Physical, Radiological, and Health Issues Related to Uranium Mining in the Navajo Nation

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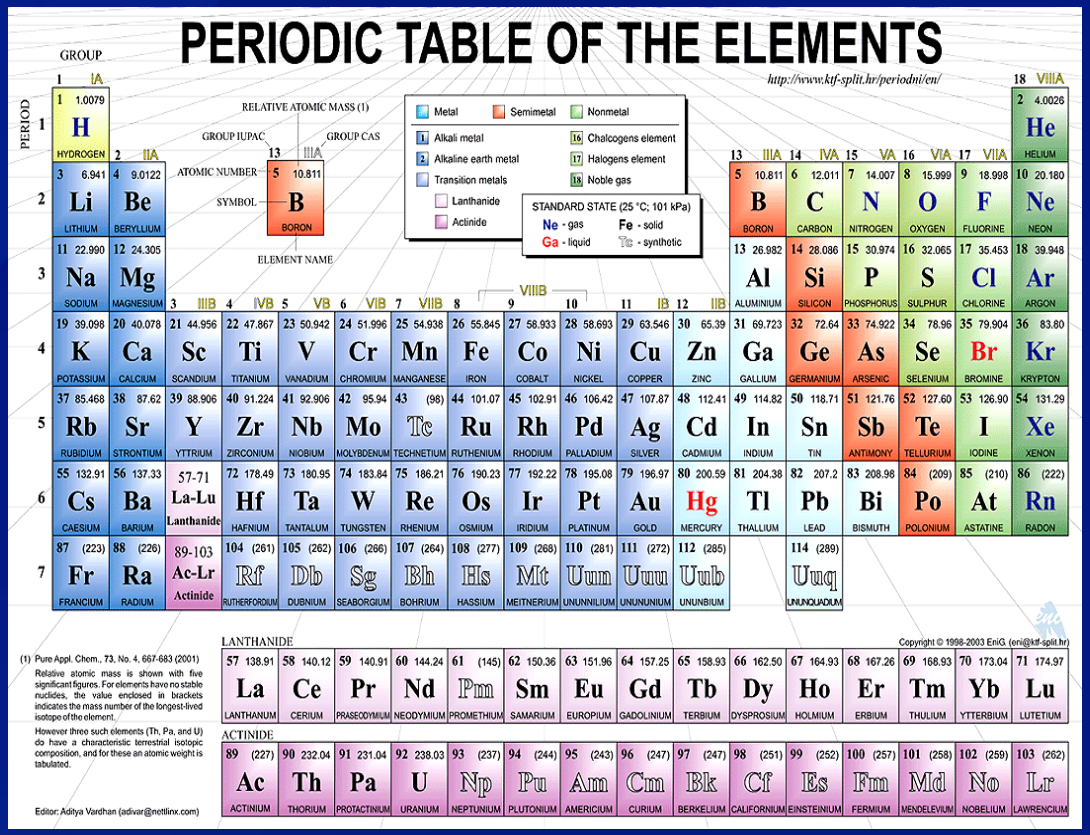
ATSDR

Topics for this presentation

- **What is uranium and where it is found**
  - Its chemical properties and hazards
  - Its radioactive properties and hazards
- **What exactly is radiation and radioactivity**
- **How is uranium processed**
- **Radon and health**
- **Uranium toxicity (disease related)**
  - Inhalation and ingestion
  - Cancer

Elemental Uranium

- Naturally occurring element
- Discovered in 1789
- 107 years later, radioactivity discovered



Uranium in the Environment

- Found in soil, rocks, surface and groundwater, air, plants, animals, and seawater
- The majority of the uranium deposits in the United States are found in the west
  - Arizona, Colorado, New Mexico, and Utah
  - Nebraska, Texas, and Wyoming

Uranium in Nature

- The ore is found as a crystaline form
- Typical ores include uraninite (pitchblende), carnotite, autunite, uranophane, and torbernite
- Also found and recovered commercially in phosphate rock, lignite, and monazite sands

Autunite

Apex Mine (Rundberg mine; Early Day Mine), Reese River District, Lander Co., Nevada, USA

Carnotite -- Monument Valley, Navajo Indian Reservation, Navajo Co., Arizona, USA

Torbernite

Tyrone Area, Burro Mountains District, Grant Co., New Mexico, USA.

Uraninite

Homestake Mine, Big Indian District (Big Indian Wash - Lisbon Valley Area), San Juan Co., Utah, USA

Uranophane

Poison Canyon Area, Grants District,
Cibola Co., New Mexico, USA

Chemical Properties

- Uranium is one of the heaviest of the naturally occurring elements
- Very dense solid -- 1192 lbs/ft^3
  - Lead is 708 lbs/ft^3
- Melts at 2075° F; boils at 7470° F
- Soluble in acids

Uranium metal properties

- Silvery-white radioactive metal
  - Can be pulled very thin
  - Can be beaten into sheets
- Is more plentiful on earth than either mercury or silver

Uranium ore and metal

In nature

Purified metal

Uranium chemical hazards

- Powder or chips will self-ignite in air at room temperature; or when exposed to heat or flames
- During storage can form a pyrophoric surface that reacts with air and moisture to ignite
- Uranium metal will also react with water at ambient temperature, swelling and disintegrating forming UO_2 and UH_3
- Hydrogen gas can be released.

Other chemical hazards

- Uranium metal can also react violently with fluorine, chlorine, bromine, nitric acid, selenium, sulfur, ammonia, trichloroethylene (TCE), or nitryl fluoride and similar compounds
- Decomposes in cold water
- Many of its compounds are yellowish or greenish.

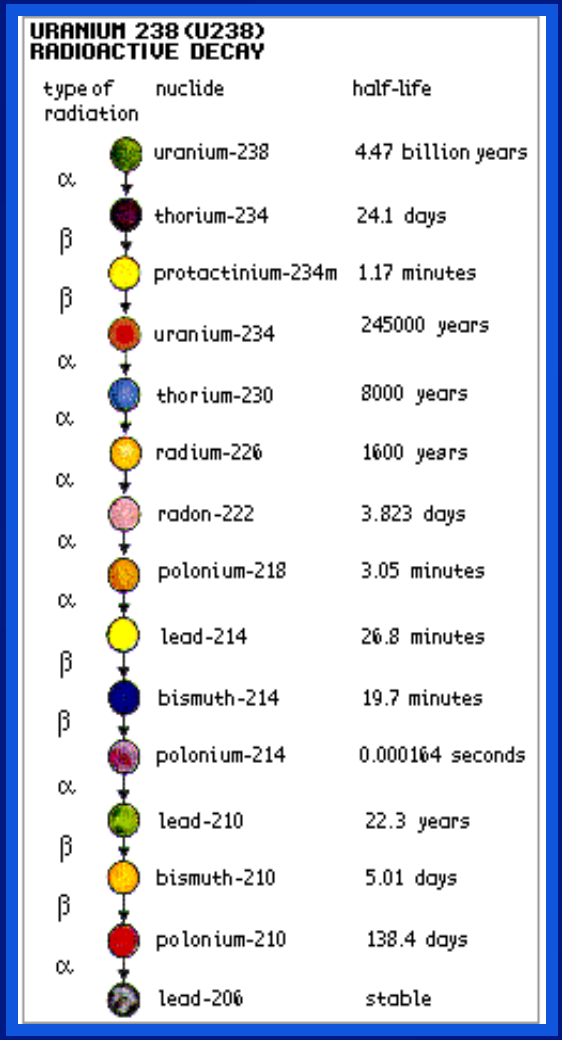
Health Hazards

- Dermatitis, renal damage, acute necrotic arterial lesions, and possibly death may occur from extreme exposure
- Isolated particles in the lungs may be a long-term cancer hazard
  - Uranium dusts are respiratory irritants, with coughing, shortness of breath as possible outcomes.
- The more soluble uranium compounds are considered most toxic to the kidneys
- Prolonged skin contact can cause damage to the underlying skin (basal) cells

SO, WHAT IS RADIATION AND RADIOACTIVITY?

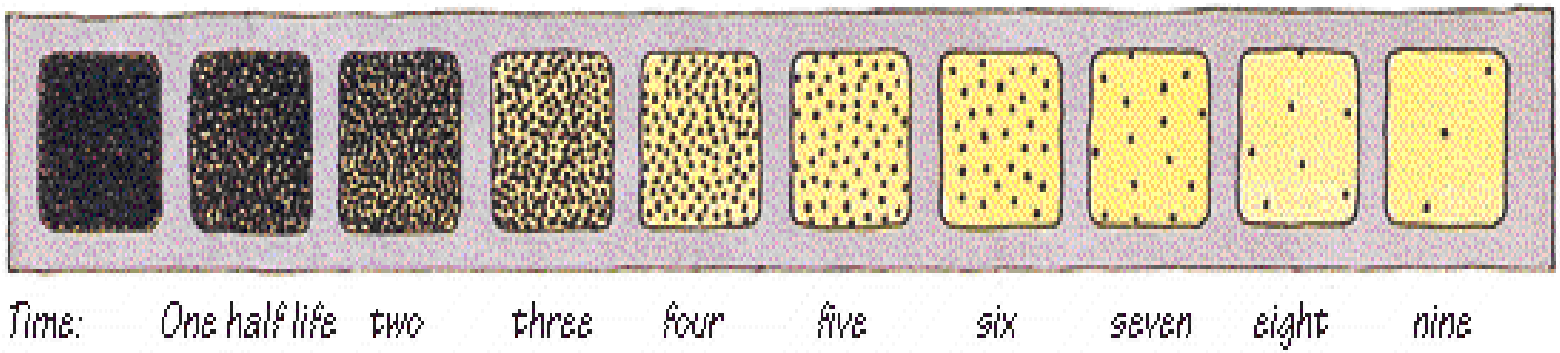
What is Radioactivity?

- Elements having an unstable or imbalanced nucleus undergo a process known as radioactive decay
  - radioactive elements called radioisotopes
  - Each of these radioisotopes must undergo a nuclear rearrangement, emitting energy, to reach a stable form
  - This process is radioactive decay
- The decay results in the formation of a new atom which may or may not be radioactive.



Half-life

- The time required for half of the atoms of a radioactive substance to decay
- Ranges from less than a millionth of a second to billions of years.



Uranium is always radioactive

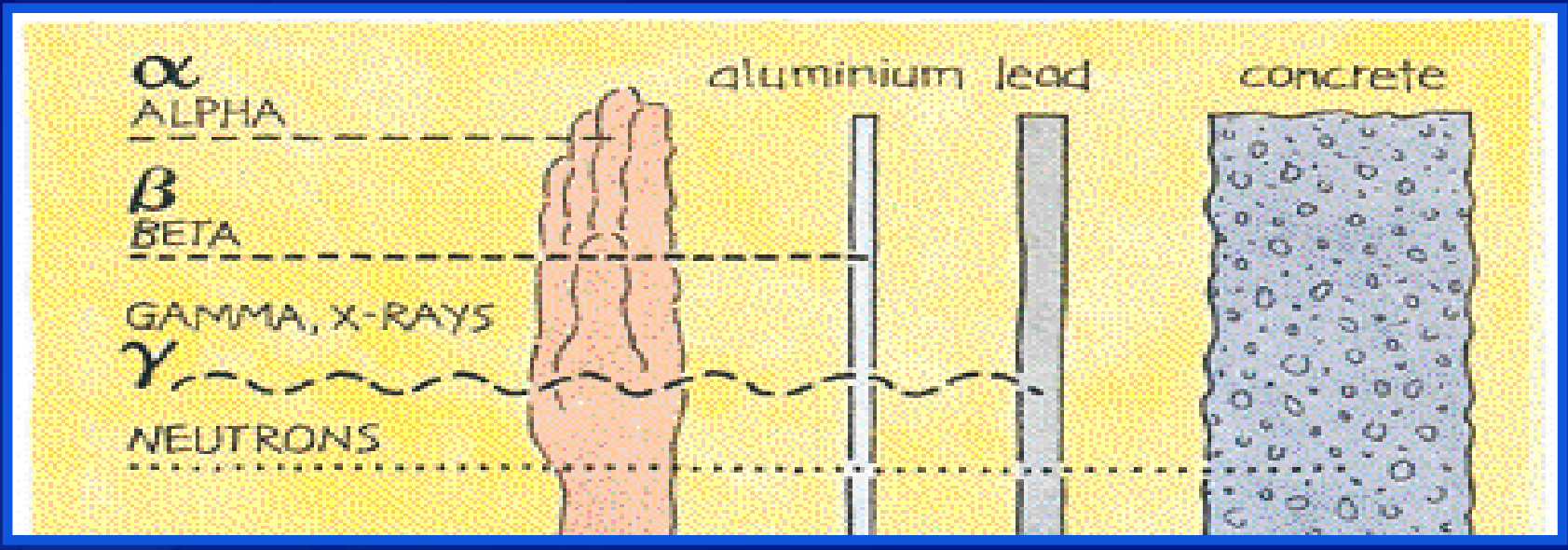
Uranium naturally occurs in 3 chemically identical forms called isotopes. These are identified by the mass of their atoms

Isotope	Average Abundance (%)	Half-life (years)	Radioactive Decay	Decay Product (all radioactive)
234	0.01	245.5 thousand	alpha	Thorium 230
235	0.72	704 million	alpha	Thorium 231
238	99.27	4.46 billion	alpha	Thorium 234

Types of radioactive decay

- There are three common types of radioactive decay
  - Alpha, beta, and gamma decay
    - Alpha and beta decay are particles
    - Gamma is pure energy similar to x-rays
  - The alpha and beta decays form new isotopes or elements but the gamma does not.
- Each of these types of decay have different hazards to plants, animals, and humans.

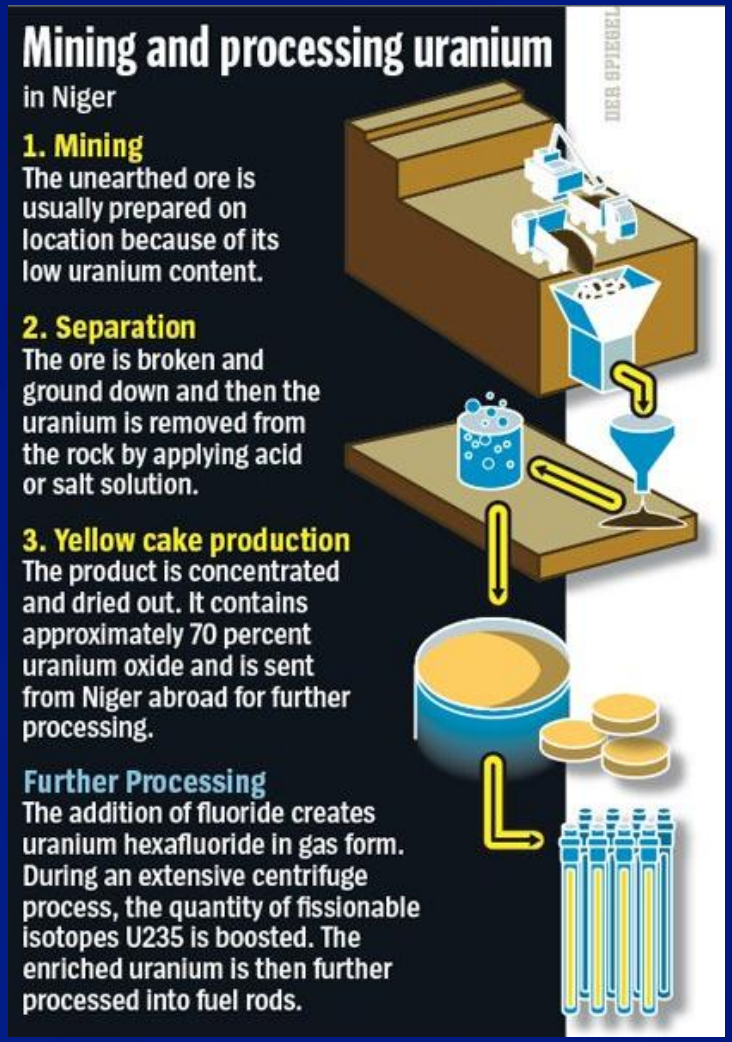
Shielding from Radiation
What can be used to block it?



WHAT HAPPENS TO THE URANIUM ORE?

Uranium Mill Processing

- Ore arrives at the mill where it is crushed
- Chemically treated with acids
- Results in two general streams
  - Uranium (not very radioactive)
  - Waste products (more radioactive)



Processed Uranium

- Uranium processed to form either "yellowcake" or "greensalt"
  - U_3O_8 or UF_4
- Waste products typically stored at the mill; contains thorium, radium, and other radioactive products in a sandy matrix
- Uranium shipped to other processors

Mine Wastes

- No exact total
- USGS estimates the approximately 4,000 open pit and underground mines in their database generated about 3.3 billion tons
  - The volume of waste (including overburden) produced by open-pit mining is a approximately 45 times greater than wastes produced from underground mining

Hazards associated with wastes

- Waste is radioactive
- Can be soluble in water
- Can contain other non-radioactive metals such as arsenic and lead
- Physical hazards

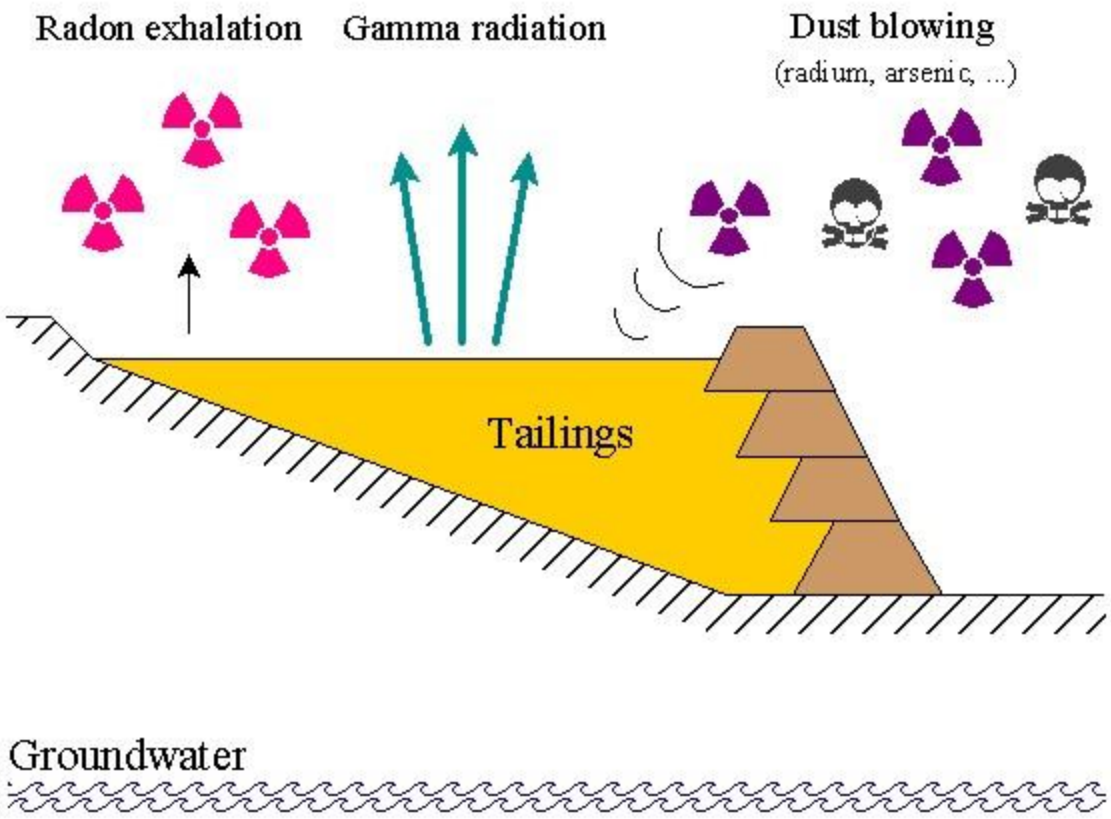
Mill waste volumes

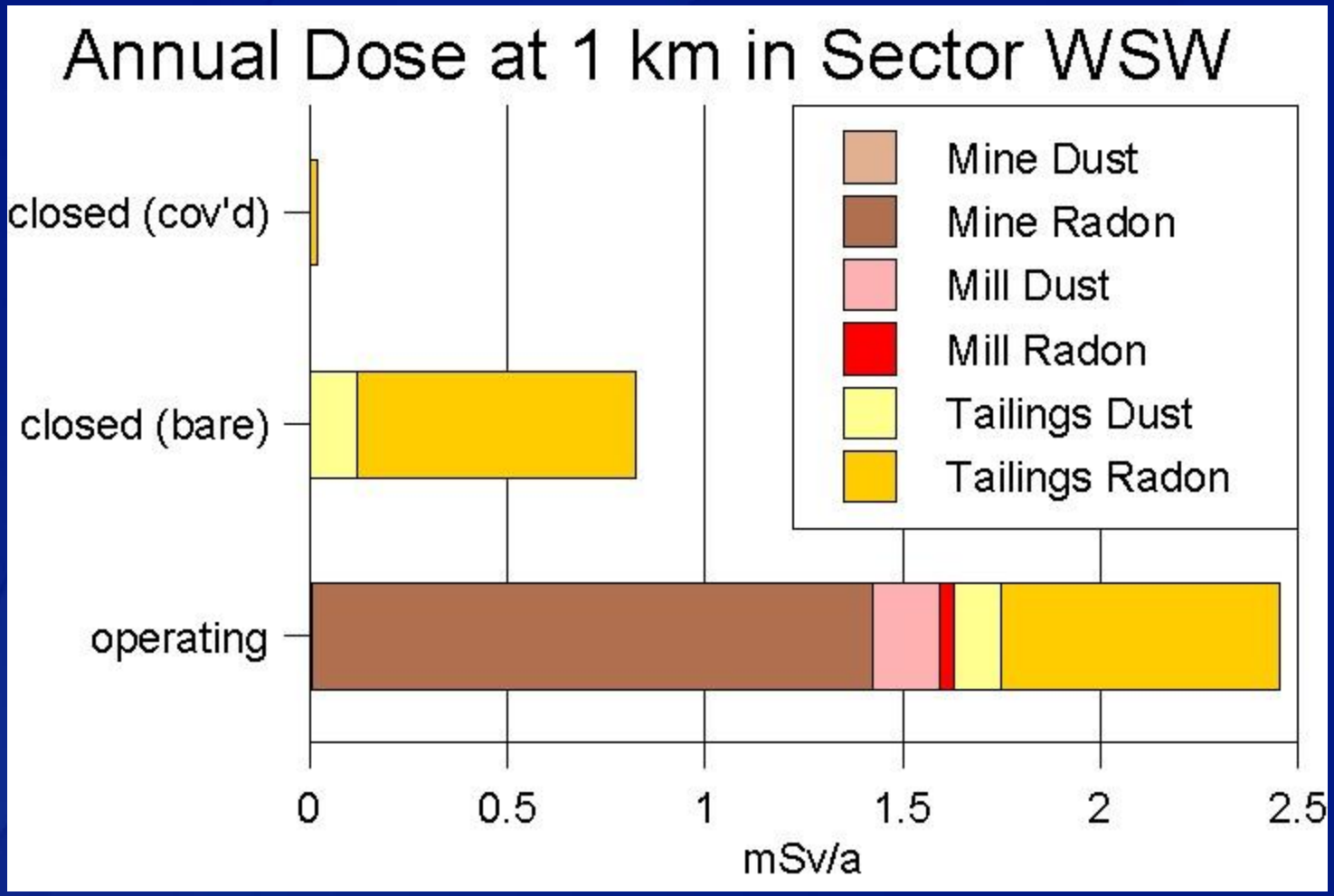
- Mill wastes are typical rock and other debris
- Licensed tailings piles contain a combined total of approximately 220 million tons
  - Range of 2.2 to 3.3 million tons each
- The 24 abandoned sites contain a total of about 28.6 million tons
  - range in size from about 55 thousand tons to about 3.3 million tons.

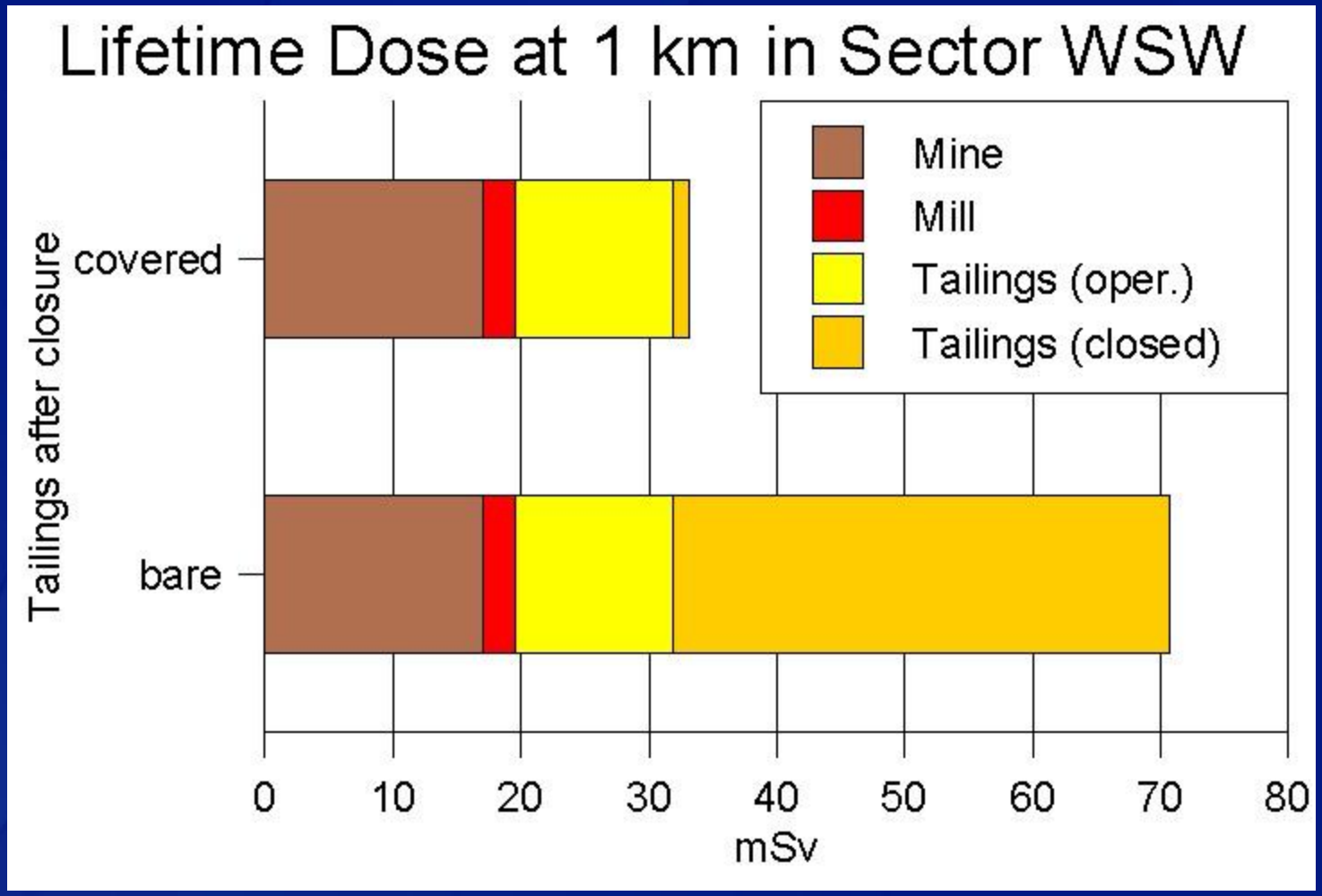
Radiation doses from uranium mine and mill wastes

Material	Calculation Parameter	Annual Dose (millirem)
0.2% U in ore	1 cm from hand	36
Mill Product	Greensalt (UF_4) Yellowcake (diuranate) Yellowcake (U_3O_8)	231 184 259
Mill Tailings	107639 sq. ft (10,000 m^2)	7172
Typical US Background	Including radon	311

Uranium Mill Tailings Hazards




Annual Dose at 1 km in Sector WSW
closed (cov'd)
closed (bare)
operating
Mine Dust
Mine Radon
Mill Dust
Mill Radon
Tailings Dust
Tailings Radon
0
0.5
1
1.5
2
2.5
mSv/a


Lifetime Dose at 1 km in Sector WSW
Tailings after closure
covered
bare
Mine
Mill
Tailings (oper.)
Tailings (closed)
0
10
20
30
40
50
60
70
80
mSv

Radon issues

- Radon (Rn-222) is produced from mine and mill wastes
  - Part of the uranium decay series
  - Radon is a gas which means its mobility rate is vastly different from that of radioactive metals.
- EPA limits emissions of radon from operating underground uranium mines
  - the operator must provide a report of their compliance to that requirement to EPA yearly.
  - Exposures to a member of the public is limited to no more than 10 millirem annually

Radon Chemistry

- An inert radioactive gas
  - Does not react to form compounds
  - Can be trapped in crystalline structures
    - Released if structures melt or dissolve
- Decays forming radioactive particulates

Radon Health Issues

- The USEPA says lung cancer kills thousands annually
  - Leading cause of lung cancer in non-smokers
- Smokers have a higher risk if also exposed to Radon

Radon health effects

- Classified as a human carcinogen by the EPA
  - Lung cancer
- Radium dial painters
  - Radium decays into Radon
  - Bone cancers resulted from radon buildup in sinuses and Ra deposited in bone.

Exposure Evaluation

- Radon is not absorbed into the body
- Measurement of ambient air is the only "easy" way to determine concentration
- Exposure limits based on the air concentration

Radon Exposure Assessment

- All habitable structures should be tested for radon
- There does not appear to be a geographical correlation with indoor radon
- Individuals should check with their state radon offices

Uranium Toxicity Issues

Inhalation

- Inhaled uranium deposits in the respiratory tract and the lungs based on particle size
  - larger particle size deposited higher in respiratory tract
- Most inhaled uranium clears the lungs and then is swallowed, then primarily excreted via the feces
- Soluble uranium dissolves and is absorbed into the blood more rapidly than insoluble forms
- Insoluble uranium compounds can reside in the lungs for years

Ingestion

- Absorption in the gut:
  - Low: <0.1 % to 6%
  - Primarily in small intestine; remainder eliminated in feces
  - Solubility of the compound influences the portion that is absorbed
- Distribution:
  - Major storage sites: bone, kidney, liver and soft tissue
- Excretion:
  - >95% excreted in feces within 2 days
  - Of the remaining 5%, excreted over at least1,500 days
  - Some urine uranium excreted in 1-6 days

Uranium Health Studies

Mill Workers

- Occupational exposure to Uranium
  - 39 uranium mill workers vs.

    36 local cement plant workers
  - Exposed for more than a year to uranium concentrations exceeding the occupational standard
  - Uranium mill workers higher excretion of urinary proteins and amino acids
  - Limitations: small sample size, no urine uranium data

Community Studies: Drinking Water Exposure and One Residential Exposure Study

Urine Uranium and Nephrotoxicity

- Uranium contaminated drinking water wells
- Well water U (<0.20 – 470 ug/L, median 6.7 ug/L)
- Urine uranium levels: GM exposed (0.038 ug/L) vs. controls (0.0043 ug/L)
- U urine range of exposed: 0.0013-4.8 ug/L
- 25 diabetics included
- Kidney function markers: glucose, phosphate, calcium, B2M, NAG, A1M, lambda and kappa light chains, albumin, creatinine
- Conclusion: No significant correlation between kidney function markers and urine uranium

Selden AI et al. Enviornmental Research 2009, 109: 486-494.

Health Effect Differences between Children and Adults

- It is not known whether exposure to uranium affects children differently
  - Very young animals absorb more uranium than adults do when fed uranium, but do not know if this happens in children
- Extremely high doses of uranium in drinking water
  - resulted in birth defects and an increase in fetal deaths in lab animals
- Not likely that uranium can cause these problems in pregnant women who are exposed to background levels of uranium in food, water, and air
  - Not known whether exposure to naturally occurring uranium can affect the developing human fetus

Case Study: Uranium well water exposure in a family

- Family: 2 adults and 5 children
  - ages: 3, 5, 7, 9, and 12 yrs)
- Well water: 46 µg/L uranium
  - ingested for 5 yrs
- Urine uranium levels: < 1 µg/L to 6.2 µg/L
- Elevated urine protein in 5/7 family members (1 adult and 9 yr normal)
- 3 yr child (lived in home since birth) – Protein excretion rate was about twice the upper limits of normal

Is kidney damage reversible?

- Animal data suggest the damage may be reversible once exposure stops
- Case Report: Failed suicide attempt
  - Ingestion of 15 g of uranyl acetate with an unknown amount of antipsychotic
  - After dialysis: renal function partially recovered after 2 wks
  - Anemia and renal dysfunction persisted for 8 wks
  - Incomplete bone marrow failure persisted for 6 m
  - Preexisting peptic ulcer may have increased absorption of U

CARCINOGENICITY

Carcinogenicity

- Uranium recently classified as NON-carcinogen
  - No human cancer of any type has ever been seen as a result of exposure to natural or depleted uranium
  - If cancers were to occur, the most likely would be bone cancers
  - No cancer has been associated with uranium exposure
- National Academy of Science reported that eating food or drinking water with background amounts of uranium will most likely not cause cancer or other health problems in most people

Carcinogen Classification of Natural Uranium

Agency	Classification
IARC - International Agency for Research on Cancer	no carcinogenicity ratings for uranium
NTP – U.S. National Toxicology Program	no carcinogenicity ratings for uranium
EPA – U.S. Environmental Protection Agency	withdrawn its carcinogenicity classification for uranium
NIOSH – National Institute of Occupational Safety and Health	considers insoluble and soluble uranium compounds to be potential occupational carcinogens as defined by OSHA carcinogen policy

Insufficient evidence to determine association

Organ Cancers

- Renal (kidney) Cancer
- Bladder Cancer
- Lung Cancer
- Bone Cancer

Other systems

- Genetic (genotoxic)
- Developmental (prenatal)
- Neurological
- Reproductive
- Cardiovascular effects
- Blood formation
- Immune effects
- Skeletal effects

Limitations of Studies

- Lack of statistical power – often small studies
- Most studies in healthy workers
- Studies lacking in individuals with chronic medical conditions (diabetes, hypertension etc)
- Period of follow-up in several studies too short to detect disease (need long-term follow-up for disease appearance)
- Exposure classification limitations are inaccurate or imprecise

Further research needed

- Impact of uranium on indigenous populations
- Routes of exposure in communities near uranium sites
  - Combined metal exposures at many uranium sites
- Human developmental effects
- Health effects at or below established exposure standards
- Defining a threshold for health effects in heterogenous populations and those with chronic health conditions

Discussion
&
Questions