

# Radioactivity

**Raw Radiation**



**Decay Rate**

**Curie (Ci)**

$3.7 \times 10^{10}$  disint/s

**Becquerel (Bq)**

$1$  disint/s

**Energy Absorbed**



**Absorbed Dose**

**Gray (Gy)**

J/kg

**Rads**

= 0.01 Gy

**Related:**

**Roentgen (Rg)**

C/kg

**Damage Done**



**Effective Dose**

**Sieverts (Sv)**

*weighted for damage:  
1 for  $\beta, \gamma$ ; 20 for  $\alpha$*

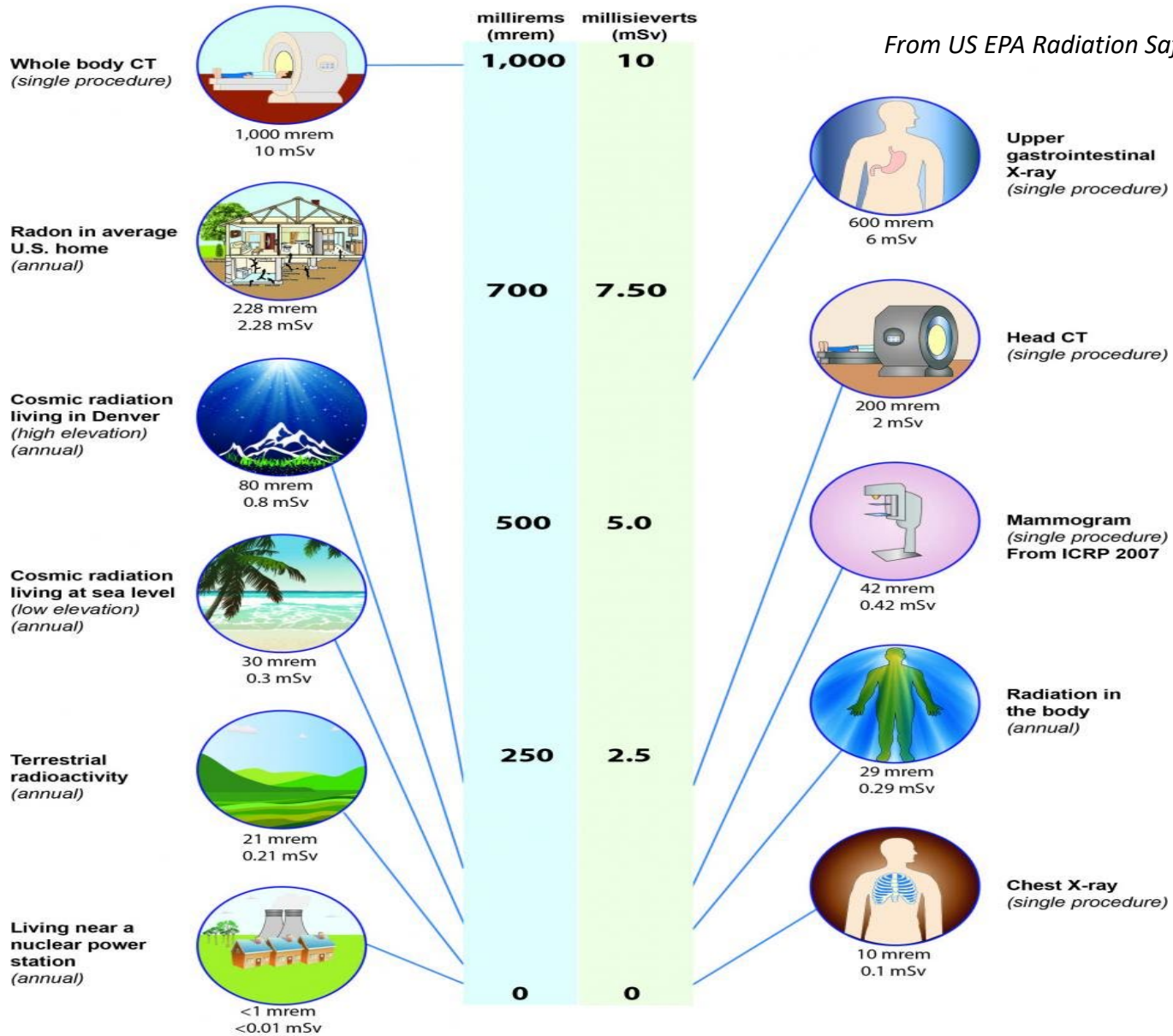
**Rem**

= 0.01 Sv

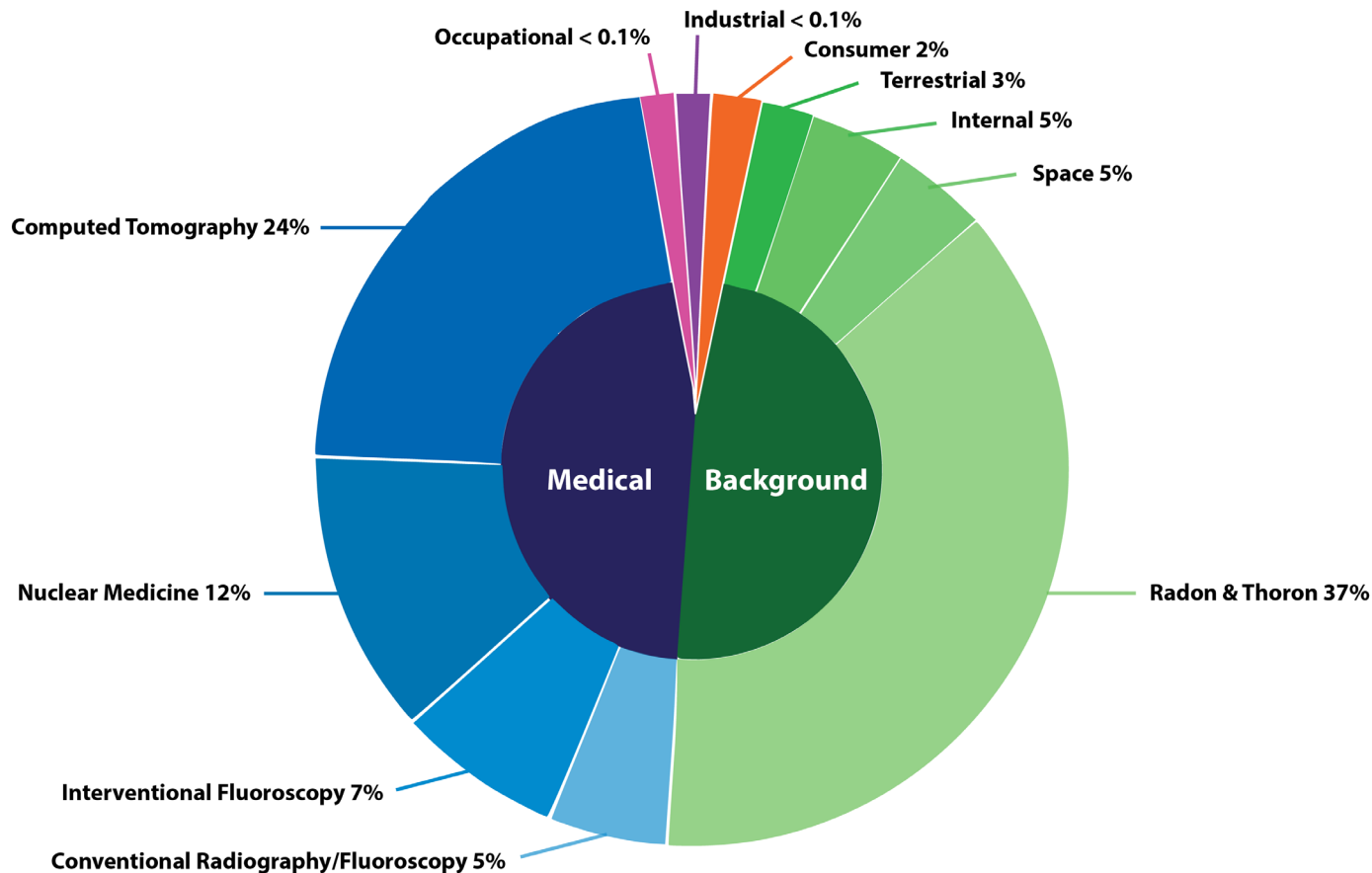
# RELATIVE DOSES FROM RADIATION SOURCES

All doses from the National Council on Radiation Protection & Measurements, Report No. 160 (unless otherwise denoted)

From US EPA Radiation Safety website



## Sources of Radiation Exposure



Average Annual Radiation Dose

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

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

# Annual Radiation Dose

Adult: 50,000  $\mu\text{Sv}$   
Considered safe

Table 7.3

Annual Radiation Dose (Sample Calculation)\*

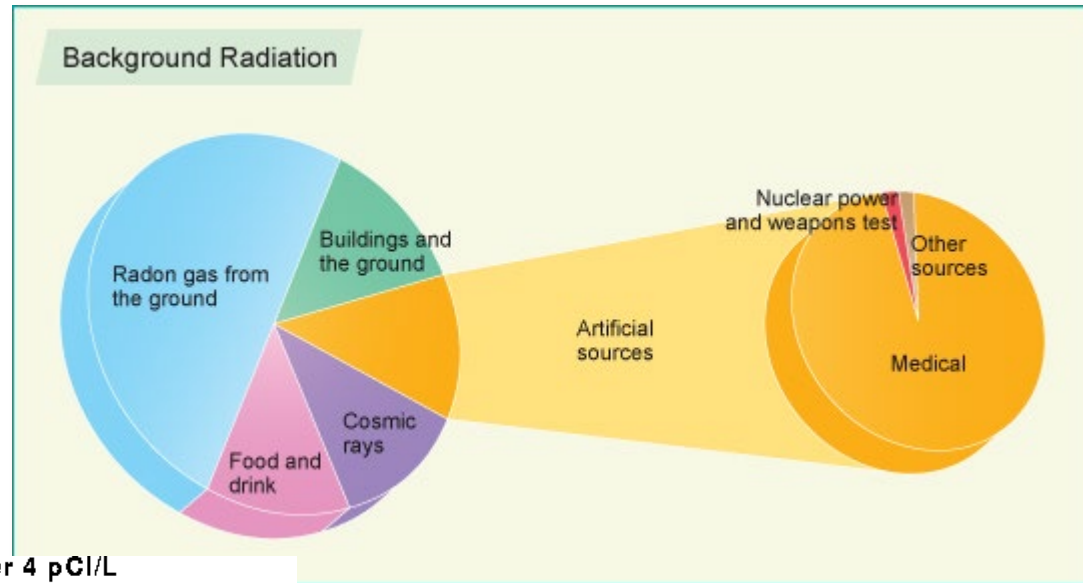
Sources of Radiation	( $\mu\text{Sv}/\text{yr}$ )
1. Cosmic radiation	
a. Sea level (U.S. average)	260
b. Additional dose if you are above sea level	
up to 1000 m (3300 ft) add 20 $\mu\text{Sv}$	20
1000 to 2000 m (6600 ft) add 50 $\mu\text{Sv}$	
2000 to 3000 m (9900 ft) add 90 $\mu\text{Sv}$	
3000 to 4000 m (13,200 ft) add 15 $\mu\text{Sv}$	
4000 to 5000 m (16,500 ft) add 21 $\mu\text{Sv}$	
2. Building material(s) used in your dwelling	
Stone, brick or concrete add 70 $\mu\text{Sv}$	
Wood or other add 20 $\mu\text{Sv}$	20
3. Rocks and soil	460
4. Food, water, and air (K and Rn)	2400
5. Fallout from nuclear weapons testing	10
6. Medical and dental X-rays	
a. Chest X-ray, add 100 $\mu\text{Sv}$ each	0
b. Gastrointestinal tract X-ray, add 5000 $\mu\text{Sv}$ each	0
c. Dental X-rays, add 100 $\mu\text{Sv}$ each	100
7. Airplane travel	
5-hour flight at 30,000 feet, add 30 $\mu\text{Sv}/\text{flight}$	300
8. Other	
a. Live within 50 miles of a nuclear plant, add 0.09 $\mu\text{Sv}$	0.09
b. Live within 50 miles of a coal-fired power plant, add 0.3 $\mu\text{Sv}$	0.3
c. Use a computer terminal, add 1 $\mu\text{Sv}$	1
d. Watch TV, add 10 $\mu\text{Sv}$	10
e. Smoke one pack of cigarettes/day, add 10,000 $\mu\text{Sv}$	0
<b>Total Annual Radiation Dose</b>	<b>3581</b>
U.S. annual average = 3600 $\mu\text{Sv}$	

\*Sample calculation is for an adult nonsmoker living in the Midwest.

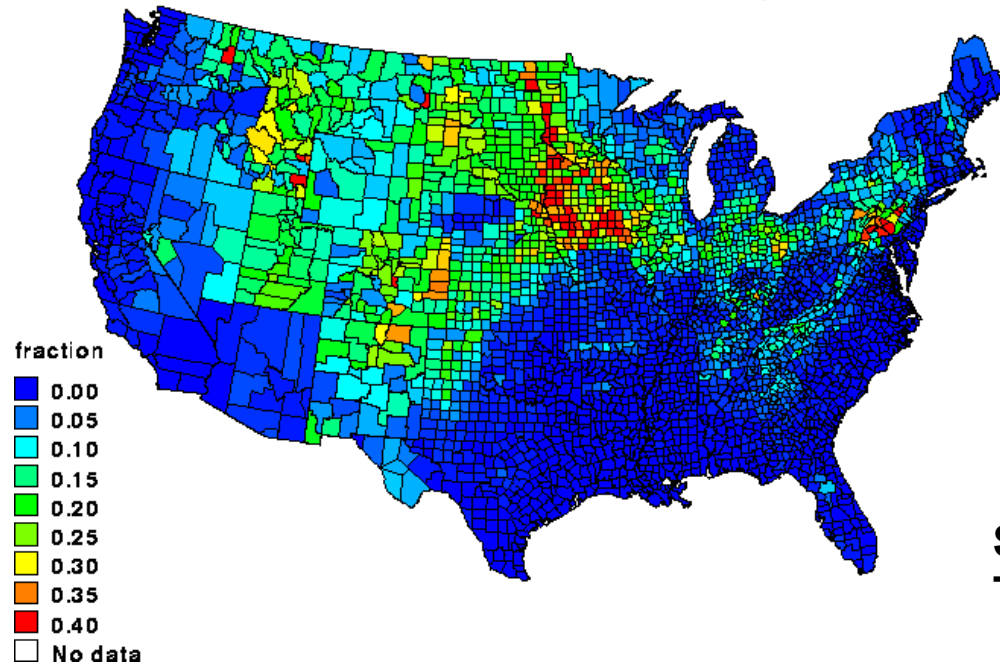
Sources: U.S. Environmental Protection Agency, American Nuclear Society.

# Radon gas

Leading cause of lung cancer in non-smokers



Predicted fraction of homes over 4 pCi/L



<http://www.world-nuclear.org/education/ral.htm>

From US EPA Radiation Safety website

See also: [Radon and Your Health](#) from The BC Lung Association

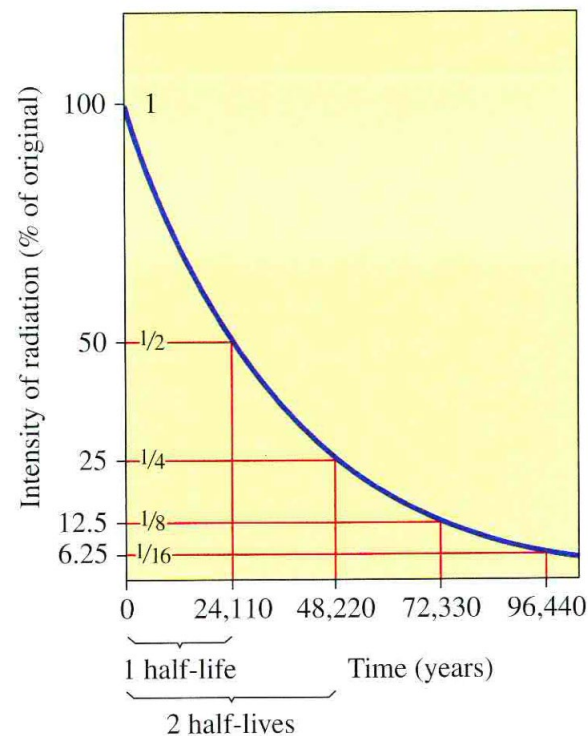
# Nuclear waste

**Half-life** is the time it takes for the radioactivity to decay by  $\frac{1}{2}$ .

## Decay of Pu-239

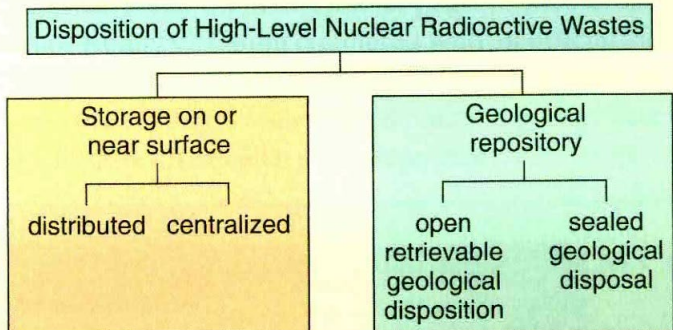
**Table 7.5** Half-Lives for Selected Radioisotopes

Radioisotope	Half-life ( $t_{1/2}$ )
uranium-238	$4.5 \times 10^9$ years
potassium-40	$1.3 \times 10^9$ years
plutonium-239	24,110 years
carbon-14	5715 years
cesium-137	30.2 years
strontium-90	29.1 years
thorium-234	24.1 days
iodine-131	8.04 days
radon-222	3.82 days
plutonium-231	8.5 minutes
polonium-214	0.00016 seconds



Chemistry in Context 6<sup>th</sup> Edition, ACS, McGraw-Hill

# Options for nuclear waste disposal



feasible, safe, secure as long as resources are continually committed

feasible, safe, secure with reduced active measures

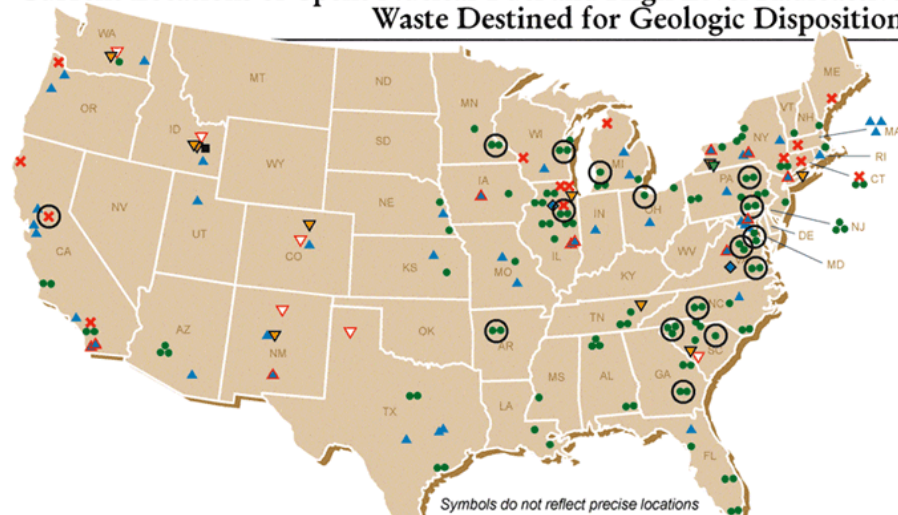
options open

decreasing degree of reversibility



wikipedia

## Current Locations of Spent Nuclear Fuel and High-Level Radioactive Waste Destined for Geologic Disposition

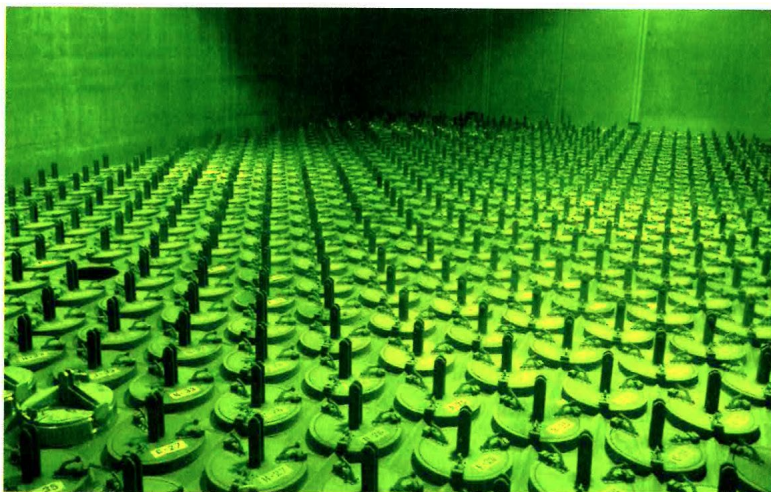


*Symbols do not reflect precise locations*

Nuclear Sites	Current Storage Locations (and Number of Locations)	Waste Quantities Projected through 2046 (in Metric Tons, except for HLW)
<ul style="list-style-type: none"> <li>63 commercial reactors operating</li> <li>9 commercial reactors shutdown</li> <li>2 commercial SNF pool storage</li> <li>43 research reactors</li> <li>13 DOE nuclear materials</li> <li>1 Navy fuels</li> </ul>	<ul style="list-style-type: none"> <li>Commercial Reactors (72 sites in 33 states), including:               <ul style="list-style-type: none"> <li>104 operating reactors, and</li> <li>14 shutdown reactors with SNF on site</li> </ul> </li> <li>Research Reactors (43 sites in 26 states), including:               <ul style="list-style-type: none"> <li>36 operating reactors, and</li> <li>11 shutdown reactors with SNF on site</li> </ul> </li> <li>Commercial SNF Pool Storage (Away-From-Reactor) (2)</li> <li>DOE-Owned SNF and HLW (10)</li> <li>Commercial HLW (1)</li> <li>Commercial Dry Storage Sites (16)</li> <li>Surplus Plutonium (6)</li> <li>Naval Reactor Fuel (1)</li> </ul>	<ul style="list-style-type: none"> <li>Commercial SNF up to 105,000</li> <li>DOE-Owned SNF 2,600</li> <li>including:               <ul style="list-style-type: none"> <li>Naval Reactor Fuel 65</li> <li>Foreign Research Fuel 16</li> </ul> </li> <li>Surplus Plutonium 50</li> <li>HLW Glass (canisters) ~22,000</li> </ul>

current locations map 010602 hgcc.th7

As of January 2002

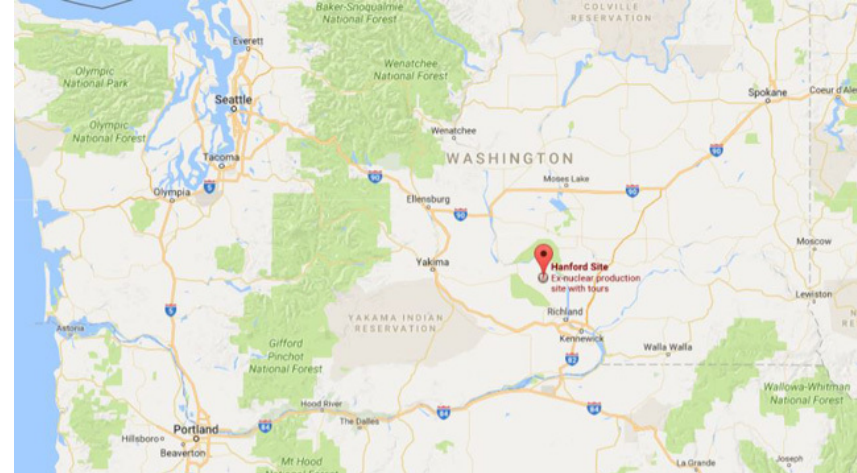


Chemistry in Context 6<sup>th</sup> Edition, ACS, McGraw-Hill

From democraticunderground.com

# Tunnel collapse renews safety concerns about Hanford nuclear site in Washington state [THE ASSOCIATED PRESS](#)

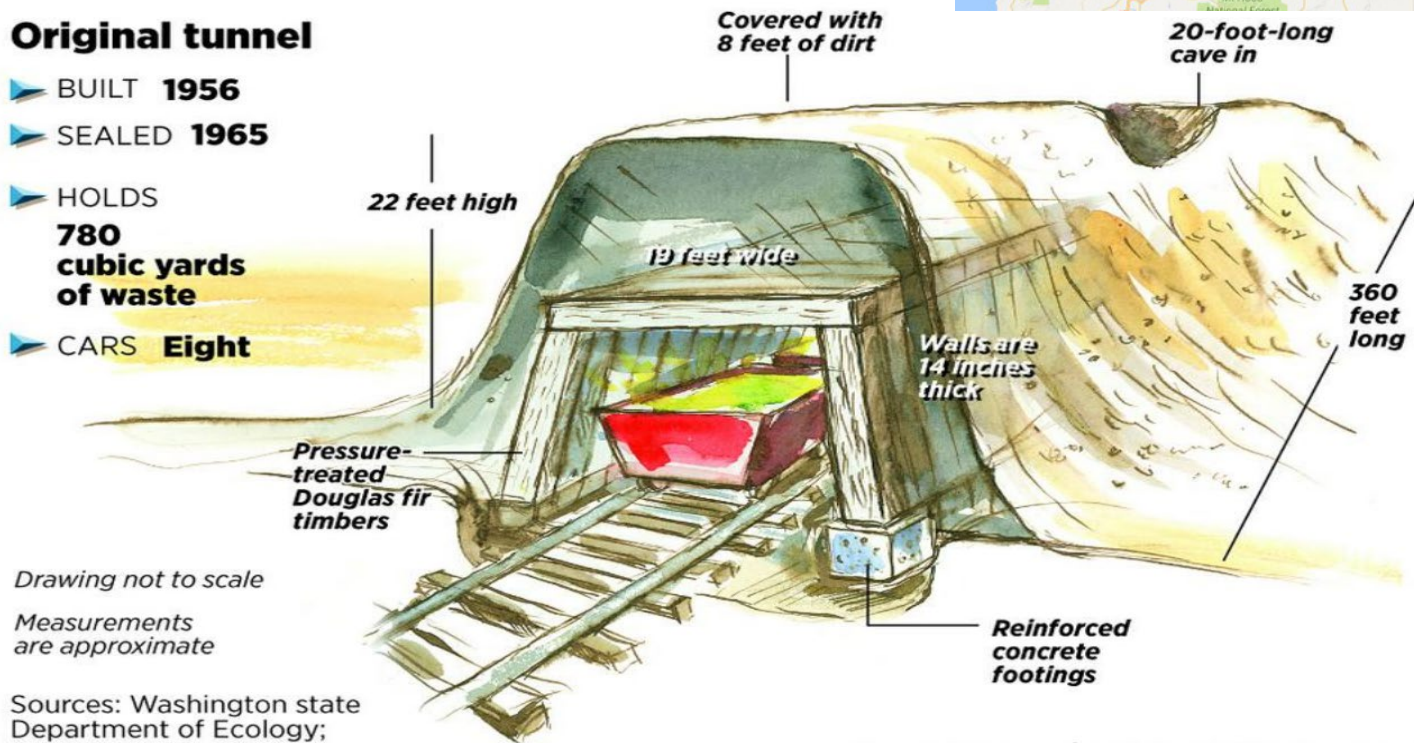
May 10, 2017 (Headline in Vancouver Sun)



## PUREX storage tunnel

### Original tunnel

- ▶ BUILT **1956**
- ▶ SEALED **1965**
- ▶ HOLDS **780 cubic yards of waste**
- ▶ CARS **Eight**



*Drawing not to scale*

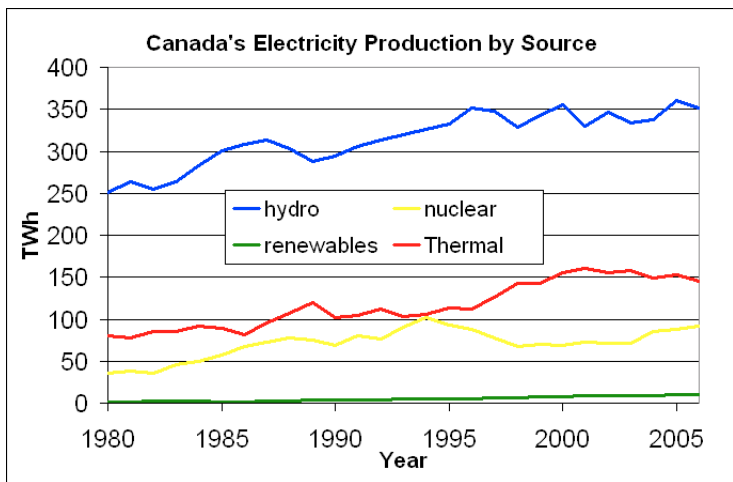
*Measurements are approximate*

Sources: Washington state Department of Ecology; The Washington Post

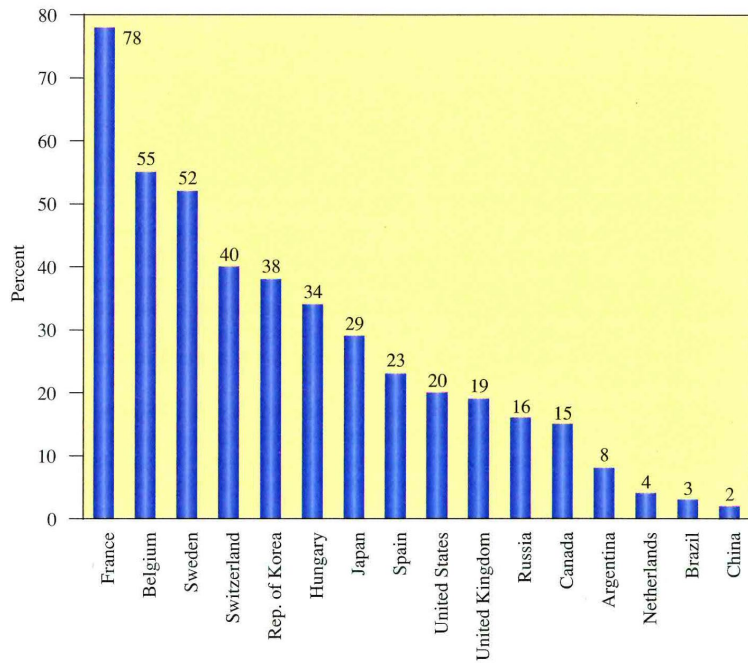
MOLLY QUINN/THE SPOKESMAN-REVIEW

See also: <https://ecology.wa.gov/Waste-Toxics/Nuclear-waste/Hanford-cleanup/PUREX>

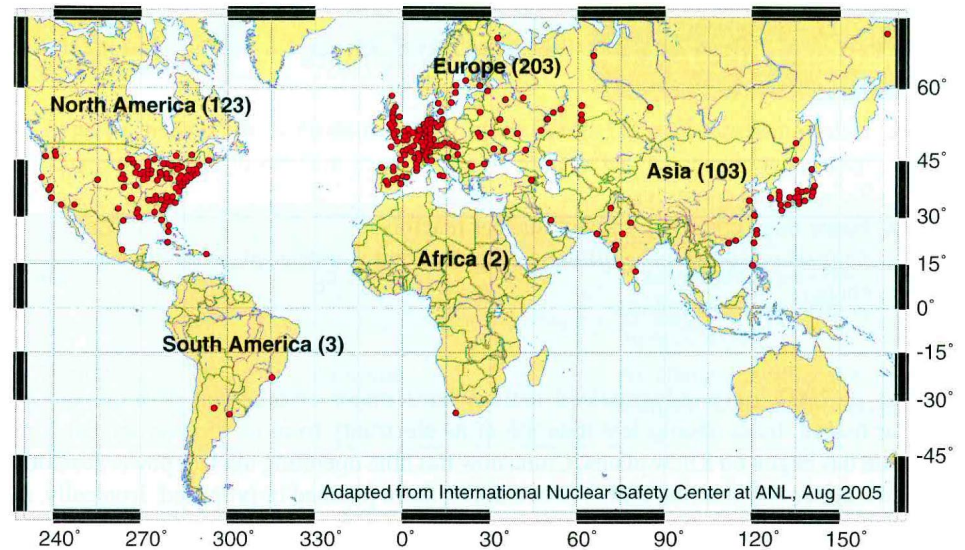




wikipedia



From businessinsider.com

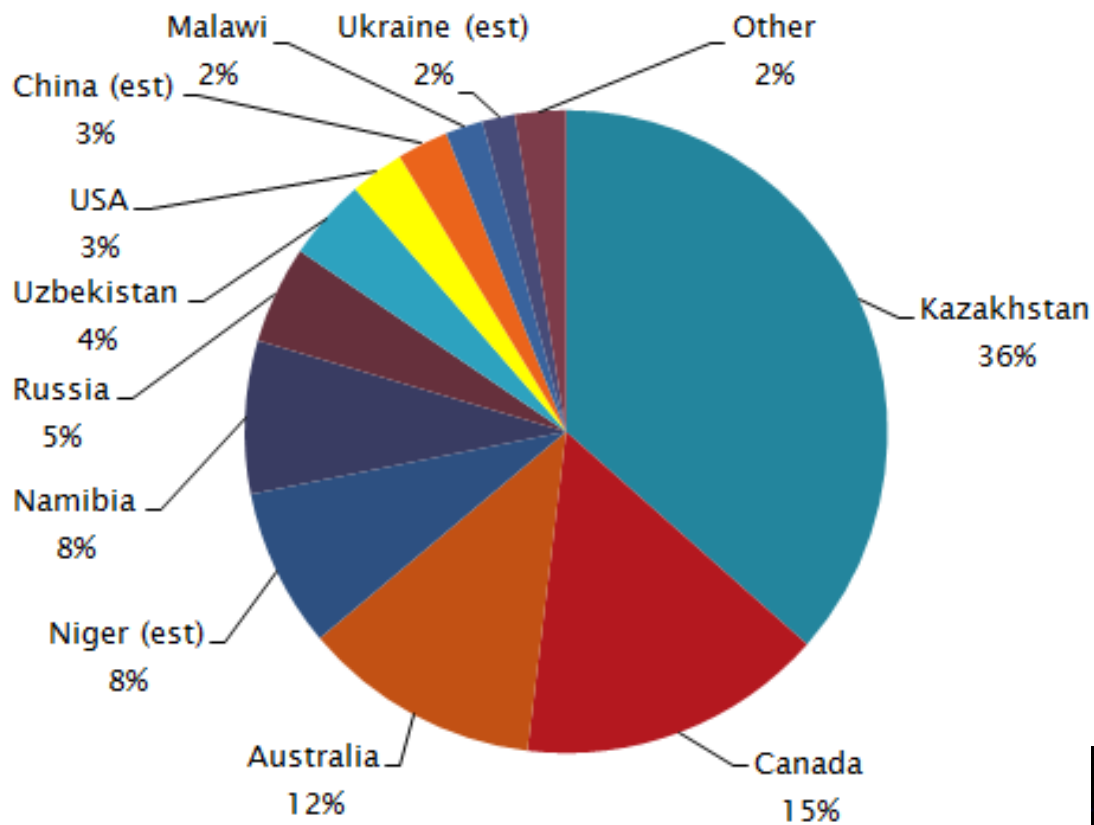


**Figure 7.10** Chemistry in Context 6<sup>th</sup> Edition, ACS, McGraw-Hill

umber of reactors in operation worldwide, as of December 2005. Some sites have more than one actor.

ource: [http://www.insc.anl.gov/pwrmaps/map/world\\_map.php](http://www.insc.anl.gov/pwrmaps/map/world_map.php)





World Uranium Mining Production 2012

### Uranium glass

