Radiation Dose, Risk, and Cleanup Standards

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Disclosure

- Much of this presentation is generic, dealing with open-source, industry-standard material
- References to Santa Susana specific issues represent my views, opinions and analysis. They do not necessarily reflect the views and opinions of The Boeing Company or the Department of Energy
- The genesis of some of this presentation is in the paper "Nuclear Decommissioning at the Santa Susana Field Laboratory"

Radiation Dose, Risk and Cleanup Standards

- What are radiation cleanup standards?
- How have they changed over the years?
- Who or what has caused that change?
- Are we limiting dose or risk?
- What is “reasonable “ in “as low as reasonably achievable” (ALARA)?
- What is the linear no threshold (LNT) “theory” of radiation risk?
- What are the illogical consequences of LNT?
- What does one-in-a-million mean?
- How clean is clean?
- How low is low?
- How safe is safe?

Acronyms

Acronym	Meaning
ALARA	As Low As Reasonably Achievable
ANSI	American National Standards Institute
AOC	Administrative Order on Consent
ARS	Acute Radiation Syndrome
BEIR	Biological Effects of Ionizing Radiation
Bq	Bequerel, Unit of Activity
CalEPA	California Environmental Protection Agency
CBG	Committee to Bridge the Gap
CDHS	California Department of Health Services (succeeded by CDPH)
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie, Unit of Activity
Cs-137	Cesium-137
DCC	Dose Compliance Concentration
DNA	Deoxyribonucleic acid
DOD	Department of Defense

Acronyms

Acronym	Meaning
DOE	Department of Energy
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
DTSC	Department of Toxic Substances Control
EIR	(California) Environmental Impact Report
EIS	Environmental Impact Statement
EIS	(Federal) Environmental Impact Statement
EO	Executive Order
EPA	(Federal) Environmental Protection Agency
ETEC	Energy Technology Engineering Center
FAQs	Frequently Asked Questions
FGR	Federal Guidance for Radiation Protection
GAO	Government Accountability Office
H_0	Null Hypothesis
HPS	Health Physics Society
ICRP	International Commission on Radiological Protection
ING	Ingestion Exposure Pathway
INH	Inhalation Exposure Pathway
INL	Idaho National Laboratory

Acronyms

Acronym	Meaning
K-40	Potassium-40
LLRW	Low-level Radioactive Waste
LNT	Linear No Threshold
LTR	(NRC) License Termination Rule
LUT	Lookup Table
LUTV	Lookup Table Value
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MLE	Multiple Lines of Evidence
MOU	Memorandum of Understanding
mrem/y	millirem per year
NAS	National Academy of Sciences
NCP	National Contingency Plan
NCRP	National Council on Radiation Protection and Measurements
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NORM	Naturally Occurring Radioactive Material
NRC	(Federal) Nuclear Regulatory Commission
NUREG	(NRC) Nuclear Regulatory Guidance Document

Acronyms

Acronym	Meaning
OSWER	(EPA) Office of Solid Waste and Emergency Response
PAG	(EPA) Protective Action Guideline
PASSFL	Parents Against SSFL
pCi/g	picocurie per gram
PEIR	Programmatic EIR
PRG	Preliminary Remediation Goal
PSR-LA	Physicians for Social Responsibility - Los Angeles
Pu-239	Plutonium-239
Q&A	Questions and Answers
R	Roentgen, Unit of Exposure
R.G.	(NRC) Regulatory Guide
Ra-226	Radium-226
Rad	Unit of Absorbed Dose
RCRA	Resource Conservation and Recovery Act
Rem	Unit of Dose Equivalent
RESRAD	RESidual RADiation computer program
RfC	Reference Concentrations (for threshold chemicals)
RfD	Reference Doses (for threshold chemicals)

Acronyms

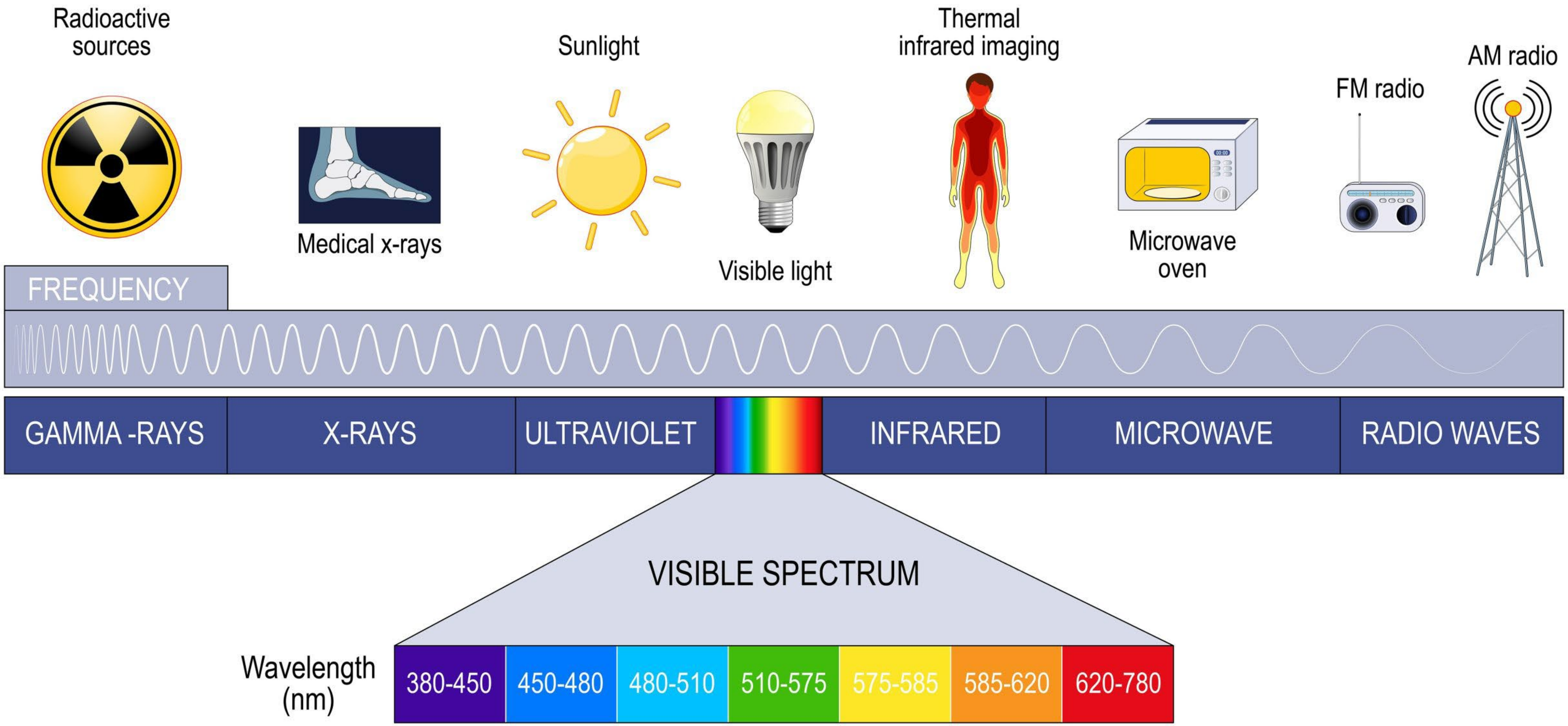
Acronym	Meaning
RHB	(California) Radiologic Health Branch
RSL	(EPA) Regional Screening Limits for Chemicals
SB	(California) Senate Bill
SEIS	Supplementary EIS
Sr-90	Strontium-90
SSFL	Santa Susana Field Laboratory
STD	Standard
Th-232	Thorium-232
U.S.	United States
U-238	Uranium-238
UMTRCA	Uranium Mill Tailings Radiation Control Act
USL	Upper Simultaneous Limit
UTL	Upper Tolerance Limit
VSL	Value of a Statistical Life

Agenda

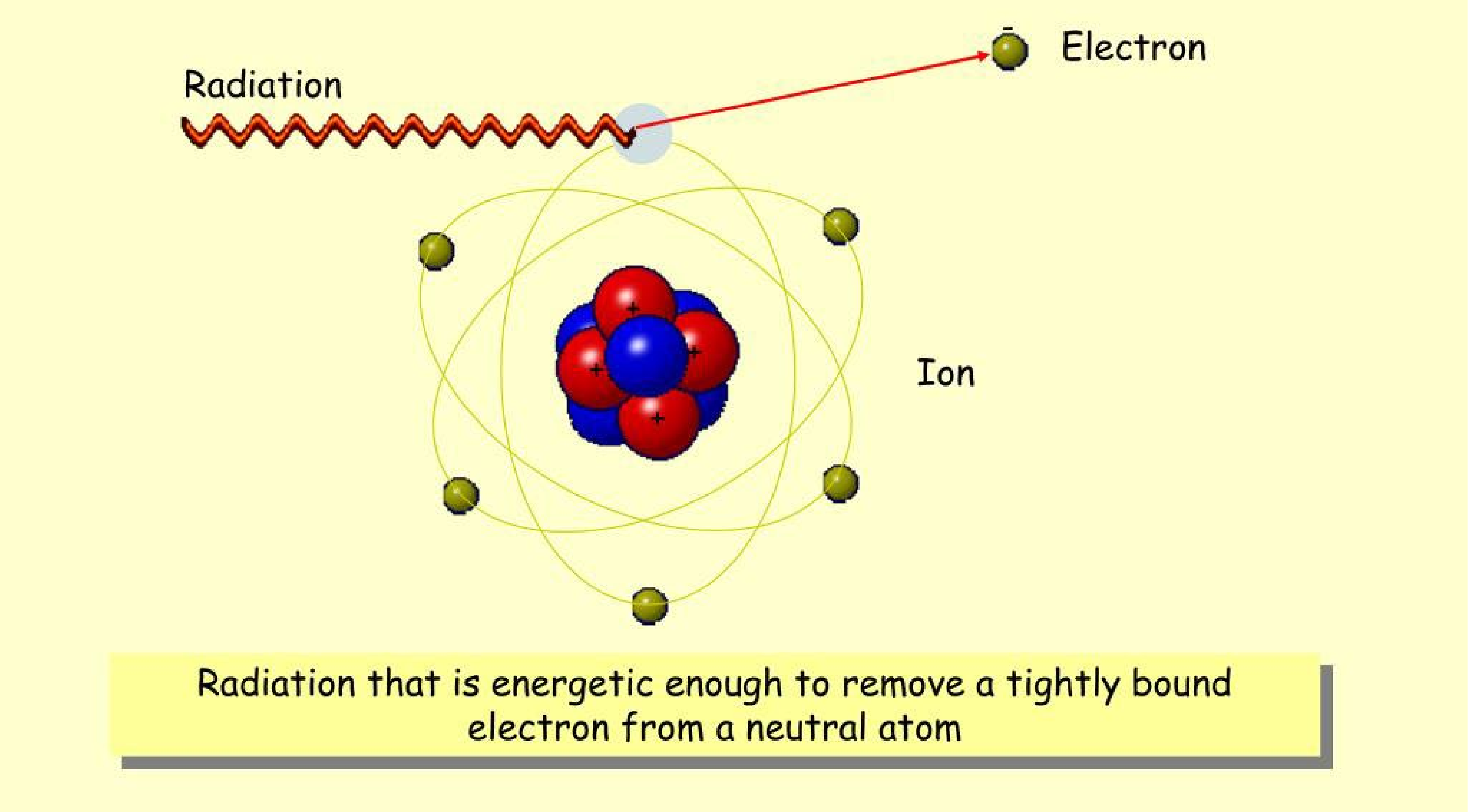
- Radiation 101 – Understanding Radiation
- Radiation Dose (Measured)
  - Background Radiation
  - Potassium-40
- Radiation Risk (Theoretical)
  - Linear No Threshold Model
- Radiation Cleanup Standards
  - Dose vs. Risk
- Legislation, Litigation and Consent Orders
- Problems Implementing Radiation Cleanup Goals
  - Land Use Scenarios
- Surface Contamination Standards
- EPA Radiological Survey of Area IV
- Recent Events related to Cleanup Standards
- To Superfund … or Not to Superfund

Radiation 101
Understanding Radiation

Electromagnetic Spectrum



Ionizing Radiation



Difference between Radioactivity and Radiation

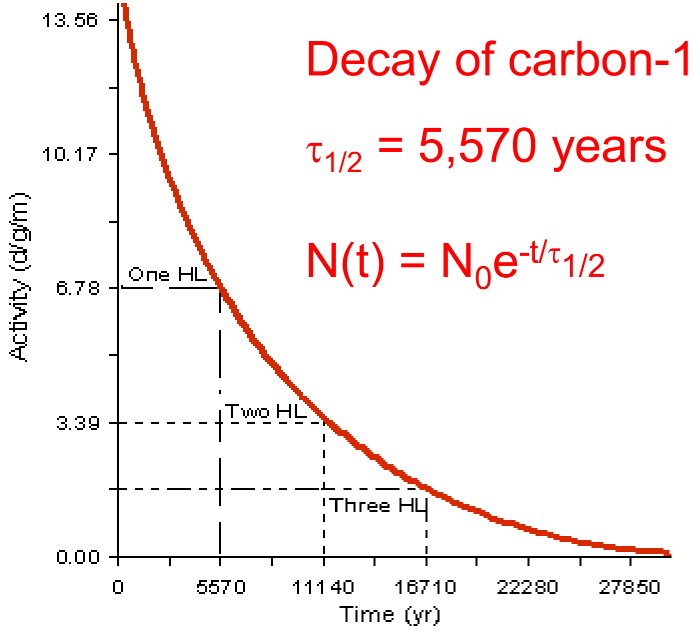
- Radioactivity is the physical action of an unstable nucleus of an atom emitting a particle (either alpha or beta) and often followed by a gamma ray
  - A radioactive atom is called a radionuclide or radioisotope
  - A collection of radioactive atoms is called radioactive material
  - Radioactivity is in general stationary (unless it becomes airborne or is in solution in surface water or groundwater)
- Radiation (ionizing) is the alphas, betas or gammas emitted from radionuclides
  - Gamma radiation travels outward from radioactive material. Its intensity decreases with the inverse of the square of the distance

Analogy of Lightbulb and Light

Radioactivity	Lightbulb
Quantity measured in curies or bequerels or disintegrations per minute (dpm)	Power measured in watts
Radiation (ionizing)	Visible Light
Intensity measured in roentgens or grays	Intensity measured in lumens
Dose or exposure (absorbed)	N/A
Measured in rem or sievert	

How Fast do Radioisotopes Decay?

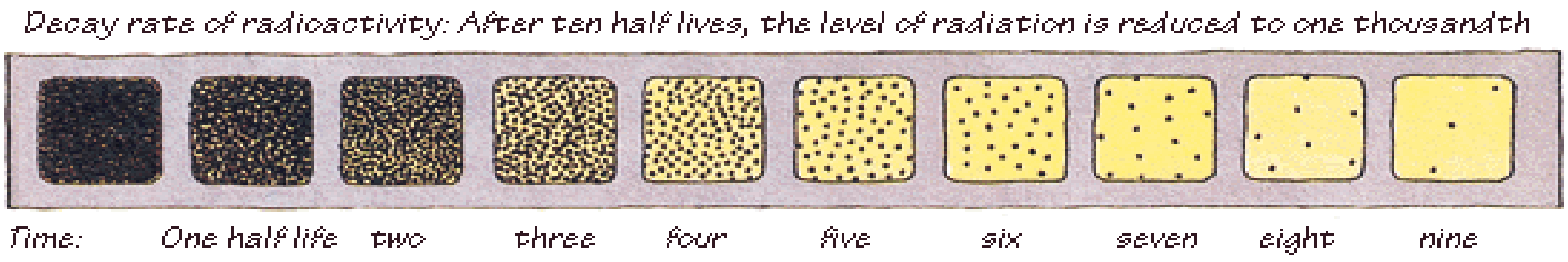
- The "half-life" describes how quickly radioisotopes decay away with time.
  - It is the time required for half of the unstable atoms to decay.
- Some Examples:
  - Some natural isotopes (like uranium, thorium and potassium-40) have half-lives that are billions of years,
  - Most medical isotopes (like Technicium-99m) last only a few hours to a few days



Decay of carbon-14

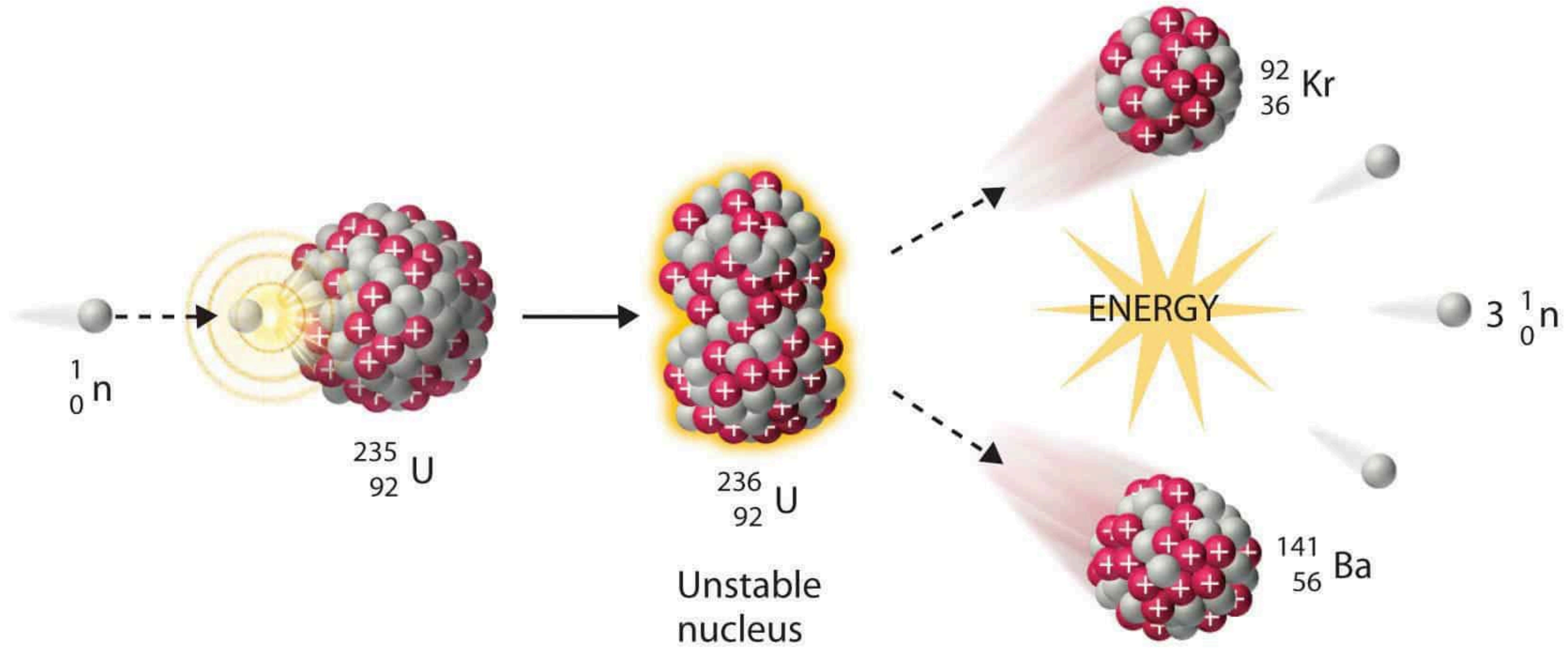
$\tau_{1/2}$ = 5,570 years

$N(t) = N_0 e^{-t/\tau_{1/2}}$

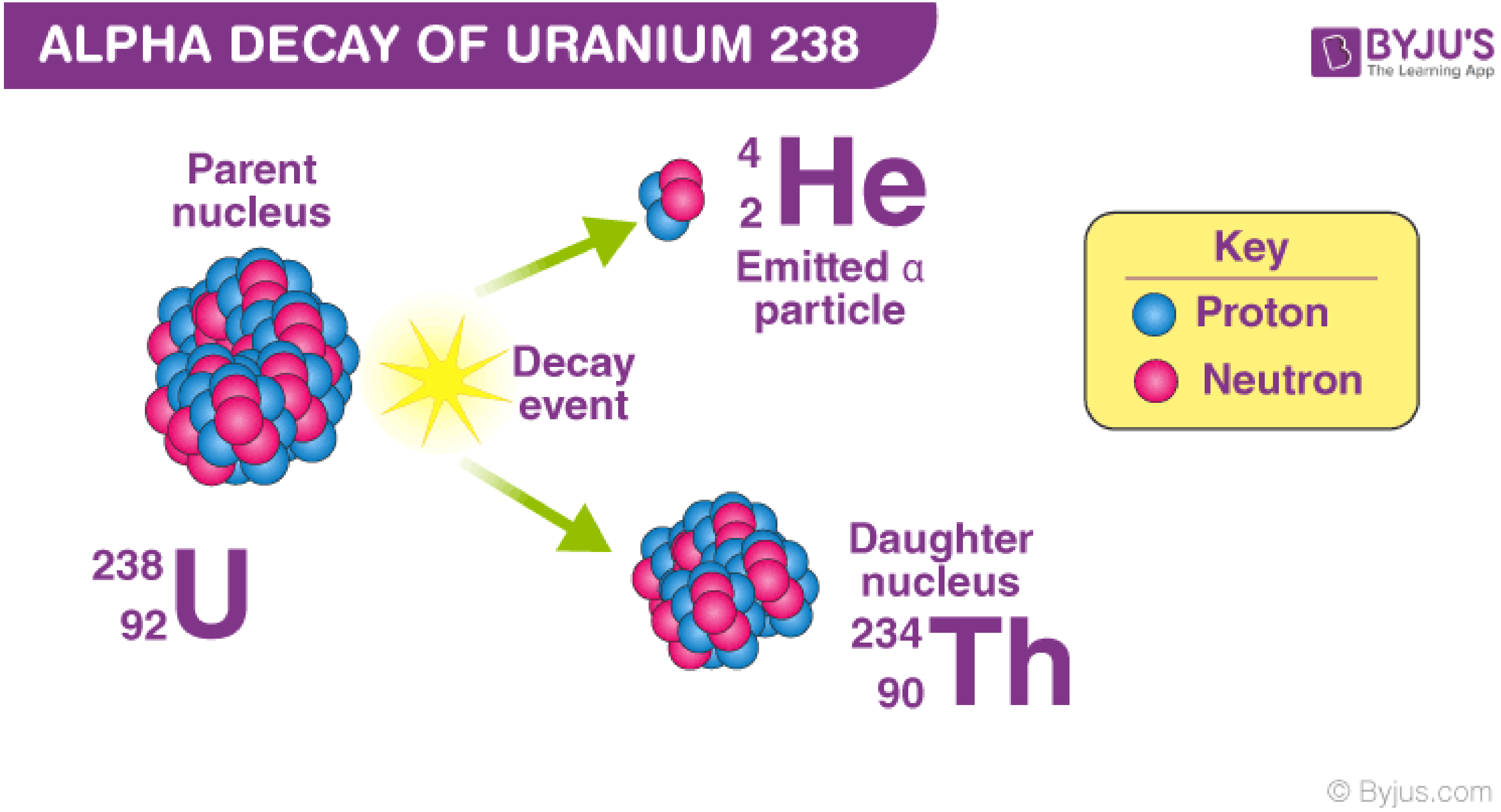


Radioisotopes decay at different rates, from fractions of a second to billions of years

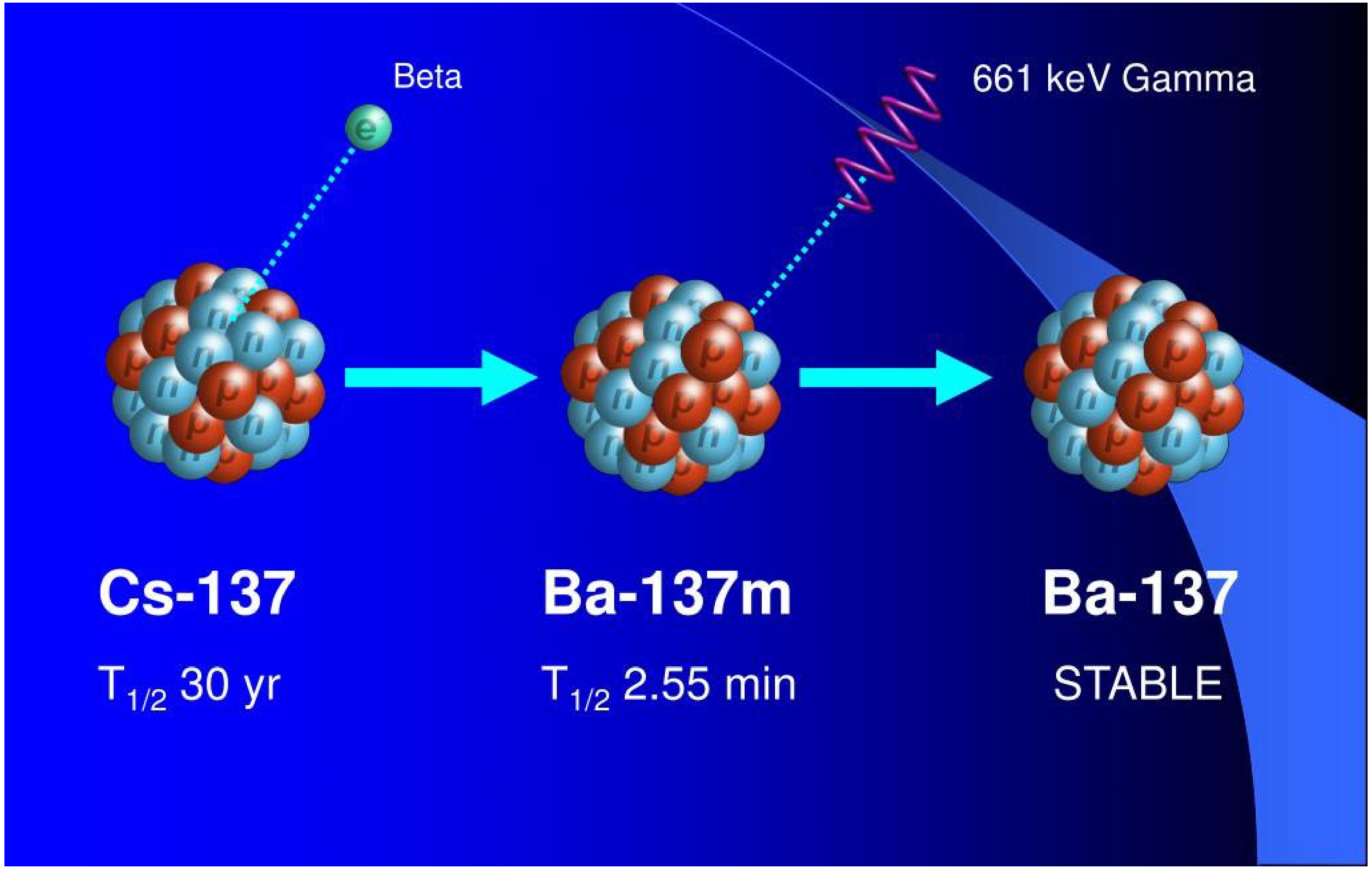
Uranium-235 Fission



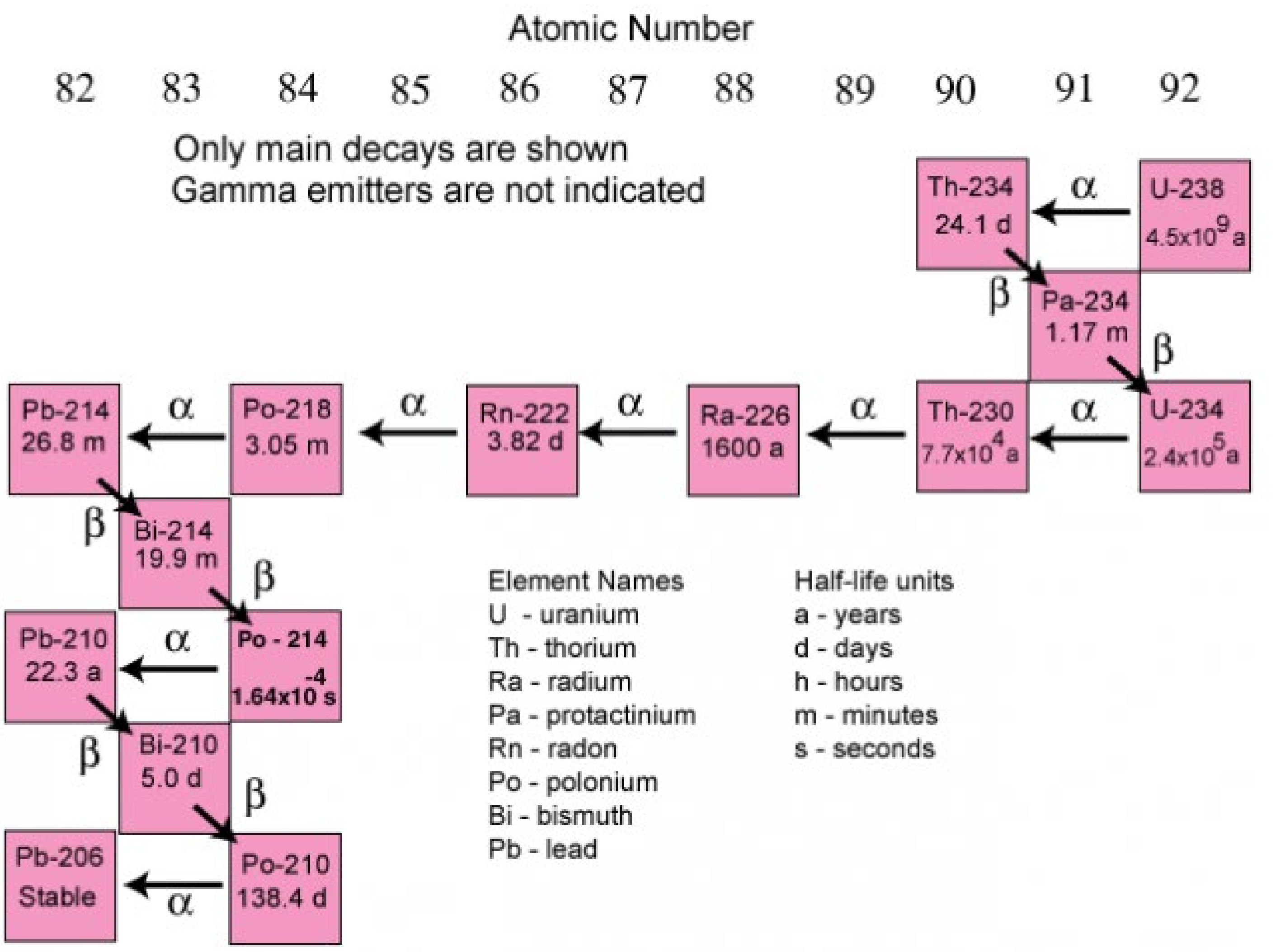
Alpha Decay of Uranium-238



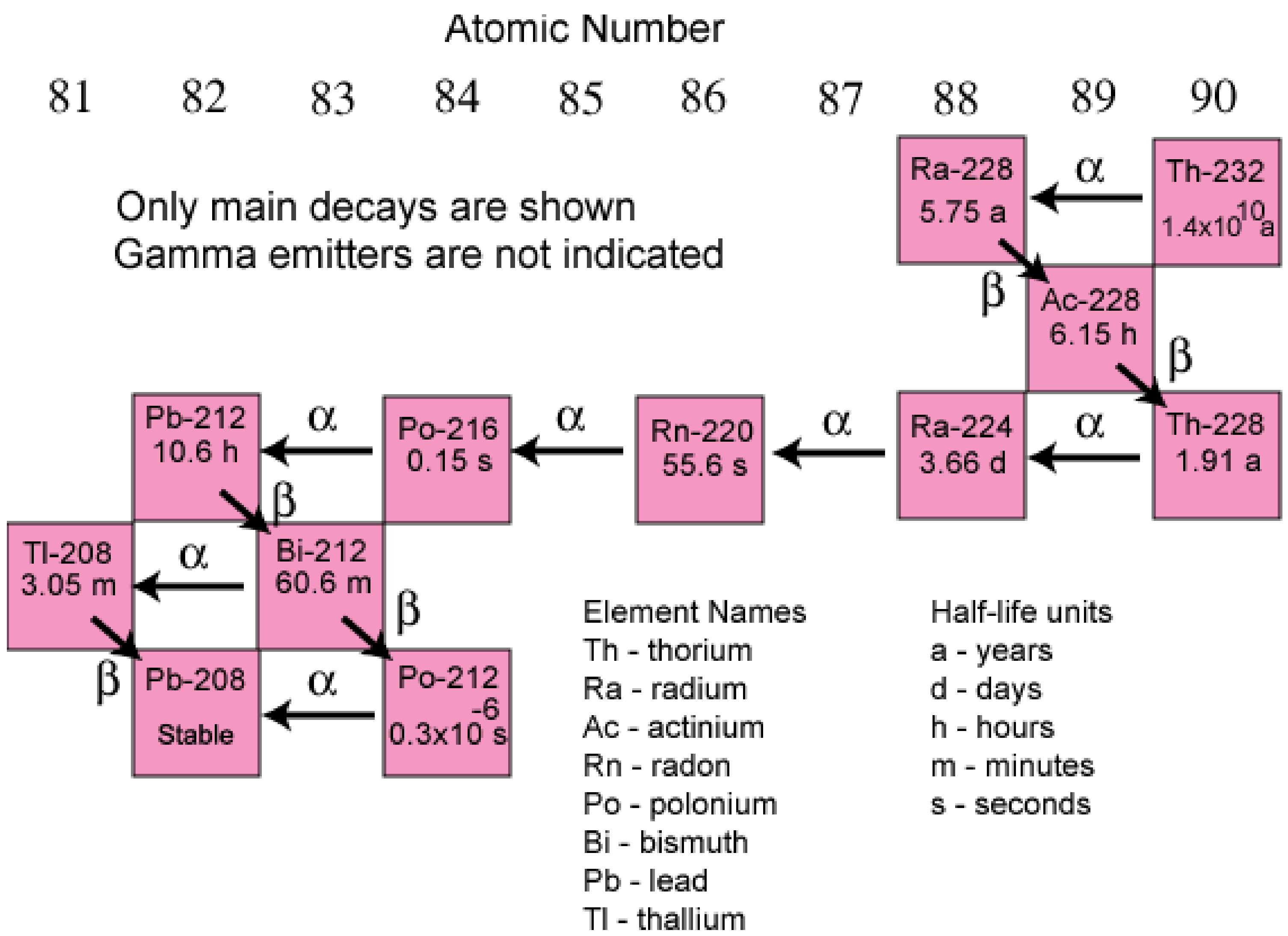
Beta-Gamma Decay of Cesium-137



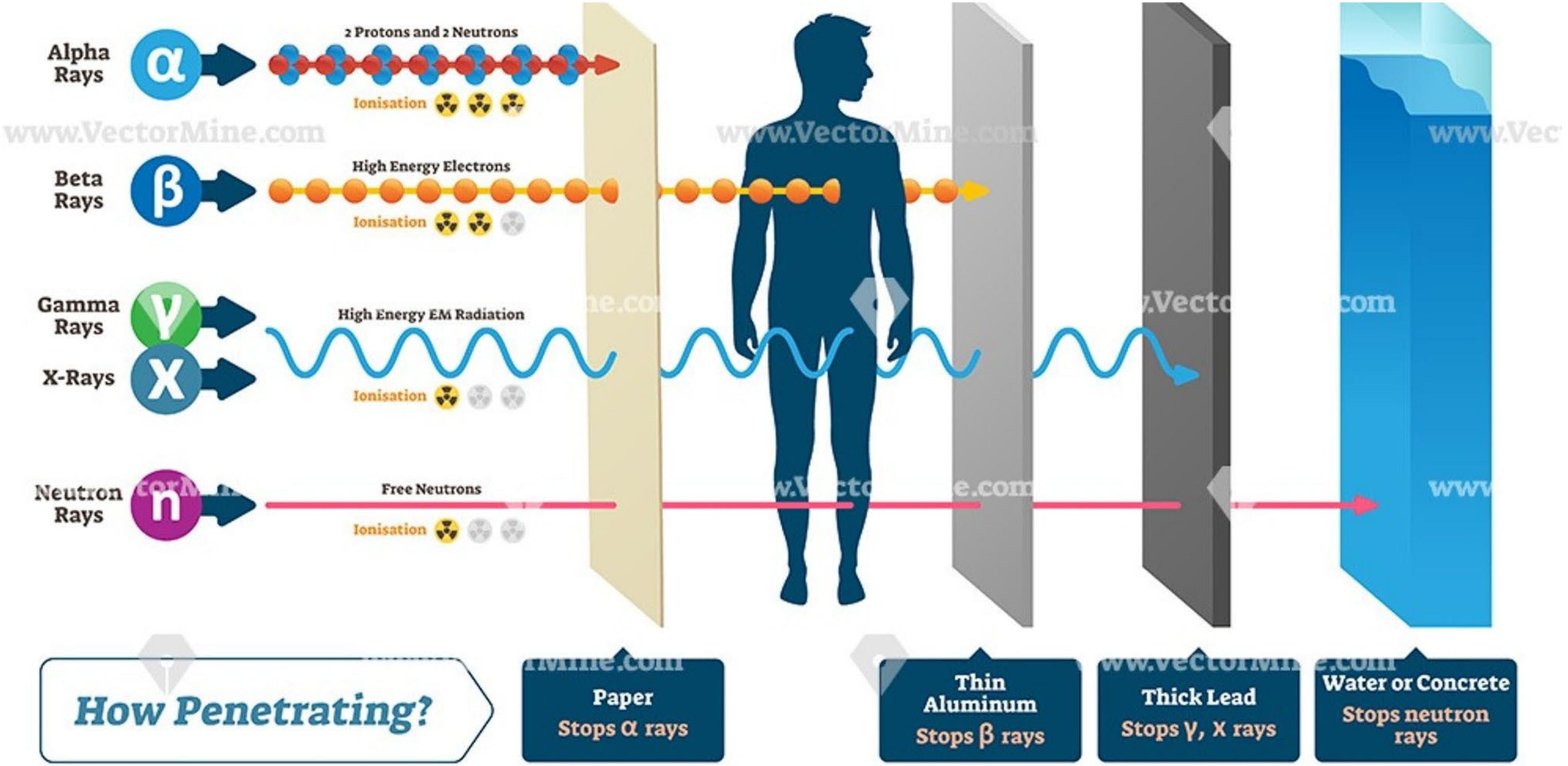
Uranium-238 Decay Series



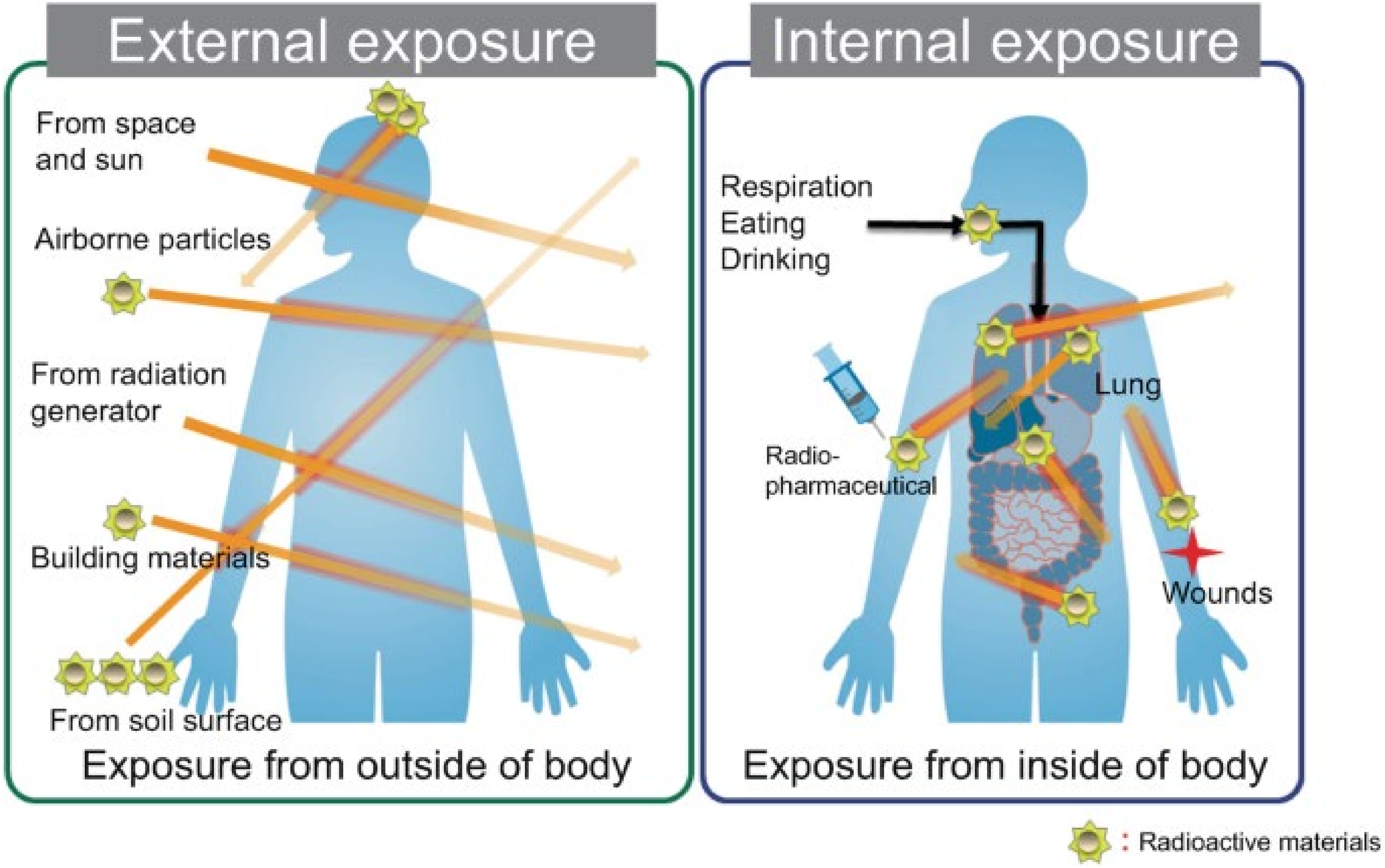
Thorium-232 Decay Series



Types of Ionizing Radiation



External vs Internal Exposure



Units

Property	Imperial/English (U.S. Standard)		Multiply by to derive	International (SI)	
	Name	Abbreviation		Name	Abbreviation
Activity	curie	Ci	37 billion	bequerel 1 decay per second	Bq
Exposure	roentgen	R	1/3876	coulomb/kilogram	C/kg
Absorbed dose	rad	rad	0.01	gray	Gy
Dose equivalent	rem	rem	0.01	sievert	Sv

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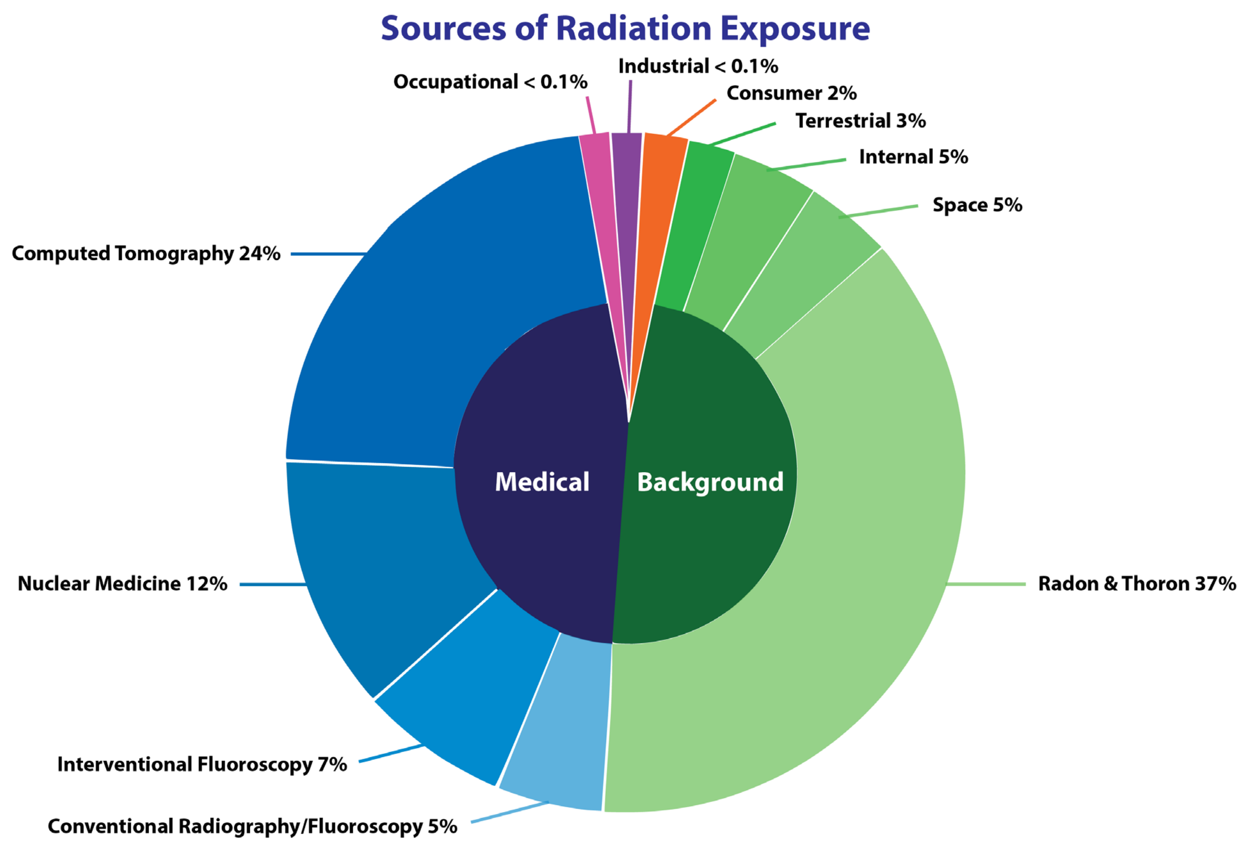
Radiation Dose

Background Radiation

- We are constantly exposed to low levels of radiation from outer space
- Low levels of naturally occurring radioactive material are in our environment, soil, rocks, water and the food we eat
- Some consumer products also contain small amounts of radioactive material

Background Radiation

Lesson 1



Average Annual Radiation Dose

Sources	Radon & Thoron	Computed Tomography	Nuclear Medicine	Interventional Fluoroscopy	Space	Conventional Radiography/ Fluoroscopy	Internal	Terrestrial	Consumer	Occupational	Industrial
Units mrem (United States) mSv (International)	228 mrem 2.28 mSv	147 mrem 1.47 mSv	77 mrem 0.77 mSv	43 mrem 0.43 mSv	33 mrem 0.33 mSv	33 mrem 0.33mSv	29 mrem 0.29 mSv	21 mrem 0.21 mSv	13 mrem 0.13 mSv	0.5 mrem 0.005 mSv	0.3 mrem 0.003 mSv

(Source: National Council on Radiation Protection & Measurements, Report No. 160)

Background and Lifestyle Radiation Sources

Source	Dose (mrem/y)	
Indoor radon (Rn-220, Rn-222)	228	
Cosmic rays (Denver)	80	
Cosmic rays (Sea level)	30	
Human body from food we eat (K-40)	29	
Soil & rocks (K-40, uranium, thorium & progeny)	21	
Weapons test fallout (Cs-137, Sr-90, Pu-239, etc.)	1	
Living within 50 miles of a coal fired power plant	0.03	
Living within 50 miles of a nuclear power plant	0.009	
Total	309	
Smoking one pack of cigarettes per day for one year	0.5 x 365 = 183	
One round trip plane ride from LA to NY per year	5	

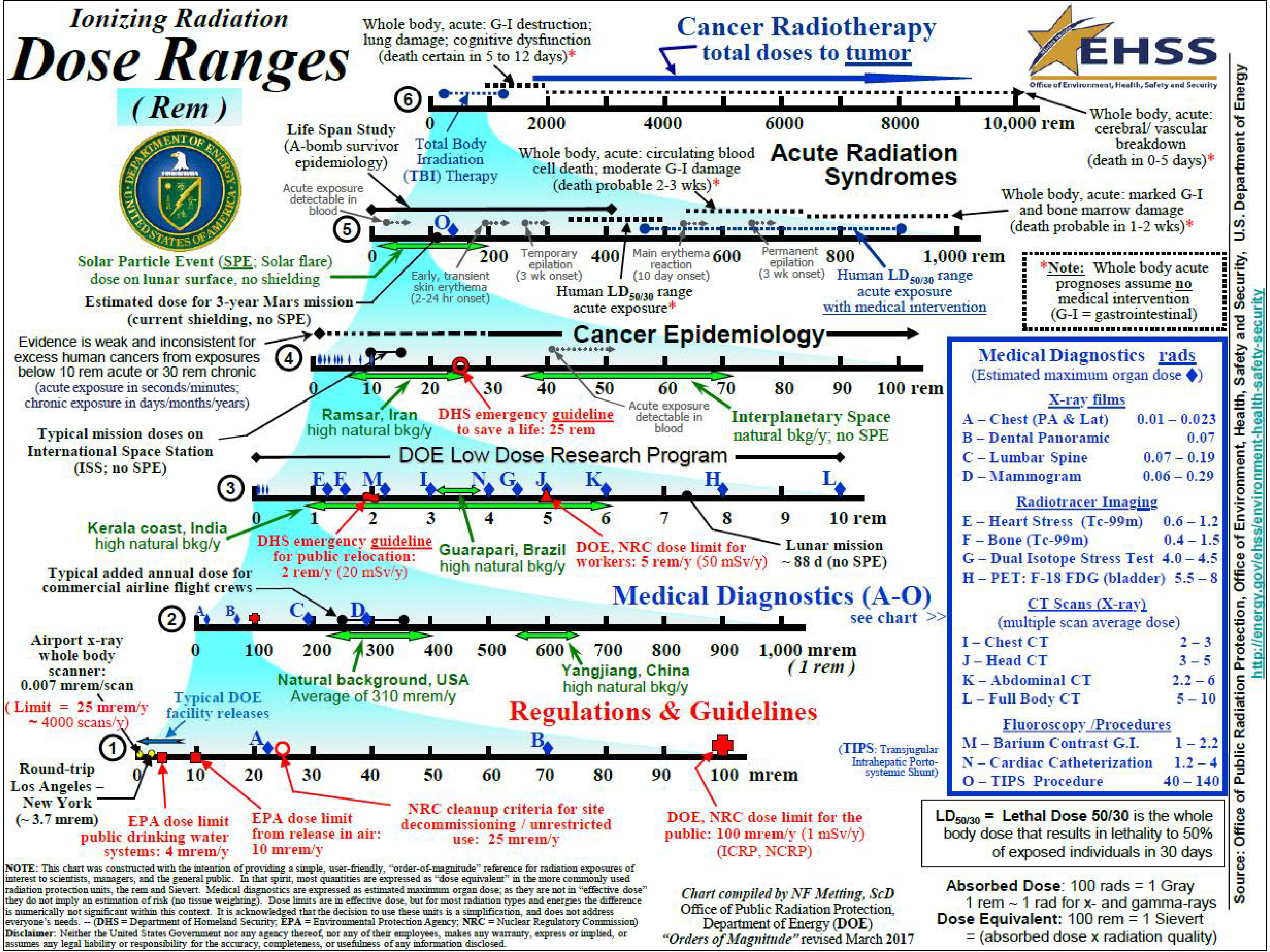
EPA, Radiation Sources and Doses

Potassium and Potassium-40

- Natural potassium (K-nat) contains 0.0117% of radioactive K-40
- K-40 half-life = 1.248 billion years
- K-40 specific activity = 7,100,000 pCi/g
- K-nat specific activity = 831 pCi/g
- Potassium chloride (KCl) is a substitute condiment for sodium chloride (NaCl) and can be bought in the supermarket
- KCl specific activity is 436 pCi/g
- Human body contains 1.5 pCi/g of K-40
- Banana contains 2.5 pCi/g of K-40
- AMA recommended daily allowance of potassium = 3.5 g of K = 2,900 pCi K-40
- EPA SSFL background threshold value (BTV) for uncontaminated soil is 30.5 pCi/g
- Rutherford, Potassium-40 Facts and Figures, August 2002

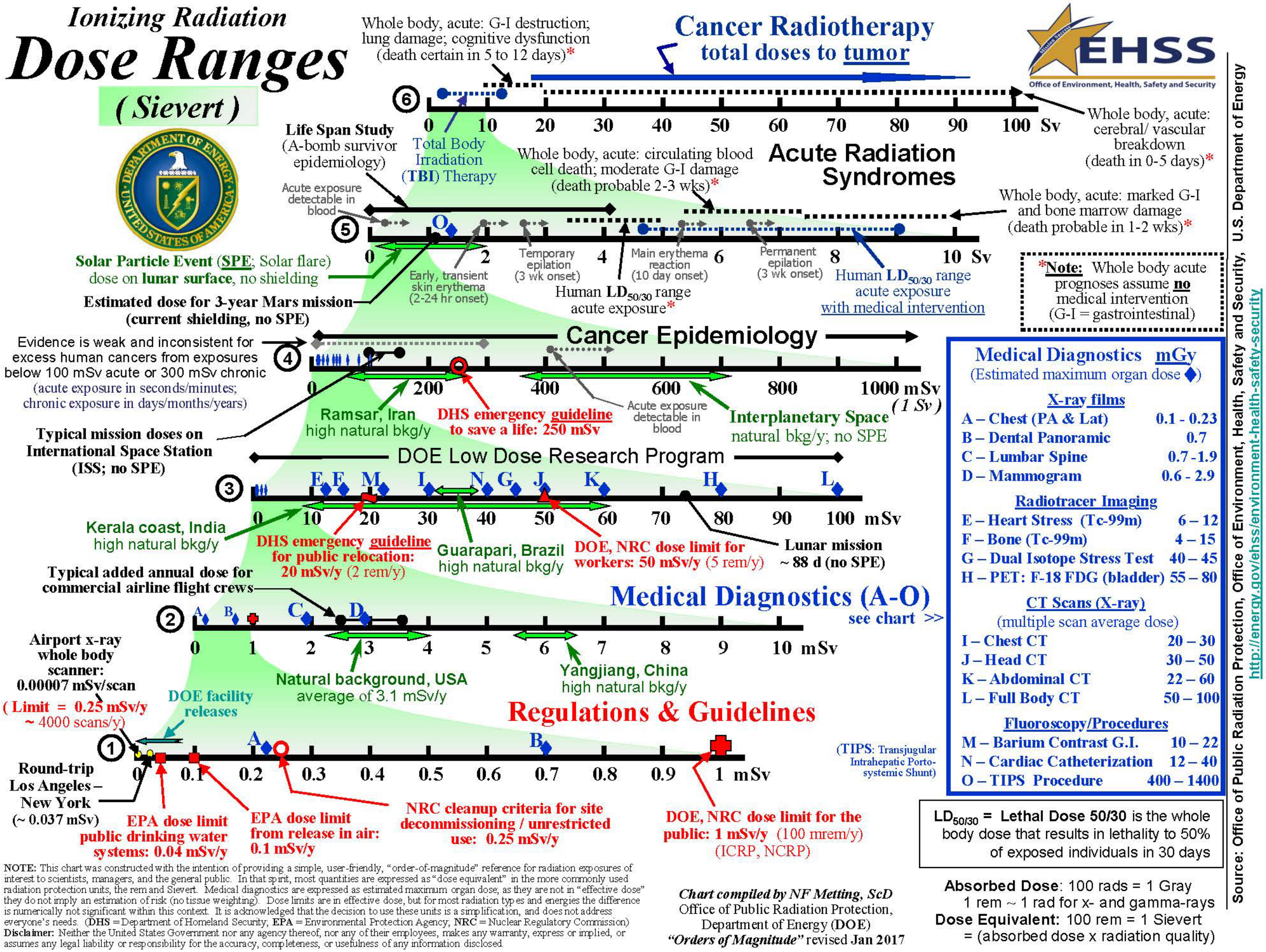
Potassium-40 in Food

- Bananas are reputed to be a good source of potassium and contain 2.5 pCi/g of K-40
- However, many foods are a better source of potassium and therefore contain higher levels of potassium-40
  - Dried fruits contain up to 10 pCi/g (dried apricots)
  - Cereals contain up to 8.8 pCi/g (wheat germ)
  - Potatoes contain 4.3 pCi/g
  - Cod contains 4.3 pCi/g
- Rutherford, Potassium-40 in Food, August 9, 2002



Ionizing Radiation
Dose Ranges
(Rem)
EHSS
Office of Environment, Health, Safety and Security
Cancer Radiotherapy
total doses to tumor
Whole body, acute: G-I destruction; lung damage; cognitive dysfunction (death certain in 5 to 12 days)*
6
0 2000 4000 6000 8000 10,000 rem
Whole body, acute: cerebral/ vascular breakdown (death in 0-5 days)*
Life Span Study (A-bomb survivor epidemiology)
Total Body Irradiation (TBI) Therapy
Whole body, acute: circulating blood cell death; moderate G-I damage (death probable 2-3 wks)*
Acute Radiation Syndromes
Whole body, acute: marked G-I and bone marrow damage (death probable in 1-2 wks)*
Acute exposure detectable in blood
5
O
0 200 400 600 800 1,000 rem
Early, transient skin erythema (2-24 hr onset)
Temporary epilation (3 wk onset)
Main erythema reaction (10 day onset)
Permanent epilation (3 wk onset)
Human LD50/30 range acute exposure*
Human LD50/30 range acute exposure with medical intervention
*Note: Whole body acute prognoses assume no medical intervention (G-I = gastrointestinal)
Solar Particle Event (SPE; Solar flare) dose on lunar surface, no shielding
Estimated dose for 3-year Mars mission (current shielding, no SPE)
Cancer Epidemiology
Evidence is weak and inconsistent for excess human cancers from exposures below 10 rem acute or 30 rem chronic (acute exposure in seconds/minutes; chronic exposure in days/months/years)
4
0 10 20 30 40 50 60 70 80 90 100 rem
Ramsar, Iran high natural bkg/y
DHS emergency guideline to save a life: 25 rem
Acute exposure detectable in blood
Interplanetary Space natural bkg/y; no SPE
Typical mission doses on International Space Station (ISS; no SPE)
DOE Low Dose Research Program
3
E F M I N G J K H L
0 1 2 3 4 5 6 7 8 9 10 rem
Kerala coast, India high natural bkg/y
DHS emergency guideline for public relocation: 2 rem/y (20 mSv/y)
Guarapari, Brazil high natural bkg/y
DOE, NRC dose limit for workers: 5 rem/y (50 mSv/y)
Lunar mission ~ 88 d (no SPE)
Typical added annual dose for commercial airline flight crews
Medical Diagnostics (A-O)
see chart >>
2
A B C D
0 100 200 300 400 500 600 700 800 900 1,000 mrem (1 rem)
Airport x-ray whole body scanner: 0.007 mrem/scan (Limit = 25 mrem/y ~ 4000 scans/y)
Typical DOE facility releases
Natural background, USA Average of 310 mrem/y
Yangjiang, China high natural bkg/y
Regulations & Guidelines
1
A B
0 10 20 30 40 50 60 70 80 90 100 mrem
Round-trip Los Angeles – New York (~ 3.7 mrem)
EPA dose limit public drinking water systems: 4 mrem/y
EPA dose limit from release in air: 10 mrem/y
NRC cleanup criteria for site decommissioning / unrestricted use: 25 mrem/y
DOE, NRC dose limit for the public: 100 mrem/y (1 mSv/y) (ICRP, NCRP)
(TIPS: Transjugular Intrahepatic Porto-systemic Shunt)
Medical Diagnostics rads
(Estimated maximum organ dose ◆)
X-ray films
A – Chest (PA & Lat) 0.01 – 0.023
B – Dental Panoramic 0.07
C – Lumbar Spine 0.07 – 0.19
D – Mammogram 0.06 – 0.29
Radiotracer Imaging
E – Heart Stress (Tc-99m) 0.6 – 1.2
F – Bone (Tc-99m) 0.4 – 1.5
G – Dual Isotope Stress Test 4.0 – 4.5
H – PET: F-18 FDG (bladder) 5.5 – 8
CT Scans (X-ray)
(multiple scan average dose)
I – Chest CT 2 – 3
J – Head CT 3 – 5
K – Abdominal CT 2.2 – 6
L – Full Body CT 5 – 10
Fluoroscopy /Procedures
M – Barium Contrast G.I. 1 – 2.2
N – Cardiac Catheterization 1.2 – 4
O – TIPS Procedure 40 – 140
LD50/30 = Lethal Dose 50/30 is the whole body dose that results in lethality to 50% of exposed individuals in 30 days
Absorbed Dose: 100 rads = 1 Gray
1 rem ~ 1 rad for x- and gamma-rays
Dose Equivalent: 100 rem = 1 Sievert
= (absorbed dose x radiation quality)
NOTE: This chart was constructed with the intention of providing a simple, user-friendly, "order-of-magnitude" reference for radiation exposures of interest to scientists, managers, and the general public. In that spirit, most quantities are expressed as "dose equivalent" in the more commonly used radiation protection units, the rem and Sievert. Medical diagnostics are expressed as estimated maximum organ dose; as they are not in "effective dose" they do not imply an estimation of risk (no tissue weighting). Dose limits are in effective dose, but for most radiation types and energies the difference is numerically not significant within this context. It is acknowledged that the decision to use these units is a simplification, and does not address everyone's needs. -- (DHS = Department of Homeland Security; EPA = Environmental Protection Agency; NRC = Nuclear Regulatory Commission)
Disclaimer: Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed.
Chart compiled by NF Metting, ScD
Office of Public Radiation Protection, Department of Energy (DOE)
"Orders of Magnitude" revised March 2017
Source: Office of Public Radiation Protection, Office of Environment, Health, Safety and Security, U.S. Department of Energy
http://energy.gov/ehss/environment-health-safety-security

Draft May 1



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A B C D
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DOE facility releases
Natural background, USA average of 3.1 mSv/y
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A B
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 mSv
Round-trip Los Angeles – New York (~ 0.037 mSv)
EPA dose limit public drinking water systems: 0.04 mSv/y
EPA dose limit from release in air: 0.1 mSv/y
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Chart compiled by NF Metting, ScD
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"Orders of Magnitude" revised Jan 2017
Source: Office of Public Radiation Protection, Office of Environment, Health, Safety and Security, U.S. Department of Energy
http://energy.gov/ehss/environment-health-safety-security

Draft May 1

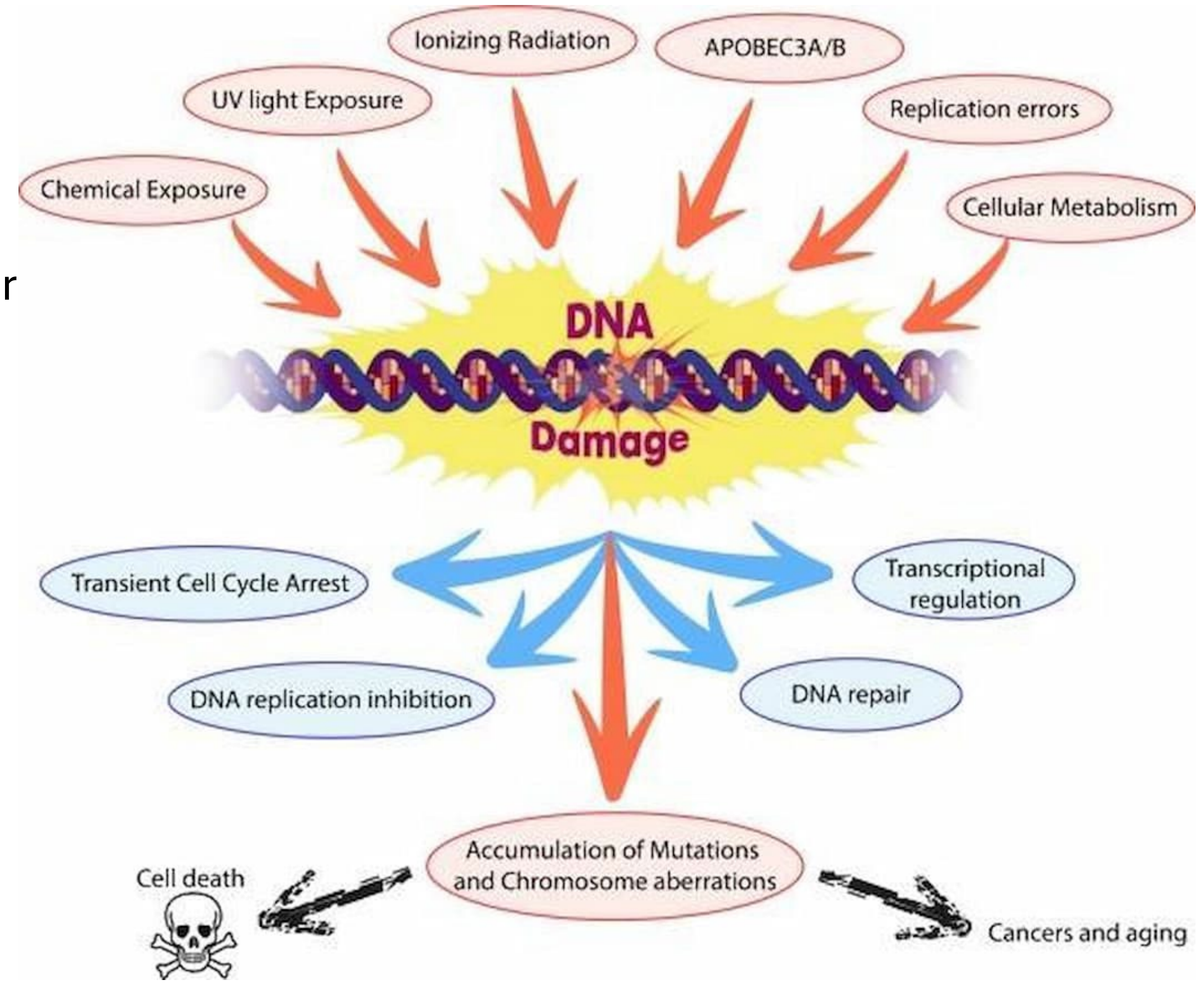
Radiation Health Effects

Somatic Health Effects from High Doses
Acute Radiation Syndrome (ARS)

Dose Range (Rem)	
70 to 200	Nausea, vomiting, drop in white blood cells, infection risk
200 to 600	More severe marrow disfunction, bleeding, infection, possible death without treatment
600 to 1,000	Severe nausea, vomiting, diarrhea, dehydration, electrolytic imbalance, high fatality
1,000 to 2,000	Rapid onset of confusion, ataxia, shock, survival unlikely
2,000 to 5,000	Collapse of circulatory and central nervous system function, death within hours to days
Above 5,000	Immediate incapacitation, death within hours

Stochastic (Probabilistic) Cancer Effects from Low Doses and Dose Rates

- Our body has ~ 60 trillion cells
- As a result of normal metabolic bodily processes, each cell suffers
  - 4 to 40 million single strand DNA each year
  - 4 to 20 thousand double strand breaks each year
  - Majority are repaired
  - Some cells die
  - Small number of cells mutate, malfunction (cancer)
- Background radiation levels cause only a very small fraction of these breaks each year
  - Single strand breaks - 2 to 3 per cell per year
  - Double strand breaks - 0.05 to 0.1 per cell per year



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    - Dose vs. Risk
- Legislation, Litigation and Consent Orders
- Problems Implementing Radiation Cleanup Goals
    - Land Use Scenarios
- Surface Contamination Standards
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Radiation Risk

All subsequent references to “radiation risk” refers to the “theoretical” cancer incidence risk calculated using the linear no threshold (LNT) model of radiation risk.

LNT posits that the smallest of exposures, well below natural background levels, will cause an incremental increase in cancer incidence and fatal cancers.

Problems with Communicating Risk to the Public

- Engineers and scientists communicate risk with the language of numbers, probability … the public deals with risk emotionally
- Involuntary vs. voluntary
- Exotic vs. everyday
- Government and big business are not credible
- Nuclear power is associated with nuclear weapons
- Public dislikes cost-benefit analyses that includes “cost of a human life”
- The “outrage” factor (radiation, cancer, babies)
- Use of hyperbole (enormous, huge, astronomical, widespread, witches brew)
- Logarithmic vs. linear scales of safety
- Validity of LNT at low doses
- Inappropriate use of collective dose impacts

Background and Lifestyle Radiation Risks

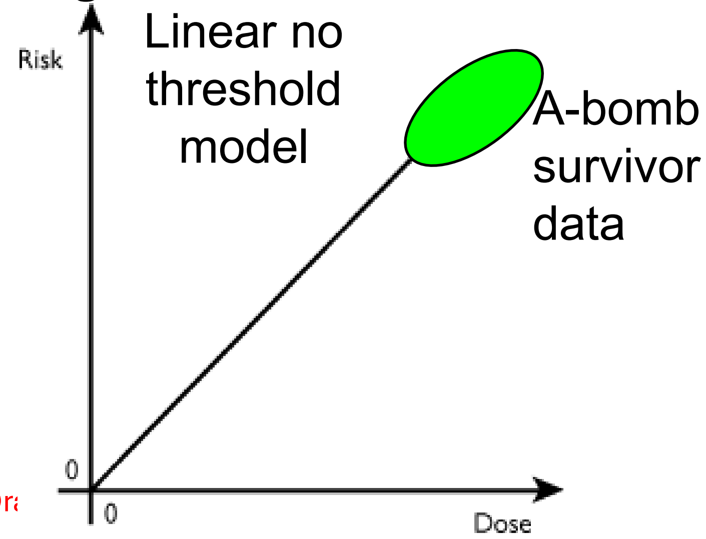
Source	Dose (mrem/y)*	80-year Lifetime Risk**
Indoor radon (Rn-220, Rn-222)	228	$18{,}240 \times 10^{-6}$
Cosmic rays (Denver)	80	$6{,}400 \times 10^{-6}$
Cosmic rays (Sea level)	30	$2{,}400 \times 10^{-6}$
Human body from food we eat (K-40)	29	$2{,}320 \times 10^{-6}$
Soil & rocks (K-40, uranium, thorium & progeny)	21	$1{,}680 \times 10^{-6}$
Weapons test fallout (Cs-137, Sr-90, Pu-239, etc.)	1	80×10^{-6}
Living within 50 miles of a coal fired power plant	0.03	2.4×10^{-6}
Living within 50 miles of a nuclear power plant	0.009	0.72×10^{-6}
Total	309	$24{,}723 \times 10^{-6} = 2.5\%$
Smoking one pack of cigarettes per day for one year	0.5 x 365 = 183	
One round trip plane ride from LA to NY	5	

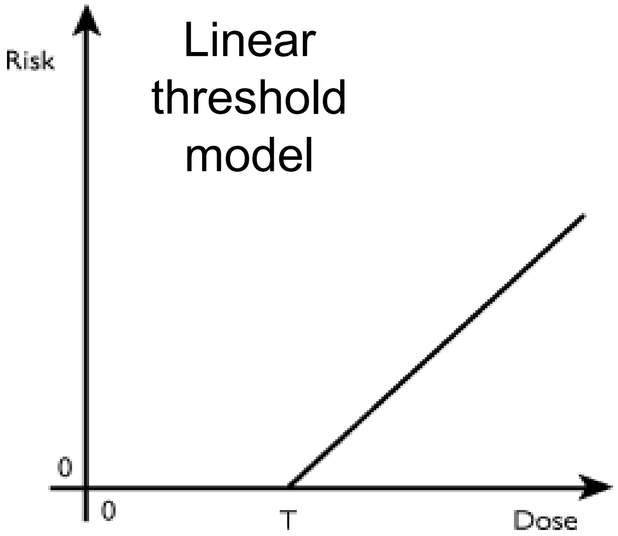
* EPA, Radiation Sources and Doses

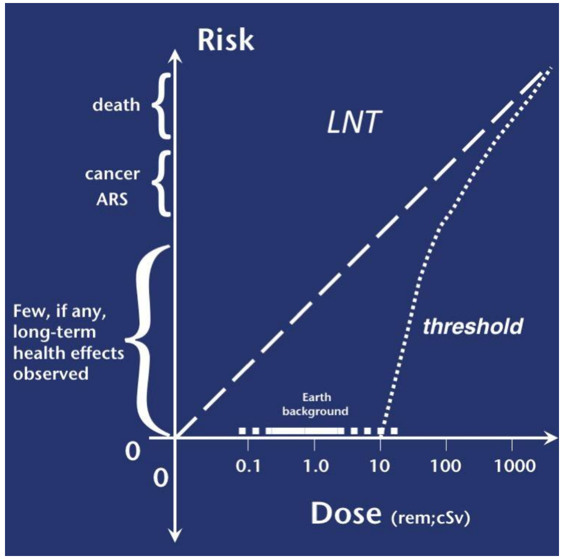
** BEIR VII cancer risk of 10^{-6} per mrem

Linear No Threshold Model of Radiation Risk

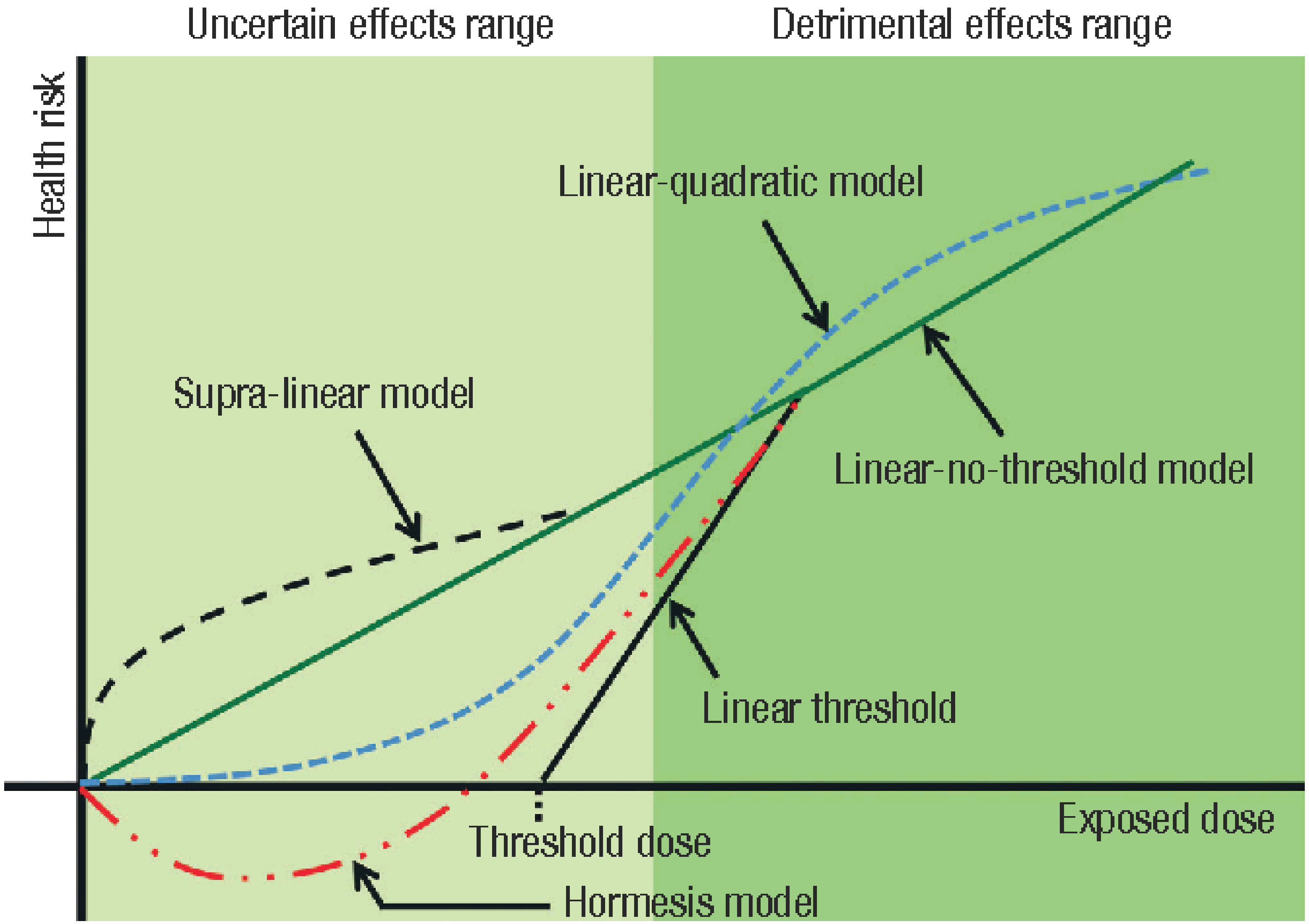
- Regulatory bodies require the use of the linear-no-threshold (LNT) model of radiation risk
- LNT assumes that the risk of cancer is proportional to the exposure level (no matter how small)
- Radiation risk at low doses is extrapolated from observed cancer effects at high doses (e.g. from atomic bomb survivors)
- No physical effects have been observed at low doses typical of background radiation levels
- Controversial, conservative, assumes no threshold, lack of health effects in high background regions







What is the Shape of the Curve in the Low Dose Region?



Linear No Threshold (LNT) Model of Radiation Risk

- Ionizing radiation, like other toxic hazards, has detrimental health effects, including cancer, at high doses and high dose rates. There is, however, considerable controversy regarding the health effects of low-level radiation, at or below typical natural background levels.
- Current "risk per exposure" ratios have been derived from studies inluding atomic bomb survivors at Hiroshima and Nagasaki.
- Various regulatory bodies, including the U.S. Environmental Protection Agency (EPA) have extrapolated these risk ratios, based on high doses, down to much lower dose levels, and all the way down to zero dose.
- Proponents of the theoretical LNT model argue that, since we do not know much about health effects at very low doses, it is prudent and conservative to presume that they exist, and that the LNT model is a simple and practical model and represents a reasonable upper bound for the risks.
- Opponents of the theoretical LNT argue that it is not supported by any scientific evidence of health effects at very low doses, and that regulations based on the LNT are excessively costly and do not achieve any real measurable public health benefit.

“Theoretical” Cancer Risks of Radiation Exposure

- The “real” risk of contracting cancer from hereditary, diet, lifestyle, and chance in the U.S. is ~ 42%
  - 420 out of 1,000
  - 420,000 out of 1,000,000
- Radiation is assumed to increase one’s cancer incidence risk using the “theoretical” LNT model
- Each additional rem of radiation exposure is assumed to increase that cancer incidence risk by approximately 0.1%
  - 1 out of 1,000
  - 1,000 out of 1,000,000

“Theoretical” radiation cancer risk is low compared to other “real” cancer risks

Biological Effects of Ionizing Radiation (BEIR V) - 1990

- *"Studies of populations chronically exposed to low-level radiation, such as those residing in regions of elevated background radiation, have not shown consistent or conclusive evidence of an associated increase in the risk of cancer."*
- National Academy of Sciences, BEIR V, "Health Effects of Low levels of Ionizing Radiation", June 1990

Location	Dose (mrem/y)	LNT Lifetime (80-year) Risk
U.S. Average	300	2.4%
Ramsar, Iran	1,000 – 26,000	8.0% - 208%
Guarapari, Brazil	500 – 17,500	4.0% - 140%
Kollam, India	500 – 7,000	4.0% - 56%

Biological Effects of Ionizing Radiation (BEIR VII) - 2006

- *“42 out of 100 people will be diagnosed with cancer during their lifetimes from causes unrelated to radiation (42%)”*
- *“1 cancer in 100 people could result from a single exposure of 10 rem of radiation (1%)”*
- *“At doses of 10 rem or less, statistical limitations make it difficult to evaluate cancer risk in humans”*
    - 1 millirem equates to an individual risk of one-in-a-million (10^{-6})
    - A one-year exposure to background radiation (300 mrem/y) equates to an annual risk of 300 x 10^{-6} = 3 x 10^{-4}
    - A lifetime exposure (80 years) to background radiation (300 mrem/y) would be a risk of 80 x 300 x 10^{-6} = 0.024 = 2.4%
- National Academy of Sciences, BEIR VII, “Health Risks from Exposure to Low Levels of Ionizing Radiation”, June 2006
- National Academy of Sciences, BEIR VII Summary, June 2006

Unintended Consequences of a Religious Belief in LNT

- BEIR VII (June 2005) states that 1 rem of exposure results in a 0.1% increase in cancer incidence risk. Therefore,
  - 1 mrem = 10^{-6} risk
  - 80-year exposure to 300 mrem/y background radiation = 2.4% risk
  - Background radiation exposure will result in 8 million cancers and 4 million deaths from cancer during the lifetimes of today's U.S. population
- EPA's risk goal of 10^{-6} for a 30-year exposure duration is equivalent to a dose goal of 0.033 mrem/y
  - ~10,000 times less than U.S. background of 300 mrem/y
  - ~1,000 times less than NRC's 25 mrem/y LTR

Population (Collective) Dose Property of LNT

- The stochastic property of LNT model allows trivially small doses to large populations to give unrealistically large theoretical cancers
- 1 rem = 0.001 cancer incidence risk = 0.0005 cancer fatality risk
- 2,000 person-rem = 1 cancer fatality (that person would have already died from acute radiation syndrome)

Dose (rem)	Risk / rem	Population Exposed	Population Dose (person-rem)	No. of Theoretical Cancers	No. of Exposed People Unaffected
1	0.001	1,000	1,000	1	999
0.1	0.001	10,000	1,000	1	9,999
0.01	0.001	100,000	1,000	1	99,999
0.001	0.001	1,000,000	1,000	1	999,999
0.0001	0.001	10,000,000	1,000	1	9,999,999
0.00001	0.001	100,000,000	1,000	1	99,999,999
0.000001	0.001	1,000,000,000	1,000	1	999,999,999

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Dose (rem)	Risk / rem	Population Exposed	Population Dose (person-rem)	No. of Theoretical Cancers	No. of Exposed People Unaffected
1	0.001	1,000	1,000	1	999
1	0.001	10,000	10,000	10	9,990
1	0.001	100,000	100,000	100	99,900
1	0.001	1,000,000	1,000,000	1,000	999,000
1	0.001	10,000,000	10,000,000	10,000	9,990,000
1	0.001	100,000,000	100,000,000	100,000	99,900,000
1	0.001	1,000,000,000	1,000,000,000	1,000,000	999,000,000

EPA’s Estimate of Lung Cancer Deaths from Indoor Radon is based on the Population Dose Property of LNT

- Average radon concentration
  - Indoor = 1.3 pCi/L
  - Outdoor = 0.4 pCi/L
- Average annual radon dose
  - Indoor = 200 mrem/y
  - Outdoor = ???
- Annually, 21,000 people in the U.S. will die of radon-induced lung cancer
  - 18,100 smokers
  - 2,900 never smokers
- EPA, Health Risk of Radon

Radiation Risks of Flying Assuming Validity of LNT at Low Collective Doses … or Fear of Flying

- Added cosmic ray dose from flying 1,000 miles = 1 mrem = 0.001 rem (EPA)
  - Dose for one round-trip LA/NY trip = 5 mrem
  - Cancer incidence risk = 0.001 per person-rem
  - Risk for one round-trip LA/NY trip = 0.005 x 0.001 = 5×10^{-6}
- Annual passenger miles on U.S. Airlines (domestic & international) = 1 trillion
- Collective dose = $10^{12} \times 10^{-6} = 10^{6}$ person-rem
- Population risk = $10^{6} \times 0.001$ = 1,000 cancers
- Annual passengers on U.S. Airlines (domestic & international) = 1 billion
- Individual radiation cancer risk of flying = 1,000 / 1,000,000,000 = 1 in a million
- Individual risk of dying in an airplane crash = 1 in 10 million
- Radiation cancer risk is 10 times greater than the risk of dying in an airplane crash

LNT Analogy of Jumping off a Roof

Jumping off a …	Probability of death
100 foot, 10 story building	~100%
10 foot shed	10%
1 foot step	1%
1 inch thick book	~0.001
0.1 inch thin magazine	10^{-4}
0.001 inch thin split hair	10^{-6}

LNT Analogy to Drinking Alcohol

- Alcohol is a poison
- Consumption of 30 shots of 70 proof alcohol in one evening will kill you
- LNT says that if 30 people at a party each drink one shot
  - 29 will have no ill effects
  - 1 person will die
  - population risk
- LNT says that if one person drinks one shot per day for a month
  - that person will die
  - cumulative individual risk

Overdosing Medications in a LNT World

- Almost all medications taken for beneficial reasons at low doses will kill you if taken at high doses … overdosing
- We know that taking 100 sleeping pills will kill you
- But we will readily take one sleeping pill and not worry about a potential 1% chance of dying in one’s sleep based on LNT
- Medications are an example of a **threshold model of risk** and of **hormesis**

Sources of Risk Compared to the CERCLA Risk Range*

Sources of Risk	10^{-4} Risk	10^{-6} Risk
30-year cancer incidence risk from drinking orange juice (contains radioactive potassium-40)	1 small glass per day	0.4 teaspoon per day
30-year cancer incidence risk from elevation change (increasing exposure to cosmic radiation)	Increase in risk moving from Santa Monica to the foothills of Beverly Hills (600-foot elevation)	Difference in risk between the feet and head of a 6-foot person
Fatal accident risk from driving	Driving an extra 127 miles per year for 30 years	Driving an extra 1 mile per year for 30 years

* Rutherford, "Radiation Risks in Everyday Life", 43rd Annual Health Physics Society Meeting, January 2010

Fallacy of the Geometric Scale of Safety

Contributions to Lifetime Cancer Risk	Radiation Exposure (mrem/year)	Lifetime Cancer Incidence Risk		
		Individual Risk (probability)	Incremental Population Risk (cancers)	Total Population Risk (cancers)
U.S. average cancer incidence	N/A	0.42	336	336
Upper EPA CERCLA risk range (1 in 10,000)	-	0.0001	0.08	336.08
Geometrical mean of CERCLA risk range (1 in 100,000)	-	0.00001	0.008	336.008
Lower EPA CERCLA risk range (1 in 1,000,000)	-	0.000001	0.0008	336.0008
Zero incremental risk level (2010 AOC Cleanup to Background)	-	0	0	336

Habitable area of Area IV of SSFL ~ 200 acres. Assumed home lot size of 1 acre consistent with neighboring Bell Canyon community to the south. Assumed 4 people per home to give 800 residents. Incremental population risk = individual risk x 800

One in a Million (10^{-6}) Chance of Death (One Micromort)*

- Driving a car 230 miles
- Walking 20 miles
- Motorcycling 6 miles
- Flying 10 commercial flights
- Living one normal day at age 40
- Struck by lightening during a 10-year period
- Smoking 1.4 cigarettes

* ChatGPT

Annual Mortality in the U.S.

- U.S. population is 340 million

Cause of Death	Actual Annual Number	Annual Individual Risk
All causes	3,000,000	86×10^{-4}
All cancer diagnoses	2,100,000	62×10^{-4}
All cancer deaths	618,000	18×10^{-4}
All accidents	223,000	6.5×10^{-4}

- U.S. background radiation = 0.3 rem/y
- Risk per rem = 0.001 (BEIR VII)

LNT Radiation Induced	Theoretical Annual Number	Annual Individual Risk
Cancer incidence	100,000	$3 \text{ X } 10^{-4}$
Cancer death	50,000	1.5×10^{-4}

Dose and Risk from the Food We Eat from the Supermarket - Radionuclides

- Internal dose is 30 mrem/y from naturally occurring K-40, Uranium, Thorium and their progeny
- Risk (26 years) = 0.030 x 26 x 0.001 = 7.8 x 10^{-4}
- Risk (80-year lifetime) = 0.030 x 80 x 0.001 = 24 x 10^{-4} (0.24%)
- On-site soil PRGs are dominated by default 100% garden produce consumption exposure pathways that limit risk to 10^{-6}

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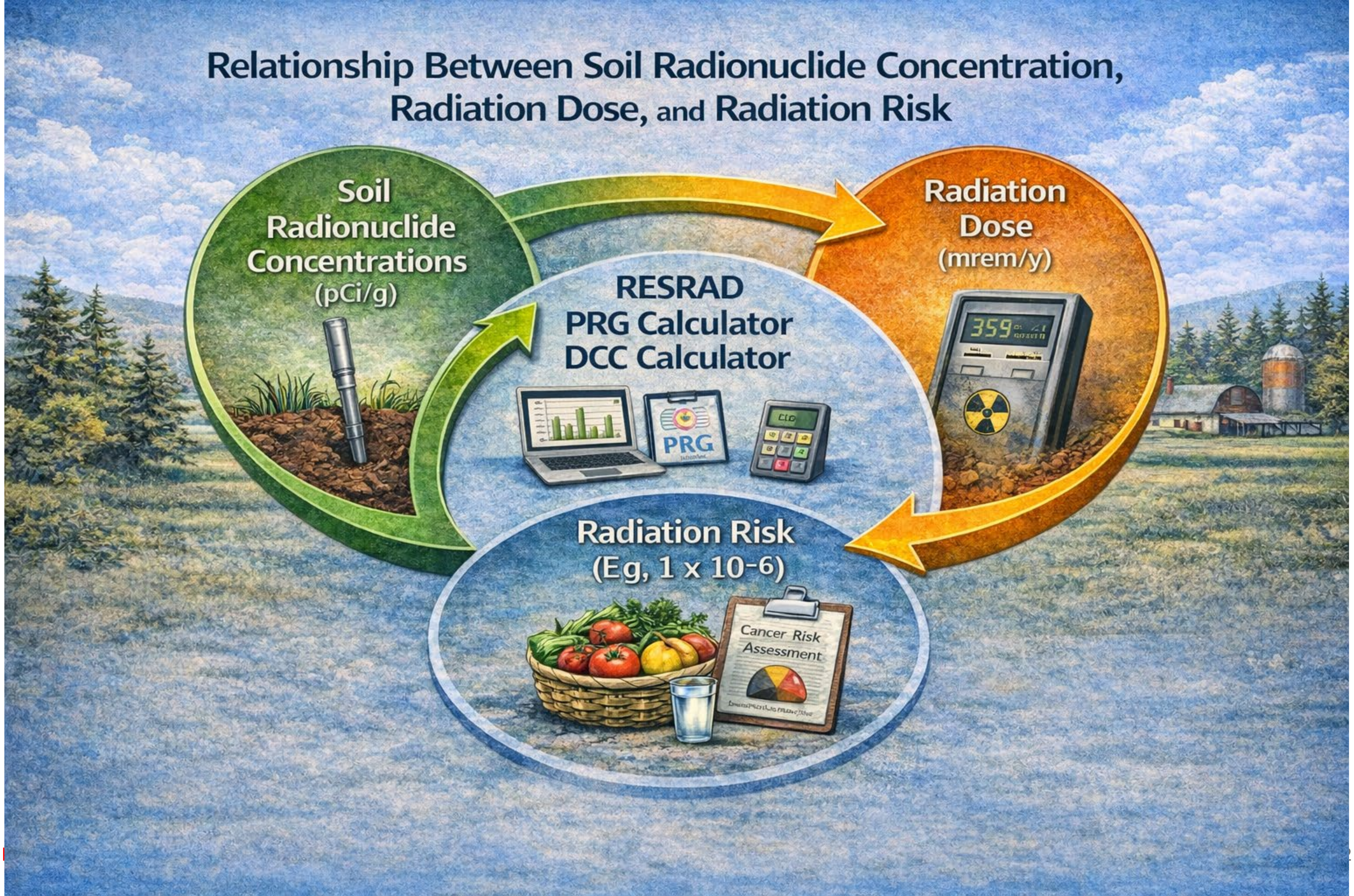
Radiation Cleanup Standards


Relationship Between Soil Radionuclide Concentration, Radiation Dose, and Radiation Risk
Soil Radionuclide Concentrations (pCi/g)
Radiation Dose (mrem/y)
RESRAD
PRG Calculator
DCC Calculator
PRG
Radiation Risk (Eg, 1 x 10-6)
Cancer Risk Assessment

Principal Cleanup Standard Software

- Argonne National Laboratory, RESRAD, RESidual RADioactivity
  https://resrad.evs.anl.gov/
- EPA, Preliminary Remediation Goal (PRG) Calculator
  https://epa-prgs.ornl.gov/radionuclides/
- EPA, Dose Compliance Concentrations (DCC) for Radionuclides at Superfund Sites
  https://epa-dccs.ornl.gov/
- Oak Ridge National Laboratory, Risk Assessment Information System
  https://rais.ornl.gov/#

MARSSIM

- Multi Agency Radiation Survey and Site Investigation Manual, NUREG-1575, Revision 1, August 2000
- EPA, NRC, DOE and DOD
- Provides guidance in
  - Number and location of soil samples, static and scanning instrument measurements
  - Non-parametric statistical methods of hypothesis testing to prove (or disprove) that building surface contamination and soil volumetric contamination goals have been met

CERCLA Evaluation Criteria

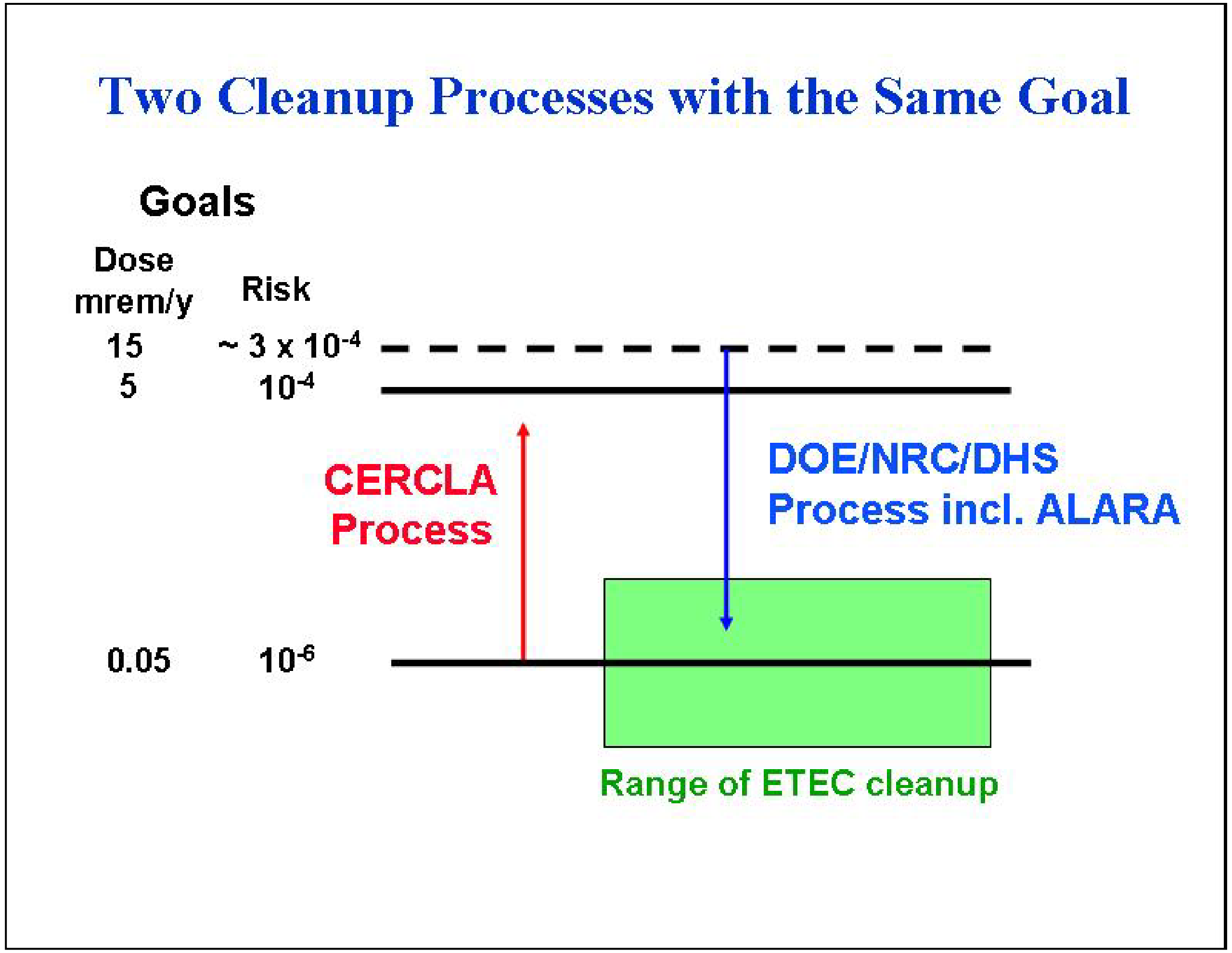
- National Oil and Hazardous Substances Pollution Contingency Plan (NCP) Subpart E (1990) [40 CFR 300.400]
- Outlines the process that selects a remedy and remedial risk goal within the acceptable risk management range of 10^{-6} and 10^{-4}
(40 CFR 300.430(e)(2)(i)(A)(2)
- 40 CFR 300.430(e)(9)(iii) – Nine evaluation criteria
  A. Overall protection of human health and the environment
  B. Compliance with ARARs
  C. Long-term effectiveness
  D. Reduction of toxicity, mobility, or volume through treatment
  E. Short-term effectiveness
  F. Implementability, feasibility
  G. Cost
  H. State acceptance
  I. Community acceptance

Cost Benefit Analysis

- NUREG-1727, "Decommissioning Standard Review Plan", Appendix D, demonstrates by quantitative cost benefit analysis that the NRC License Termination Rule of 25 mrem/y is already ALARA
- Using NUREG-1727 methodology, two remedial projects at SSFL were shown to save one theoretical cancer fatality at a cost of,
  - $1.5 billion
  - $3.2 billion
- These figures significantly exceeded the US Government's value of a statistical life (VSL) of $5.5 million in 1999 dollars
- Rutherford, Radiation Risk and Cleanup Standards, 2007 HPS Conference, January 23, 2007

Comparison of Dose-based Cleanup and Risk-based Cleanup

- 2007 graphic during DOE/ETEC's transition from dose-base standards to risk-based standards



Features of Cleanup Frameworks

	MARSSIM	CERCLA Superfund	2010 AOC
Authors	EPA, NRC, DOE, DOD	EPA	DTSC, CBG
Sites	All radiologically contaminated sites	All Superfund sites and sites where EPA is the lead or co-regulator	SSFL only
Hypothesis Testing	Compares reference area **distribution** to sampled area **distribution** using non-parametric hypothesis testing	Compares reference area **distribution** to sampled area **distribution** using non-parametric hypothesis testing	Compare **single** sample data to **single** parametric LUTV
Reasonable maximum exposure (RME)	Not applicable	Yes	No
Exposure point concentration (EPC) - area averaging	Not applicable	Yes	No
Where to sample	Yes	Yes	No
How many samples to take	Yes	Yes	No
Performs risk assessment	Not applicable	Yes	No
Remedial Goal	**Dose = 15 to 25 mrem/y**	**Cancer risk = 10^{-6} to 10^{-4}**	**Background**

Wide Range of Regulatory "Safe" Dose Standards for the Public

Dose (mrem/y)	Standard	Citation
100	Annual dose limit for members of the public at a site boundary, NRC and DOE	10 CFR 20.1301 DOE O 458.1
50	NRC Airborne Effluent	10 CFR 20.1302, Appendix B
25	NRC License Termination Rule (1997)	10 CFR 20.1402 Subpart E
15	EPA Safe Dose (1994)	40 CFR 196 (Draft)
15	EPA Annual dose limit for members of the public around Yucca Mountain	40 CFR 197
12	EPA Safe Dose (2014)	OSWER 9285.6-20
10	EPA Airborne NESHAPS dose limit for DOE Facilities	40 CFR 61 Subpart H
4	EPA dose limit for beta/gamma emitters in drinking water	40 CFR 9, 141 and 142
1	De minimis dose limit	ANSI/HPS N13.12-2013

SSFL Radiation Dose Cleanup Standards (1998)

- March 1996 - Proposed
- August 1996 - Approved by California Department of Health Services
- September 1996 - Approved by DOE
- December 1998 - N001SRR140131, "Approved Sitewide Release Criteria for Remediation of Radiological Facilities at the SSFL"

- Soil
  - SSFL dose-based standard of 15 mrem/y for residential land use
  - Consistent with EPA and NRC dose standards at the time
- Building structures
  - SSFL surface contamination limits based on
    - NRC Regulatory Guide 1.86
    - DOE Order 5400
    - CDHS DECON-1
  - Consistent with ANSI/HPS N13.12-2013 based on 1 mrem/y

EPA's 15 mrem/y vs. NRC's 25 mrem/y

- June 1994 - EPA issues draft 40 CFR 196, "EPA Radiation Site Cleanup Regulation" proposing **15 mrem/y** radiation cleanup standard for soil contamination
- September 1994 - EPA issues Technical Support Document (EPA 402-R-96-011 A) providing basis for **15 mrem/y**
- August 1994 - NRC issues draft Generic EIS (NUREG-1496) also recommending **15 mrem/y**
- July 1997 - NRC selects **25 mrem/y** in final Generic EIS (NUREG-1496)
- July 1997 - NRC publishes 10 CFR 20.1402 specifying **25 mrem/y** as the License Termination Rule
- August 1997 - EPA issues OSWER 9200.4-18 establishing **15 mrem/y** as a cleanup goal that is protective of public health and the environment, equivalent to a risk of 3 x 10^{-4}, and consistent with the CERCLA acceptable risk range. EPA claims 15 mrem/y is safe, and 25 mrem/y is unsafe

EPA's Reduction of 15 mrem/y to 12 mrem/y

- OSWER 9285.6-20, "Radiation Risk Assessment at CERCLA Sites: Q&A", question 35, June 13, 2014
- EPA reduces "safe" dose rate from 15 to 12 mrem/y and reduces exposure duration from 30 to 26 years to accommodate increases in risk/dose ratios while maintaining 3×10^{-4} as a "safe" risk goal

Date	Risk/dose (risk/rem)	Basis	Exposure Duration (Years)	"Safe" dose rate (mrem/y)	"Safe" risk approximates to 3×10^{-4}
1990 1991 1997	7.6×10^{-4}	BEIR V ICRP 60 OSWER 9200.4-18	30	15	3.42×10^{-4}
1999	8.46×10^{-4}	FGR 13	30	12	3.05×10^{-4}
2006	1.14×10^{-3}	BEIR VII	26	12	3.56×10^{-4}

SSFL Radiation Dose Cleanup Standards for Soil (1998) Compared to the EPA Background Threshold Value (BTV)

Radionuclide		Soil Concentration for 15 mrem/y (pCi/g)	SSFL Background Threshold Value (pCi/g)
Potassium-40	Naturally occurring	27.6	30.5
Uranium-238	Naturally occurring & nuclear fuel	90.9	1.68
Thorium-232	Naturally occurring	1.53	2.95
Radium-226	Naturally occurring	0.199	1.82
Cesium-137	Man-made	9.2	0.193
Strontium-90	Man-made	36.0	0.075
Plutonium-239	Man-made	33.9	0.0142

EPA/NRC Memorandum of Understanding (2002)

- OSWER 9295.8-06a, Memorandum of Understanding between EPA and NRC", October 9, 2002
- Agreement that ensured soil cleanup standards of NRC licensed facilities used during decommissioning and license termination meet the EPA CERCLA requirements
- Most MOU soil cleanup levels are based on achieving a 10^{-4} risk level for reasonably anticipated future residential land use (25% produce consumption), based on the online PRG calculator
- MOU levels for Th-232 and Ra-226 (5 pCi/g) are based on UMTRCA (40 CFR 192)

SSFL Cleanup Standards (1998) compared to EPA/NRC MOU Table 1(2002)

Radionuclide		SSFL Cleanup Standard for 15 mrem/y (pCi/g)	EPA/NRC MOU for Residential (pCi/g)
Potassium-40	Naturally occurring	27.6	-
Uranium-238	Naturally occurring & nuclear fuel	90.9 (30)	74
Thorium-232	Naturally occurring	1.53 (5)	5
Radium-226	Naturally occurring	0.199 (5)	5
Cesium-137	Man-made	9.2	6
Strontium-90	Man-made	36.0	23
Plutonium-239	Man-made	33.9	259

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California Legislation, Litigation and SSFL Consent Orders Impacting Radiation Cleanup Standards

California Legislation

- 2000-2004 Sacramento legislation seeking to ...
  - oppose established federal and state decommissioning regulations
  - impose zero risk goals at SSFL
  - mandate waste disposal of decommissioned material as LLRW
  - transfer of regulation of radioactive materials at SSFL from CDPH/RHB to DTSC
- SB-243, SB-1970, SB-1444, AB-2214, SB-13, SB-201, SB-208, SB-415, SB-1456

SB-1970 (2002) and E.O. D-62-06

- SB 1970 attempted to legislate that all "decommissioned material" that had met all federal and state cleanup standards and had been "released for unrestricted use " should nevertheless go to a licensed LLRW disposal facility
- California Governor, Gray Davis vetoed this bill, but as a compromise, issued Executive Order D-62-02, prohibiting the disposal of "decommissioned material" at Class III or unclassified landfills in California
- Effectively, D-62-02, known as the Governor's Moratorium, required that "decommissioned material" be disposed to Class I, hazardous waste disposal facilities, or Class II facilities in the State of California.
- D-62-02 did NOT require decommissioned material to be shipped out of State to LLRW disposal sites
- D-62-02 was silent on recycling and imposed no restrictions on recycling decommissioned material in the State
- Subsequently, Boeing complied with D-62-02, and with the approval of DOE and DTSC disposed of all decommissioned material at Class I hazardous waste facilities in California

Senate Bill SB-990 (2007)

- State Senator Sheila Kuehl was used as proxy pawn by Dan Hirsch
- Mandated agricultural (rural residential) land use instead of “reasonably anticipated future land use” of recreational open space, or even conservative residential land use
- Transferred authority for radiological remediation in California from the Department of Public Health Radiologic Health Branch (DPH/RHB) to the DTSC
  - DPH/RHB enforces federal NRC rules under the Agreement State law
  - DTSC has no expertise in regulation of radioactive material
- Boeing issues a white paper Technical Feasibility of Detecting Radionuclide Contamination in Soil at a 10^{-6} Risk Level for Agricultural Land Use

Litigation

- CBG vs CDHS (2002)
  - Plaintiffs object to adoption of NRC 25 mrem/y License Termination Rule
  - DHS looses and rescinds all numerical decommissioning guidelines
- NRDC and CBG vs DOE (2004-2007)
  - Plaintiffs object to DOE’s choice of 15 mrem/y cleanup goal in an Environmental Assessment: demand an Environmental Impact Statement
  - DOE looses and delays soil cleanup by 20+ years
- PSR-LA vs DTSC, CDPH and Boeing (2013-2023)
  - Plaintiffs claim decommissioned material is LLRW and “underground” cleanup standards were not approved
  - Plaintiffs loose
  - As of 2026, five subject Boeing buildings in Area IV remain untouched, a delay of 13+ years

2010 AOC - Cleanup to Background

- Dispensed with all EPA CERCLA risk assessment guidance,
    - no exposure point concentrations
    - no reasonable maximum exposure
    - no non-parametric hypothesis testing
    - no comparison of site distributions to background distributions,
    - no MARSSIM procedures
- Every analyte of every soil sample should not exceed look-up table values (LUTV) based on background threshold values (BTV)
- Soil defined to include all anthropogenic building structures, even though no BTV established for structural surfaces
- Chemical soil disposal recognized non-haz. vs. haz. soil, but radionuclides not accorded the same flexibility
- 2010 AOCs violated CEQA and NEPA, in that it predetermined cleanup goals and remedies, before completion of the DTSC EIR and the DOE and NASA EISs

Collusion between DTSC and CBG

- In 2025, a California Public Records Act (PRA) request unearthed a disturbing long-standing email communication between Dan Hirsch, past DTSC management (Rick Brausch, Norm Riley, Maziar Movassaghi), Linda Adams (former CalEPA Secretary) and staff of former State Senator Sheila Kuehl
  - Hirsch clearly authored SB-990 with the express approval and assistance of DTSC
  - Movassaghi, Brausch and , anticipating the downfall of SB-990, drafted the 2010 AOCs
  - DTSC attorneys claimed that they were unable to locate any written documents recording the drafting of the 2010 AOCs during the period August 2009 and December 2010
- On April 6, 2026, an open letter was sent to DTSC Director Kathleen Butler and Energy Secretary Chris Wright, proposing that DTSC and DOE agree to terminate the 2010 AOC and replace it with more conventional cleanup remedies consistent with those used in the rest of the U.S. DTSC and DOE are "evaluating" the proposal

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- Radiation 101 – Understanding Radiation
- Radiation Dose (Measured)
  - Background Radiation
  - Potassium-40
- Radiation Risk (Theoretical)
  - Linear No Threshold Model
- Radiation Cleanup Standards
  - Dose vs. Risk
- Legislation, Litigation and Consent Orders
- Problems Implementing Radiation Cleanup Goals
  - Land Use Scenarios
- Surface Contamination Standards
- EPA Radiological Survey of Area IV
- Recent Events related to Cleanup Standards
- To Superfund … or Not to Superfund

Problems With Implementing Radiation Cleanup Standards

Moving the Goal Posts

- Dose 25 mrem/y
- Dose 15 mrem/y
- Dose 12 mrem/y
- Risk 10^{-6} to 10^{-4}
- Residential 25% produce consumption
- Residential 100% produce consumption
- Agricultural 100% all food consumption (SB-990)
- Exposure duration from 30 years to 26 years
- Zero dose, zero risk (2010 AOC)

Needle in a Haystack

- Signal to noise ratio <<1
- It's hard to prove the negative
- "Absence of evidence" is not the same as "evidence of absence"
- You have not looked hard enough
- Scientific method
  - Define null hypothesis as "existence of risk or contamination"
  - Test to either reject or accept

- LNT - Search for cancer risk from low doses << background doses
- SSFL - Search for levels of contamination << background variability

Reducing the “Remedial Goal / Background” Ratio to <<1

- Gross Cleanup goal = Background + incremental net cleanup goal
- 15 mrem/y net soil concentration goals were >> soil background therefore detailed knowledge of background was unimportant
- 10^{-6} net soil concentrations are << soil background therefore detailed knowledge of background is very important
- Cesium-137
  - 9.2 pCi/g >> 0.193 pCi/g (15 mrem/y)
  - 0.06 pCi/g < 0.193 pCi/g (residential, 10^{-6})
  - 0.04 pCi/g < 0.193 pCi/g (residential, 10^{-6}, 100% consumption)
  - 0.00 pCi/g <<< 0.193 pCi/g (background)

Hypothesis Testing

- In hypothesis testing, the null hypothesis (H_0) is what you assume true unless evidence shows otherwise
- Critics of LNT argue that the wrong null hypothesis is used in LNT
- LNT effectively assumes *“low dose radiation is harmful until proven safe”*
  - Analogous to assuming guilty until proven innocent in a court of law
- The proper null hypothesis should be *“low dose radiation is safe, until proven harmful”*
  - Analogous to assuming innocence until proven guilty in a court of law
- Except that the null hypothesis in MARSSIM assumes that a site is contaminated, and rejecting the null is proof that a cleanup goal has been met

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Principal Land Use Scenarios


Recreator Land Use Scenario
for Radionuclide PRGs
Hiking
Camping
Fishing
Berry Picking
Exploring Old Structures
ATV Riding
Swimming & Boating
External Exposure
Ingestion of Soil & Water
Inhalation of Dust
Ingestion of Wild Foods
Ingestion of Wild Foods
Potential Radiation Pathways & Exposure Routes


Residential Land Use Scenario
for Radionuclide PRGs
Keene
Wood Lane
Backyard
External Exposure
Ingestion of Soil
Inhalation of Dust
Ingestion of Produce
Ingestion of Drinking Water
Potential Radiation Pathways & Exposure Routes
Under EPA/CERCLA default assumptions, including

Preliminary Remediation Goals (PRG) for Residential Exposure Pathways

- Inhalation (INH)
- Ingestion (ING)
- External (EX)
- Produce Consumption (PC)

$$\mathrm{PRG}_{\mathrm{TOTAL}} = \frac{1}{\frac{1}{\mathrm{PRG}_{\mathrm{INH}}} + \frac{1}{\mathrm{PRG}_{\mathrm{ING}}} + \frac{1}{\mathrm{PRG}_{\mathrm{EX}}} + \frac{1}{\mathrm{PRG}_{\mathrm{PC}}}}$$

Residential Garden Produce Consumption – Radionuclides (PRG) and Chemicals (RSL)

- Prior to December 2016, EPA PRGs and RSLs for residential land used 25% garden produce consumption as a default
- Today, EPA PRGs and RSLs for residential land use 100% garden produce consumption as a default
  - EPA has failed to provide a reason for this change
- Since garden produce consumption frequently is the dominant exposure pathway (ingestion, inhalation, direct and produce consumption) that influences the total PRGs and RSLs, this major change in garden produce consumption resulted in a major reduction in most radionuclide PRGs and chemical RSLs

100% Residential Produce Consumption

- **Assumes 100% of the fruit and vegetable annual diet for all household residents is grown in the family backyard and consumed**
- Apples, citrus (oranges, limes, lemons), berries (blackberries, blueberries, boysenberries, cranberry, elderberries, loganberries, mulberries, raspberries), strawberries, peaches, pears
- Asparagus, beets, broccoli, cabbage (brussel sprouts, red cabbage, savoy, bok-choy) carrots, corn, cucumber, lettuce, lima beans, okra, onion, peas, peppers, pumpkin, snap bean, tomato, potato
- **Physical impossibility to grow all this produce in a typical family backyard on a ¼ acre lot**

Residential Risk is Dominated by External Exposure Pathway for No Produce Consumption

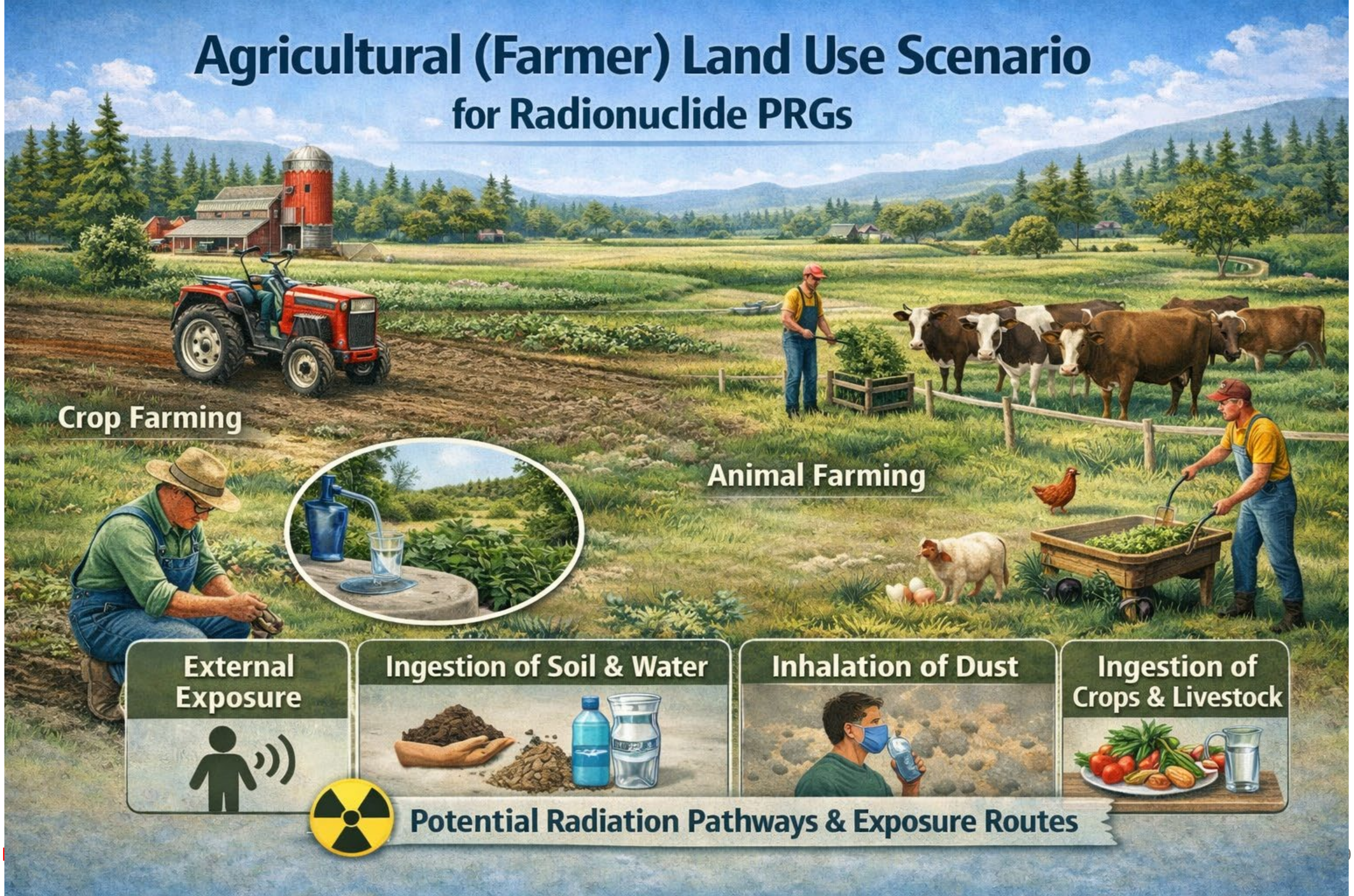
RESIDENTIAL PRELIMINARY REMEDIATION GOALS*	Radionuclides (pCi/g)						
	K-40	U-238	Th-232	Ra-226	Cs-137	Sr-90	Pu-239
Exposure Route							
Ingestion	1.53E+01	1.44E-01	3.08E-01	1.67E-01	2.79E+01	**8.87E+00**	**3.92E+00**
Inhalation	3.80E+04	5.84E+01	3.65E+01	1.51E+02	9.97E+04	2.62E+04	1.52E+02
External	**1.45E-01**	**1.36E-02**	**1.02E-02**	**1.39E-02**	**6.06E-02**	**8.00E+00**	5.54E+02
Produce Consumption	6.05E-03	2.03E-03	2.06E-03	2.25E-03	1.19E-01	4.78E-03	5.04E-01
Total (100% produce)	5.81E-03	1.74E-03	1.70E-03	1.91E-03	4.01E-02	4.77E-03	4.45E-01
Total (25% produce)	2.07E-02	4.91E-03	4.49E-03	5.29E-03	5.37E-02	1.90E-02	1.32E+00
Total (0% produce)	**1.44E-01**	**1.24E-02**	**9.87E-03**	**1.28E-02**	**6.05E-02**	**4.21E+00**	**3.80E+00**

* EPA Preliminary Remediation Goals for Radionuclides, February 3, 2026

Residential Risk is Dominated by 100% Produce Consumption Exposure Pathway

RESIDENTIAL PRELIMINARY REMEDIATION GOALS*	Radionuclides (pCi/g)						
	K-40	U-238	Th-232	Ra-226	Cs-137	Sr-90	Pu-239
Exposure Route							
Ingestion	1.53E+01	1.44E-01	3.08E-01	1.67E-01	2.79E+01	8.87E+00	3.92E+00
Inhalation	3.80E+04	5.84E+01	3.65E+01	1.51E+02	9.97E+04	2.62E+04	1.52E+02
External	1.45E-01	1.36E-02	1.02E-02	1.39E-02	**6.06E-02**	8.00E+00	5.54E+02
Produce Consumption	**6.05E-03**	**2.03E-03**	**2.06E-03**	**2.25E-03**	1.19E-01	**4.78E-03**	**5.04E-01**
Total (100% produce)	**5.81E-03**	**1.74E-03**	**1.70E-03**	**1.91E-03**	**4.01E-02**	**4.77E-03**	**4.45E-01**
Total (25% produce)	2.07E-02	4.91E-03	4.49E-03	5.29E-03	5.37E-02	1.90E-02	1.32E+00
Total (0% produce)	1.44E-01	1.24E-02	9.87E-03	1.28E-02	6.05E-02	4.21E+00	3.80E+00

* EPA Preliminary Remediation Goals for Radionuclides, February 3, 2026



Agricultural (Farmer) Land Use Scenario
for Radionuclide PRGs
Crop Farming
Animal Farming
External Exposure
Ingestion of Soil & Water
Inhalation of Dust
Ingestion of Crops & Livestock
Potential Radiation Pathways & Exposure Routes

100% Farmer All Food Consumption

- Assumes 100% of all food consumed by a farmer’s family is grown and/or raised on the farm
- Apples, citrus (oranges, limes, lemons), berries (blackberries, blueberries, strawberries), peaches, pears
- Asparagus, beets, broccoli, cabbage, carrots, corn, cucumber, lettuce, lima beans, okra, onion, peas, peppers, pumpkin, snap bean, tomato, potato
- Poultry, eggs, beef, dairy, swine, finfish, shellfish

EPA PRGs (10^{-6}) for Key Land Uses vs. Soil Background

Radionuclide	Source	Background (BTV) (pCi/g)	Open Space, Recreational* (pCi/g)	Residential 0% produce consumption ** (pCi/g)	Residential 25% produce consumption ** (pCi/g)	Residential 100% produce consumption ** (pCi/g)	Agricultural 100% all food consumption ** (pCi/g)
Potassium-40	NORM	30.5	5.21	0.144	0.0207	0.00581	0.0000485
Uranium-238	NORM	1.68	13.6	0.0124	0.00491	0.00174	0.00000256
Thorium-232	NORM	2.95	0.703	0.00987	0.00449	0.00170	0.00000186
Radium-226	NORM	1.82	0.497	0.0128	0.00529	0.00191	0.00000732
Cesium-137	Man-made	0.193	2.31	0.0605	0.0537	0.0401	0.0000830
Strontium-90	Man-made	0.075	36.5	4.21	0.0190	0.00477	0.0000325
Plutonium-239	Man-made	0.0142	18.3	3.80	1.32	0.445	0.000000484

* RAIS Radionuclide PRG Calculator, February 3, 2026

** EPA Preliminary Remediation Goals for Radionuclides, February 3, 2026

No produce consumption – K-40 risk is 0.42 times the risk of Cs-137
100% produce consumption – K-40 is 6.9 times the risk of Cs-137

EPA PRGs (10^{-6}) for Key Land Uses vs. Soil Background

Radionuclide	Source	Background (BTV) (pCi/g)	Open Space, Recreational* (pCi/g)	Residential 0% produce consumption ** (pCi/g)	Residential 25% produce consumption ** (pCi/g)	Residential 100% produce consumption ** (pCi/g)	Agricultural 100% all food consumption ** (pCi/g)
Potassium-40	NORM	30.5	5.21	0.144	0.0207	0.00581	0.0000485
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Thorium-232	NORM	2.95	0.703	0.00987	0.00449	0.00170	0.00000186
Radium-226	NORM	1.82	0.497	0.0128	0.00529	0.00191	0.00000732
Cesium-137	Man-made	0.193	2.31	0.0605	0.0537	0.0401	0.0000830
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* RAIS Radionuclide PRG Calculator, February 3, 2026

** EPA Preliminary Remediation Goals for Radionuclides, February 3, 2026

No produce consumption – K-40 risk is 0.42 times the risk of Cs-137
100% produce consumption – K-40 is 6.9 times the risk of Cs-137

Plutonium-239 is 75-250 **less** radiotoxic than common NORM radionuclides

Cesium-137 (Cs-137) and Potassium-40 (K-40)

- Cesium-137 is the predominant nuclear fission product and contaminant found in Area IV soil
  - Half life 30 years, beta/gamma emission 662 keV
  - Local EPA background BTV from nuclear weapons testing = **0.193 pCi/g**
- Potassium-40 is the dominant naturally occurring radioactive material (NORM) in soil on the planet
  - Half life 1.28 billion years, beta and gamma emissions (1,461 keV)
  - Local EPA background BTV = **30.5 pCi/g**
- For land use scenarios with no produce consumption (open space and residential 0% produce consumption), K-40 is **0.43 times** the radiation risk of the same concentration of Cs-137
- For residential land use scenarios with 100% produce consumption, K-40 is **6.9 times** the radiation risk of the same concentration of Cs-137

Agricultural Risk is Dominated by Finfish/Shellfish Exposure Pathways ???

AGRICULTURAL (PRG)	Radionuclides (pCi/g)						
	K-40	U-238	Th-232	Ra-226	Cs-137	Sr-90	Pu-239
Exposure Route							
Ingestion	1.06E+01	1.00E-01	2.14E-01	1.16E-01	2.23E+01	7.14E+00	2.73E+00
Inhalation	2.36E+04	3.63E+01	2.27E+01	9.41E+01	7.13E+04	1.88E+04	9.46E+01
External	4.84E-02	4.56E-03	3.40E-03	4.66E-03	2.33E-02	3.10E+00	1.85E+02
Produce Consumption	3.71E-03	1.25E-03	1.27E-03	1.38E-03	8.15E-02	3.39E-03	2.99E-01
Finfish Consumption	**6.15E-05**	1.66E-04	7.68E-05	2.06E-04	**8.47E-05**	3.63E-03	**7.08E-07**
Shellfish Consumption	2.55E-04	**2.62E-06**	**1.91E-06**	**7.74E-06**	7.03E-03	**3.31E-05**	1.53E-06
Beef Consumption	3.25E-02	9.93E-03	2.79E-02	1.07E-02	1.45E-01	8.73E-01	4.53E+02
Dairy Consumption	9.73E-03	7.49E-03	1.40E-02	1.08E-02	7.65E-02	1.14E-01	5.55E+00
Swine Consumption	Omitted	4.24E-02	Omitted	Omitted	6.44E-02	2.27E+00	2.49E+01
Poultry Consumption	5.51E-01	1.14E-03	Omitted	1.25E-03	8.79E-02	4.65E+00	1.21E+01
Egg Consumption	9.98E-02	1.60E-03	Omitted	1.74E-03	1.07E+00	5.48E-01	5.49E+01
Total (100% produce)	**4.85E-05**	**2.56E-06**	**1.86E-06**	**7.32E-06**	**8.30E-05**	**3.25E-05**	**4.84E-07**

* EPA Preliminary Remediation Goals for Radionuclides, February 3, 2026

Comparison of Cs-137, K-40 and Ra-226 Residential Risk at Background

Property	Cs-137	K-40	Ra-226
NORM or nuclear fission product	Fission product	NORM	NORM
Half-life (years)	30.1	1.28 billion	1,600
Specific activity (Ci/g)	87	0.000007	1
Gamma energy (keV)	662	1,461 (11%)	186 (3.5%)
EPA Background Threshold Value - BTV (pCi/g)	0.193	30.5	1.82
EPA Residential 10^{-6} PRG (no consumption) (pCi/g)	0.0605	0.144	0.0128
EPA Residential 10^{-6} PRG (100% consumption) (pCi/g)	0.0401	0.00581	0.00191
No consumption risk at BTV	**3.19×10^{-6}**	**212×10^{-6}**	**142×10^{-6}**
100% consumption risk at BTV	**4.81×10^{-6}**	**$5,250 \times 10^{-6}$**	**953×10^{-6}**

Risk of background Cs-137 is ~1,000 times less than background K-40.
Cs-137 concentration in one of 3,735 EPA soil samples was ~1,000 times greater than background.
Therefore, risk of **uniform Cs-137 contamination 1,000 times background** is equal to risk of normal K-40 background.

EPA Dose Compliance Concentrations (DCC)

Radionuclide	Source	Background (BTV)	Former RESRAD 15 mrem/y residential (10% produce consumption)*	EPA 15 mrem/y DCC residential (25% produce consumption)**	EPA 15 mrem/y DCC residential (100% produce consumption)**
		pCi/g	pCi/g	pCi/g	pCi/g
Potassium-40	NORM	30.5	27.6	8.58	2.5
Uranium-238	NORM	1.68	90.9	0.803	0.24
Thorium-232	NORM	2.95	1.53	0.657	0.197
Radium-226	NORM	1.82	0.199	0.872	0.263
Cesium-137	Man-made	0.193	9.2	12.6	9.31
Strontium-90	Man-made	0.075	36.0	2.9	0.727
Plutonium-239	Man-made	0.0142	33.9	91.0	29.1

* RESRAD, N001SRR140131. August 22, 1996
** EPA, DCC, March 21, 2026

EPA Dose Compliance Concentrations (DCC)

Radionuclide	Source	Background (BTV)	Former RESRAD 15 mrem/y residential (10% produce consumption)*	EPA 15 mrem/y DCC residential (25% produce consumption)**	EPA 15 mrem/y DCC residential (100% produce consumption)**
		pCi/g	pCi/g	pCi/g	pCi/g
Potassium-40	NORM	30.5	27.6	8.58	2.5
Uranium-238	NORM	1.68	90.9	0.803	0.24
Thorium-232	NORM	2.95	1.53	0.657	0.197
Radium-226	NORM	1.82	0.199	0.872	0.263
Cesium-137	Man-made	0.193	9.2	12.6	9.31
Strontium-90	Man-made	0.075	36.0	2.9	0.727
Plutonium-239	Man-made	0.0142	33.9	91.0	29.1

* RESRAD, N001SRR140131. August 22, 1996
** EPA, DCC, March 21, 2026

Plutonium-239 is 12-150 **less** radiotoxic than common NORM radionuclides

Debunking the Scary Stuff

Debunking the Scary Stuff about Plutonium

- Activists love to use the scary specter of plutonium-239 with a 24,000-year half life
  - Myth: "one of the most toxic substances on earth"
  - Fact: Google "the most toxic substances on earth" gets you an AI Overview …
    - botulinum toxin, maitotoxin, batrachotoxin, tetanus toxin and radioactive polonium-210. Naturally occurring Po-210 is in tobacco leaves and gives 0.5 mrem/y for a 1pack/day smoker. Pu-239 is not mentioned.
  - Fact: Nuclear Regulatory Commission 10 CFR 20 Appendix B airborne limits for members of the public
    - Pu-239 (man-made) 2×10^{-14} μCi/mL
    - Th-232 (NORM) 4×10^{-15} μCi/mL
    - Airborne Th-232 is **5 times more radiotoxic** than airborne Pu-239
    - Th-232 soil BTV is **~200 times greater** than Pu-239 soil BTV
  - Fact: EPA PRGs
    - Plutonium-239 is 75-250 **less** radiotoxic than common NORM radionuclides based on risk
  - Fact: EPA DCCs
    - Plutonium-239 is 12-150 **less** radiotoxic than common NORM radionuclides based on risk

Debunking the Scary Stuff about Area IV Cesium

- Fact: Activists love to use the meme … “EPA found Cs-137 at 1,000 times background”
- Reality:
  - EPA found Cs-137 in **one of 3,735** soil samples at 196 pCi/g, approximately 1,000 times background
  - Only **8 of 3,735** samples exceeded the conservative residential former DOE and DPH approved Cs-137 cleanup standard
  - No samples exceeded the EPA acceptable risk range for the realistically anticipated future land use of recreational open space
  - Using a residential, 100% produce consumption land use
    - Risk of background Cs-137 is ~1,000 times less than the risk from background K-40.
    - Therefore, risk of **uniform Cs-137 contamination 1,000 times background** is equal to risk of uniform K-40 background.
    - The risk from **one sample of Cs-137 contamination 1,000 times background** is equal to 1/3735 the risk of uniform K-40 background.

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Surface Contamination Cleanup Standards

Acceptable Surface Contamination Levels

- Nuclear Regulatory Commission
  - Regulatory Guide 1.86 Termination of Operating Licenses for Nuclear Reactors, Table 1, Acceptable Surface Contamination Levels (withdrawn)
  - NUREG-1757, Vol 1, Rev. 2, Section 15.11.1.1, Release of Solid Materials with Surface Residual Radioactivity.
  - Fuel Cycle Policy and Guidance Directive FC-83-23, Guidelines for Decontamination of Facilities and Equipment Prior to release for Unrestricted Use or Termination of Byproduct, Source and Special Nuclear Material Licenses
- ANSI/HPS N13.12-2013, Surface and Volumetric Radioactivity Standards for Clearance (based on < 1 mrem/y)
- Department of Energy, DOE-STD-1241-2023, Implementing Release and Clearance of Property Requirements
- CDPH Radiologic Health Branch, IPM-88-2 (withdrawn)

DOE-STD-1241-2023

Table 1. DOE Total Residual Surface Activity Guidelines:

Allowable Total Residual Surface Activity (dpm/100 cm^2)

Radionuclides	Avg	Max	Removable
Group 1—Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2—Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3—U-natural, ^{235}U, ^{238}U, associated decay products, alpha emitters	5,000	15,000	1,000
Group 4—Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr and others noted above	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)	N/A	N/A	10,000

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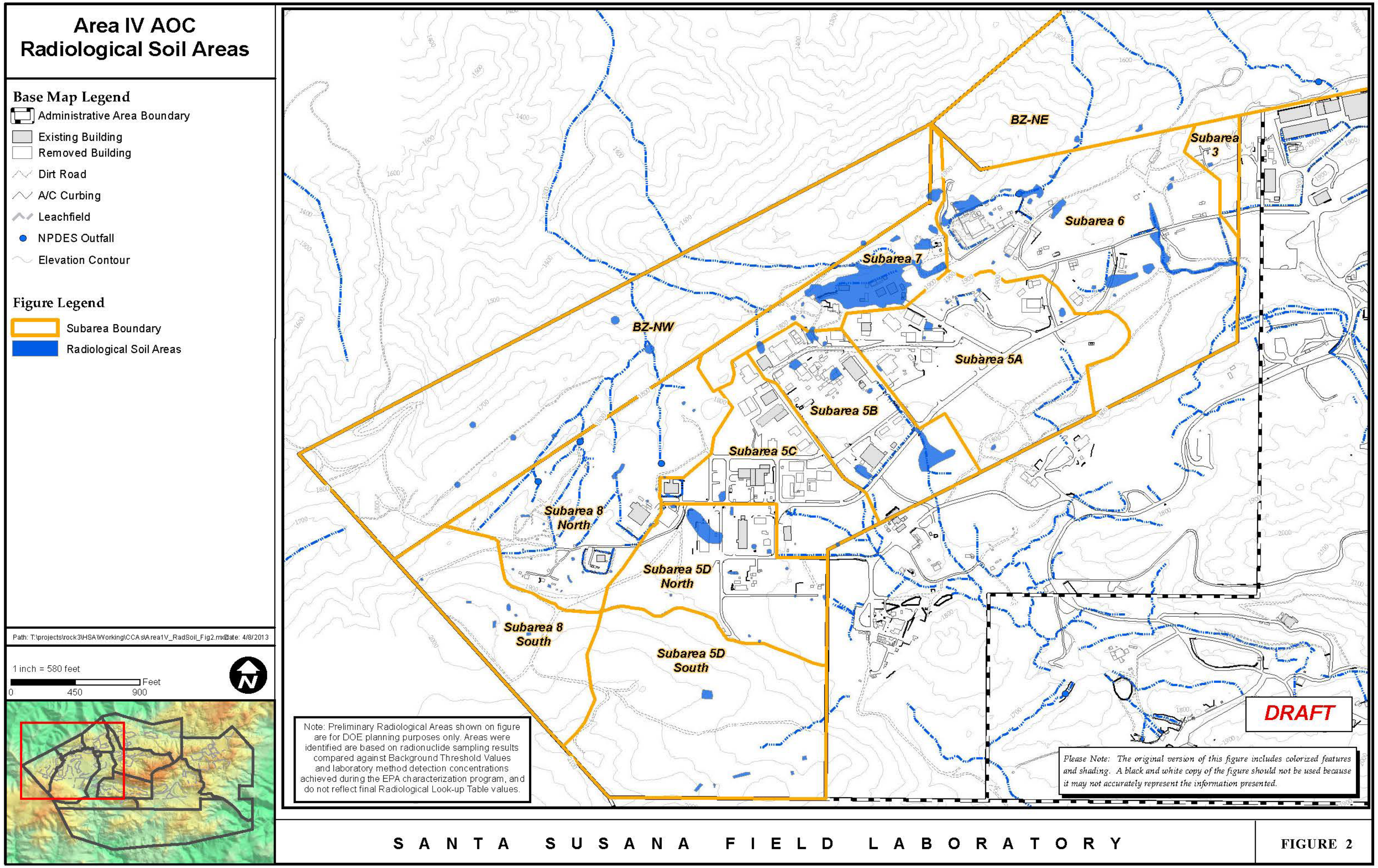
EPA Radiological Survey of Area IV (2008 – 2012)

EPA Estimates of Background

- EPA made ten statistical estimates of background, succeeding in confusing the public, and testing its own credibility
- Demonstrated that "background" is an ill-defined gray area
- Distinction between BTV and the higher LUTV resulted in a raucous public meeting
- The debate became "what is, and is not background" instead of "what is safe and what is not safe"
- Subsequently, DTSC confused the issue even more by re-defining a "new" BTV based on the 95/95UTL instead of the 95%USL

Abbr.	Name	Derivation	Value (pCi/g)	
			Cs-137	Sr-90
RTL	Radiological Trigger Level (Original)	Max(BTV : 2σ UCL MDC) + 1.645*U_M using Round 1 data	0.207	0.485
RTL	Radiological Trigger Level (Revised)	Max(BTV : 2σ UCL MDC) + 1.645*U_M using Round 1 data	0.225	0.645
USL95	95% Upper Simultaneous Limit	ProUCL	0.193	0.0750
BTV	Background Threshold Value	USL95	0.193	0.0750
FAL_A	Field Action Level (Lab. A)	Max(BTV : 2σ UCL MDC)	0.193	0.387
FAL_B	Field Action Level (Lab. B)	Max(BTV : 2σ UCL MDC)	0.193	0.0750
RRC_A	Radiological Reference Level (Lab. A)	Max(BTV : 2σ UCL MDC) + 1.645*U_M using full data set	0.225	1.02
RRC_B	Radiological Reference Level (Lab. B)	Max(BTV : 2σ UCL MDC) + 1.645*U_M using full data set	0.225	0.117
LUT	Look Up Table Value	Min(RRC_A : RRC_B)	0.225	0.117
UTL95-95	95% Upper Tolerance Limit with 95% Coverage	ProUCL	0.151	0.0554

EPA Found Soil Above Background in only a Few Scattered Locations



EPA Area IV Soil Results Exceeding Background

Radionuclides	Number of Samples	Activity Range (pCi/g)		Background Threshold Values[1] (pCi/g)
		Low	High	
Man-Made Radionuclides				
Americium-241	3	0.0484	0.0589	0.0162
Cesium-137	291	0.194	196	0.193
Cobalt-60	4	0.0228	0.0480	0.00556
Curium-243/244	2	0.0178	0.0647	0.0147
Europium-152	6	0.0460	0.165	0.0169
Europium-154	1	0.136		0.0251
Nickel-59	1	23.9		0.344
Plutonium-238	2	0.0137	0.0492	0.00425
Plutonium-239/240	14	0.0233	0.187	0.0142
Strontium-90	153	0.0750	21.3	0.0750
Tritium	1	7.38		7.38

Summary of EPA Soil Sample Exceedances (2012)

- EPA analyzed 3,735 Area IV soil samples
- EPA reported results for ~128,000 analytes

Radionuclide	DOE & State Approved 1998 Dose Limit (15 mrem/y)*		Background Threshold Value (BTV)	
	pCi/g	Exceedances	pCi/g	Exceedances
Cesium-137	9.2	8 (0.2%)	0.193	291 (7.8%)
Strontium-90	36	0 (0.0%)	0.075	153 (4.1%)
Plutonium-239	33.9	0 (0.0%)	0.0142	14 (0.4%)

*Limited number of exceedances demonstrates the effectiveness of prior remediation to DOE and State approved dose limit

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Recent Events Related to Cleanup Standards (Chemical and Radiological)

DOE Disposes Decommissioned Material and Debris from Non-Radiological Buildings as LLRW (2020-2021)

- 2020 Amendment to Order on Consent
  - DTSC orders DOE to dispose of decommissioned material from decommissioned buildings (4019. 4029, 4133) as low-level radioactive waste, in **violation** of the 2002 Executive Order D-62-02, and in **violation** of the 2023 Court Order striking down the 2013-2023 PSR-LA Complaint
  - DTSC orders DOE to dispose of demolition debris from buildings with no history of radiological use (4038, 4057, 4462, 4463) as low-level radioactive waste in **violation** of common sense
- DOE mis-characterizes NRC manifest data for waste going to Energy*Solutions*

DTSC/Boeing Settlement Agreement (2022)

- Following 15-month secret mediation talks, a Settlement Agreement was reached between DTSC and Boeing
    - Chemicals would be remediated using suburban residential land use with 100% produce consumption
    - Radionuclides would be cleaned up to background
- Twelve years earlier, Boeing had refused sign the background mandate of the 2010 AOCs. Why was it now agreeing to background for radionuclides now?
- What was the rationale behind different cleanup goals for chemicals and radionuclides?
- Although the radionuclide background was trumpeted by politicians and regulators, it was not mentioned in the 31-page settlement summary but was relegated to Exhibit 5, Attachment 5, page 179 of the 796-page document.
- The radionuclide background cleanup decision clearly violated CEQA, no matter how much DTSC denied it

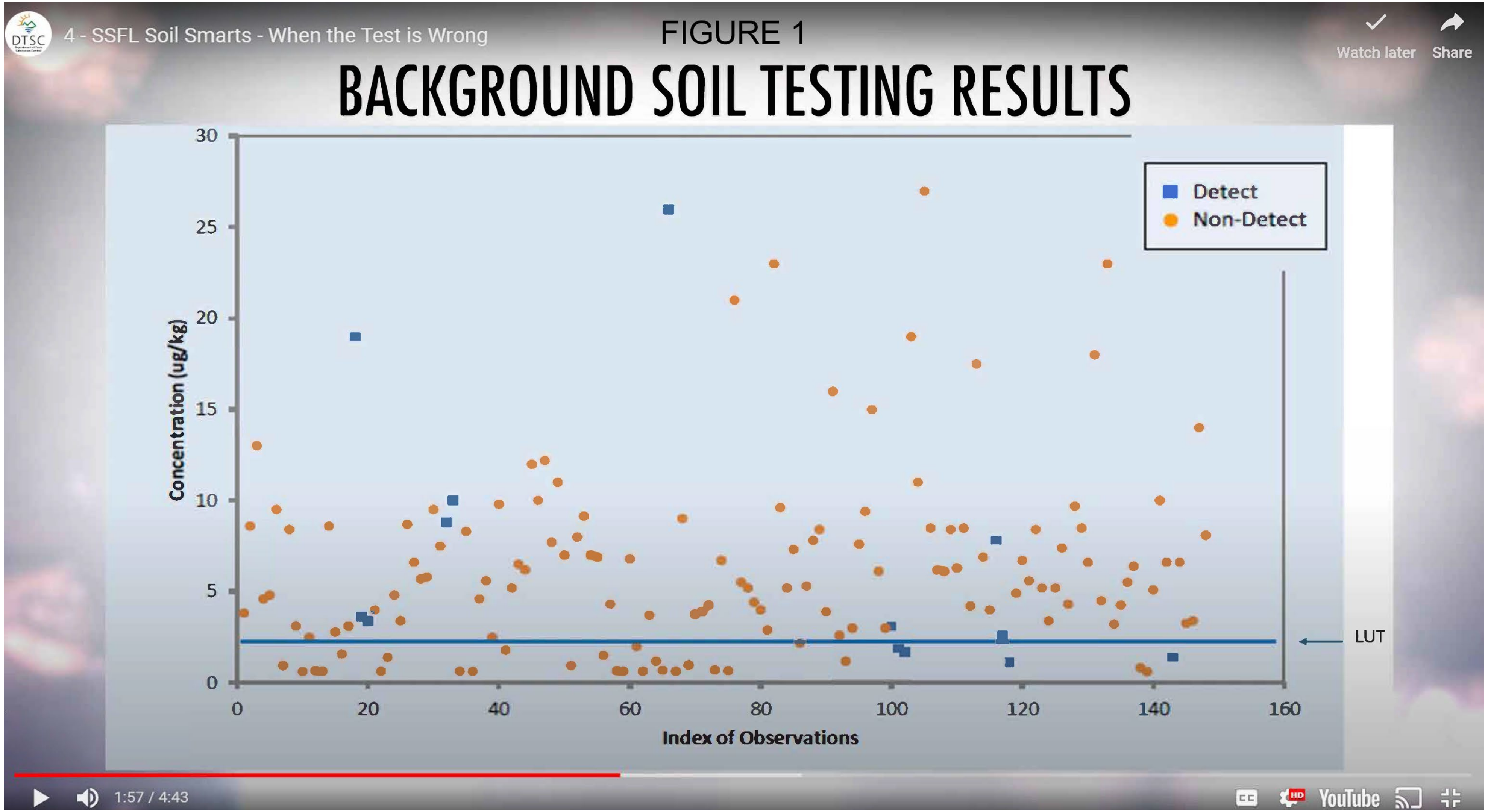
DOE Standard DOE-STD-1241-2023 (2023)

- “Implementing Release and Clearance of Property Requirements”
- DOE-STD-1241-2023 adopts and promulgates for all DOE sites
  - 25 mrem/y plus ALARA for real property based on NRC 10 CFR 20.1402
  - 1 mrem/y for personal property
    - Surface contamination limits for personal property identical to Reg. Guide 1.86 and NUREG-1757, Vol. 1, Rev. 2, Section 15.11.1.1
    - Volumetric contamination limits based on ANSI/HPS N13.12-2013
  - 5 pCi/g of radium-226 in soil based on EPA UMTRCA regulations
- Nowhere does the standard require
  - cleanup to background
  - CERCLA risk assessment
  - 10^{-6} risk limits

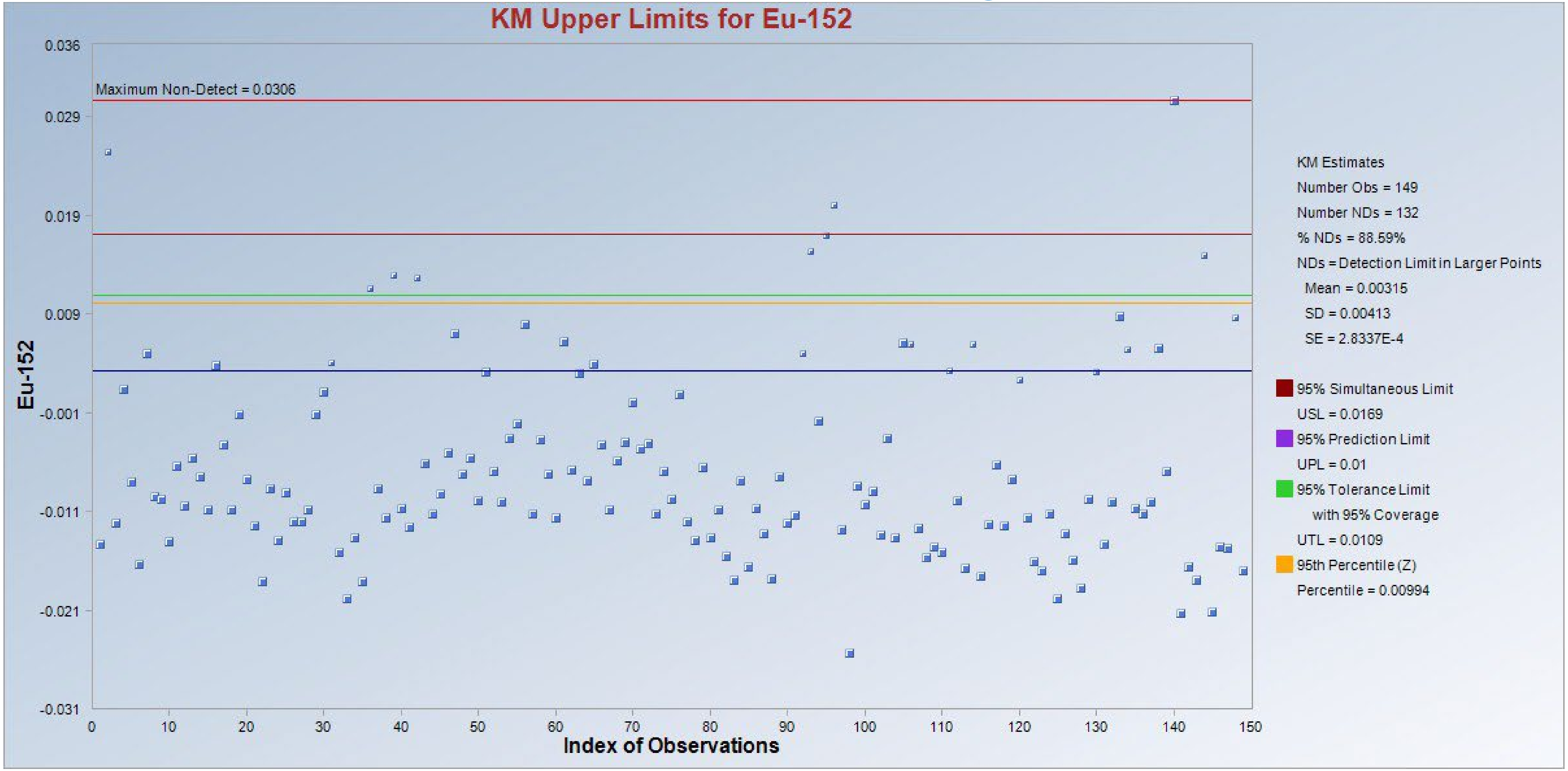
DTSC Soil Smarts
Multiple Lines of Evidence (2024-2026)

- DTSC has recognized that the 2010 AOCs are impossible to implement
- DTSC's choice of chemical "lookup table values" (LUTV) to represent background remedial goals has been based on unrealistic and unachievable chemical "method reporting limits" (MRL)
- This has led to DTSC implementing a process known as "multiple lines of evidence" (MLE) to select alternate remedial goals
- The public has viewed this as reneging on the promise of background cleanup
- Rutherford, "Chemical Questions on Data Presented in Soil Smarts Workshops", December 7, 2024

2,4- Dichlorophenoxybutyric acid (2,4-DB) DTSC Background Data



Europium-152 – EPA Background Data



DOE Supplemental Environmental Impact Statement (SEIS) (2024-2026)

- DOE follows DTSC's lead and proposes implementation of MLE in its attempt to comply with the 2010 AOCs
- The public has viewed this as reneging on the promise of background cleanup

GAO-25-107565 Compares Eight DOE Cleanup Sites (2025)

- The non-partisan General Accountability Office (GAO) summarized cleanup status at eight DOE cleanup sites, Hanford, Los Alamos, Oak Ridge, Savanah River, Idaho, Livermore, Nevada and ETEC
- Hanford, Idaho, Livermore, Oak Ridge, and Savanah River are on the National Priorities List (NPL) and DOE has entered into an interagency agreement with EPA whereby remediation under EPA CERCLA risk assessment guidance is implemented
- Other than ETEC, none of the other seven DOE sites use background as a cleanup goal
- Why does DOE allow itself to be railroaded by DTSC at ETEC?
- GAO-25-107565, Nuclear Waste Cleanup, September 26, 2025
- Rutherford, GAO-25-107565, September 29, 2025

Negative Consequences of LNT and ALARA

- Source of activists' mantra *"there is no safe level of radiation"*
- "As Low As Reasonably Achievable"
  - ALARA is a process, not a numerical goal, and certainly not a goal of zero
  - What is reasonable? Requires a cost-benefit analysis, balancing dose/risk averted with cost incurred. Requires use of a "cost of human life" which is not "politically correct" or acceptable to the public
- SB-990 (2007) was struck down in federal court as unconstitutional
- 2010 AOCs are not implemental, DTSC MLE and DOE SEIS
- 2013-2023 failed 10-year litigation by PSR-LA et. al.
- Costly disposal of tens of thousands of tons of DOE's decommissioned material and non-radiologic demolition debris as LLRW (2020)

Executive Order 14300 Section 5(b) (2025) Ordering the Reform of the Nuclear Regulatory Commission

- Directs the NRC to reconsider its use of the linear no threshold (LNT) model and the process that aims to keep radiation exposures "as low as is reasonably achievable (ALARA)."
  - *Section 1: "The NRC utilizes safety models that posit there is no safe threshold of radiation exposure and that harm is directly proportional to the amount of exposure. Those models lack sound scientific basis and produce irrational results, such as requiring that nuclear plants protect against radiation below naturally occurring levels. A myopic policy of minimizing even trivial risks ignores the reality that substitute forms of energy production also carry risk, such as pollution with potentially deleterious health effects."*
  - *Section 5(b): "Adopt science-based radiation limits. In particular, the NRC shall reconsider reliance on the linear no-threshold (LNT) model for radiation exposure and the "as low as reasonably achievable" standard, which is predicated on LNT. Those models are flawed, as discussed in section 1 of this order. In reconsidering those limits, the NRC shall specifically consider adopting determinate radiation limits, and in doing so shall consult with the Department of Defense (DOD), the Department of Energy (DOE), and the Environmental Protection Agency."*
- In reality, NRC has always been a dose-based regulatory agency
- It is the EPA that has used the theoretical LNT model as the basis of its risk-based radiation regulations for CERCLA Superfund sites and imposed this policy on NRC and DOE

HPS / NCRP Response to EO 14300

- HPS/NCRP Webinars on Trump Nuclear Related Executive Orders, June 9 & 10, 2025
  - Rutherford, Comments on EO 14300, June 18, 2025
  - Radiation Protection Policy in a Nuclear Era: Recommendations from Health Physicists in Response to EO 14300, January 2026
    - ALARA is not required or expected for public exposures already below regulatory limits. This is particularly relevant in environmental cleanup or in scenarios where background radiation dominates total exposure.
  - Regulatory Harmonization and Expanded Nuclear Power, January 14, 2026

NRC Response to EO 14300

- Webinar hosted by NRC. Reconsidering the NRC's Radiation Protection Framework, July 16, 2025
  - Presentations by numerous stakeholders supporting and opposing nuclear power
  - PowerPoint Slides
  - Transcript
  - YouTube Video
- Rutherford, Rebuttal to Dan Hirsch's presentation to NRC Meeting on EO 14300, August 5, 2025
- NRC regulations are primarily dose-based, not risk-based
- NRC plans major changes to 10 CFR 20 in 28 different areas in 2026

DOE Response to EO 14300

- Other EO's have required expedited nuclear research and development of new reactor designs to which DOE is concurring
- EO 14300 Response
  - INL/RPT-25-85463, "Reevaluation of Radiation Protection Standards for Workers and the Public Based on Current Scientific Evidence." July 2025. Recommends elimination of ALARA.
  - Memorandum EXEC-2025-013258, approved by the Secretary of Energy, "Approval to Eliminate ALARA from All DOE Directives and Regulations." January 9, 2026.

EPA Response to Executive Orders

- Immediate response unknown
- Although EO 14300 is aimed primarily at NRC, it also targets EPA since EPA is the primary proponent of risk-based LNT
- Significant revision or scrapping of LNT would have a seismic impact on EPA’s risk-based policies, its radiation Superfund program and its PRG calculators
- Stay tuned

Factual Errors in Superior Court Decision on PASSFL Lawsuit

- “Parents Against SSFL” lost a court battle regarding the DTSC/Boeing Settlement Agreement
- Page 3. The Court incorrectly states that USEPA has regulatory authority over SSFL. It does not. SSFL is not a Superfund Site. USEPA’s 2007 recommendation that SSFL be listed on the Superfund NPL was denied by Linda Adams (Secretary of CalEPA) in 2008, preferring that SSFL be regulated by DTSC under SB-990 (struck down in federal court) and later by the 2010 AOCs.
- Pages 8 and 15. The Court incorrectly states that the Settlement Agreement originally called for 25% garden produce consumption. It did not. The Settlement Agreement has always called for a 100% garden produce consumption. The final PEIR increased the garden produce consumption to 100% from the 25% in the draft PEIR in response to the change in the USEPA default consumption.
- See next slide

Boeing Resident Garden Produce Consumption - Chemicals

- USEPA changes its default garden produce consumption radionuclide PRGs from 25% to 100% (December 2016)
- Draft PEIR, Section 1.3.3.1, September 2017 - 25%
- Settlement Agreement, page 6, May 9, 2022 - 100%
- Draft PEIR, Section 1.3.3.1, Revised February 2023 - 100%
- Final PEIR, Section 0.4.5, June 2023 - 100%

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To Superfund or …

- 1989-2003 - USEPA conducts four assessments of SSFL (1) and Area IV (3) and concludes Superfund listing is not justified
- November 30, 2007 - In a fifth assessment, USEPA finally concludes *"the site is recommended for further assessment under CERCLA"* based on groundwater contamination of TCE
- December 6, 2007 - USEPA recommended to Governor Schwarzenegger that SSFL be added to the Superfund list
- Activists, legislators and the community are overjoyed
- December 21, 2007 - Dan Hirsch is quoted in the Daily News, saying, *"the community has been praying for a decade that this site would be added to the Superfund list. If the governor blocks Superfund listing, he would be doing a favor to the polluter and a grave injustice to the people who live near the site."*

… Not to Superfund

- January 15, 2008 - Only twenty-five days later, Dan Hirsch, along with a multitude of other activist organizations changed their tune, and sent a letter to CalEPA demanding that the State defer supporting Superfund listing, preferring instead the more restrictive "agricultural land use" requirements of SB-990 to the "reasonably anticipated future land use" requirements of CERCLA guidance (open space), and ultimately preferring the "cleanup-to-background" requirements of the 2010 AOCs.
- January 15, 2008 – The same day, Linda Adams (Secretary of CalEPA) concurred with activist demands and replied to the USEPA that California requests deferment of Superfund listing.
- Demonstrates a pre-planned collusion between CalEPA and activists to derail prior Boeing/Schwarzenegger/Kuehl agreement to donate land to the State in return for Kuehl amending SB-990 to suburban residential land use
- DOE and the Water Board supported Superfund listing
- SSFL is still not a Superfund site today

Additional Information on philrutherford.com

- Phil Rutherford *Consulting*
  https://philrutherford.com/
- Radiation Cleanup Standards
  https://philrutherford.com/radiation_cleanup_standards.html
- Radiation Risk
  https://philrutherford.com/radiation_risk.html
- Radiation Dose, Risk and Cleanup standards (This PowerPoint)
  https://philrutherford.com/SSFL/Cleanup_Standards/Radiation_Dose_Risk_and_Cleanup_Standards.pdf
- Santa Susana Field Laboratory
  https://philrutherford.com/ssfl.html
- Offsite Impact of the Santa Susana Field Laboratory
  https://philrutherford.com/SSFL/Offsite_Impact_of_SSFL.pdf
- Nuclear Decommissioning at the Santa Susana Field Laboratory:
  20+ Years of Politics vs. Science
  https://philrutherford.com/SSFL/Nuclear_Decommissioning_at_SSFL.pdf

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