

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

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Agency for Toxic Substances and Disease Registry

Division of Health Assessment and Consultation

#### **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

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			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cí	Es	Fm	Md	No	Lr		
ε	Editor: Aditya Vardhan (adivar@nettlinx.com)			ACTINIUM	THORIUM	PROTACTINIUM	URANIUM	NEPTUNIUM	PLUTONIUM	AMERICIUM	CURIUM	BERKELIUM	CALIFORNIUM	EINSTEINIUM	FERMIUM	MENDELEVIUM	NOBELIUM	LAWRENCIUM	

### **Uranium in the Environment**

Found in soil, rocks, surface and groundwater, air, plants, animals, and seawater
The majority of the uranium deposite in the United

- 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

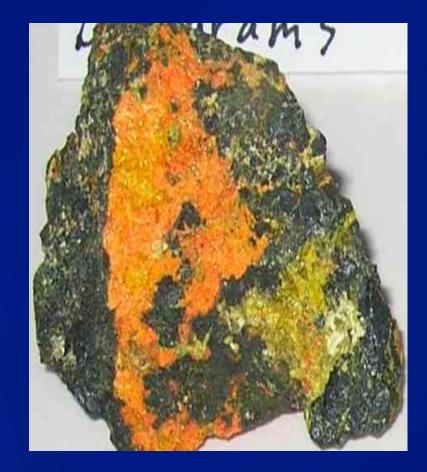


#### **Autunite**

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

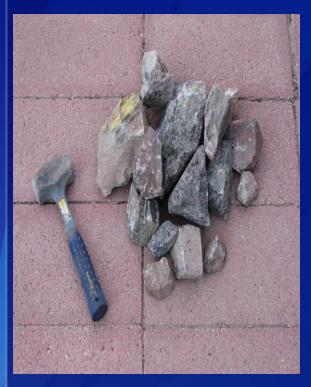
### **Chemical Properties**

Uranium is one of the heaviest of the naturally occurring elements
 Very dense solid -- 1192 lbs/ft<sup>3</sup>
 Lead is 708 lbs/ft<sup>3</sup>
 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<sub>2</sub> and UH<sub>3</sub>
- 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

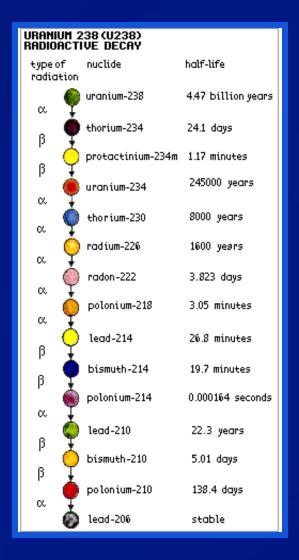
Uranium dusts are respiratory irritants, with coughing, shortness of breath as possible outcomes.
 The more soluble uranium compounds are considered most toxic to the kidneys
 Prolonged skin contact can cause damage to the

underlying skin (basal) cells

# SO, WHAT IS RADIATION AND RADIOACTIVITY?

# What is Radioactivity?

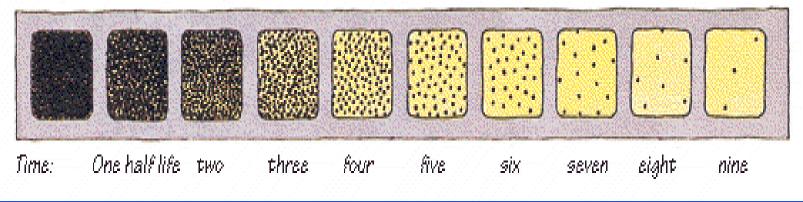
- Elements having an unstable or imbalanced nucleus undergo a process known as radioactive decay
  - radioactive elements called radioisotopes
  - Each of these radioisotopes must undergo a nuclear rearrangement, emitting energy, to reach a stable form
  - This process is radioactive decay
- The decay 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.

Decay rate of radioactivity: After ten half lives, the level of radiation is reduced to one thousandth



## Uranium is always radioactive

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

lsotope	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

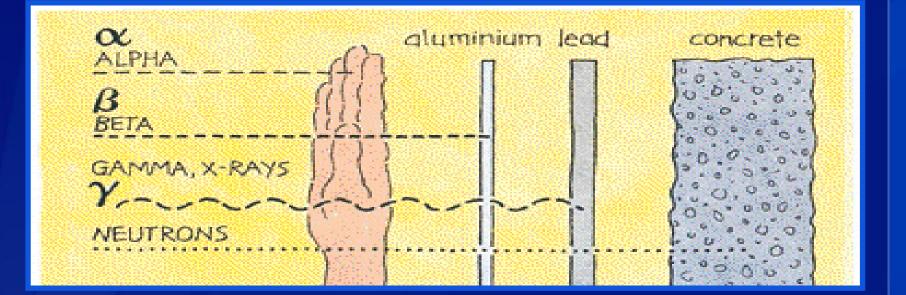
There are three common types of radioactive decay

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)

#### Mining and processing uranium

in Niger

1. Mining

The unearthed ore is usually prepared on location because of its low uranium content.

#### 2. Separation

The ore is broken and ground down and then the uranium is removed from the rock by applying acid or salt solution.

#### 3. Yellow cake production The product is concentrated

The product is concentrated and dried out. It contains approximately 70 percent uranium oxide and is sent from Niger abroad for further processing.

#### **Further Processing**

The addition of fluoride creates uranium hexafluoride in gas form. During an extensive centrifuge process, the quantity of fissionable isotopes U235 is boosted. The enriched uranium is then further processed into fuel rods.

#### **Processed Uranium**

➢ Uranium processed to form either "yellowcake" or "greensalt" >U<sub>3</sub>O<sub>8</sub> or UF<sub>4</sub> ➤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

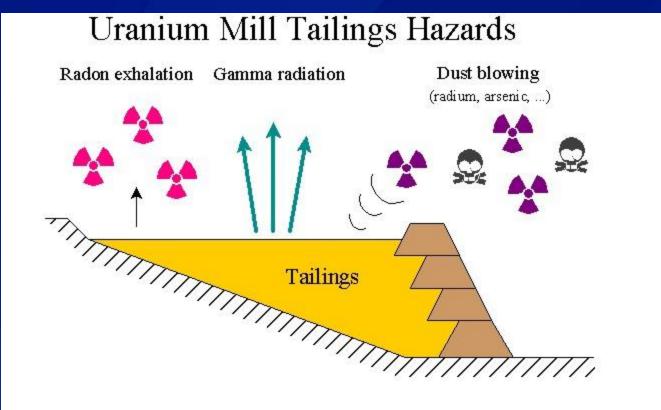
Waste is radioactive
 Can be soluble in water
 Can contain other non-radioactive metals such as arsenic and lead
 Physical hazards

### Mill waste volumes

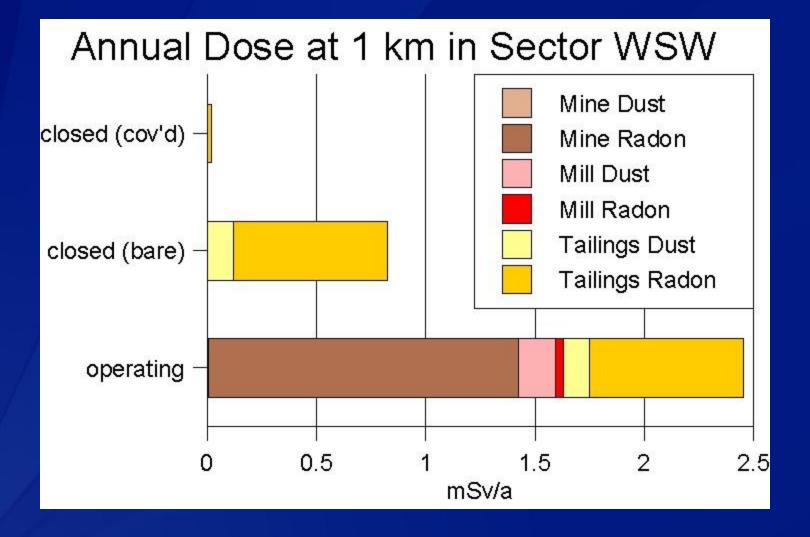
> Mill wastes are typical rock and other debris Licensed tailings piles contain a combined total of approximately 220 million tons Range of 2.2 to 3.3 million tons each > The 24 abandoned sites contain a total of about 28.6 million tons  $\succ$  range in size from about 55 thousand tons to about 3.3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

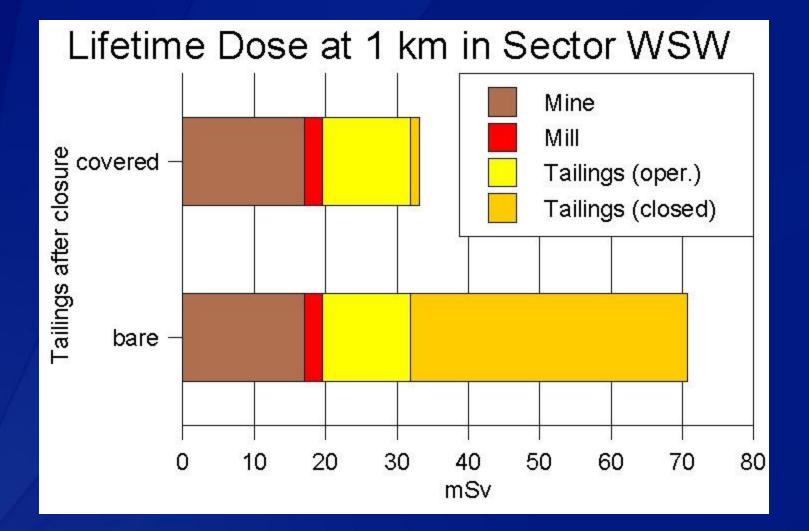
# Radiation doses from uranium mine and mill wastes

Material	<b>Calculation Parameter</b>	Annual Dose (millirem)
0.2% U in ore	1 cm from hand	36
Mill Product	Greensalt (UF <sub>4</sub> ) Yellowcake (diuranate) Yellowcake (U <sub>3</sub> O <sub>8</sub> )	231 184 259
Mill Tailings	107639 sq. ft (10,000 m²)	7172
Typical US Background	Including radon	311









## **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

 $\succ$  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
  - Iarger 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%</p>

- > 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)</li>
   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

# 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  $\succ$  ingested for 5 yrs  $\succ$  Urine uranium levels: < 1 µg/L to 6.2 µg/L  $\succ$  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

