemical species, especially HTO that thermodynamically wants to stay in the water, becoming fairly well-mixed in days to weeks.



But mixing is never perfect

What is the effect of discharging all of the Pilgrim tritiated water into Cape Cod Bay?

But mixing is never perfect, so we can look at various degrees of mixing to see the effects:

100% mixed	→ 1.90×10^{-8} µCi/ml	= 19.0 pCi/L	<< 20,000 pCi/L
10% mixed	→ 1.93×10^{-8} µCi/ml	= 19.3 pCi/L	<< 20,000 pCi/L
1% mixed	→ 2.18×10^{-8} µCi/ml	= 21.8 pCi/L	<< 20,000 pCi/L
0.1% mixed	→ 4.90×10^{-8} µCi/ml	= 49.0 pCi/L	<< 20,000 pCi/L

But discharge will be over time, no more than 40,000 gal/day, each packet dispersed in a few days to a few weeks before all of the water is discharged.

However, other radionuclides in seawater total about 350 pCi/L (13 Bq/l) mostly from K-40, Rb-87, U-238, Th-232 with much higher energies than tritium, giving Cape Cod Bay a total radioactivity of about

600,000,000,000,000 Bq (15,000,000,000,000,000 pCi) from these others that, unlike tritium, can theoretically concentrate up the food chain, but never do to any significant degree

What Happens After the Tritium Enters the Water?

So at some point, the tritium will be fairly mixed in Cape Cod Bay at somewhere less than the worst case - 1.8 Bq/L = 49 pCi/L

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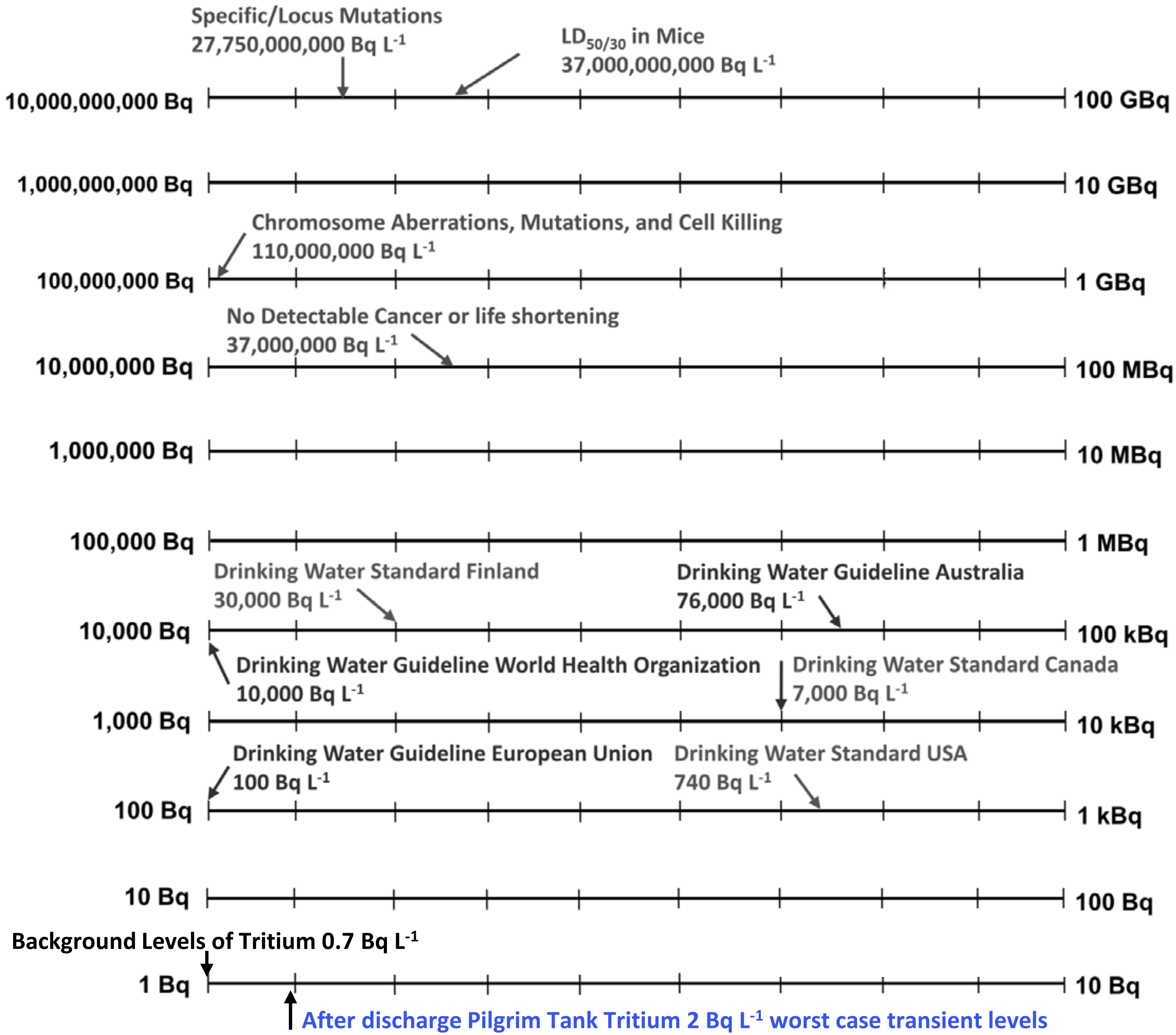
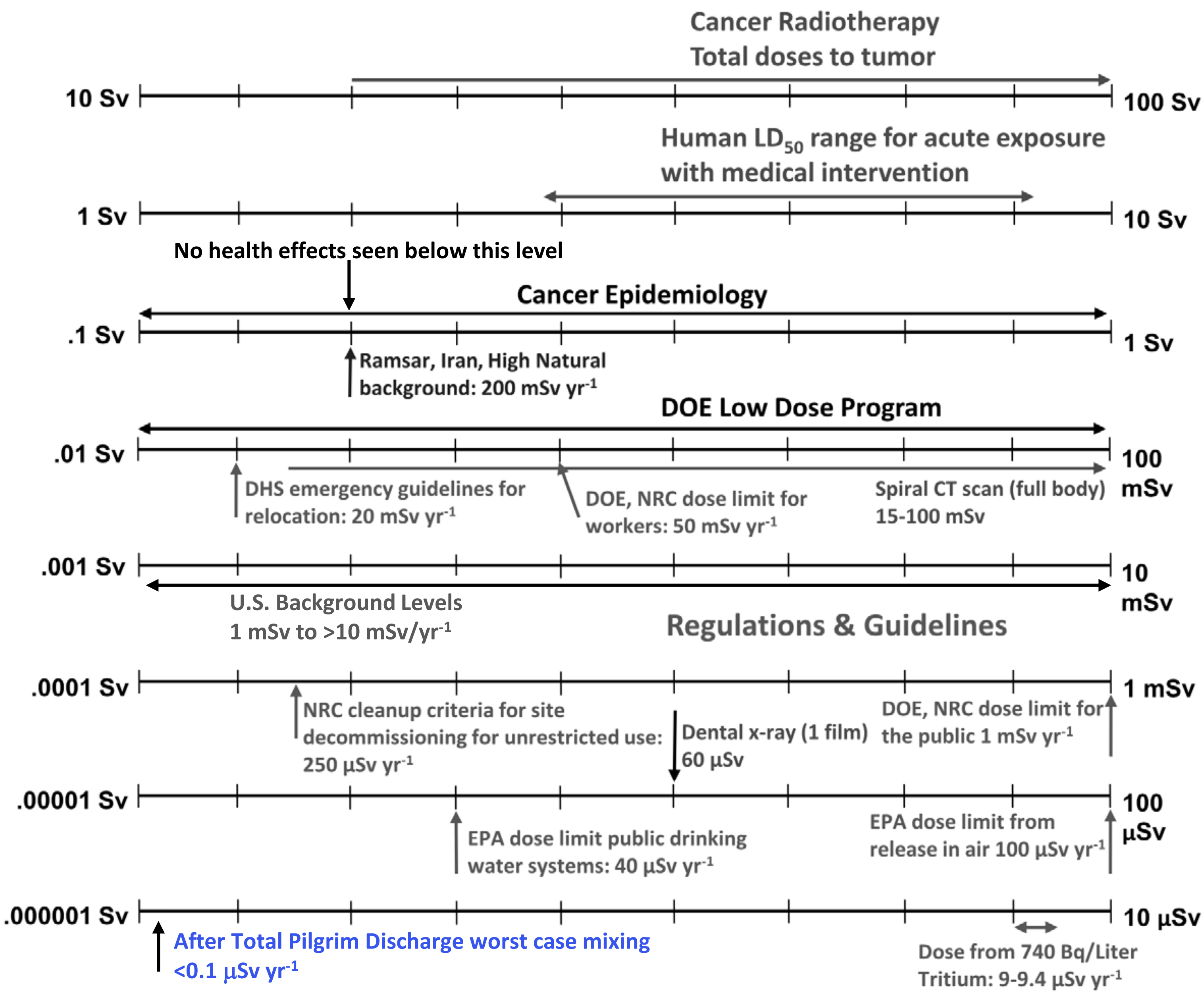
Tritium Activity, Biological Effects, and Regulations (Bq L^{-1})



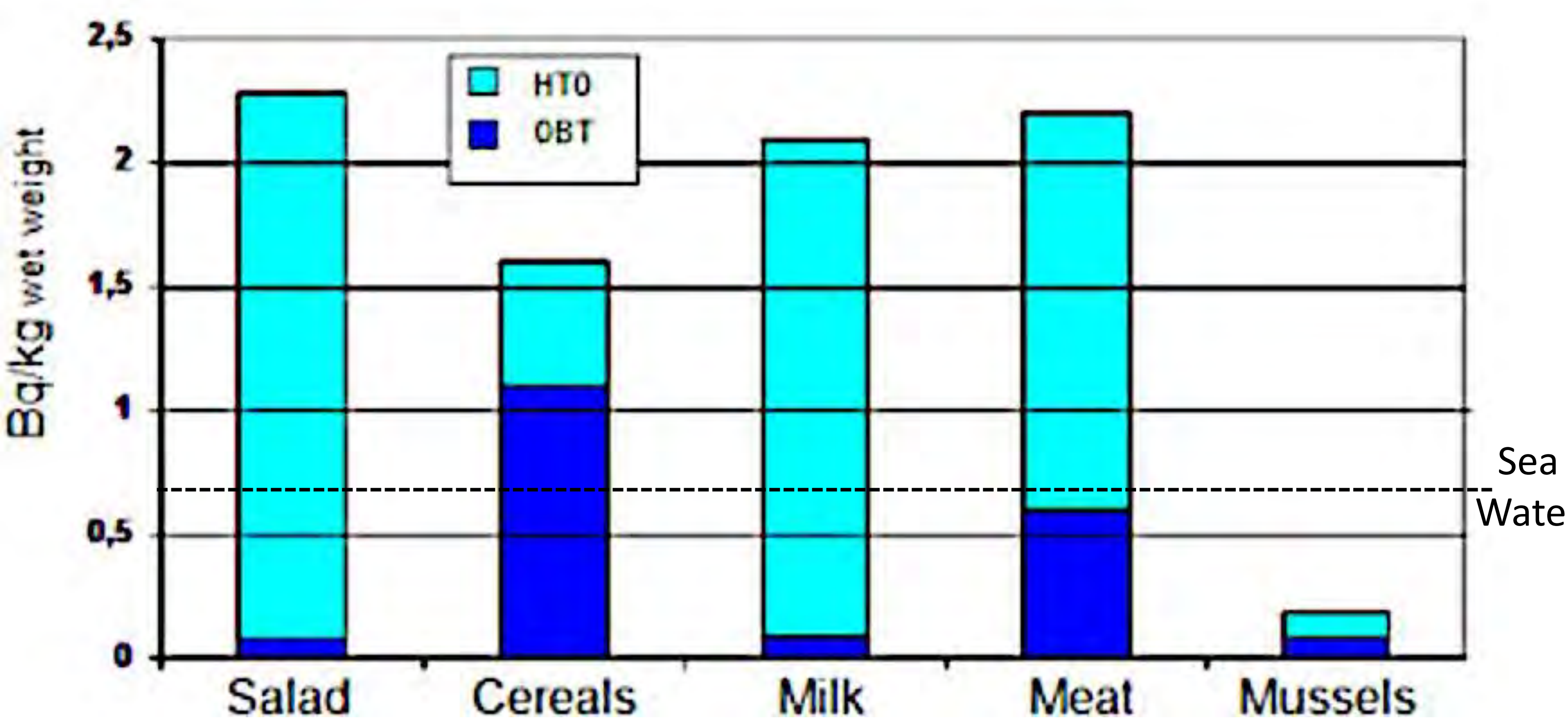
Ionizing Radiation Dose Ranges Chart (Sv yr^{-1})



TRITIUM IN THE ENVIRONMENT

French Institute of Radiation Protection and Nuclear Safety, IRSN, 2012

HTO and OBT in foodstuffs in areas of France not influenced by nuclear facility releases



FIXATION AND LONG-TERM ACCUMULATION OF TRITIUM FROM TRITIATED WATER IN AN EXPERIMENTAL AQUATIC ENVIRONMENT

Pacific Northwest National Laboratory, 1975

HTO water was introduced to an experimental freshwater pond with carp, clams, crayfish, periphyton, pondweed and sediments, for 8 months at concentrations of 37,000 Bq/l. All components were sampled on a predetermined schedule. The pond was maintained on uncontaminated replacement waters for an additional 8 months to determine the rate of ^{3}H elimination.

After the first day, HTO in all biota approached an equilibrium with pond water. Final concentration factors of 0.89; 0.87, 0.82, 0.92, 0.77, 0.88 were calculated for carp, clam, crayfish, snail, periphyton, and pondweed.

After only several hours of exposure, the HTO concentration in the organisms were about 90% of that of environmental water.

OBT initially increased rapidly in all biota sampled, but slowed with time. Final concentration factors for carp, clam, crayfish, snail, periphyton, and pondweed were calculated to be 0.49, 0.10, 0.53, 0.54, 0.15, and 0.62.

Loss of tritium from pond waters occurred exponentially with time with less than 10% of the final equilibrium concentration remaining after the first month. Rate of loss of tritium from both animal and plant species was also rapid, with animal forms generally eliminating their respective tritium burdens more rapidly than plant forms. Sediments tended to eliminate tritium more slowly.



Table IV. The Ratio of OBT/HTO for Carp, Clam, Crayfish, Snail, Periphyton and Pondweed Exposed to HTO for Seven Months

Organism	OBT/HTO
Clam	0.17
Periphyton	0.44
Carp	0.71
Crayfish	0.79
Snail	0.94
Pondweed	1.31



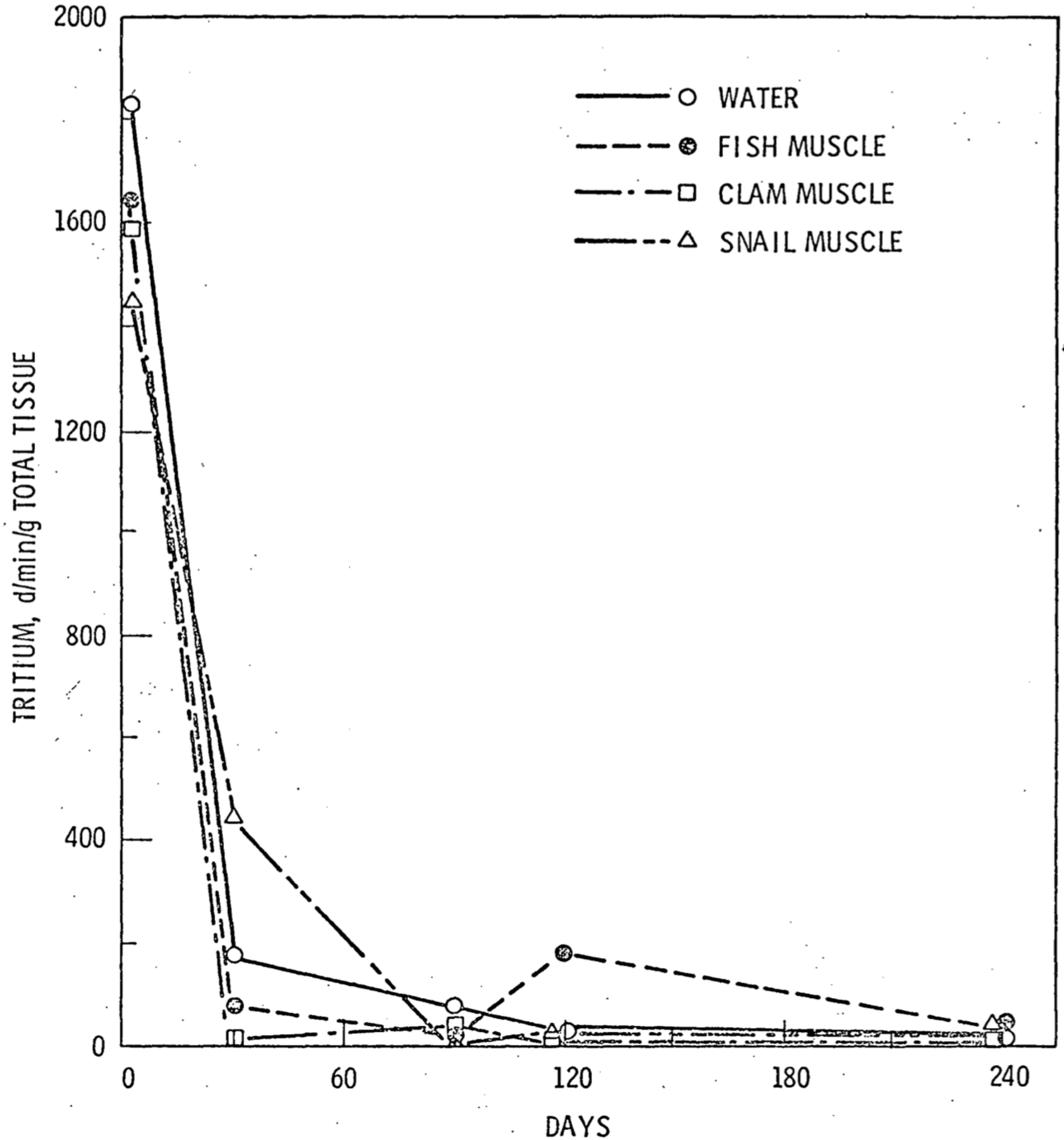


Figure 4. Elimination of tritium from fish, clam, and snail.

TRITIUM (3H) RETENTION IN MICE: ADMINISTERED AS HTO, DTO OR AS ^{3}H-LABELED AMINO-ACIDS (OBT)

Nicholas D. Priest,*† Melinda S.J. Blimkie,* Heather Wyatt,* Michelle Bugden,* Laura A. Bannister,* Yann Gueguen,‡ Jean-Rene Jourdain,‡ and Dmitry Klokov*

Health Phys. 112(5):439–444; 2017

Separate cohorts of long-lived female CBA/CaJ live mice weighing about 20 g each were fed or injected with ^{3}H administered as HTO, DTO and OBT. OBT was derived from ^{3}H-bound to the amino acids alanine, proline and glycine.

Mice were entered into the study at 8 wk of age when they started ingesting either HTO or OBT ad libitum.

Six mice were allocated to each treatment group. During the period of ingestion exposure, after 1, 7, 15, and 30 d, some of these groups of mice were euthanized for analysis.

Other groups of mice were euthanized at 2, 4, 8, 16, 32, 64, and 128 d.

For injection studies, mice were injected with 15,000 Bq of ^{3}H.

For ingestion studies, Mice were fed continuously for 30 days either 10,000 Bq/l HTO, 1,000,000 Bq/l HTO or 20,000,000 Bq/l HTO

or

10,000 Bq/l OBT, 1,000,000 Bq/l OBT or 20,000,000 Bq/l OBT.

Table 1. Mean and standard deviation of ^{3}H-body content as either HTO or OBT, following the administration of either ^{3}H-light water

For toxicity studies in which mice were exposed to ^{3}H for 28 days at the level of 1,000,000 Bq/l, the cumulative average body radiation doses are 1.1 mGy for HTO and 1.4 mGy for OBT, a difference of only 27%.

	Time (hours)		mean ± SD (%)		mean ± SD (%)	
	Tritium as water in body					
	3		97.87	4.08	92.89	5.72
	7		94.58	4.54	93.16	6.67
	24		65.89	3.17	69.16	1.48
2 days -	48	τ_2 = 2 d	46.71	1.58	51.87	1.63
4 days -	96		23.53	1.81	28.15	2.11
16 days -	384		0.64	0.15	0.76	0.11
	Organically bound tritium in body					
	3		3.81	0.45	2.28	1.42
	7		2.64	0.45	2.52	0.80
	24		2.61	0.16	2.96	0.28
2 days -	48		2.35	0.12	2.13	0.46
4 days -	96	τ_2 = 4 d	1.78	0.22	1.96	0.13
16 days -	384		0.60	0.12	0.67	0.10

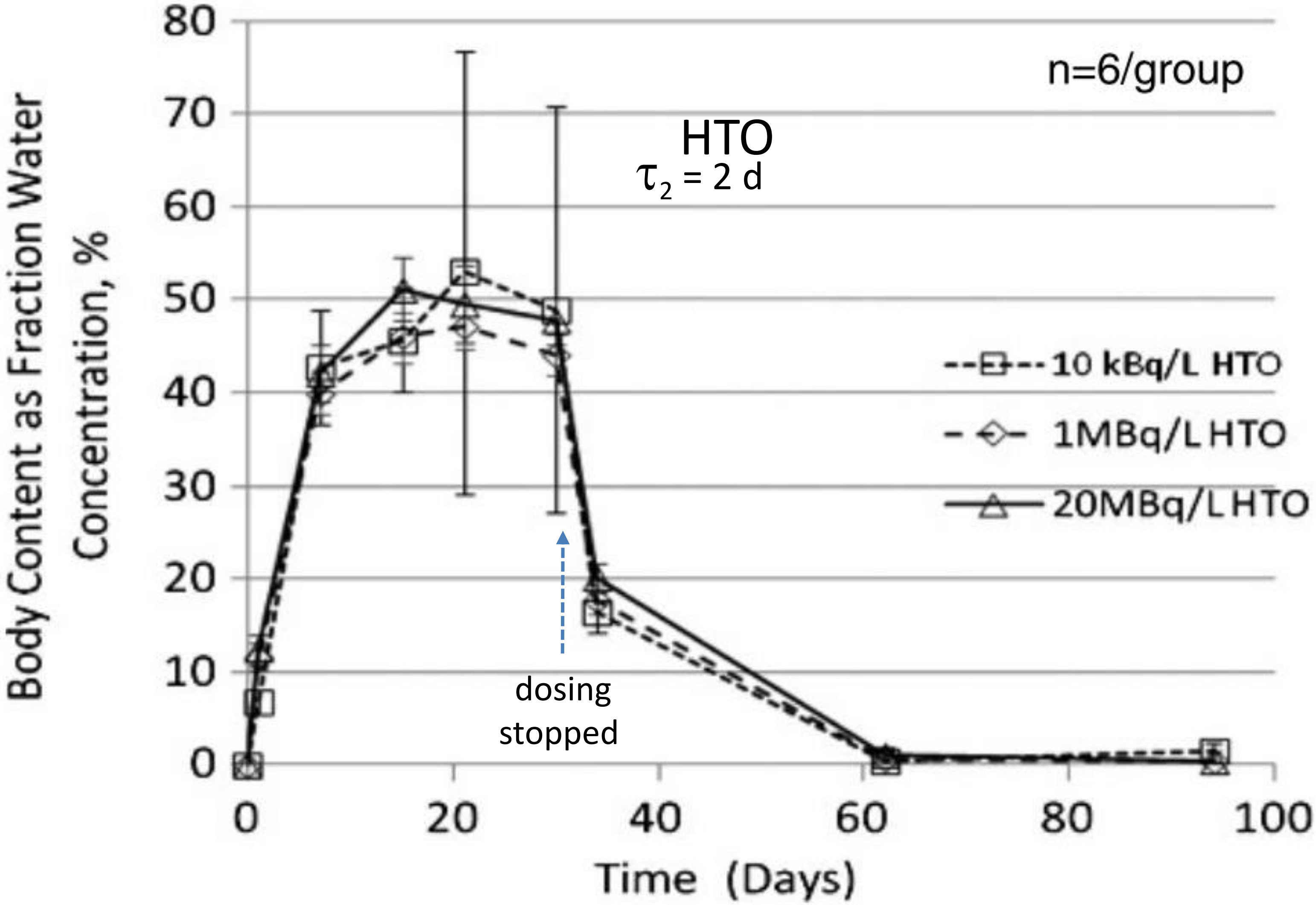


Fig. 3. The concentration of ^{3}H in mice that ingested HTO at three levels of dosage. Results are presented as a percentage fraction of the concentration of ^{3}H in the water ingested. This shows that after ~10 d, the body content reaches an approximate equilibrium at ~50% of the concentration in the drinking water.

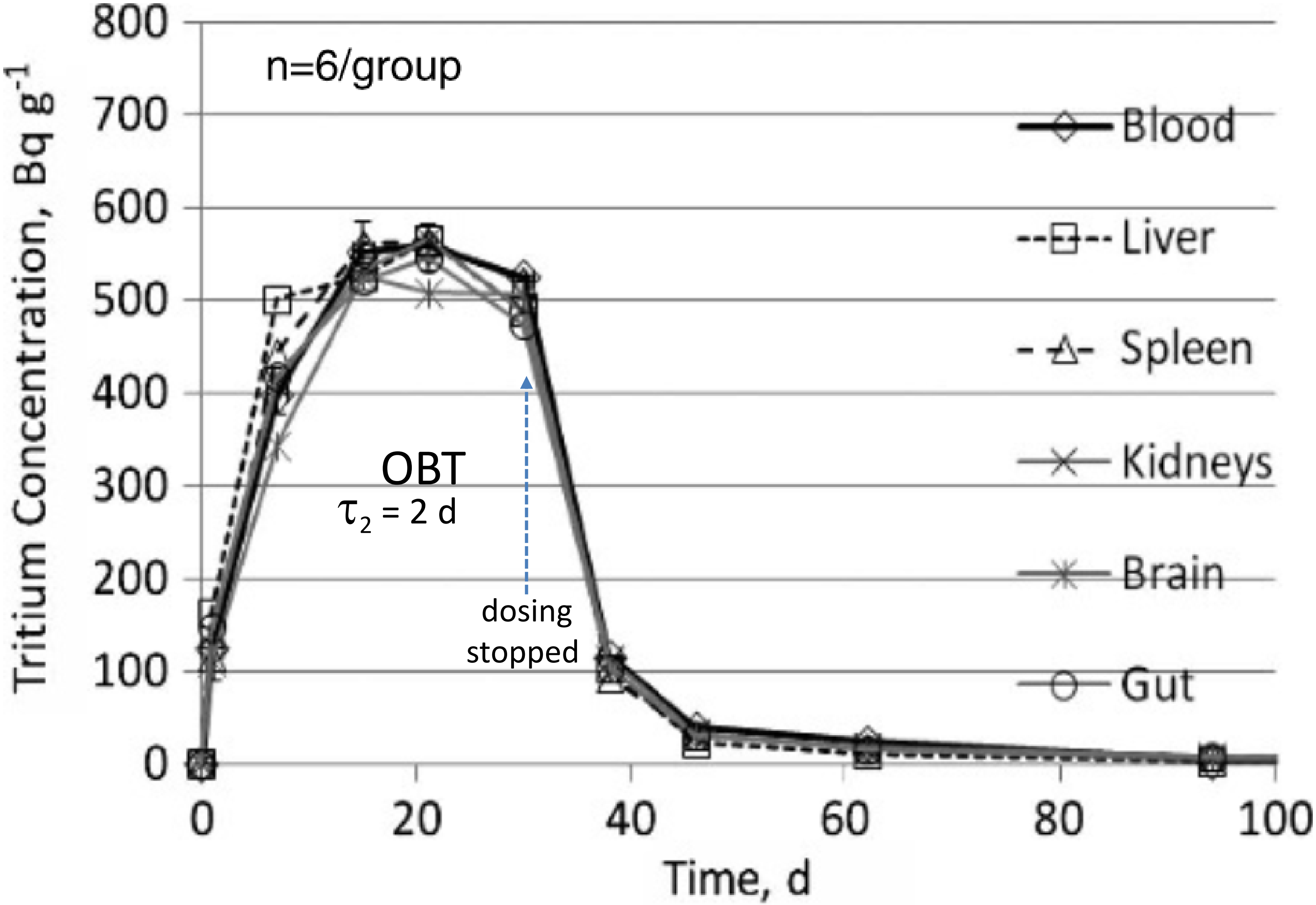
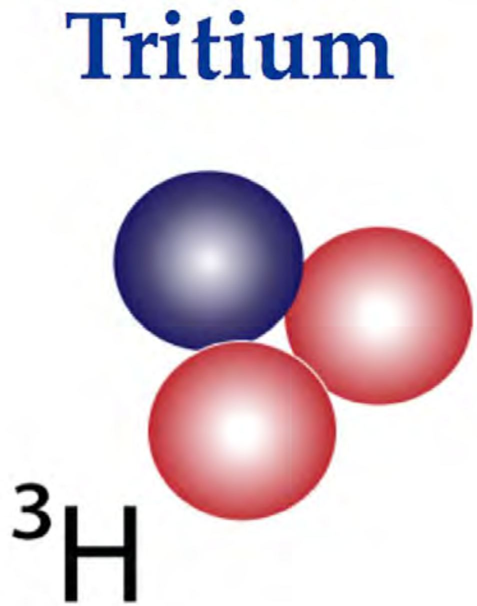


Fig. 4. The concentration of ^3H in different soft tissues as a function of time during and post the 30-d administration of ^3H as ^3H-labeled amino acids (1 MBq L^{-1}).

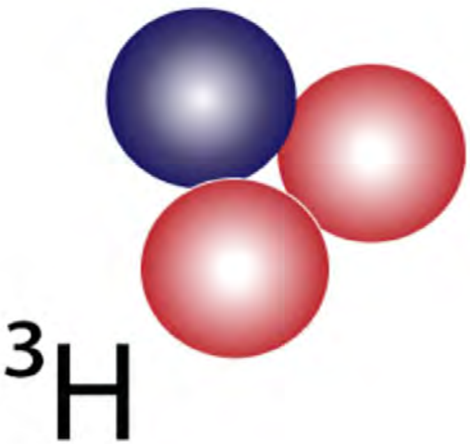


The Possibility of Discharging Tritiated Water into Cape Cod Bay

Total amounts of ^3H in Bq and concentrations of ^3H in Bq/l that could be discharged to Cape Cod Bay are extremely low compared to the amount of ^3H already in Cape Cod Bay (or in any seawater) and millions of times less than the amount and concentrations required to harm sea life or human life.

Although not necessary, the water could be discharged slowly in a controlled manner, as has been done under regulatory overview at every nuclear power plant in history, including Pilgrim, as no adverse problems have ever been observed from that practice.

Tritium



Uptake and Elimination in Biota

Uptake of ^{3}H in all biota is fairly rapid. Elimination of HTO is about as rapid.

The binding of ^{3}H to become OBT is highly variable among organisms but mollusks like clams and oysters bind the least. Elimination of OBT is slower than for HTO, but not significantly so as to affect health and the environment.

Estimates of the maximum dose from the discharged Pilgrim water to the public are less than 1 mrem/yr (0.01 mSv/yr).

Comparison of Normal Background Radiation with 1 mrem/yr Worst-Case Peak Dose from Pilgrim Discharged Water (NCRP 2013)

Normal annual exposure from natural radiation

About 620 mrem/yr


- Radon & Thoron gas 230 mrem
- Human body 30 mrem
- Rocks, soil 20 mrem
- Cosmic rays 30 mrem


Normal annual exposure from man-made radiation

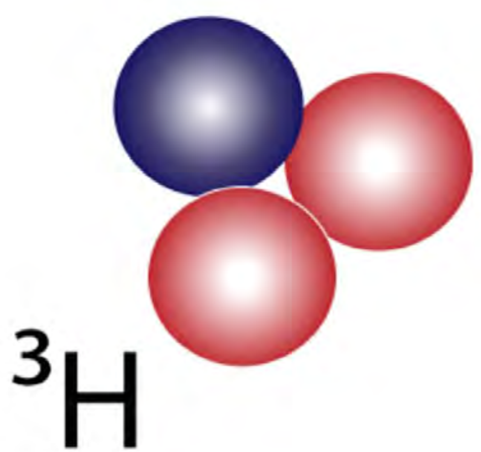
About 70 mrem/yr

Move to Denver 50 mrem/yr

- Medical procedures 295 mrem
- Consumer products 12 mrem
- One rnd-trip coast to coast airplane flight 4 mrem
- Watching color TV 1 mrem
- Sleeping with another person 1 mrem
- ^{3}H Pilgrim water release less than 1 mrem
- Weapons test fallout less that 1 mrem
- Nuclear industry less than 1 mrem




Tritium



After 50 years of field and laboratory experiments, and environmental and biological monitoring, the scientific community has never observed any humans or organisms in the environment to have been harmed by ^3H at any level from any source

Only in the laboratory can we get ^3H levels high enough to cause harm, by enriching materials, water or food in ^3H almost a billion times above normal levels which takes large amounts of energy and advanced procedures

Questions?

How to Assess Risk

- Regulations assume that radiation risks to humans and the environment exist as a result of any exposure, no matter how small (LNT)
- Exposure to natural background is, on average, about 3 mSv/yr (300 mrem/yr), although global regional averages range from 0.03 mSv/yr to over 100 mSv/yr (10 rem/yr)
- There is no evidence of public health risks at exposures less than 100 mSv/yr (10 rem/yr). Any possible risk is well below the noise level of all other cancer risks faced by humans and the ordinary risks of everyday life
- As an example, regulations require nuclear waste disposal systems to meet release criteria, especially 0.04 mSv/yr (4 mrem/yr) to downgradient drinking water supplies, which is 100 times less than the background in Boston. Moving from Boston to Denver will give you an extra 50 mrem/yr.

How to Assess Risk

The Massachusetts Department of Public Health determines relative risk of exposure to ionizing radiation above background using the linear, no-threshold dose-response hypothesis, but only when above background, which this water will not be.

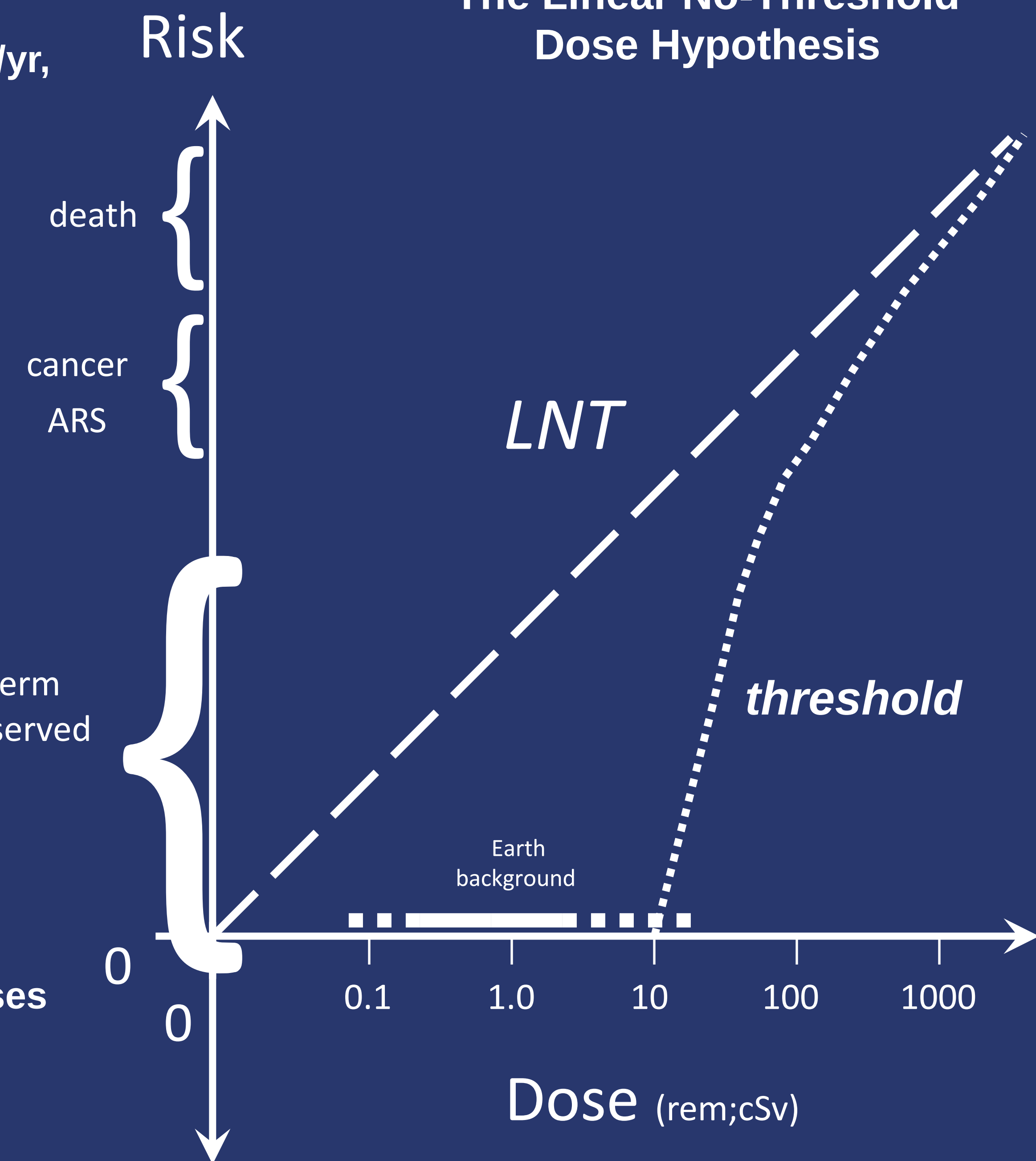
But assuming a risk coefficient of 5%/Sv from LNT, then the perceived lifetime risk at 1 mSv represents:

0. 05/Sv-yr x 0. 001 Sv x 70 years = 0.0035 = 0.35% additional risk on top of the natural cancer risk of about 40% for the general public.

EPA says that less than 1 mSv (public dose limit of 100 mrem) is safe and does not add any access cancers to the public.

Small chronic doses of radiation, < 10 rem(cSv)/yr, iseasily handled by cellular repair mech-anisms that evolved as a normal adaptive response with the emergence of the eukaryotic cell 2.3 billion years ago

The Linear No-Threshold Dose Hypothesis



The health risk from doses <10 rem/y (<0.1 Sv/y) cannot be significantly distinguished from zero

The Problem With LNT

LNT assumes we have no immune system

Our immune system is very efficient at repairing radiation damage

- changes in gene expression as a function of radiation dose (Yin et al. 2003)
- Stimulates Nrf2 antioxidant response system, as O_2 and O□ (McDonald 2010)
- by-stander effects within tissue matrices (Y Pacheco 2019; CD4$^+$ T cells)
- protective changes in the reactive oxygen status of the cells (Spitz et al. 2004; Azzam et al. 2002; Murley et al. 2011)
- apoptosis, which selectively eliminates transformed cells (Bauer 2007; Portess et al. 2007)
- protective control of the cellular and molecular responses by tissue-matrix interactions (Barcellos-Hoff and Brooks 2001; Barcellos-Hoff and Costes 2006)
- radioactivated immune cells/molecules include TGF-β_1, IL-10, NF-κB, polymorphonuclear leukocytes, and macrophages (Wilson et al. 2021)

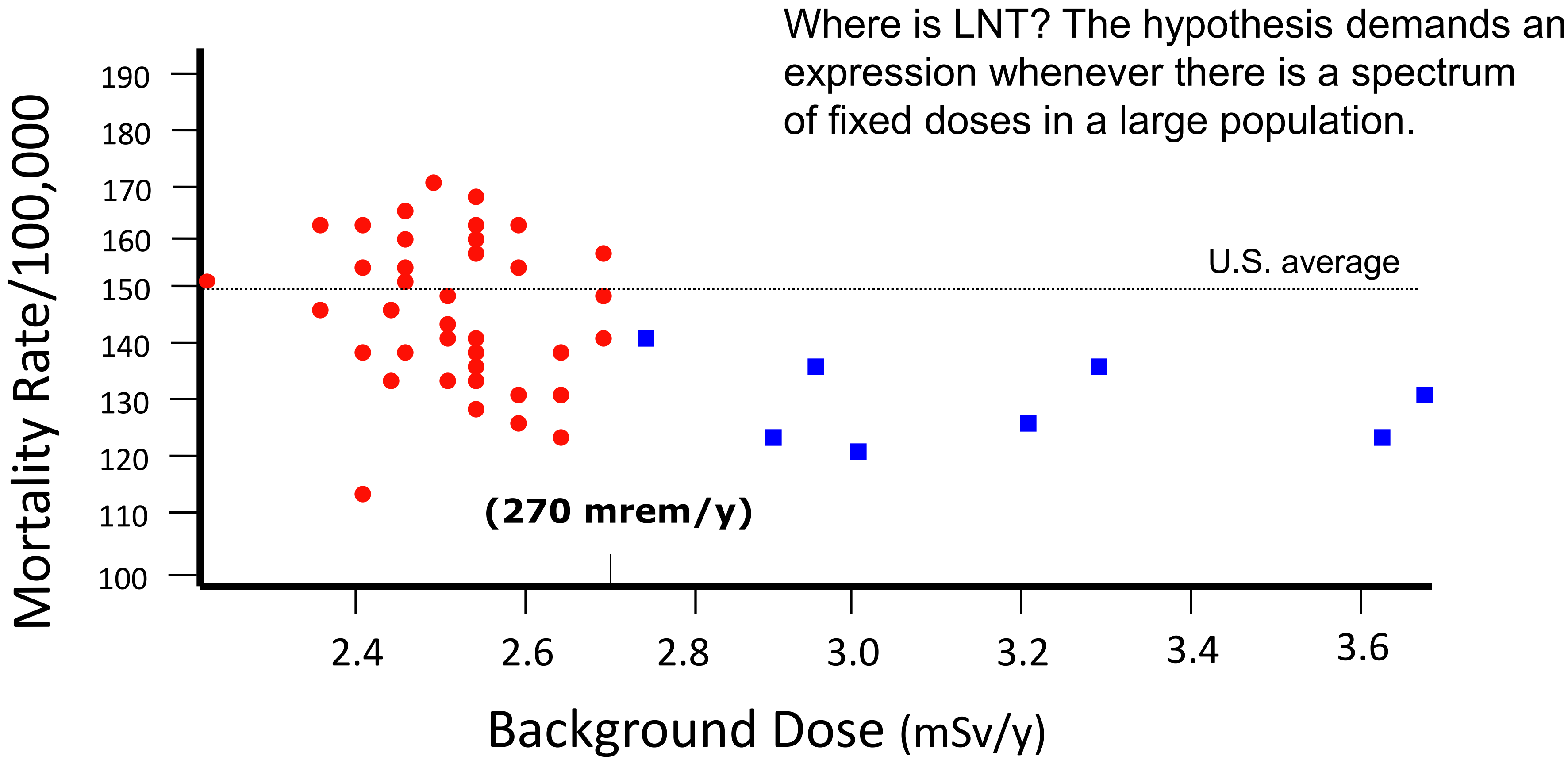
What Are Some Of The Costs Associated With Exceptionally-Low Radiation Limits?

Our regulatory limits are so far down in the noise as to be meaningless from a public health standpoint

- the noise of background radiation levels
- the noise of everyday risks

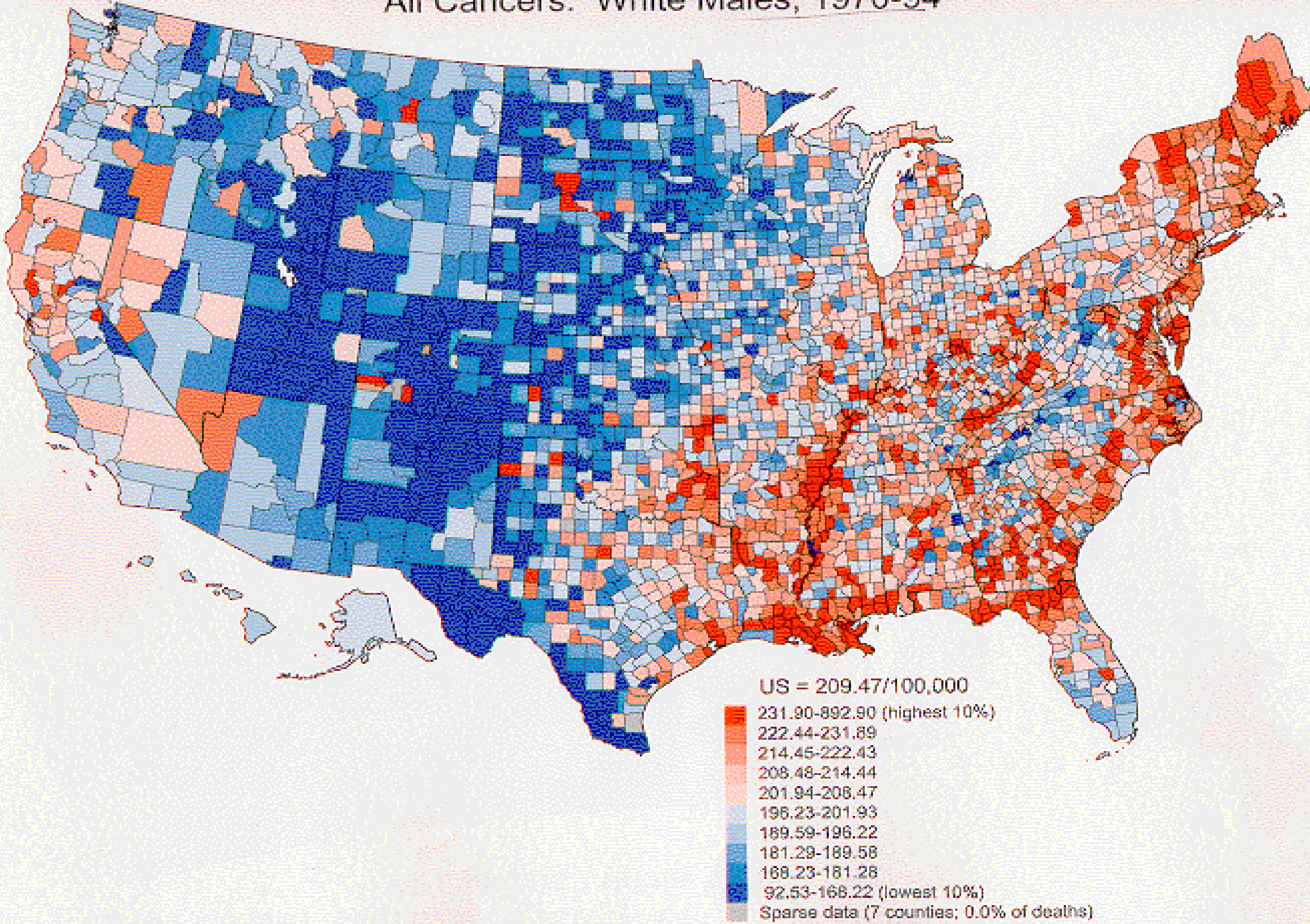
LNT demands that there be an observable effect as a function of dose

Background Radiation Differences on Annual Cancer Mortality Rates/100,000 for each U.S. State over a 17-Year Period (adapted from Frigerio and Stowe, 1976 with correction for dose using more recent background data from radon).



Cancer Mortality Rates by County (Age-adjusted 1970 US Population)

All Cancers: White Males, 1970-94



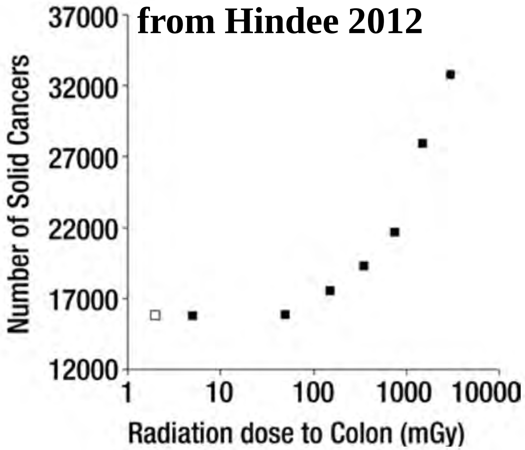
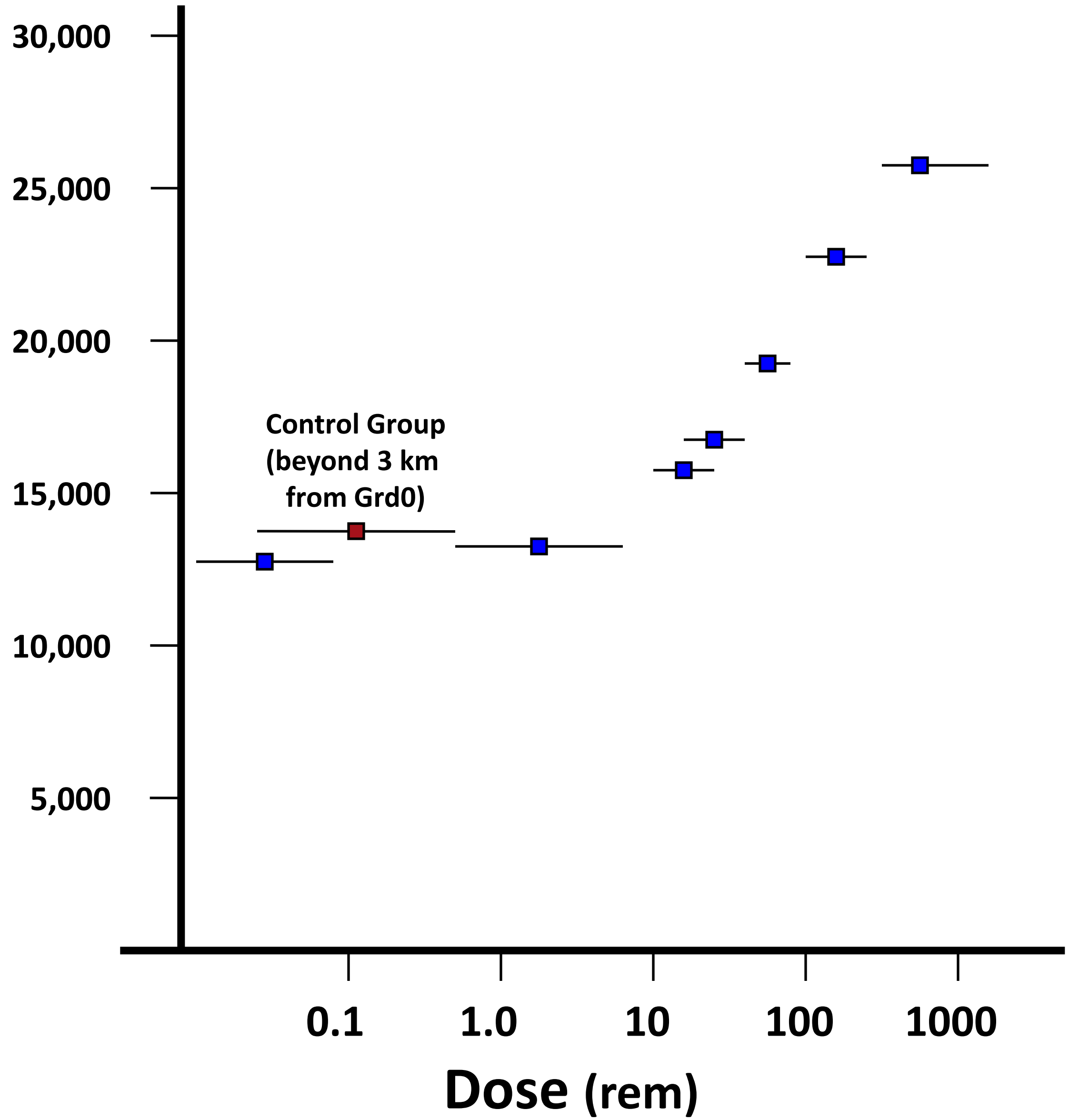


Figure 5: Graph shows number of solid cancers as a function of absorbed dose. ☐ = people who were not in the cities at the time of the bombing.

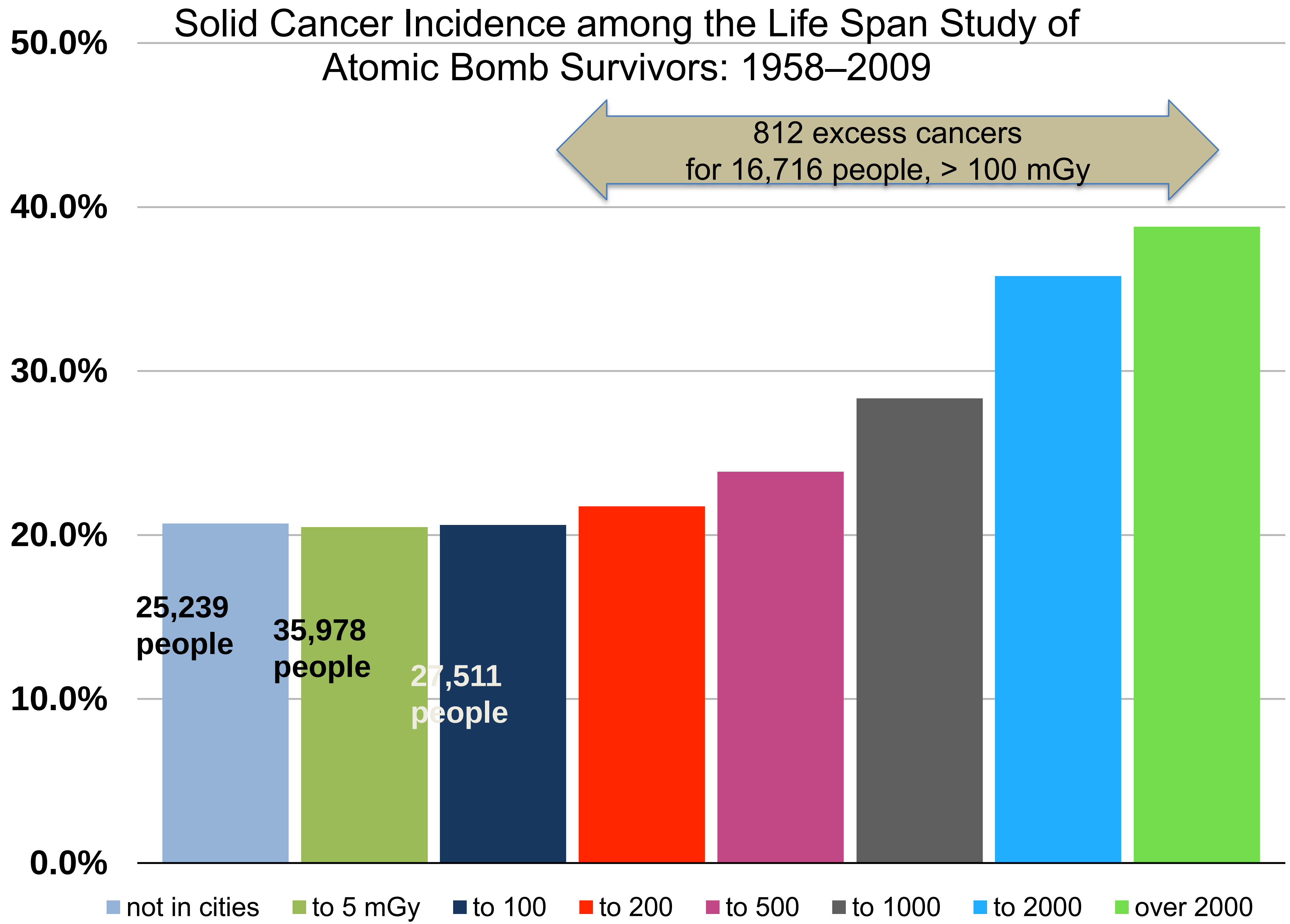
Solid Cancers per 100,000 population in the Atomic Bomb Survivor Cohort of 79,901 subjects (data from 1994 ICRP).



Number of Solid Cancers over 40 years

(per 100,000 population)

normalized per 100,000	dose range
13,748	> 3 km from Grd0
12,806	< 0.1 rem
13,494	0.5-10 rem
15,476	10-20 rem
16,752	20-50 rem
19,094	50-100 rem
23,949	100-200 rem
26,808	> 200 rem



Source: Hargraves

Some behavioral risks facing Americans over the past 5 years

alcohol consumption

automobile driving

coal industry

construction

food poisoning

iatrogenic

murder

mining

nuclear industry

opioid deaths

police work

smoking tobacco

accidental falls (> 65 yrs old)

Activity	Number of Deaths in U.S. over the past 5 years
smoking	2,400,000
iatrogenic *(medicine gone wrong)*	950,000
alcohol	500,000
opioid deaths	400,000
automobile accidents	180,000
accidental falls (> 65 yrs old)	140,000
coal use (19% of U.S. power)	60,000
murder	80,000
food poisoning	25,000
construction	5,000
police work	800
mining	360
nuclear industry (19% of U.S. power)	1

Activity	Number of Deaths in U.S. Normalized to Sub-Population	Relative Danger Index
1) smoking (43.4 million smokers)	2,400,000	0.07059
2) alcohol (60 million impacted Americans)	500,000	0.00833
3) iatrogenic (180 million receive medical treatment)	950,000	0.00527
4) opioid deaths (100 million prescribed)	400,000	0.00400
5) accidental falls (46 million over 65 yrs)	140,000	0.00304
6) police work (720,000 police officers)	800	0.00111
7) mining (350,000 miners)	360	0.00103
8) automobile accidents (190 million drivers)	180,000	0.00094
9) construction (7.7 million workers)	5,000	0.00065
10) murder (300 million impacted)	80,000	0.00027
11) coal use (240 million impacted)	60,000	0.00025
12) food poisoning (304 million eat every day)	25,000	0.00008
13) nuclear industry (60 million)	1	0.0000001

Energy Source	Mortality Rate (deaths per trillion kWh)	
Coal – global average	100,000	(40% of global electricity)
Coal – China	170,000	(64% of China's electricity)
Coal – U.S.	10,000	(19% of U.S. electricity)
Oil	36,000	(36% of global energy, 8% of global electricity)
Natural Gas	4,000	(25% of global electricity)
Biofuel/Biomass	24,000	(21% of global energy)
Solar	440	(< 1% of global electricity)
Wind	150	(~ 2% of global electricity)
Hydro – global average	1,400	(15% of global electricity, 171,000 Banqiao dead)
Hydro – U.S.	0.1	(7% of U.S. electricity)
Nuclear – global average	40	(11% of global electricity w/Chernobyl&Fukushima)
Nuclear – U.S.	0.1	(20% of U.S. electricity)

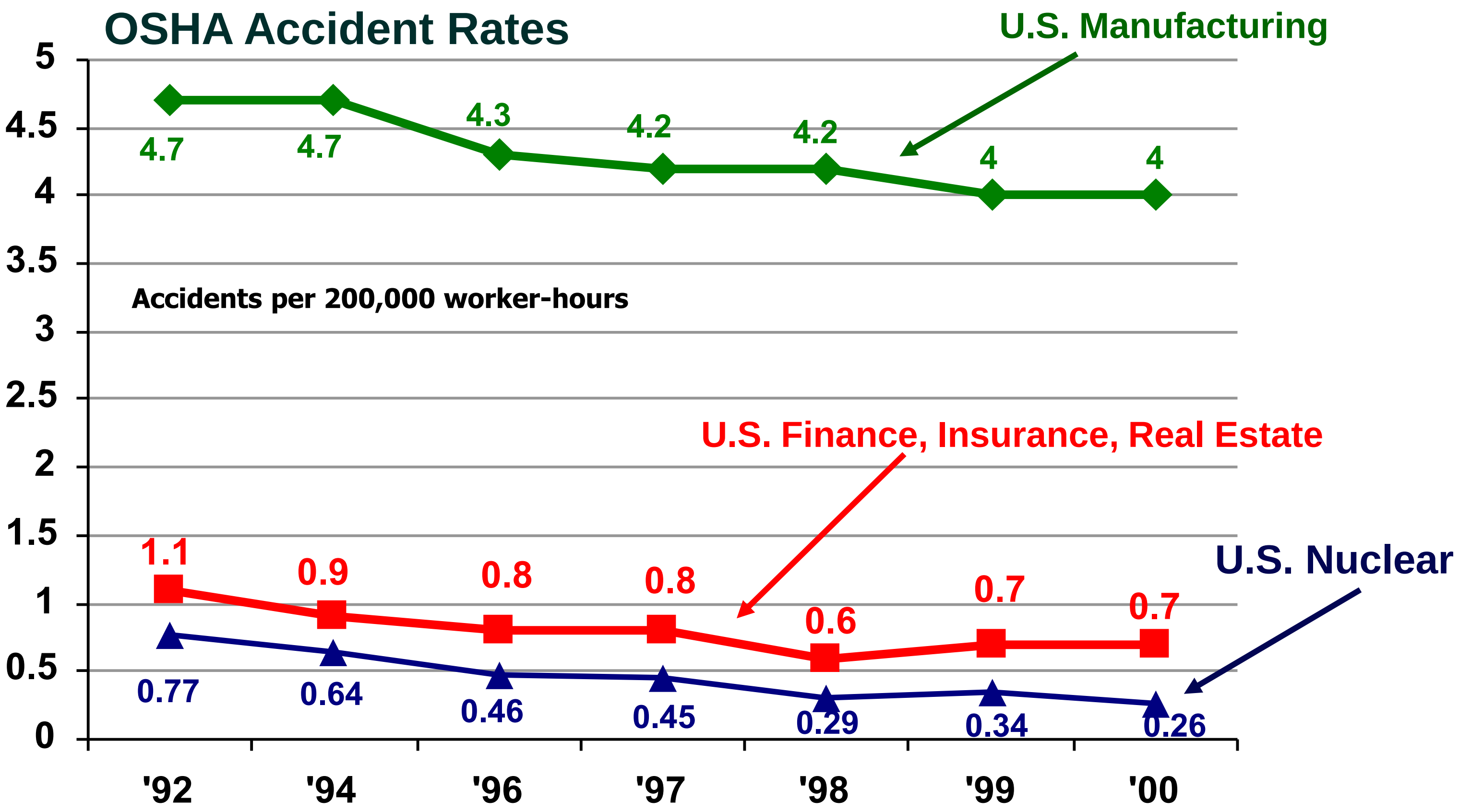
Sources –World Health Organization; CDC; 1970 – 2011

U.S. Government assigns a value of $7 million to a human life


Beijing, China > 80% coal

Beijing, China

Even non-lethal routine accidents are dramatically lower in the nuclear industry than in any other industry



Why is Everyone So Afraid of Nuclear Energy?

1) Incorrect, but intentional, association with nuclear weapons during the Cold War - 1945

2) Inaccurate and purposefully simplistic modeling of health effects of low radiation doses (LNT) - 1959

Because we told them to be!

3) Misunderstanding of the nature and amount of nuclear power waste - 1976
   - not much of it (<< 1 km^3 worldwide)
     - over 20,000 km^3 of direct solid coal waste
   - we know what to do with it

Unknown to most, transuranic waste (bomb waste) continued on into the salt as planned, leading to the Waste Isolation Pilot Plant.

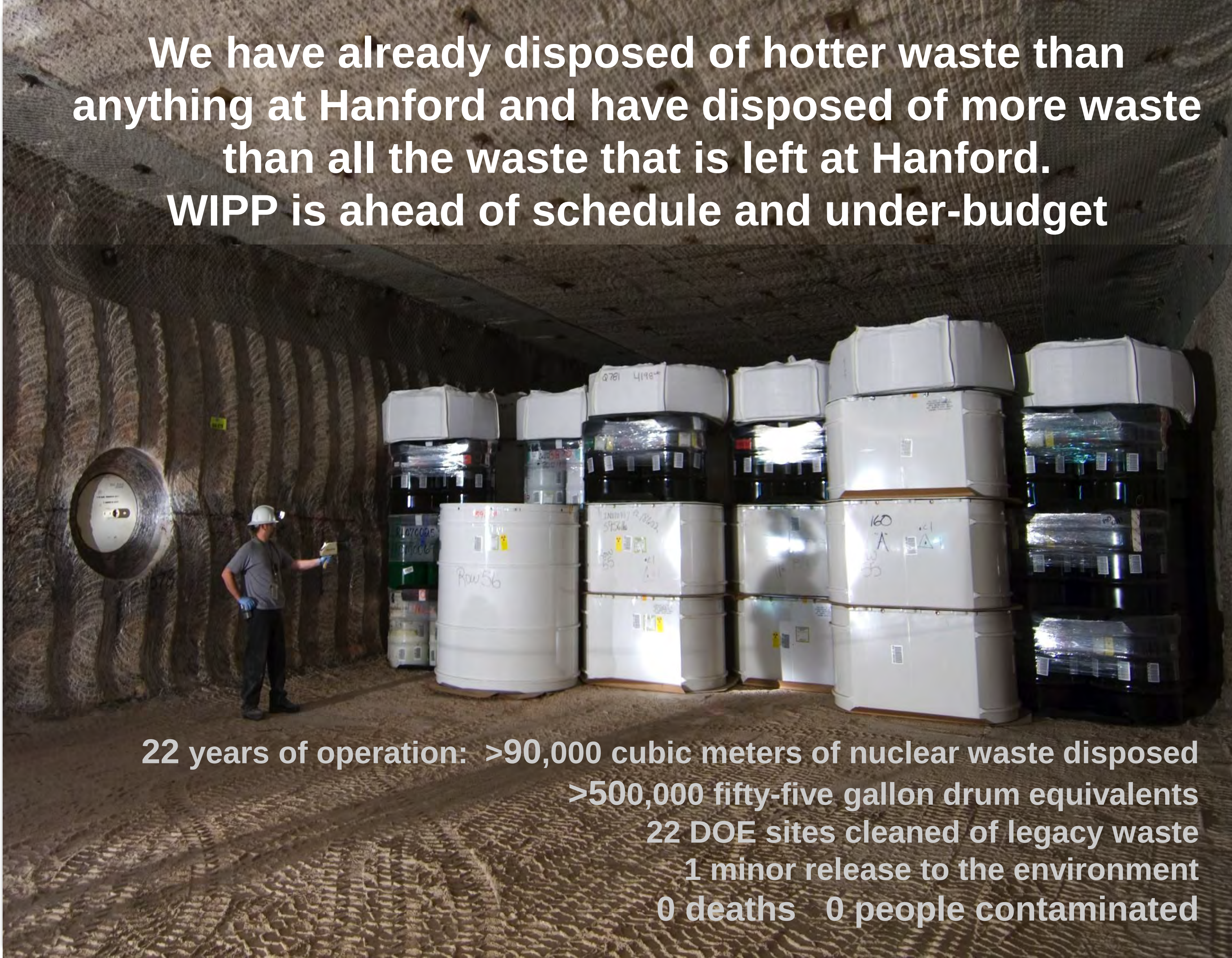
WIPP has shown that geologic disposal of nuclear waste is safe and cost-effective

Only defense-generated TRU waste *presently* permitted: 100 nCi/g to 23 Ci/L of alpha-emitting ^{239}Pu equivalents but WIPP was originally designed to handle all nuclear waste

Location of WIPP

16 miles^2 set aside in the 1992 Land Withdrawal Act - when WIPP is full, only 1/2 mile^2 will have been used

We have already disposed of hotter waste than anything at Hanford and have disposed of more waste than all the waste that is left at Hanford.
WIPP is ahead of schedule and under-budget



22 years of operation: >90,000 cubic meters of nuclear waste disposed
>500,000 fifty-five gallon drum equivalents
22 DOE sites cleaned of legacy waste
1 minor release to the environment
0 deaths   0 people contaminated

What Are Some Of The Costs Associated With Exceptionally-Low Radiation Limits?

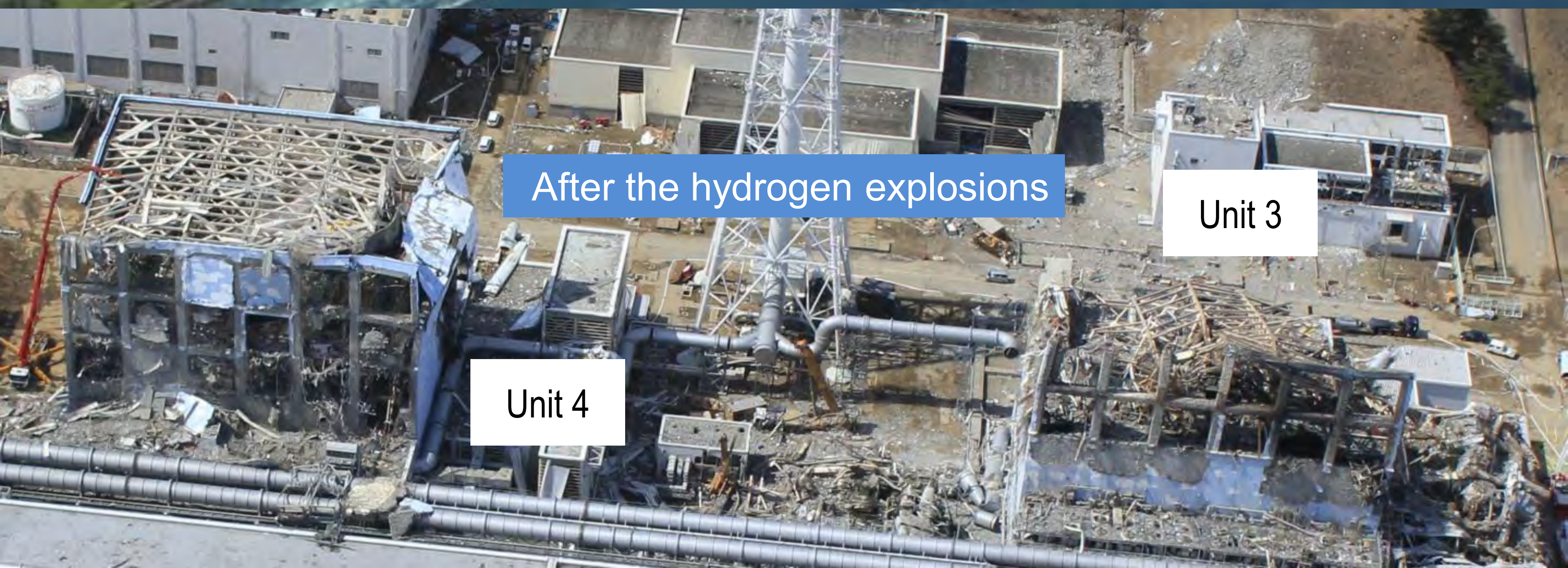
- Commercial Nuclear Industry – increases costs and increases fear of nuclear power in the public
- Environmental Concerns – fear prevents nuclear power from addressing climate change, human health and the environment
- Nuclear Waste – increases cost of repositories and prevents siting at most optimum geographic and geologic locations
- Medicine - causes radiation phobia that prevents certain medical diagnostics and treatments involving radiation
- Emergency Preparedness - after nuclear/radiological accidents, it causes extreme radiation phobia that has harmed or killed more people than the incident itself (Fukushima, Chernobyl, future dirty bomb attack) and that prevents reasonable emergency planning and effective responses to future disasters

What Are Some Of The Costs Associated With Exceptionally-Low Radiation Limits?

Causes extreme radiation phobia following nuclear or radiological incidents and accidents

- Loss of lives and severe injuries associated with frantic evacuations
- Increased suicides and psychosomatic disorders
  - Increased drug/alcohol/cigarette abuse
- Unnecessary permanent abandonment of properties for contamination well within the levels of natural Earth background
- Extreme costs of clean-up relative to actual risk


Unit 4
Unit 3
Unit 2
Unit 1


After the hydrogen explosions
Unit 3
Unit 4

What Are Some Of The Costs Associated With Emergency Preparedness and Execution?

Forced evacuation of 160,000 from provinces surrounding Fukushima resulted in about 1,600 deaths mainly of elderly and disabled. Most adults could have returned after 2 months (I-131)

According to the World Health Organization -

- no acute radiation injuries or deaths among workers or public from exposure to radiation resulting from Fukushima accident.
- the lifetime radiation-induced cancer risks are much smaller than the lifetime baseline cancer risks.
- For about 160 workers who received whole body effective doses over 100 mSv, expected increased cancer risks will not be detectable against the normal statistical fluctuations in cancer incidence for this population.

What Are Some Of The Costs Associated With Emergency Preparedness and Execution?

Over 50% of residents have returned, mostly older citizens, but the damage has been done – Government estimates the cost at over US$200 billion.

- at an average of $39,000 per capita GDP, revenue losses since 2011 exceed $40 billion for that cohort
- $12 billion in compensation paid to displaced residents
- Unnecessary shutting of all nuclear plants, most were not at risk
  - increased fossil fuel use by about 25%
  - increased energy prices by about 20%
  - lowered air quality (estimates of > 15,000 additional premature deaths from fossil fuel particulate emissions)

What Are Some Of The Costs Associated With Emergency Preparedness and Execution?

- Japan's Government foolishly *lowered* the radiation limits on food after Fukushima thinking that would appear as proactive

Regulatory Limits On Radioactivity In Foods (in Bq/kg)

Country	Milk	Foodstuffs	Babyfoods
Japan	*200*	*100*	*50*
U.S.	*1,200*	*1,200*	*1,200*
E.U.	*1,000*	*1,250*	*400*

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- destroyed much of the farming and fishing industry in northern Japan, mostly in areas unaffected by any radiation: >$10 billion losses

But with its own Chernobyl effect, the Fukushima disaster proved to make the fisheries off the coast a *de facto* marine protected area and fish stocks have tripled in these waters since 2011

What Are Some Of The Costs Associated With LNT for The Nuclear Industry?

A NPP spends about $20 million/yr in rad protection, waste handling and emergency prep, in large part to address the fear and regulatory requirements associated with LNT-based limits

- >$1 billion/year for the industry

Premature closings/planned shutdowns of nuclear reactors within the U.S. by 2025, with no safety or engineering reasons, just short-term profits, fear and politics, presently stands at 25, losing –

- 5 trillion kWhs of low-carbon power worth over $800 billion
- 600,000 man-years of direct labor worth $70 billion in salaries
- 2 million man-years of indirect jobs worth over $100 billion
- over $6 billion in local and state taxes
- 15,000 tons of SNF orphaned onsite

What Are Some Of The Costs Associated With LNT for Nuclear Waste Disposal?

Main effect has been to completely stop our nuclear waste disposal program because of fear, preventing science-based decisions:

- gave us glass over grout for HLW, even thought grout is better, and cheaper, for most HLW
  - the Hanford vitrification program, not including repository costs, will exceed $90 billion versus $30 billion for grouting and disposal elsewhere (not including repository costs), versus $30 billion for grouting in-place, even though there is no statistical difference in their risks.
- has made it impossible to site a repository and has prevented us from correctly reclassifying HLW at Hanford to TRU/LLW
- unnecessary engineered barriers at Yucca Mt, such as Ti-drip shields ($30 billion), increasing total disposal costs by over $300 billion

How Much Do We Consider the Value of Human Life to be?

What are the costs of regulating radiation doses to such low levels?

$7 million is the value of a human life according to EPA

$316,000 is the average paid out in health care over a life

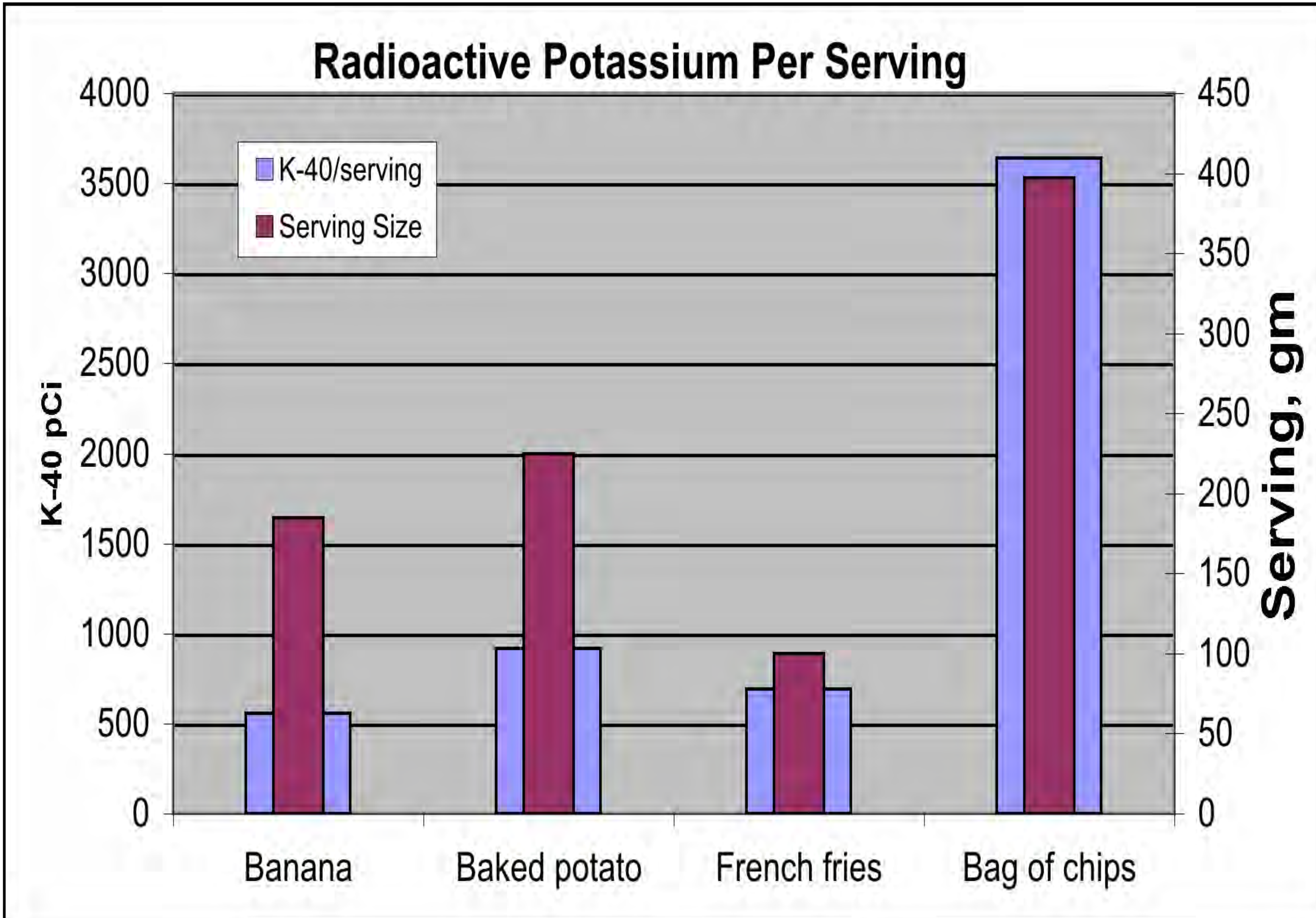
$129,000 is the average historic legal value of a human life

$12,420 (death benefit to families of deceased soldiers)

$45 million (value of a single healthy human life when chopped up and sold on the black market for body parts)

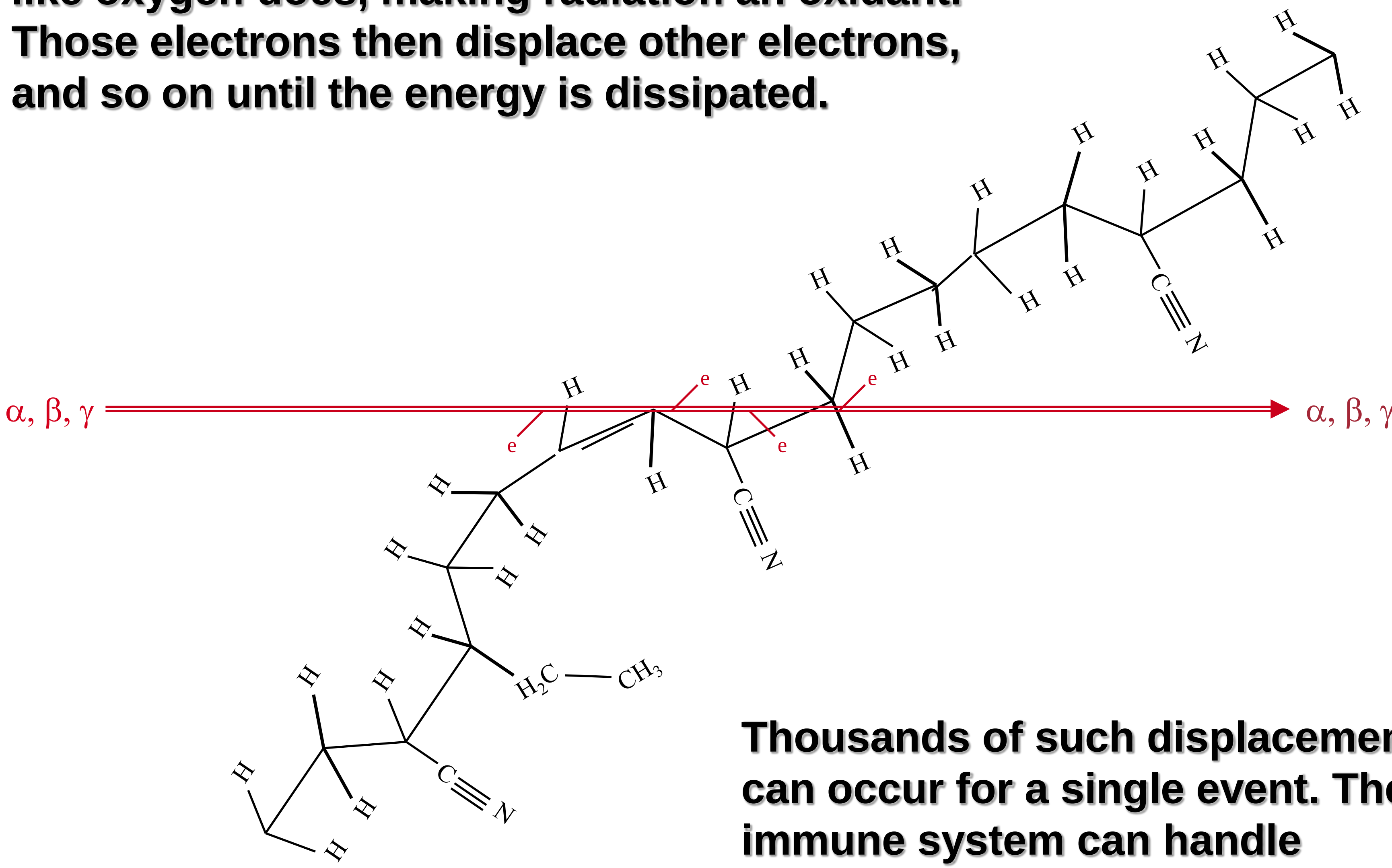
$2.5 billion per theoretical human life saved (LNT vs 0.1 Sv/yr)

$100 per human life saved by immunization against measles, diphtheria, and pertussis in developing countries



Source: Dan Yurman, 2011

Ionizing radiation causes damage primarily by displacing electrons in the target material, just like oxygen does, making radiation an oxidant. Those electrons then displace other electrons, and so on until the energy is dissipated.



Thousands of such displacements can occur for a single event. The immune system can handle millions of such events per day.

Separate from the currents and wave action, there is also the process of simple diffusion occurring in the seawater

$$x = (Dt)^{1/2}$$

where

x is distance in cm

D is the diffusion coefficient (cm^2/sec)

t is time (sec)

D for HTO = 2.3×10^{-5} cm^2/sec

D for ^3H = 9.2×10^{-5} cm^2/sec

Or about 15 ft/day for HTO and 60 ft/day for ^3H

Concentration decreases as $1/r^2$