An Attempt At Making The Science Understandable: Citizens Guide to Uranium

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Premise

- We (U industry, scientists) have believed since the beginning of commercial nuclear industry that the science provides the obvious answers to addressing concerns of citizens and public officials
- If they don't "get it", its their problem, not ours
- WRONG!! - its our problem since without public acceptance we cannot move forward without a great deal of pain, if at all
- It is in America's best interest for us to figure this out
- We must move beyond our "professional arrogance" and figure out how to make the science – that in fact does provide the answers ***Understandable***

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A Humble Attempt At Making The Science Understandable

A Citizen's Guide to Uranium

SENES CONSULTANTS LIMITED

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Introduction

In my work as a health physicist, I do a lot of public speaking and interact with the public on issues related to development of uranium mining and milling ("uranium recovery") in the U.S. Understandingly, the public has important concerns about this. In a "question and answer" format below, I have tried to capture what are some of the most common concerns heard from citizens and address them based on the best scientific information we have, representing information well documented in peer-reviewed scientific literature and consensus positions from both national and international scientific standard setting bodies and related committees. Some of the more important of these scientifically-based references are provided to support the information given below. Practical space limitations prevent completeness in this regard in some cases. Visit the Health Physics Society's web site or feel free to contact me directly for additional references, information or detail – Steve Brown.

Inside this issue:

In Q/A Format, *A Citizens Guide* Answers the Following Questions

- What is uranium and where does it come from?
- How much uranium and associated elements ("decay products") are in the food we eat, water we drink and in soil under are feet?
- How radioactive is uranium and uranium ore compared to consumer products we use everyday that contain radioactive substances?
- Are existing regulations for uranium recovery facilities adequate to protect the public from additional radiation exposure above our natural background exposure?

In Q/A Format, A Citizens Guide Answers the Following Questions (continued)

- What are the potential health effects from exposure to uranium?
- What about the known health impacts (e.g., lung cancer) to many uranium miners who worked underground in the 1950's and 1960's?
- How is uranium extracted from the earth?
- What is uranium used for and why is it important?
- Don't scientists disagree on many of the health and safety concerns associated with uranium and radiation exposure in general?

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Some Common and Critical Misconceptions: Examples

- Uranium becomes radioactive when mined
- Environment is “radiation free” w/o nuclear industry
- No “safe” level of radiation exposure - any amount is potentially harmful
- Health impacts to early U miners in 1950’s and 1960’s translate directly to workers and public today
- Scientists disagree on basic principles of radiation safety
- Almost anyone with an advanced degree (including lawyers) can be an expert in anything

What is Uranium and Where Does it Come From ?

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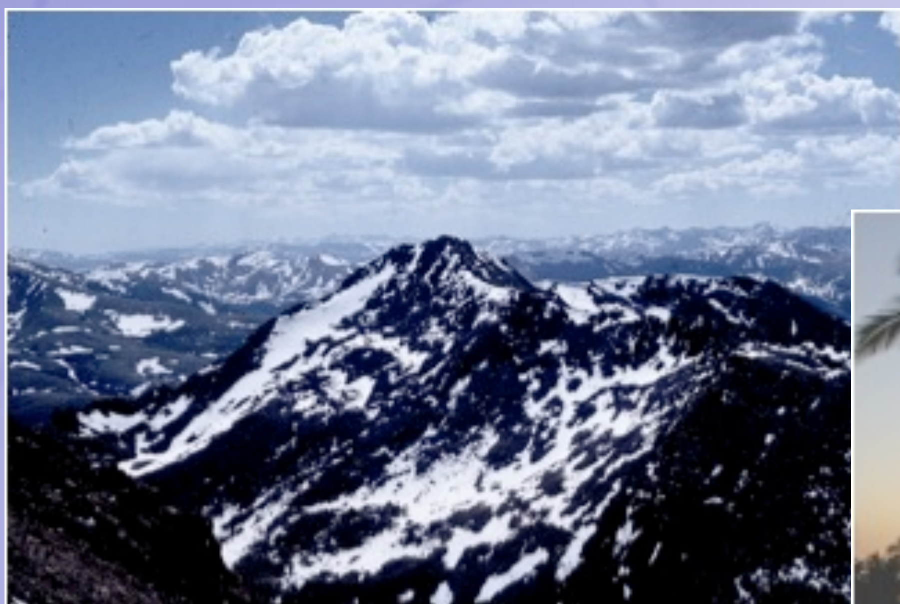
Uranium in the Natural Environment

- "Primordial" element part of Earth's formation 4.5 billion years ago (originated in supernovas)
- Deposited on land by volcanic action over geologic time
- Dissolved by rainfall and carried into underground formations
- Chemical conditions in some locations resulted in concentration into "ore bodies"
- Fairly common element in Earth's crust (soil, rock) and in groundwater and seawater, typically 2-4 ppm - as common as tin, tungsten, molybdenum, etc.
- A square mile of earth, one foot deep, will typically contain over a ton of uranium; one acre of land, one foot deep, typically has 3 - 4 lbs

Our Radioactive Natural Environment – Everyday Sources of Radiation Exposure to Humans



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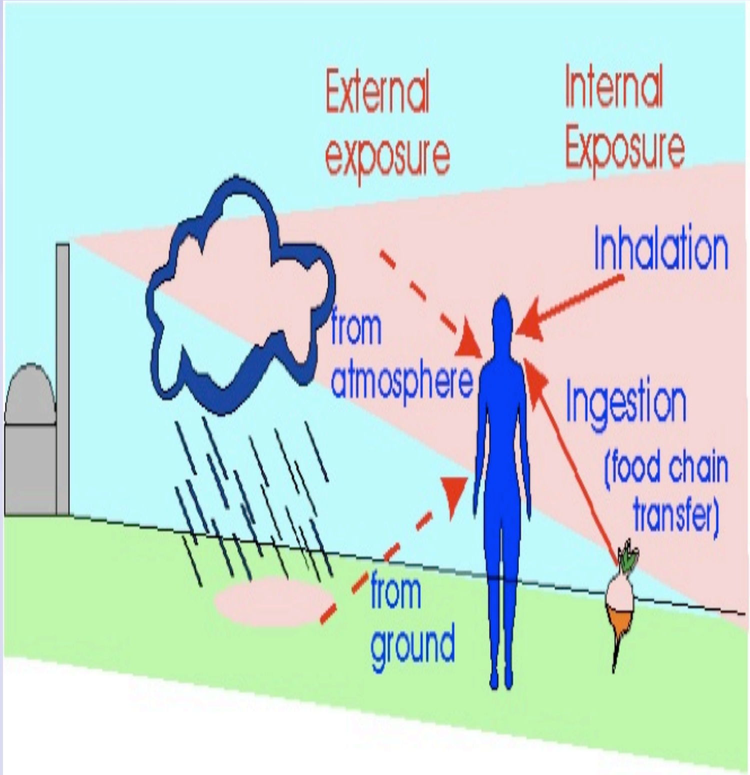
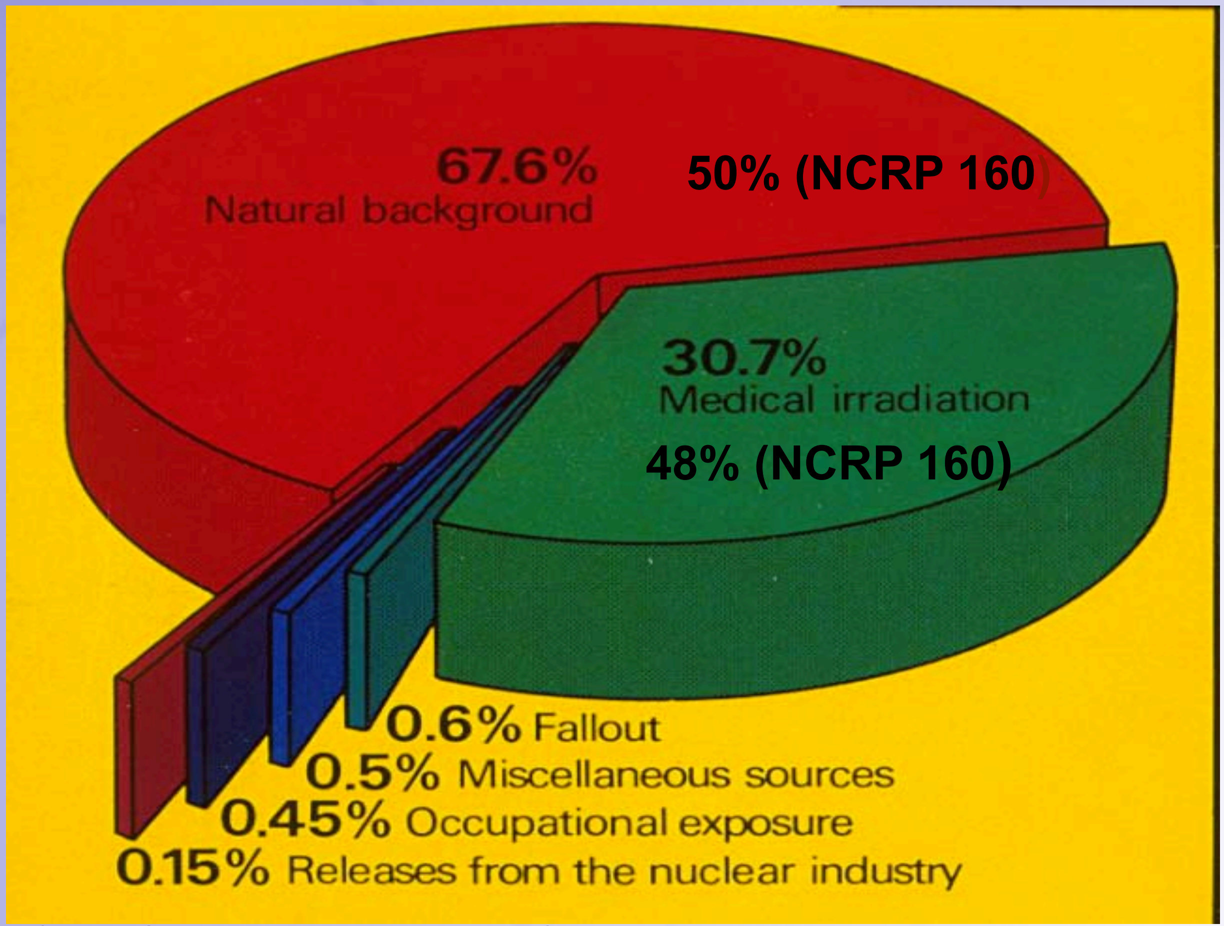
We Live in a Radioactive Environment – It's Always Been This Way

- We are continuously bombarded with radiation from space and earth's surface
- Uranium is a common element in rock and soil
- Uranium is in the food and water we consume everyday
- Background radiation in Rocky Mtn. States can be several times higher than other parts of the U.S. – Elevation and Mineralization!

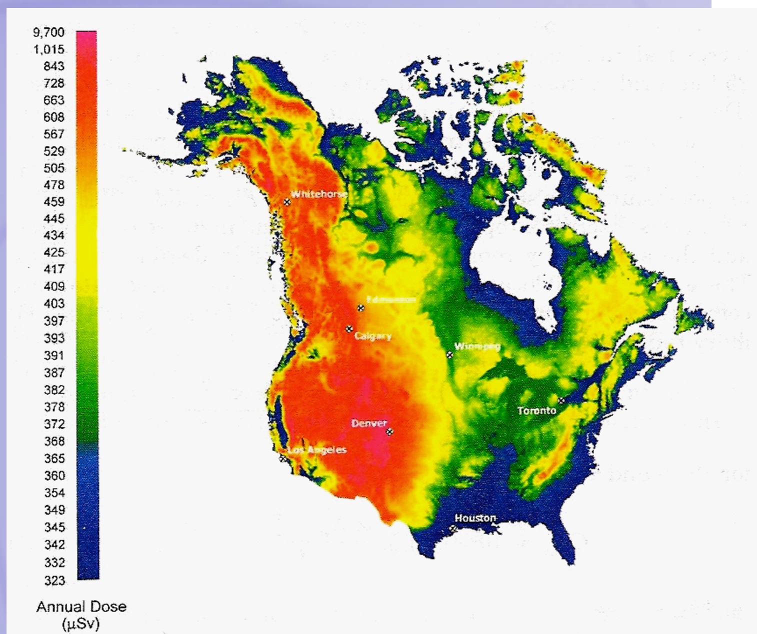


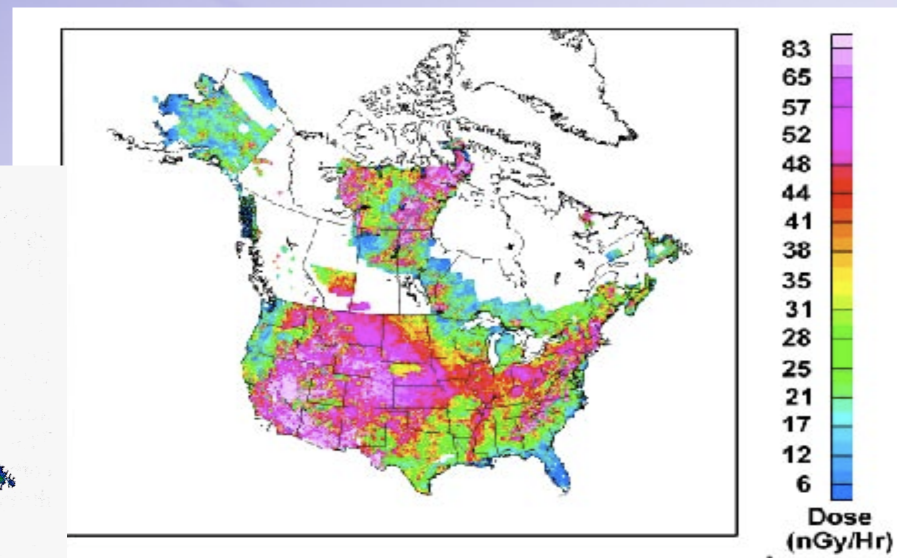
Sources of Radiation Exposure to Humans



Update from NCRP Report 160, National Council on Radiation Protection and Measurements
***Ionizing Radiation Exposure of the Population of the United States,* 2006**

Cosmic Ray and Terrestrial Background Varies Considerably Across US





National Council on Radiation Protection and Measurements; NCRP Report No. 160,
***Ionizing Radiation Exposure of the Population of the United States*. 2006**

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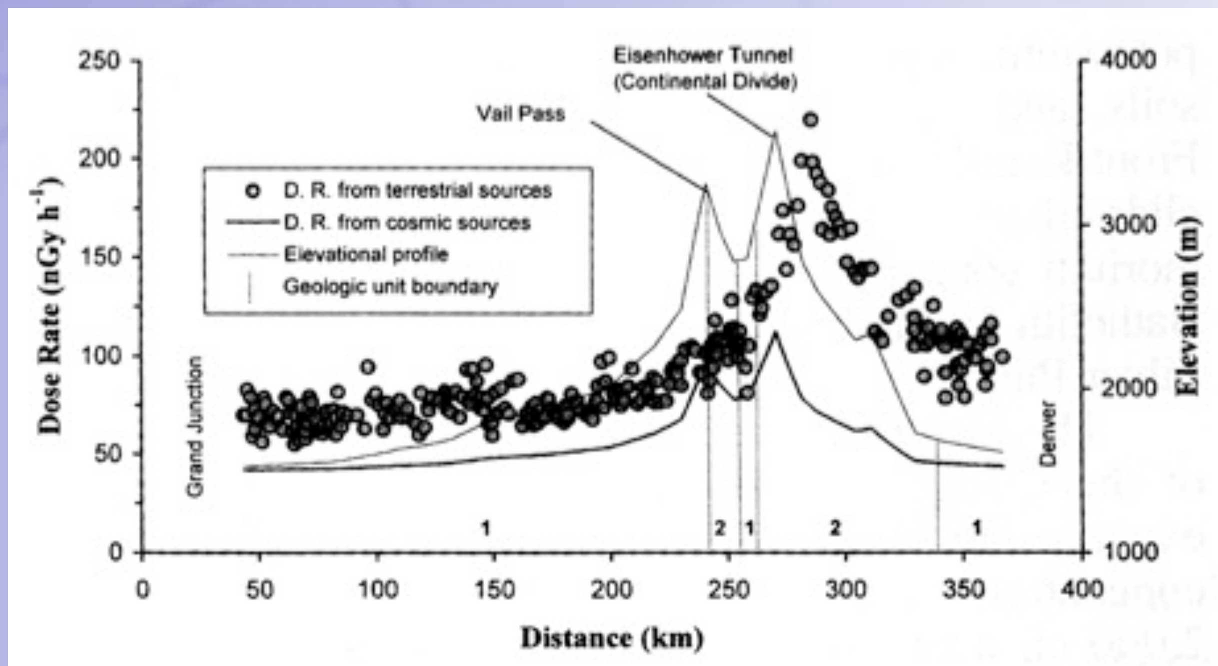
Variability of Natural Background from Place to Place – Example: Colorado



Stone, JM, Whicker, RD et al, *Spatial Variations in Natural Background Radiation: Absorbed Dose Rates in Air in Colorado.*
Health Physics, Vol. 9(5), May 1999

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Natural Background Levels and Regulatory Limits for Protection of the Public

Table of Natural Background Radiation*

Source	U.S. Average[1]	Colorado Average[2]	Leadville[2]
Cosmic radiation (from space)	34	50	85
Terrestrial radiation (from the ground)	22	49	97
Internal: Ingested from food and water and inhaled naturally occurring radon and its decay products	254	301	344
TOTAL	310	400	526

* In units of mrem/year- mrem (millirem) is a unit of effective radiation dose. One rem is 1,000 mrem.

[1] National Council on Radiation Protection and Measurements. *Ionizing radiation exposure of the population of the United States*. NCRP Report No. 160; 2006.

[2] Moeller D, Sun LSC. Comparison of natural background dose rates for residents of the Amargosa Valley, NV, to those in Leadville, CO, and the states of Colorado and Nevada. Health Phys 91:338-353; 2006.

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Annual Background Radiation Exposure vs. Annual Public Exposure Limits: U Mines and Mills

- Background Levels (from previous slide)
  - > Colorado average = 400 mrem
  - > Leadville, Colorado = 526 mrem
  - > U.S. average = 310 mrem
- Regulatory Limits
  - > EPA drinking water standard = 4 mrem[1]
  - > EPA limit for all exposure pathways = 25 mrem[2]
  - > NRC Limit with radon = 100 mrem; excluding radon = 25 mrem[3]

[1] U.S. Environmental Protection Agency. Radionuclides in drinking water. Available at: http://www.epa.gov/safewater/radionuclides/index.html.

[2] U.S. Environmental Protection Agency. Environmental radiation protection for nuclear power operations, 40 CFR 190.10; 2006.

[3] U.S. Nuclear Regulatory Commission; Domestic Licensing of Source Material ; 10 CFR 40

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Radiation Background in Kerala India

- Unusually high natural radiation background has been known for many years due to natural thorium in the monazite sands of the region
- Annual outdoor exposure levels as high as 7000 mrem have been measured where people live
- Recent epidemiological studies have concluded no excess cancers in over 69,000 residents studied for 10 years[1]

[1] R Naire, B Rajan, et al; Background radiation and cancer incidence in Kerala,India—Karunagappally cohort study; Health Physics, 96,1, January, 2008

How Much Natural Radioactive Uranium is in the Food We Eat, Water We Drink and in the Soil Under Our Feet?

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How Common are Uranium and its Daughter Products[1] in Nature?[2]

- Typical concentration in soil and rocks (pCi*/gram):
  - > Uranium = 0.6 – 3.0
  - > Uranium in phosphate rock used for fertilizers = 40 – 80
  - > Radium = 0.4 – 3.6
  - > Thorium = 0.2 – 2.2

[1] Daughter products = those chemical elements that uranium decays into as a result of its radioactive properties. Thorium and radium are also radioactive.

[2] Sources: (1) National Council on Radiation Protection and Measurements. Natural background radiation in the United States. Washington, DC: National Council on Radiation Protection and Measurements; NCRP Report No. 45; 1975. (2) National Council on Radiation Protection and Measurements. Exposure of the population in the United States and Canada from natural background radiation. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 94; 1992 (updates and supersedes NCRP Report No. 45).

*pCi = picocurie, one-trillionth of a curie, the amount of radioactivity where approximately two atoms decay per minute. Picocurie is a measure of the amount of radioactivity.

How Much Uranium is in the Food and Water We Eat and Drink?

- Typical annual uranium intake in example foods:
  - > Whole-grain products: 10 pCi
  - > Meat: 50-70 pCi
  - > Fresh fruit: 30-51 pCi
  - > Potatoes: 67-74 pCi
  - > Bakery products: 39-44 pCi

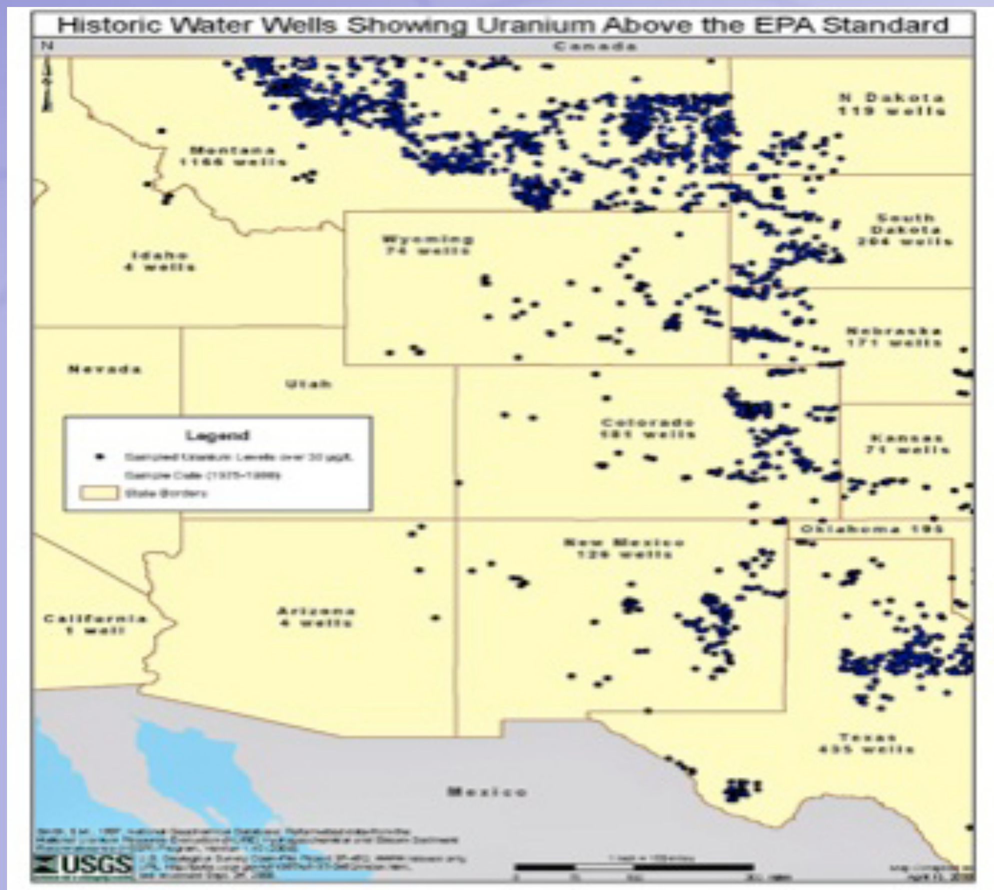
Sources: (1) National Council on Radiation Protection and Measurements. Exposures from the uranium series with emphasis on radon and its daughters. Bethesda, MD: National Council on Radiation Protection and Measurements; NCRP Report No. 77; 1987. (2) Welford GA, Baird R. Uranium levels in human diet and biological materials. Health Phys 13(12):1,321-1,324, 1967 (values for three U.S. cities—New York City, Chicago, San Francisco).

Natural Uranium in Groundwater

- Can vary considerably from place to place depending on local mineralization, hydrology and geochemistry
- Although typically a few micrograms / liter (a few pCi / liter), U has been measured in public drinking water sources 10 -100 + greater than this
- No permanent health effects have been observed in populations drinking water for generations with these high natural levels

Sources:(1) *Assessing Potential Risks from Exposure to Natural Uranium in Well Water. Hakonson-Hayes A.C, P.R.* Fresqueza,, F.W. Whicker, Journal of Environmental Radioactivity, 59 (2002)
(2) *Public Health Goal for Uranium in Drinking Water.* Office of Environmental Health Hazard Assessment California Environmental Protection Agency, 1997 (3) U.S. Dept. of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. *Toxicological Profile for Uranium. 1999.*

U Levels in Groundwater > EPA Drinking Water Standard (30 micro grams per liter) Are Common



Data from USGS open file report 97-492, 2006; reformatted 1975 – 1980 data from U.S. NURE HSSR program

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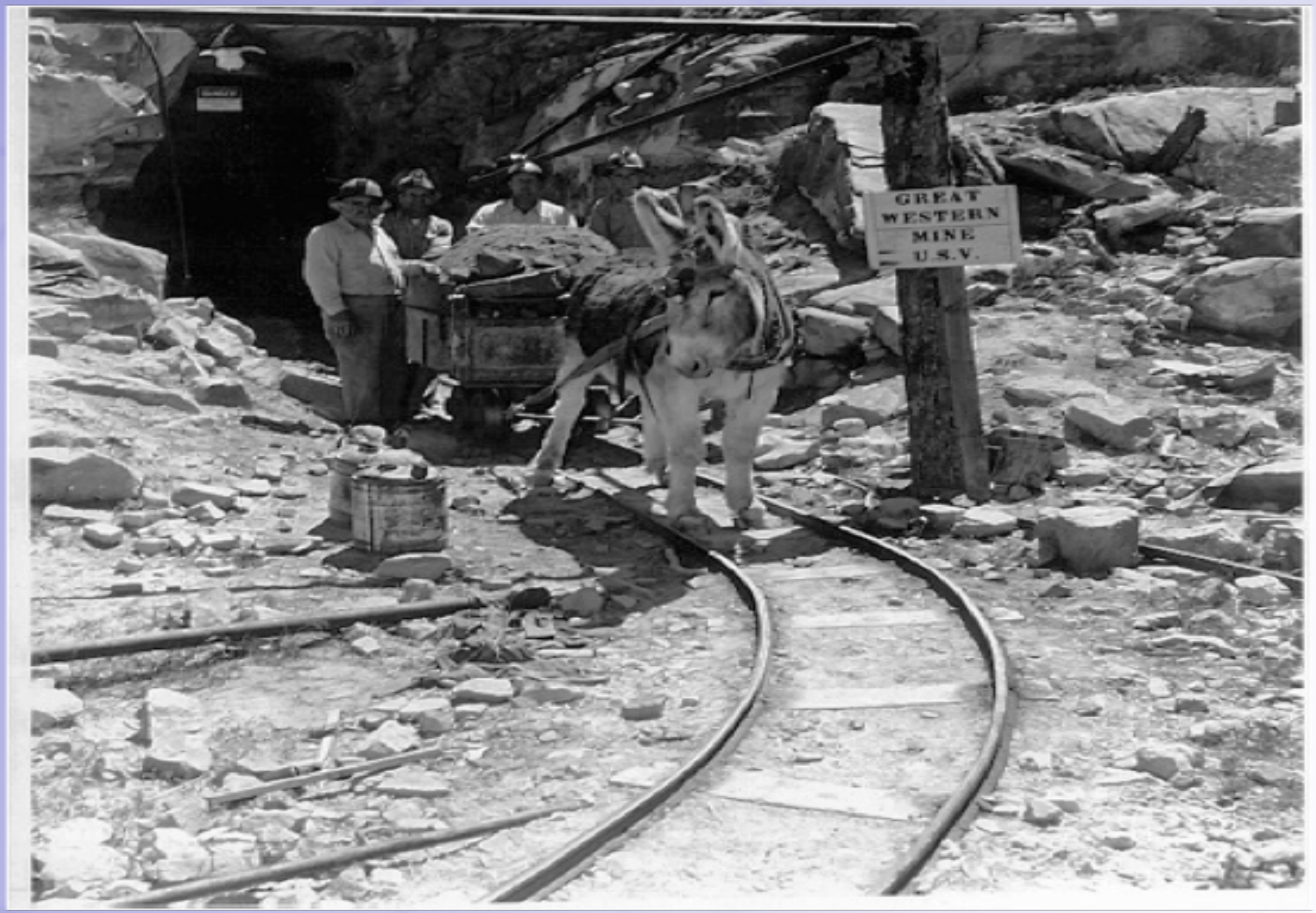
Radioactivity of Uranium Ore and Some Consumer Products



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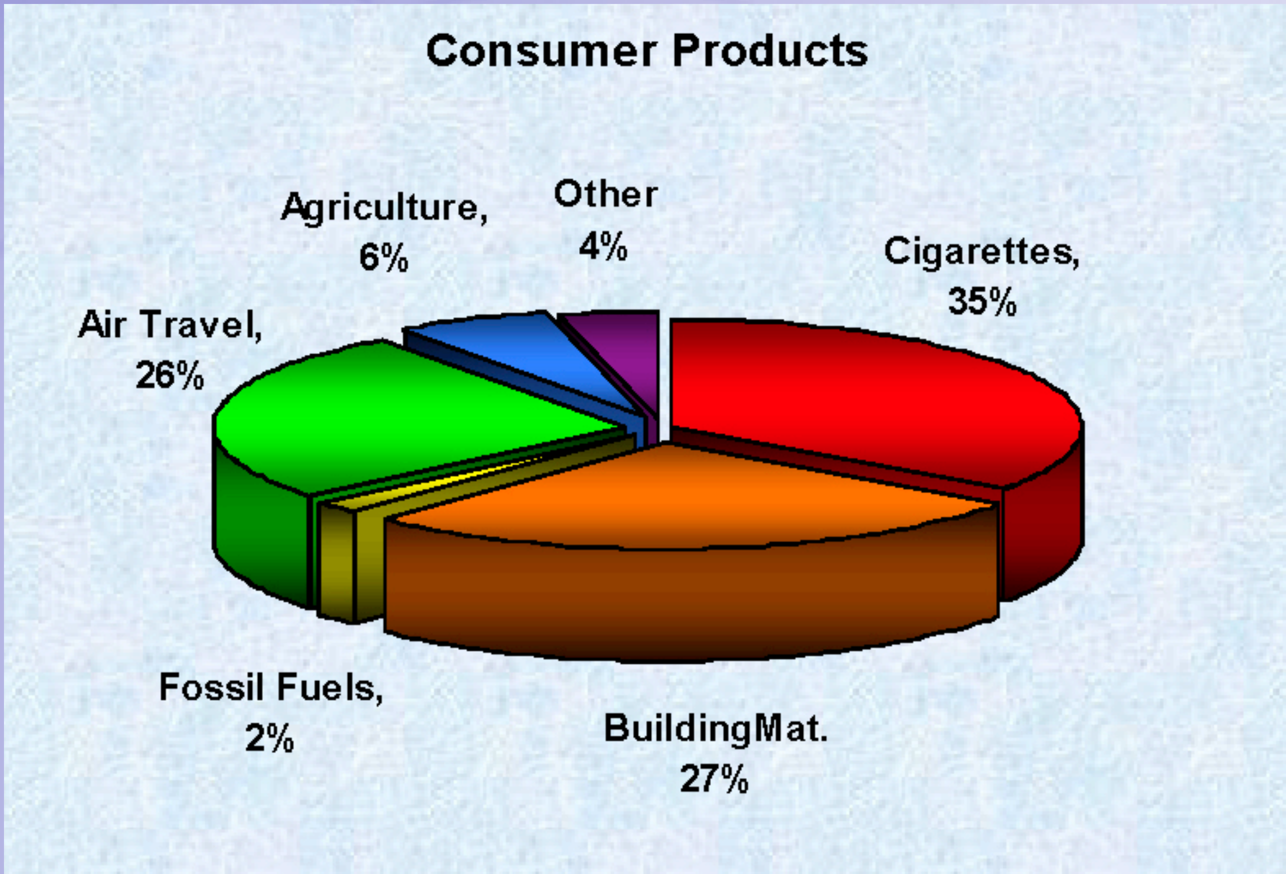
Exposure From Consumer Products Used Every Day



National Council on Radiation Protection and Measurements; NCRP Report No. 160, "Ionizing Radiation Exposure of the Population of the United States", 2006

Radioactivity of Uranium Ore

- Typical uranium ore contains 670 pCi/gram of uranium (assuming 1,000 ppm of uranium in the ore)
- A handful (about 10 grams) = about 7,000 pCi
- Considering the numerous daughter products, the handful of ore = about 70,000 total pCi

Radioactivity of Some Consumer Products [1]

- Household smoke detector (americium) = average of 50,000,000 pCi
- Household smoke detector (radium) = 50,000 pCi[1]
- Typical older (pre-1970) luminous wrist watch dials (radium) = up to 4,500,000 pCi
- Typical modern luminous wrist watch dials: radioactive hydrogen (tritium) average of 1,300,000,000 and promethium average of 45,000,000 pCi

[1] National Council on Radiation Protection and Measurements. Radiation exposure from consumer products and miscellaneous sources. NCRP Report No. 56; 1977

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Radioactivity of Some Consumer Products (continued)

- Coal fly ash = 6 - 20 pCi/gram uranium[1]
- Coal fly ash in TVA Kingston spill, Dec. 2008 (> billion gallons) = 6 - 8 pCi / gram radium > 1,000,000,000,000 pCi total in spill [2]
- Additional consumer products containing naturally occurring radioactivity include fertilizers (uranium, thorium, potassium), gas lantern mantles (thorium), glass and ceramics (uranium as coloring agent)[3]

[1] U.S. Geological Survey, Fact Sheet FS-163-9, October, 1997. Values actually stated as 10 - 30 ppm
[2] Duke University, Nichols School of Environment, January 2008.
See http://www.nicholas.duke.edu/index.html
[3] Health Physics Society. Consumer products containing radioactive materials. Health Physics Society Fact Sheet. Available at: www.hps.org/hpspublications/radiationfactsheets.html.

Radiation Exposure in Perspective - Cigarette Smoking

- A cigarette smoker gets about 1000 mrem / year effective dose above background from Polonium 210 in tobacco smoke
- So a smoker's effective dose = 10 X annual public exposure limit (100 mrem – U.S.NRC)
- Chest X ray = 8 mrem so for smoker = 125 chest X rays / year !!
- Assuming 15 % of population smokes, their total dose / year = 30 X more than the total annual dose to all workers at the 104 nuclear power plants in U.S. + all workers at U.S.DOE nuclear installations + all crews on U.S. Navy nuclear ships

See Moeller DW and Sun C, *Thinking Outside the Box: Polonium 210 in Cigarettes – A Needless Source of Radiation Exposure*, Health Physics News,37,4,April 2009

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What are the Potential Health Effects from Exposure to Uranium?[1]

- Uranium is a heavy metal and acts similar to lead (another heavy metal) in the body.
- Accordingly, for natural uranium, national and international human exposure standards are based on the possible **chemical toxicity** of uranium (e.g., effect on kidney—nephrotoxicity), not on radiation and possible "cancer effects" (radiotoxicity)

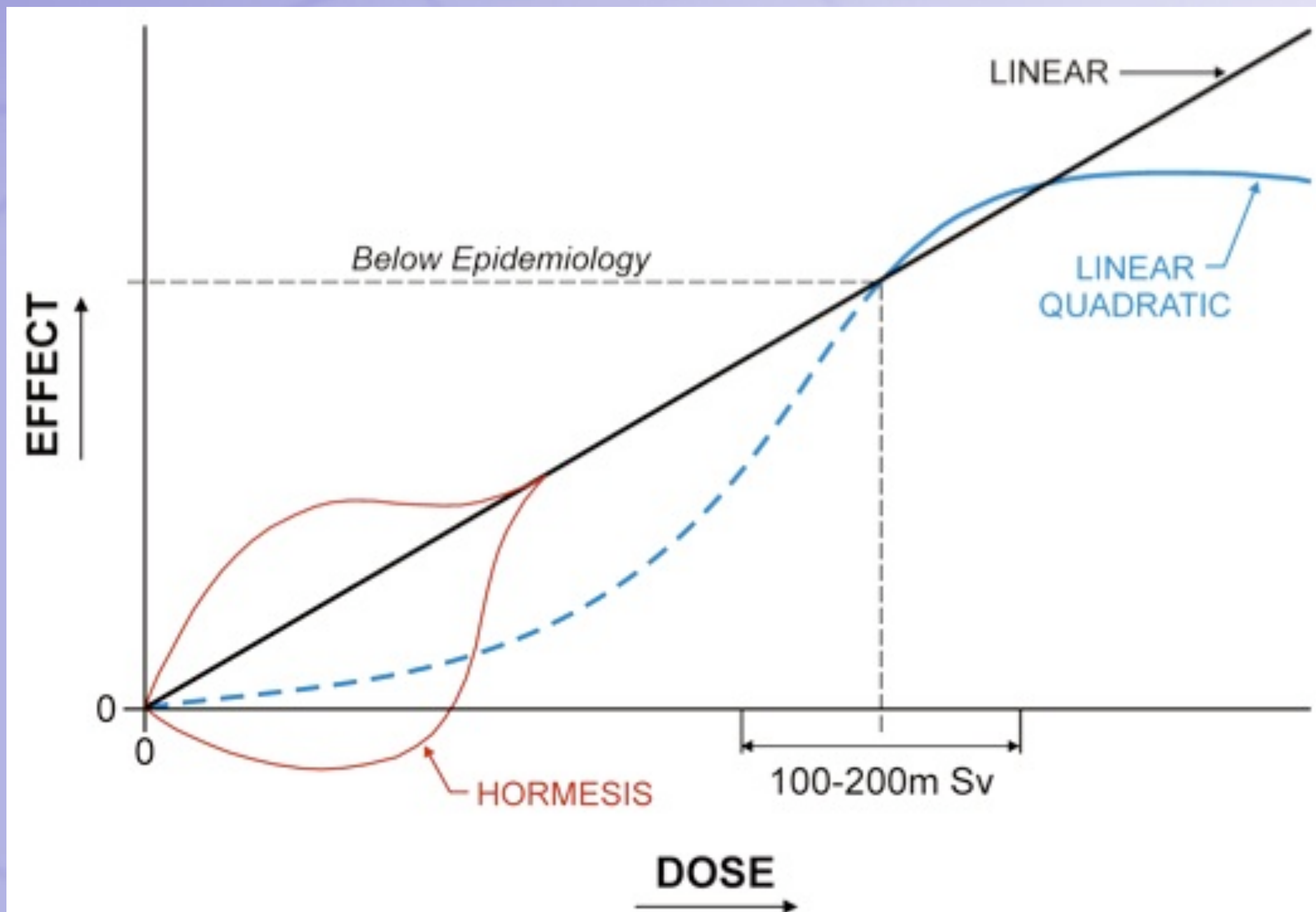
[1]Sources: (1) U.S. Nuclear Regulatory Commission. Standards for protection against radiation. 10 CFR Part 20; 1992. (2) International Commission on Radiological Protection. Limits for intakes of radionuclides by workers. ICRP Publication 30, Part 1.1979. (3) Agency for Toxic Substances and Disease Registry. Toxicological profile for uranium. Department of Health and Human Services, Public Health Service; 1999. Available at: http://www.atsdr.cdc.gov/toxprofiles/tp150.html.

Health Effects of Ionizing Radiation are Well Understood

- International and National Authorities rely on the work of scientific committees such as:
  - > United Nations Scientific Committee on the Effects of Ionizing Radiation (UNSCEAR);
  - ➢ National Academy of Science, Biological Effects of Ionizing Radiation (BEIR) Committees;
  - > National Council on Radiation Protection (NCRP), and others

  for their evaluation of the scientific information on health effects of exposure to ionizing radiation

Dose Response Model Generally Accepted by International and National Scientific Bodies (UNSCEAR, BEIR, NCRP)



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Despite Public Confusion and Misunderstanding, Health Effects In Populations Living Near Uranium Facilities Have Been Well Studied

According to[1]:

- U.S. Department of Public and Human Services, Agency for Toxic Substances and Disease Registry
- National Cancer Institute
- Journal of Radiation Research
- Journal of Radiation Protection

Based on studies and data collected over 50 years, ***there is No scientific evidence that uranium exploration, mining, or milling activities result in additional cancers*** in populations living nearby

[1] Specific references can be provided on request

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Example Conclusions from Studies on Health Impacts on Populations Living Near Uranium Mines and Mills

" The absence of elevated mortality rates of cancer in Montrose County over a period of 51 years suggests that the historical milling and mining operations did not adversely affect the health of Montrose County residents."[1]

"No unusual patterns of cancer mortality could be seen in Karnes County over a period of 50 years suggesting that the uranium mining and milling operation had not increased cancer rates among residents."[2]

[1] *Cancer and Noncancer Mortality in Populations Living Near Uranium and Vanadium Mining and Milling Operations in Montrose County, Colorado, 1950 -2000. Boice,* JD, Mumma, MT et al. Journal of Radiation Research, 167:711-726; 2007

[2] *Mortality in a Texas County with Prior Uranium Mining and Milling Activities, 1950 – 2001. Boice, JD,* Mumma, M et al. Journal of Radiological Protection, 23:247 – 262; 2003

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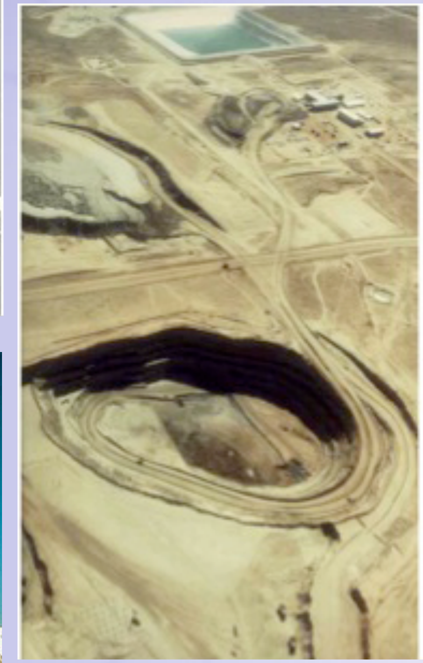
Underground Uranium Miners in the 1950's and 60's

- Miners were exposed to very high levels of uranium decay products ("radon daughters") in poorly ventilated underground mines and some were severe smokers which increased dose
- Follow up of 68,000 former miners indicated 2700 lung cancers – much higher than expected incidence*
- These working conditions existed before Federal agencies (OSHA, MSHA, NRC) and laws to protect workers throughout American industry (manufacturing, construction, mining, etc.)
- Levels of exposure 10 – 100 X current worker standards

•Dr. John Boice, International Epidemiology Institute, Vanderbilt University – personal communication; summary of numerous references which can be provided upon request

How is Uranium Extracted from the Earth ?



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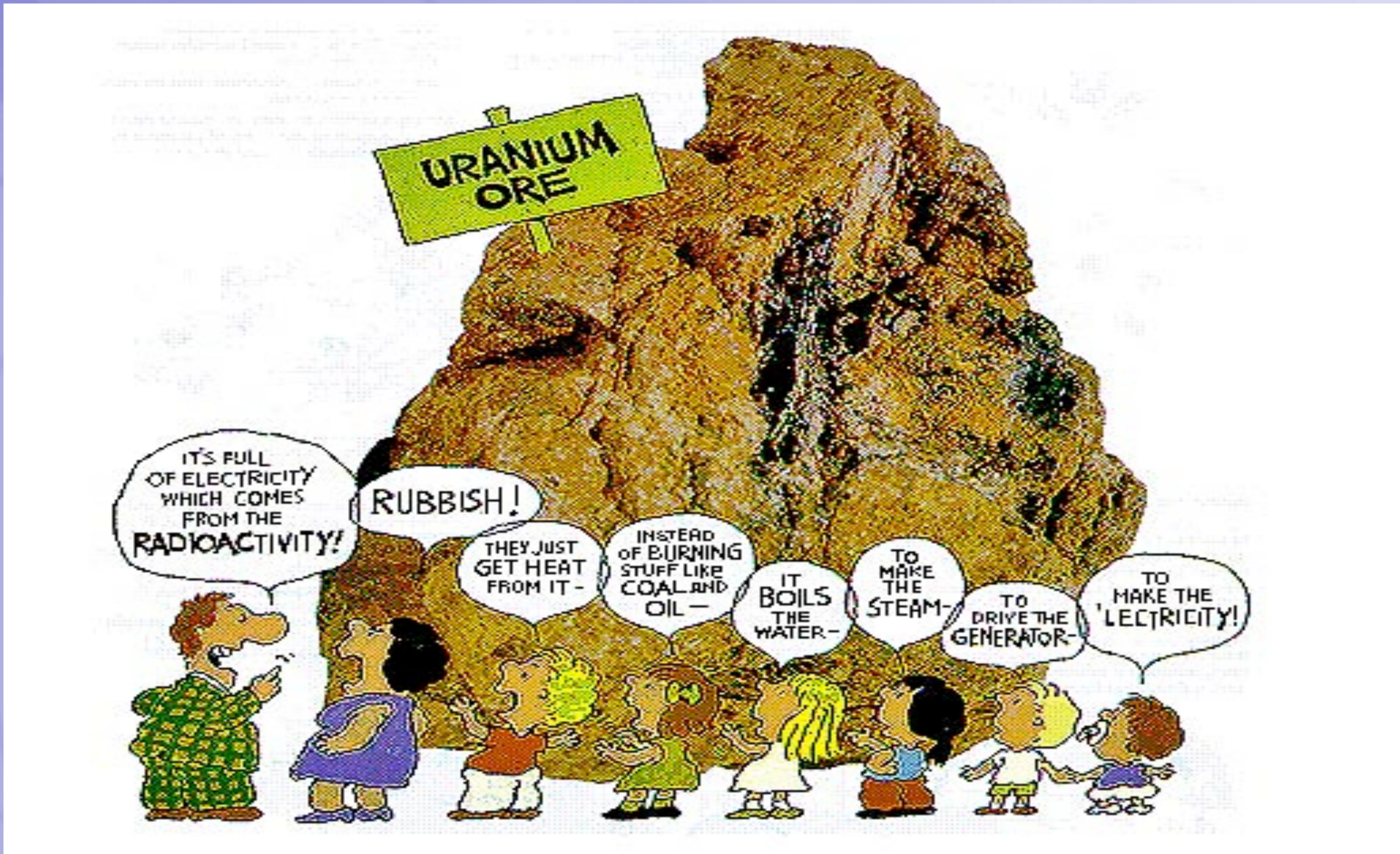
The Uranium Fuel Cycle - What is Uranium Used For and Why is it Important?



Courtesy of Australian Uranium Association at www.aua.org.au

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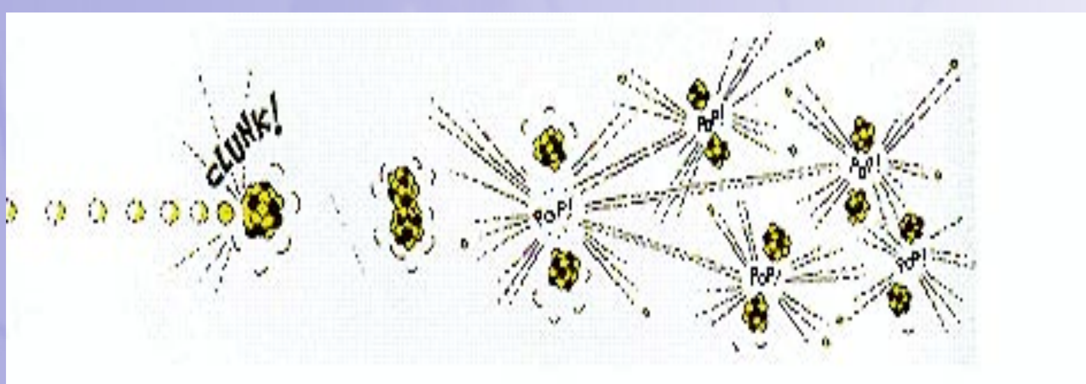
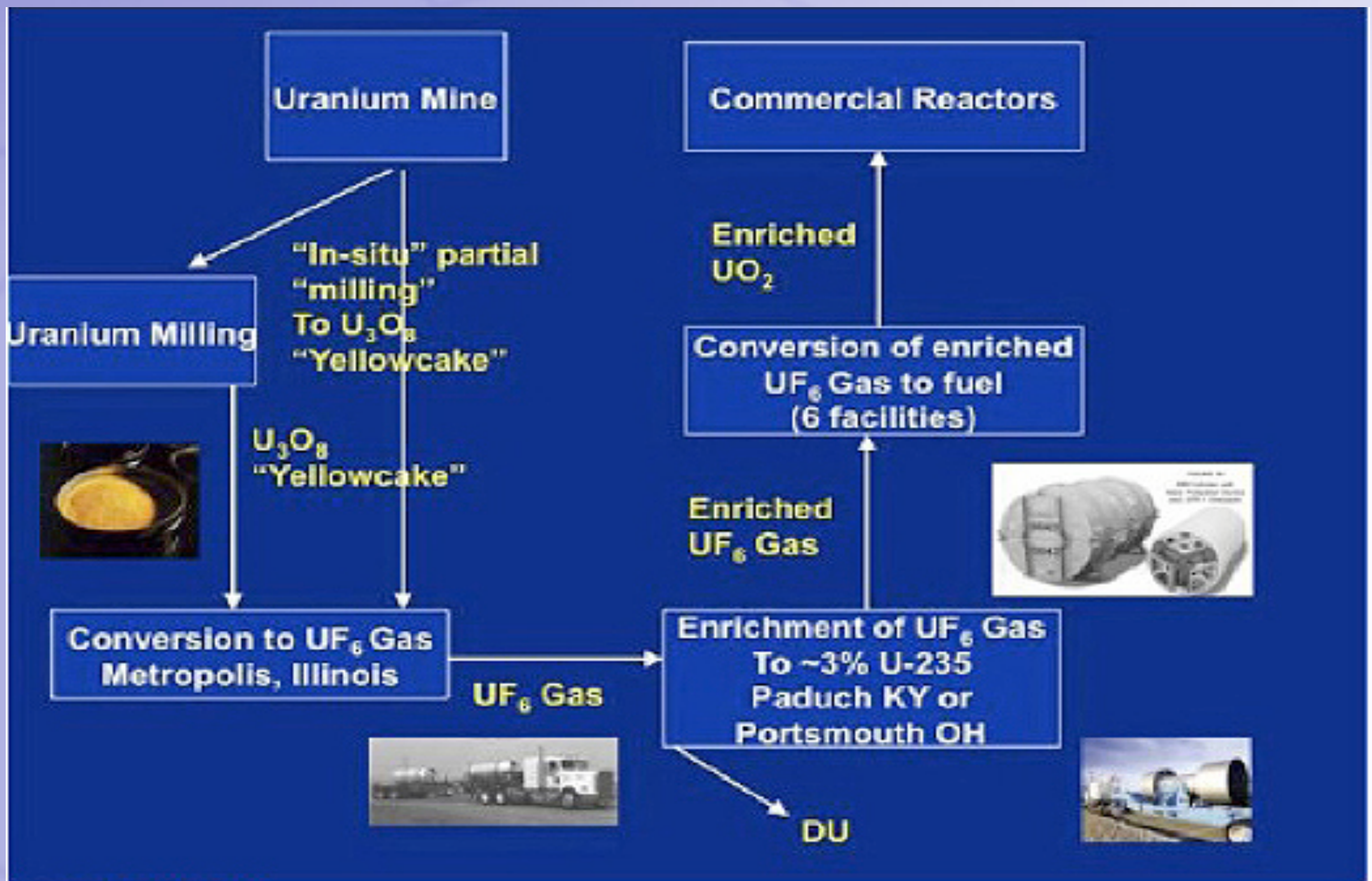
What is Uranium Used For?

- Number one use = Electricity generation via nuclear fission. Approximately 20 percent of U.S. electricity is generated by uranium fuel in nuclear power plants (over 400 plants currently world wide and many more planned)
- Uranium fission in nuclear reactors makes isotopes used in medicine (e.g., ^{99}Mo, which produces ^{99m}Tc for diagnostic imaging studies – used in over 70% of all nuclear medicine procedures)



Nuclear fission—each "fission" of a ^{235}U atom by a neutron results in release of radiation (heat, light, gamma and x rays), more neutrons, and other particles

What is Uranium Used For?: Commercial Uranium Fuel Cycle



What is Uranium Used For?

- One pound of yellowcake has energy equivalence of 35 barrels of oil[1] and one 7-gram (1/4-ounce) uranium fuel pellet has an energy-to-electricity equivalent 17,000 cubic feet of natural gas or 1,780 pounds of coal [2]
- Other uses include coloring agent in ceramics and glass, military armor and armament, counterweights on ships and aircraft, radiation shielding (extremely dense and heavy metal but relatively flexible)

[1] David Bradish, Mgr. Energy information, Nuclear Energy Institute

[2] U.S. Department of Energy, Energy Information Administration

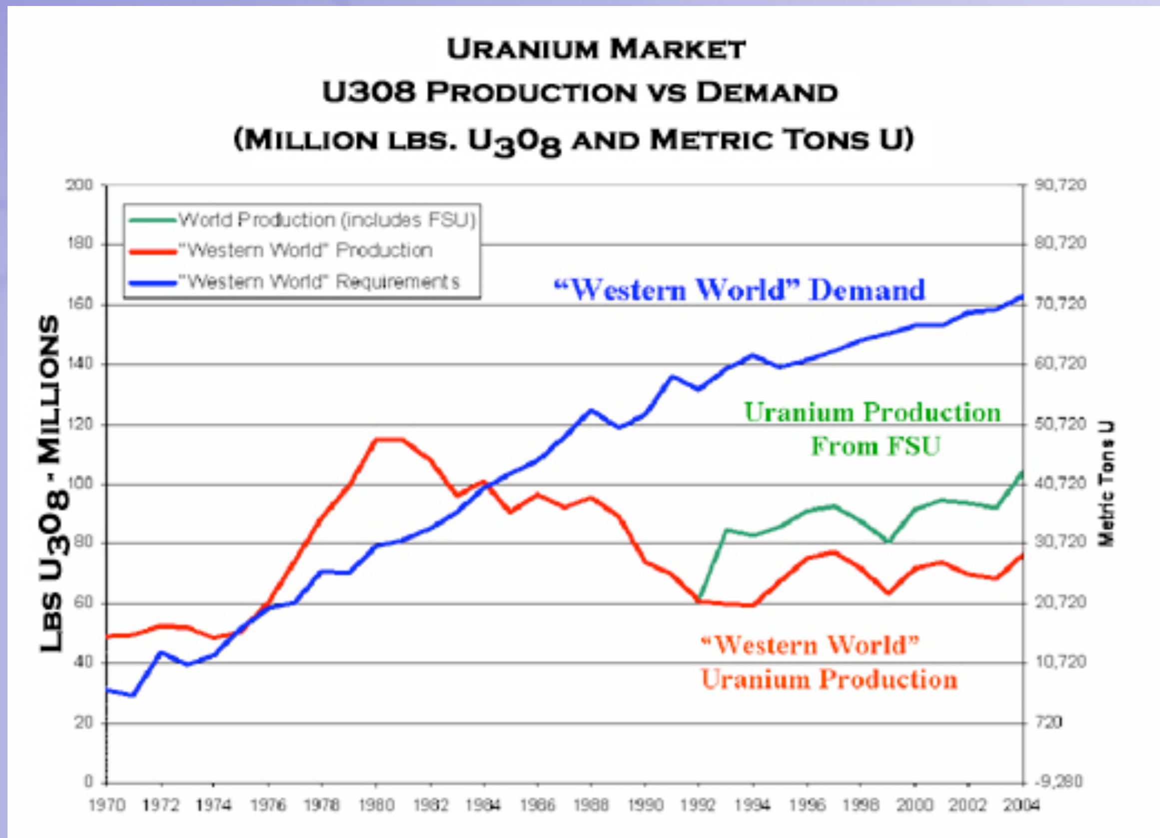
Why is Domestic Uranium Recovery Important: America's Energy Needs

- Currently, U.S. fleet of 104 nuclear power plants provide 20% of the U.S.' base load electricity
- These plants consume about 60 million pounds of uranium fuel per year, and new plants expected to come on line in next 10 - 20 years
- The U.S. currently produces about 5 million pounds of uranium fuel per year

Why is Domestic Recovery Important: America's Energy Needs

- As is our current situation with oil, we are highly reliant on foreign sources
- Some of these regimes (now and/or in future) may not be friendly to the U.S.
- "Exploding" economies like China and India plan on building large numbers of new nuclear plants in next 2 decades and will compete for world wide uranium supplies

Why is Domestic Uranium Recovery Important: Basic Reality of Supply and Demand



Uranium Producers of America
http://www.uraniumproducersamerica.com/supply.html

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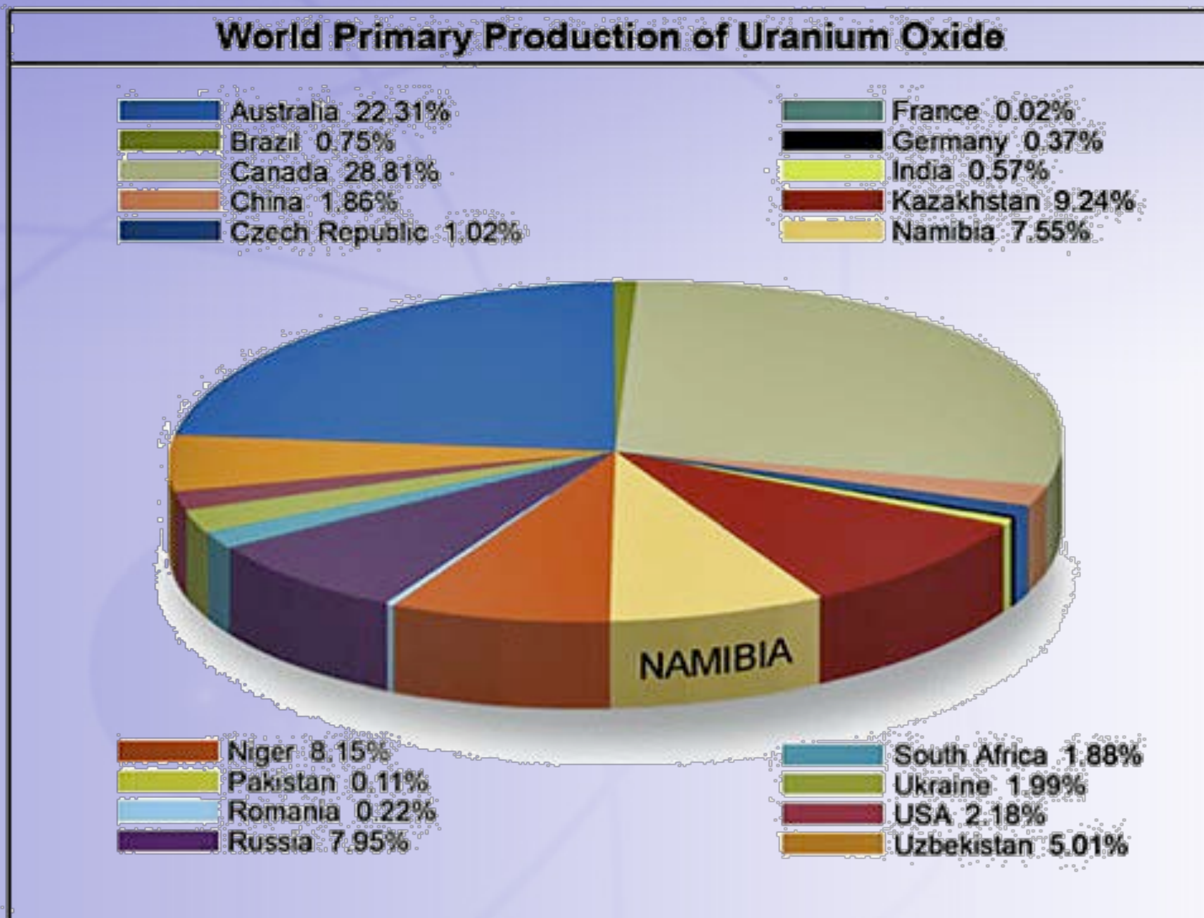
World-Wide Uranium Production



Uranium Producers of America @ http://www.uraniumproducersamerica.com

Don't Scientists Disagree on Radiation Effects?

- Vast majority really do not
- Human health effects from radiation have been extensively studied and are well understood
- Much info presented here = "consensus science" – generally agreed upon position of national and international bodies of experts
- As a society, we have to do better job in "weighing the evidence" including expertise and experience of the "speaker" specific to the subject matter
- Upon objective evaluation, we will often find relative weight of claims are not equal at all

Apply the Challenge of Dr. Carl Sagan

" Remarkable claims demand remarkable evidence"

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Some Final Thoughts # 1

The daily advance of science will enable us and future generations to administer the Commonwealth with wisdom

- Thomas Jefferson

- Thomas Jefferson to Lafayette, 1823: In *The Writings of Thomas Jefferson; Lipscomb* and Bergh, editors, 20 volumes , 1903-1904

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Some Final Thoughts # 2

The goal of science is the gradual removal of prejudices; which is belief in the absence of evidence

- Niels Bohr

- *Atomic physics and human knowledge*. John Wiley 1958 p 31

Questions?

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