U.S. EPA Tribal Radiation Education Activities:

Uranium

United States Environmental Protection Agency

U.S. EPA Tribal Radiation Education Activities: **Uranium**

Historically, uranium was used as a coloring agent in decorative glass and ceramics. From the late 1940s to 1970s, the United States experienced a uranium mining and milling boom driven by the demand for nuclear weapons and nuclear power. Along with the mining and milling boom, scientists were testing nuclear weapons and conducting environmental studies with radioactive waste. These activities have impacted Native Americans, Alaska Natives and their lands.

Today, the greatest use of uranium continues to be for power generation. Uranium is also used in industrial and research processes. Uranium mining and milling continues today in the U.S., but on a small scale.

Target Audience and Activity Topics

The Uranium activities are designed to teach middle and high school students about the significance of uranium and its decay products, such as radium and radon. Students will learn about the penetrating powers and effects of radiation and analyze the benefits and impacts of radiation exposure. Students will examine related radiation myths and facts and explore uranium and radiation-related science and engineering jobs. With a greater understanding of uranium and radiation, students can dispel myths and fears and be advocates for their community.

NOTE: The term “radiation” used in these activities generally refers to ionizing radiation, unless otherwise indicated.

Activity Times

All U.S. Environmental Protection Agency (EPA) Radiation Education Activities can be used individually or modified and combined to create multiple lessons. Activity options allow you to customize the activities to fit the time you have available (e.g., 1–2 class periods) and meet the needs and interests of your students.

The time needed to complete activities is between 45-60 minutes, not including optional activities or extensions.

Next Generation Science Standards

The concepts within these activity sets can be used to support the following science standards:

- PS1. Structure and Properties of Matter
- PS4. Waves and Electromagnetic Radiation
- ESS3. Earth and Human Activity

Common Core State Standards (CCSS)

The concepts in the Vocabulary Activities align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

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Uranium: Teacher Background Information

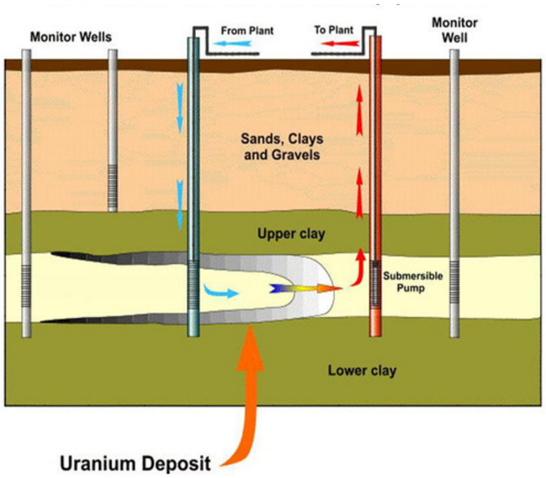
Uranium is a trace element commonly found in rocks, soil, water, plants and animals. Geologically, uranium is generally found in sandstone deposits, with some found in volcanic remanants (for example, breccia deposits of the Grand Canyon). The main U.S. sandstone deposits of uranium are in the Colorado Plateau, Northern Arizona, the Wyoming Basin, the Texas Coastal Plain and Nebraska. The largest single source of uranium ore in the U.S. is the Colorado Plateau located in the Four Corners intersection of Colorado, Utah, New Mexico and Arizona.

Uranium Mining and Milling

The U.S. mining industry extracts (removes) uranium from the ground through several methods:

1. Physically removing the rock ore through open-pit mining or underground mining.
    - Open-pit mining involves stripping away or excavating the topsoil and rock that lie above the uranium ore.
    - Underground mining involves extracting rock through a tunnel or opening in the side of a hill or mountain, or digging a shaft from the surface into the underlying ore zone.
2. Chemically dissolving the uranium out of the rock ore is done through either heap leaching or in-situ leaching.
    - Heap leaching (not presently used in the U.S.) is the process of sprinkling chemicals on above-ground piles of crushed ore-bearing rock in a lined pit and collecting uranium through underground drains. Either acid or alkaline solutions may be used to remove uranium from the host ore rock.
    - In-situ leaching (presently the most common method used in the U.S.) involves drilling wells deep underground and using chemicals (typically alkaline and include sodium bicarbonate and oxygen mixed with water) to dissolve the uranium before it is pumped to the surface as a liquid through wells.

Open pit mining.
Source: U.S. Geological Survey



In-situ leaching.
Source: U.S. Nuclear Regulatory Commission

Milling is the process that removes uranium from the ore. The ore is crushed and ground-up, treated with chemical solutions to dissolve the uranium, and separated from the solution. The final, dried uranium product is commonly called "yellowcake."

Tailings (waste produced from the milling processes) contain radioactive elements like thorium, radium, polonium and radon, along with other chemical elements. Tailings are placed in huge mounds called tailings piles, stored in special waste disposal facilities with underground liners to keep contaminated fluids from contaminating groundwater, or covered with water to reduce the amount of radon gas released into the air. Tailing piles and disposal sites are generally located close to mining and milling sites.

Benefits and Impacts

Uranium miner.
Source: National Institute of Environmental Health Sciences

The uranium mining boom began with the U.S. Atomic Energy Commission buying and stockpiling uranium for nuclear power and weapons development. Today, uranium is used as fuel for nuclear power generation, for industrial purposes, and in manufacturing and research.

Radium, thorium and other radioactive elements are mined with uranium and are found in the tailings. Radium was historically used for medicine and in consumer products like hair tonic, toothpaste, ointments, elixirs and glow in the dark watches and clock faces. Today, radium is only used in research.

During the boom, uranium mines provided economic advantages for tribal communities including jobs, development of new roads and airstrips for airports, and money spent by non-tribal workers for food, lodging and other services. However, tribal communities are facing many environmental and public health concerns. The Navajo Nation has more than 500 abandoned uranium mines, four inactive uranium milling sites and a former dump site that have not been properly cleaned up. The lasting impacts of these sites have led the Navajo Nation to ban uranium mining and exploration on its lands. Most of the world's production of uranium today comes from mines in Kazakhstan, Canada and Australia. In 2012, six underground mines and five in-situ leaching operations were in operation within the U.S. As of 2014, five in-situ leaching sites were in operations and two conventional mills were in standby (not in operation).

Radiation Exposure

Radioactive dust and high levels of radon in abandoned mine and milling sites and former dump and testing sites makes these areas unsafe. Radioactive materials that are not properly cleaned up can be spread by wind and water runoff, affecting surrounding areas, humans and animals. Structures built close to abandoned uranium mines, or with contaminated materials from mining areas, are at risk of having elevated radiation and radon levels.

Ionizing radiation, emitted (given off) from these radioactive elements, can damage living tissue by changing cell structure and damaging DNA. The amount of damage depends on the type of radiation, the exposure pathway, the radiation's energy, the rate which the energy is absorbed (dose rate) and the total amount of radiation absorbed.

Children are more sensitive to ionizing radiation than adults because children are still in the process of growing. There are more cells dividing and a greater opportunity for radiation to disrupt the growth process. The U.S. Environmental Protection Agency's (EPA) radiation protection standards take into account the differences in sensitivity due to age and gender.

Radiation Protection

People should NEVER:

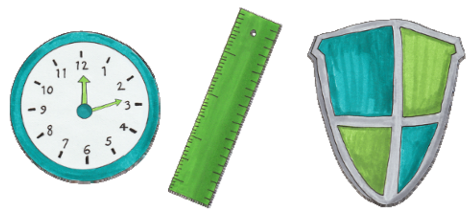
- Enter an abandoned mine, or herd lifestock in them.
- Disturb abandoned mine, mill, dump or test sites.
- Handle, dispose or re-use abandoned equipment at these sites.
- Swim or drink water from open pit mine lakes.
- Drink the water from streams and springs near these sites.

- Remove rock or soil from these sites or use materials from the sites for building construction.

People living near former uranium mines, mills and dump and testing sites can contact their local or state geological survey office or bureau of health to determine if they are at risk due to increased levels of radiation in the area where they live.

Basic radiation protection concepts can be applied separately or in combination to help limit people's exposure to increased radiation levels:

- Time: limiting time near the radiation source.
- Distance: increasing the distance from a radiation source.
- Shielding: placing material or a barrier between a person and a radiation source.



Time, Distance and Shielding

Highlights in Uranium History

Dates	Historical Events
1400s	Uranium was mined to create a red-orange color in ceramics.
1789	Martin Klaproth, a German chemist, discovered uranium and named it after the planet Uranus.
1871	The first radium/uranium ore was discovered in the U.S. in gold mines near Central City, Colorado.
1896	Henri Antoine Becquerel discovered that uranium is radioactive.
1938	Otto Hahn and Fritz Strassman discovered that uranium could be split to release energy (fission).
1939	World War II begins.
1942 to 1946	The Manhattan Project was led by the U.S. and supported by the United Kingdom and Canada. The project researched and developed the first atomic bombs during World War II.
1945	The first atomic bomb is tested in New Mexico before the bombing of Japan in Hiroshima and Nagasaki during the final stages of World War II.
1945 to 1991	The Cold War as a long period of tension and distrust between democratic and communist countries. During this period, the U.S. and the Soviet Union (viewed as superpowers) raced to develop stockpiles of nuclear weapons.
1945 to 1992	Nuclear testing took place in the U.S. and around the world in attempts to find peaceful uses for atomic energy.
1946	The Atomic Energy Act was signed to regulate civilian and military use of nuclear materials and promote atomic energy development for safe and peaceful use.
1947	Uranium mining and milling boom began in the U.S. Before World War II, the U.S. purchased uranium from other countries or got it from vanadium deposits in Utah and Colorado on the Colorado Plateau. During the boom, mine operators extracted nearly 4 million tons of uranium ore from the Navajo Nation alone. Uranium mining also took place in the Lakota lands in the Black Hills of South Dakota, the Spokane reservation in Washington, and the Tohono O'odham Nation, west of Tucson, Arizona. The boom continued until the early 1970s.

Dates	Historical Events
1949 to 1956	Colorado and the U.S. Public Health Service began a study of radiation safety in uranium mines and mills. They conducted environmental studies of the mines and epidemiological studies of the miners.The mine studies concluded in 1956, but the epidemiological study continued.
1959	Miners are provided with a U.S. Public Health Service pamphlet warning them of possible radon exposure while working in the mines. This is the first government-issed document addressing the possible health risks to the miners from working in the mines. The pamphlet was not widely distributed and some mine operators downplayed the possible radon exposure.
1960	The U.S. Public Health Service released a report to the mining states highlighting the link between uranium mining and lung cancer. However, the federal government continued to defer to the states for the creation and enforcement of safety measures in mines that were not Atomic Energy Comission property.
1965	Utah, Colorado and New Mexico study pollution from uranium mills and discover twenty miles of the Animas River devoid of life downstream from Durango, CO mill. New Mexico and Colorado pass regulations requiring maintenance of abandoned uranium mill tailings piles and outlawing direct discharges to rivers. Industry largely ignored the rules.
1967	The U.S. Secretary of Labor announced a federal standard for radon and its daugthres in uranium mines supplying the federal government.
1970 to present	Uranium mining and milling decreased greatly after the Atomic Energy Commission no longer needed to purchase uranium. The demand for uranium started to exceed the worldwide supply in the mid- to late-2000s.
1978	The Uranium Mill Tailings Radiation Control Act made the federal government liable for the pollution and required the cleanup of abandoned uranium mills, mill tailings, and homes built with contaminated mill tailings (waste containing radioactive elements like thorium, radium, polonium and radon). States contributed 10%, the federal government 90%.
1979	The Church Rock Spill occurred in New Mexico. Radioactive dust from uranium mining and milling was contained in a man-made lake. The dike broke and 93 million gallons of radioactive material (uranium, thorium, radium and polonium) flooded the land and went into the Rio Puerco. Animals died from drinking the contaminated water and people who came in contact with the water experienced burns.
1979	The Three Mile Island accident occurred when there was a partial nuclear meltdown in one of the two Three Mile Island nuclear reactors in Pennsylvania.
1986	An explosion and fire occurred at the Chernobyl Nuclear Power Plant in Ukraine. Radioactive particles were released into the atmosphere which spread over much of the western Soviet Union and Europe.
1987	The National Institute for Occupational Safety and Health (NIOSH) released a major study that recommended lowering the occupational radon dose for uranium miners from 4 WLM/year (approximately 5 rem per year) to 1 WLM/year. The recommendations were not followed and remain at 4 WLM/y today.
1990	Congress passed the Radiation Exposure Compensation Act (RECA). RECA represents an official government apology to victims of America's Cold War nuclear program. RECA expressly acknowledges the U.S.' failure to warn three groups of victims: uranium miners, on-site atomic test victims and

Dates	Historical Events
	downwind communities exposed to fallout from the atomic bomb tests.
2005	The Navajo Nation became the first indigenous government to ban uranium mining and exploration on its lands.
2006 and 2007	Congress, led by Henry Waxman (D-California, Chair of the Budget and Government Oversight Committee) sought direct testimony from Navajo officials and demanded a plan of action from the five federal agencies responsible for what Waxman described as a “40 year history of bipartisan failure and a modern American tragedy.”
2008 to 2012	Congress authorized a comprehensive 5-year plan to coordinate the cleanup of contaminated structures, soil and water in the Navajo Nation. The joint effort involves the EPA, Department of Energy, Nuclear Regulatory Commission, Bureau of Indian Affairs and the Indian Health Service.
2011	Japan’s Fukushima Daiichi nuclear disaster occurred when the nuclear power plant was hit by a tsunami that was triggered by an earthquake.

Additional Resources:

- RadTown USA: www3.epa.gov/radtown
- Radiation Basics: http://www2.epa.gov/radiation/radiation-basics
- Radiation: Facts, Risks and Realities: http://www2.epa.gov/sites/production/files/2015-05/documents/402-k-10-008.pdf

Uranium Vocabulary Activities

The concepts surrounding radiation can be complex. By conducting a vocabulary activity before beginning an activity or series of activities, students will have a shared base knowledge.

Materials and Resources

- *Vocabulary Materials* document.
- Materials noted in activity suggestions.

Common Core State Standards (CCSS)

The concepts in this activity align with the following CCSS English Language Arts Standards for Literacy in History/Social Studies, Science, & Technical Subjects:

- Key Ideas and Details: CCSS.ELA-LITERACY.RST.6-12.2
- Craft and Structure: CCSS.ELA-LITERACY.RST.6-12.4
- Vocabulary Acquisition and Use: CCSS.ELA-LITERACY.L.6-12.6

Vocabulary by Activity

Activity 1: Uranium, Radium and Radon	• Atom • Electron • Neutron • Nuclear energy • Proton • Radiation	• Radioactive atom • Radioactive decay • Radium • Radon • Uranium • Uranium mining
Activity 2: Radiation and Uranium Myths and Facts	• Atom • Alpha particle • Beta particle • Gamma rays • Ionizing radiation • Nuclear energy • Radiation	• Radioactive atom Radioactive decay • Radiation exposure • Radon • Uranium • Uranium mining • Uranium milling
Activity 3: Uranium Ore Sources in the U.S.	• Ionizing radiation • Uranium	• Uranium mining • Uranium milling
Activity 4: Uranium Mining Methods	• Ionizing radiation • Radiation • Radioactive atom • Radium	• Radon • Uranium • Uranium mining • Uranium milling
Activity 5: Radiation Contamination and Exposure	• Direct exposure • Exposure pathways • Inhalation • Ingestion • Ionizing radiation • Man-made radiation	• Natural (background) radiation • Radioactive contamination • Radon • Uranium • Uranium mining

Activity 6: Radiation Cleanup and Advocacy	• Ionizing radiation • Nuclear energy • Radiation exposure	• Uranium • Uranium mining • Uranium milling

Activity Suggestions

- **Identifying images.**
  - Print the applicable images from the *Vocabulary Materials* document.
  - Display the images around the room or spread them out in an open area on the floor.
  - Pronounce the vocabulary words one at a time. NOTE: You can provide the definition of the given word at this time or after students have identified the words.
  - Have students take turns identifying the words in an active manner. Suggestions include having students move to and identify the correct image, use a flashlight to point to the correct image (being careful to avoid light in another person's eyes), drive a remote control car to the correct image or throw a bean bag to land on the correct image.
- **Matching words and images.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Give each student a vocabulary word or image. Options: Fold or ball up the copies and let each student select one. Have students trade their copy with another student once or twice. NOTE: You may need to participate to have an even number of participants.
  - Direct students to find the person with the matching word or image.
  - Review the matches to confirm they are correct.
  - Pronounce each word and provide a definition.
- **Spelling the words.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the words and images at the front of the classroom.
  - Pronounce each word and provide a definition.
  - Conduct a spelling activity:
    - Have students create a word scramble or word find activity; trade papers and complete the activity.
    - Play spelling basketball. Divide the class into two teams. Pronounce a vocabulary word. Have a student (alternating between teams) spell or write the word on the board. Students that spell the word correctly are given an opportunity to shoot a basket (use a trash can) with a ball of paper (ball) from a designated distance (or varying distances for a different number of points). The team that scores the most points wins. You can have students provide a definition for extra points.
- **Creating definitions.**
  - Print the applicable words and images from the *Vocabulary Materials* document.
  - Display the words and images at the front of the classroom.
  - Pronounce the vocabulary words.
  - Have students work in pairs or small groups to hypothesize and create a definition for each vocabulary word.
  - Options: Direct one student from each pair/group to rotate and join another pair/group or have two pairs/groups join together. Direct the newly formed groups to compare their definitions and modify them if desired.
  - Review each pair/group's definitions, have students discuss what they agree/disagree with and confirm the accurate definition.

Activity 1: Uranium, Radium and Radon

Objectives

Students will:

- Determine the atomic structures of uranium, radium and radon.
- Describe the characteristics of each.
- Examine the benefits and risks of each.

NOTE: Students should have an understanding of the periodic table and how to use the information to determine the atomic structure of elements.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standards:

- PS1. Structure and Properties of Matter.
- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- *Uranium Past and Present* images (one per student, pair or group or display with a computer and projector).
- *Uranium, Radium and Radon Worksheet* (one per student, pair or group) and *Uranium, Radium and Radon Teacher Answer Key*.
- *Periodic Table of Elements* (one per student, pair or group).
- Student computers with Internet access or provide print versions for students (optional):
    - RadTown: www3.epa.gov/radtown
    - Nuclear Power Plants: www3.epa.gov/radtown/nuclear-plant.html
    - Uranium Mines: www3.epa.gov/radtown/uranium-mines.html
    - Radionuclide Basics: Uranium: http://www2.epa.gov/radiation/radionuclide-basics-uranium
    - Radionuclide Basics: Radium: http://www2.epa.gov/radiation/radionuclide-basics-radium
    - Radionuclide Basics: Radon: http://www2.epa.gov/radiation/radionuclide-basics-radon

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Atom
- Electron
- Neutron
- Nuclear energy
- Proton
- Radiation
- Radioactive atom
- Radioactive decay
- Radium
- Radon
- Uranium
- Uranium mining

Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Share the *Uranium Past and Present* images. Explain that a uranium mining boom took place in the U.S. from the mid-1940s to 1970s. During this period thousands of uranium mines were in operation, primarily in the Western part of the U.S.

3. Ask students why uranium was mined and how it is used today. Uranium was mined primarily for the development of nuclear weapons and then for power generation. The images show the industrial uses today include:
   - A nuclear power plant: Nuclear power plants produce electricity through a heat-generating process known as "fission" in which neutrons split uranium atoms to produce large amounts of energy.
   - A nuclear-powered supercarrier: A small nuclear reactor powers submarines, supercarriers, icebreakers and other ships. In the defense industry, depleted uranium metal is used for armor plating and armor-piercing projectiles.

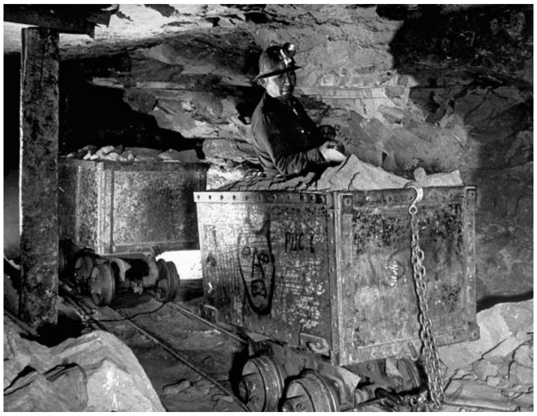
4. Distribute the *Uranium, Radium and Radon Worksheet*. Direct students to use the *Periodic Table of Elements* to complete the activity. The atomic number will provide students with the number of protons and electrons. They can calculate the neutrons by subtracting the atomic number from the atomic mass. Resources may include information from the Environmental Protection Agency (EPA) webpages listed in the Materials and Resources section.

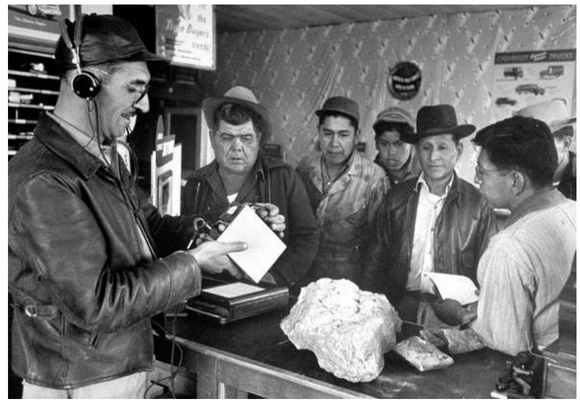
5. Review student responses as a class using the *Uranium, Radium and Radon Teacher Answer Key*. Conclude by asking students to share at least one thing they learned about uranium, radium or radon.

6. Optional activities or extensions: Have students examine:
   - The atomic structure and physical characteristics of each element.
   - The types of radiation each emits (alpha particles, beta particles and gamma rays), the potential exposure pathways (direct exposure, ingestion and inhalation), the potential health effects and the potential protection measures people can take to avoid exposure to these elements. Information about uranium, radium and radon can be found online at: http://www2.epa.gov/radiation/radionuclides.
   - Explore how the uranium to lead decay chain can be used in radioactive dating to calculate the age of rocks or organic material.

Uranium Past and Present

Uranium Mining Boom: 1947 to 1970





Uranium miner (left) and prospectors with a large uranium ore (right).
Source: National Institute of Environmental Health Sciences

Industrial Uses Today

Energy

Defense
Source: White House photo by David Bohrer

Uranium, Radium and Radon Worksheet

Name: ________________________________ Date: ____________________

Use a periodic table to complete the following table and determine the number of protons, electrons and neutrons.

Element	Symbol	Atomic Number	Atomic Mass	Atomic Structure	Group/Family and Properties
Uranium				Protons: Electrons: Neutrons:	
Radium				Protons: Electrons: Neutrons:	
Radon				Protons: Electrons: Neutrons:	

1. How are we exposed to these elements?

   Natural (background) sources:

   ____

   ____

   Man-made sources:

   ____

   ____

2. What is the connection between these elements?

   ____

   ____

3. Explain how the elements' atomic structures relate to their radioactive properties.

   ____

   ____

   ____

4. Why is exposure to these elements a concern?

   ____

   ____

   ____

Periodic Table of Elements

Element Name Atomic Number Symbol Atomic Weight

- Alkali metals
- Alkaline earth metals
- Transition metals
- Post-transition metals
- Metalloid
- Lanthanides
- Actinides
- Nonmetals
- Halogens
- Noble gases

Period \ Group	1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1	Hydrogen 1 H 1.008																	Helium 2 He 4.003
2	Lithium 3 Li 6.94	Beryllium 4 Be 9.012											Boron 5 B 10.81	Carbon 6 C 12.01	Nitrogen 7 N 14.01	Oxygen 8 O 16.00	Flouride 9 F 19.00	Neon 10 Ne 20.18
3	Sodium 11 Na 22.99	Magnesium 12 Mg 24.31											Aluminium 13 Al 26.98	Silicon 14 Si 28.09	Phosphorus 15 P 30.97	Sulfur 16 S 32.06	Chlorine 17 Cl 35.45	Argon 18 Ar 39.95
4	Potassium 19 K 39.10	Calcium 20 Ca 40.08	Scandium 21 Sc 44.96	Titanium 22 Ti 47.88	Vanadium 23 V 50.94	Chromium 24 Cr 52.00	Manganese 25 Mn 54.94	Iron 26 Fe 55.85	Cobalt 27 Co 58.93	Nickel 28 Ni 58.69	Copper 29 Cu 63.55	Zinc 30 Zn 65.39	Gallium 31 Ga 69.72	Germanium 32 Ge 72.64	Arsenic 33 As 74.92	Selenium 34 Se 78.96	Bromine 35 Br 79.90	Krypton 36 Kr 83.79
5	Rubidium 37 Rb 85.47	Strontium 38 Sr 87.62	Yttrium 39 Y 88.91	Zirconium 40 Zr 91.22	Niobium 41 Nb 92.91	Molybdenum 42 Mo 95.94	Technetium 43 Tc (98)	Ruthenium 44 Ru 101.1	Rhodium 45 Rh 102.9	Palladium 46 Pd 106.4	Silver 47 Ag 107.9	Cadmium 48 Cd 112.4	Indium 49 In 114.8	Tin 50 Sn 118.7	Antimony 51 Sb 121.8	Tellurium 52 Te 127.6	Iodine 53 I 126.9	Xenon 54 Xe 131.3
6	Caesium 55 Cs 132.9	Barium 56 Ba 137.3	57-70 *	Hafnium 72 Hf 178.5	Tantalum 73 Ta 180.9	Tungsten 74 W 183.9	Rhenium 75 Re 186.21	Osmium 76 Os 190.2	Iridium 77 Ir 192.2	Platinum 78 Pt 195.1	Gold 79 Au 197.0	Mercury 80 Hg 200.5	Thallium 81 Tl 204.4	Lead 82 Pb 207.2	Bismuth 83 Bi 209.0	Polonium 84 Po (209)	Astatine 85 At (210)	Radon 86 Rn (222)
7	Francium 87 Fr (223)	Radium 88 Ra (226)	89-102 **	Rutherfordium 104 Rf (265)	Dubnium 105 Db (268)	Seaborgium 106 Sg (271)	Bohrium 107 Bh (270)	Hassium 108 Hs (277)	Meitnerium 109 Mt (276)	Darmstadtium 110 Ds (281)	Roentgenium 111 Rg (280)	Copernium 112 Cn (285)	Ununtrium 113 Uut (284)	Ununquadium 114 Uuq (289)	Ununpentium 115 Uup (288)	Ununhexium 116 Uuh (293)	Ununseptium 117 Uus (294)	Ununoctium 118 Uuo (294)

* Lanthanoids	Lanthanum 57 La 138.9	Cerium 58 Ce 140.1	Praseodymium 59 Pr 140.9	Neodymium 60 Nd 144.2	Promethium 61 Pm (145)	Samarium 62 Sm 150.4	Eurpoium 63 Eu 152.0	Gadolinium 64 Gd 157.2	Terbium 65 Tb 158.9	Dysprosium 66 Dy 162.5	Holmium 67 Ho 164.9	Erbium 68 Er 167.3	Thulium 69 Tm 168.9	Ytterbium 70 Yb 173.0	Lutetium 71 Lu 175.0
** Actinoids	Actinium 89 Ac (227)	Thorium 90 Th 232	Proactinium 91 Pa 231	Uranium 92 U 238	Neptunium 93 Np (237)	Plutonium 94 Pu (242)	Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Bobelium 102 No (259)	Lawrencium 103 Lr (262)

Uranium, Radium and Radon Teacher Answer Key

Element	Symbol	Atomic Number	Atomic Mass	Atomic Structure	Group/Family and Properties
Uranium	**U**	**92**	**238**	**Protons: 92** **Electrons: 92** **Neutrons: 330**	**Part of the actinide series; silvery white, weakly radioactive metal**
Radium	**Ra**	**88**	**226**	**Protons: 88** **Electrons: 88** **Neutrons: 138**	**Alkaline earth metal; naturally radioactive, silvery-white metal that blackens when exposed to air**
Radon	**Rn**	**86**	**222**	**Protons: 86** **Electrons: 86** **Neutrons: 136**	**Noble gas; colorless, odorless, and tasteless radioactive element**

1. How are we exposed to these elements?

   Natural (background) sources: **Uranium, radium and radon are naturally occurring radioactive elements found in soil, rock and water.**
   Man-made sources: **Man-made activities, like digging and mining, can bring these elements to the surface. These elements may also be found in radioactive waste from human activities like mining, milling and nuclear power generation.**

2. What is the connection between these elements?
   Uranium decays to form radium and radon. Exposure to radon can cause lung cancer.

3. Explain how the elements' atomic structures relate to their radioactive properties.
   An atom is unstable (radioactive) if the forces among the particles that make up the nucleus are unbalanced from an excess of either neutrons or protons. Unstable nuclides of any element can exist. However, almost all elements that are heavier than bismuth, which has 83 protons, have an unstable nucleus; they are radioactive and are known as "heavy nuclides."

4. Why is exposure to these elements a concern?
   These elements tend to pose more of a concern when they exist in high concentrations (e.g., in radioactive waste) rather than in their natural state. Concentrations of these elements can contaminate the soil, water and air. People and animals may also be contaminated by or exposed to these elements. Exposure to these elements may pose health effects. For example, radon can cause lung cancer.

Activity 2: Radiation and Uranium Myths and Facts

Objectives

Students will:

- Explore their views of radiation and uranium.
- Assess their knowledge of radiation and uranium.
- Examine and correct any radiation and uranium misconceptions they may have.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standards:

- PS1. Structure and Properties of Matter.
- PS4. Waves and Electromagnetic Radiation.
- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- *Uranium Myths and Facts Quiz* (one per student, pair or group) and *Uranium Myths and Facts Teacher Answer Key*.
- *Uranium Views Worksheet* (optional; one per student, pair or group).
- Board or computer and/or projector for listing students' responses (optional for step 2).

Time

45-60 minutes, not including optional activities or extensions.

Vocabulary

- Atom
- Alpha particle
- Beta particle
- Gamma rays
- Ionizing radiation
- Nuclear energy
- Radiation
- Radioactive atom
- Radioactive decay
- Radiation exposure
- Radon
- Uranium
- Uranium mining
- Uranium milling

Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Ask students to share what they know about radiation, radioactive elements like uranium, and radiation exposure. List their responses for all to see.

3. Review the list and ask the class to decide whether each is a fact or myth. If students have not previously done so, ask them to provide examples of myths (such as radiation exposure will make you glow).

4. Explain that we may receive misinformation from various sources (like movies, comics, video games, other media sources and people) and perceive it to be true when in fact it is not.

5. Explain to the students that they will be completing a myths or facts quiz. The quiz is not to be graded but is a fun way to determine what students know about uranium. Let them know that it's okay if they don't know the answers to the quiz. It's meant to be a learning tool. Distribute, and direct students to complete, the *Uranium Myths and Facts Quiz*.

6. Conclude by reviewing the correct responses using the *Uranium Myths and Facts Teacher Answer Key*. Determine what the greatest misconceptions were for the class based on incorrect responses. Discuss how this activity has changed or confirmed students thinking about radiation. Explain that an important part of science and gaining knowledge is to investigate and verify information with reliable resources.

7. Optional activities or extensions:
    - Have students share the *Uranium Myths and Facts Quiz* (or create another quiz or survey to share) with community members, siblings or parents. Analyze the responses and determine how educated community members are about uranium-related radiation.
    - Direct students to complete the *Uranium Views Worksheet* by talking with friends, family and community members. Answers from students will vary.
    - Select all or several events from the *Highlights in Uranium History* (see the *Uranium: Teacher Background Information*) and print each event on a separate sheet of paper. Options include printing the dates with the event, having students research the event to determine the date or range of dates, or providing the dates after students form predictions about when the events occurred. Provide students with an event and direct them to create a timeline by lining up in the order in which the events occurred. Review and confirm the correct order of events. Discuss how these events have potentially led to myths that exist today and how these events have also led to us learning facts about uranium and radiation.
    - Have students create public messages that educate the public and address misinformation and misconceptions. Ideas may include brochures, posters, cartoons, videos or radio announcements, raps, poems and articles. These materials could be shared within the school and community.

Uranium Myths and Facts Quiz

Name: ________________________________ Date: ____________________

Read each statement. Mark whether each statement is "True" or "False" depending on what you think or believe to be correct.

☐ **True**	☐ **False**	1. Uranium is a man-made element.
☐ **True**	☐ **False**	2. Uranium (U) is a silvery-white, weakly radioactive metal in the actinide series of the periodic table.
☐ **True**	☐ **False**	3. Uranium atoms are unstable and decay (forming other elements like radium and radon) until they become stable lead atoms.
☐ **True**	☐ **False**	4. Uranium decays at a quick rate.
☐ **True**	☐ **False**	5. Any amount of uranium exposure will cause you to develop cancer.
☐ **True**	☐ **False**	6. Waste from uranium mining and milling remains radioactive forever.
☐ **True**	☐ **False**	7. Most of the radiation that we are exposed to is man-made.
☐ **True**	☐ **False**	8. Uranium gives off radiation (alpha particles, beta particles and gamma rays) as it decays.
☐ **True**	☐ **False**	9. Gamma rays produce short wavelengths at a high frequency and can penetrate the body and damage living tissue.
☐ **True**	☐ **False**	10. People are more at risk from radon exposure in their home than living near a nuclear power plant.
☐ **True**	☐ **False**	11. Uranium was discovered during World War II when the atomic bomb was developed.
☐ **True**	☐ **False**	12. Radioactive mining and milling waste can get into our food, water and air supplies.
☐ **True**	☐ **False**	13. I can reduce my risk of uranium exposure by using time, distance and shielding protection measures.
☐ **True**	☐ **False**	14. Children and adults are equally sensitive to radiation exposure.

Uranium Myths and Facts Teacher Answer Key

☐ **True**	☑ **False**	1.	Uranium is a man-made element. **Uranium is a naturally occurring element found in rock, soil, water, air and our bodies.**
☑ **True**	☐ **False**	2.	Uranium (U) is a silvery-white, weakly radioactive metal in the actinide series of the periodic table. **Uranium (U) is a heavy metal with an atomic number of 92 and atomic weight of 238. It serves as an energy source because it is radioactive and gives off radiation that can be used for many purposes.**
☑ **True**	☐ **False**	3.	Uranium atoms are unstable and decay (forming other elements like radium and radon) until they become stable lead atoms. **Radioactive atoms emit energy waves (photons) or high speed particles. This process is known as radioactive decay.**
☐ **True**	☑ **False**	4.	Uranium decays at a quick rate. **Uranium decays at a slow rate. The decay process can take billions of years.**
☐ **True**	☑ **False**	5.	Any amount of uranium exposure will cause you to develop cancer. **The amount of damage depends on the type of radiation, its energy and the total amount of radiation absorbed. Also, some human cells are more sensitive to radiation.**
☐ **True**	☑ **False**	6.	Waste from uranium mining and milling remains radioactive forever. **The radioactivity of the waste reduces with time. However, it can take many thousands of years before some of these materials no longer pose a risk.**
☐ **True**	☑ **False**	7.	Most of the radiation that we are exposed to is man-made. **Generally, half of our exposure to radiation comes from man-made sources and half from natural (background) radiation. The largest source of man-made radiation is medical exposure.**
☑ **True**	☐ **False**	8.	Uranium gives off radiation (alpha particles, beta particles and gamma rays) as it decays. **As uranium decays and forms other elements, some atoms (like uranium-238, radium-226 and polonium-210) emit alpha particles (positively charged; made of two protons and two neutrons) from the atom's nucleus. Most isotopes decay by a combination of alpha particles, beta particles and gamma rays.**
☑ **True**	☐ **False**	9.	Gamma rays produce short wavelengths at a high frequency and can penetrate the body and damage living tissue. **Radiation is energy that travels in the form of waves or high speed particles. Gamma rays produce ionizing radiation found at the short wavelength, high frequency end of the electromagnetic spectrum. The high energy of gamma rays can penetrate the body like x-rays and damage tissue and DNA.**

☑ **True**	☐ **False**	10. People are more at risk from radon exposure in their home than living near a nuclear power plant. **Radon exposure accounts for 37 percent of our annual exposure to radiation, and living in a home or area with high radon levels can be very harmful to your health. Radon can be an issue in any region and living near a nuclear power plant does not make you more or less likely to have a high level of radon in your home or school. Nuclear power plants implement many radiation protection measures to limit your exposure to radiation. Therefore, living near a power plant barely increases your overall radiation exposure.**
☐ **True**	☑ **False**	11. Uranium was discovered during World War II when the atomic bomb was developed. **Radiation is all around us and has been present since the birth of this planet. Martin Klaproth, a German chemist, discovered uranium in 1789. However, the demand for and recognition of, uranium increased after World War II.**
☑ **True**	☐ **False**	12. Radioactive mining and milling waste can get into our food, water and air supplies. **Radioactive waste that is not cleaned up or properly stored can get into food, water and air supplies. This increases the risk of inhaling, ingesting or experiencing direct exposure to radiation.**
☑ **True**	☐ **False**	13. I can reduce my risk of uranium exposure by using time, distance and shielding protection measures. **Basic radiation protection concepts (time, distance and shielding) can be applied separately or in combination to help limit people's exposure to increased radiation levels.**
☐ **True**	☑ **False**	14. Children and adults are equally sensitive to radiation exposure. **Children are in the process of growing. There are more cells dividing and a greater opportunity for radiation to disrupt the growth process. Recent U.S. Environmental Protection Agency (EPA) radiation protection standards take into account differences in sensitivity due to age.**

Uranium Views Worksheet

Name: ______________________________ Date: ____________________

Answer the following questions.

1. My community views uranium and radiation as:
   ____
   ____
   ____

2. What misconceptions did I (and my community) have about uranium and radiation?
   ____
   ____
   ____

3. What led to these misconceptions about uranium and radiation?
   ____
   ____
   ____

4. Explain how my views of uranium and uranium mining changed from this activity or why have they not changed?
   ____
   ____
   ____

Activity 3: Uranium Ore Sources in the U.S.

Objective:

Students will:

- Examine a map of U.S. uranium mines.
- Share personal stories about the impacts of uranium mining on their family.
- Examine the benefits and impacts of uranium mining on communities.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- *Uranium Ore: Benefits and Impacts Worksheet* (one per pair or group) and *Uranium Ore: Benefits and Impacts Teacher Answer Key*.
- *U.S. Uranium Mines* map (display with computer and projector or copy and share with students).
- Student computers with Internet access if allowing students to research in class.

Time

45-60 minutes, not including optional activities or extensions. Alternatively, students could complete the activity outside of class and discuss their findings in the next class period.

Vocabulary

- Ionizing radiation
- Uranium
- Uranium mining
- Uranium milling

Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Poll students to determine how many are aware of any active or abandoned uranium mines within their state or region. In preparation, you may want to contact your regional Environmental Protection Agency office (http://www2.epa.gov/radiation/forms/contact-us-about-radiation-protection#tab-2) to confirm the location of any nearby mines.

3. Display the *U.S. Uranium Mines* map. Have students examine the map and proximity of active or abandoned uranium mines near their community.

4. Allow students to share stories of family members who have worked in uranium mines and any impact this has had on their family. Alternatively, you can share excerpts from *The History of Uranium Mining and the Navajo People* www.ncbi.nlm.nih.gov/pmc/articles/PMC3222290/.

5. Explain that the U.S. uranium mining boom started in the mid-1940s during World War II. Once the U.S. built a stockpile of uranium in the 1970s, the mining industry slowed. Many uranium mines were abandoned without restoring the land to its original state. Past mining activities and the abandoned mines have greatly impacted Native American communities.

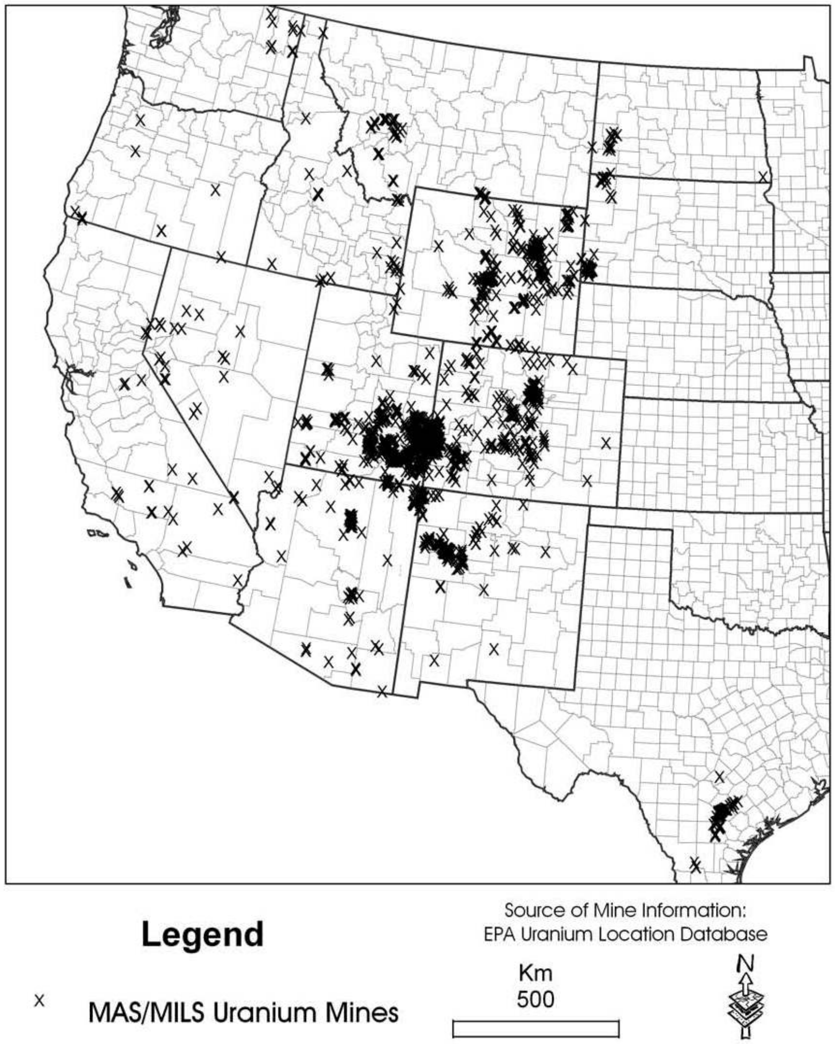
6. Distribute the *Uranium Ore: Benefits and Impacts Worksheet* to pairs or groups. Direct students to research and identify benefits and impacts of uranium mining in the 1940s to 1970s. Students can use the *Uranium: Teacher Background Information* (Uranium Mines section), *The History of Uranium Mining and the Navajo People,* family members and other resources to complete the worksheet.

7. Conclude by discussing student responses as a class using the *Uranium Ore: Benefits and Impacts Teacher Answer Key* and ask students to share something they learned from the activity.

8. Optional activities or extensions: Have students:
    - Prepare for and debate the pros and cons of whether uranium mining should continue in the U.S. or in their area.
    - Research the benefits and impacts of uranium mining in other countries including Kazakhstan, Canada and Australia.
    - Develop a skit or song about the benefits and impacts of uranium mining.

U.S. Uranium Mines

Closed and Abandoned Uranium Mines



Source: (U.S. EPA 2006b)

Uranium Ore: Benefits and Impacts Worksheet

Name: ________________________________ Date: ___________________

Answer the following questions.

1. Research and identify the societal, economic and environmental benefits and impacts of uranium mining and milling in the 1940s to 1970s.

	Benefits	**Impacts**
Societal		
Economic		
Environmental		

2. How has your community benefited from or been impacted by uranium mining and milling?

____

____

____

____

3. What activities or regulations have been put in place to address the impacts of uranium mining on Native Americans and Alaska Natives?

____

____

4. In 2012, six underground mines and five in-situ leaching operations were in operation within the U.S. As of 2014, five in-situ leaching sites were in operations and two conventional mills were in standby (not in operation). Should the mining and milling of uranium continue in the U.S.? Explain your answer.

____

____

Uranium Ore: Benefits and Impacts Teacher Answer Key

1. Identify or hypothesize the societal, economic and environmental benefits and impacts of uranium uses, mining and milling in the 1940s to 1970s.

	Benefits	**Impacts**
Societal	**People may have felt proud to support the Cold War and reduce our dependence on foreign oil and uranium supplies.**	**People didn't understand or were not fully told about the hazards or risks.**
Economic	**For tribal communities, the mines provided economic advantages including jobs at the mines and mills, development of new roads and airstrips, and money spent by non-tribal workers for food, lodging and other services.**	**Some miners began getting sick and dying. That likely placed economic burdens on the family. The Radiation Exposure Compensation Act (RECA) was passed to compensate families.**
Environmental	**Some may have believed and promoted the message that nuclear power is clean energy with little impact on the environment.**	**Tribal lands were disrupted by mining. Some mines were abandoned (and sometimes not restored to their original state). Water supplies were contaminated.**

2. How has your community benefited from or been impacted by uranium mining or abandoned uranium mines?
   Answers may vary.

3. What activities or regulations have been put in place to address the impacts of uranium mining on Native Americans and Alaska Natives?
   The Uranium Mill Tailings Radiation Control Act (UMTRCA) required the cleanup of abandoned mill tailings, but not mines. RECA pays victims of the Cold War nuclear program. Controls and radiation protection standards have been put in place to protect uranium miners. The Navajo Nation has banned uranium mining and exploration on its lands. Congress authorized a comprehensive 5-year plan to coordinate the cleanup of contaminated structures, soil and water in the Navajo Nation.

4. In 2012, six underground mines and five in-situ leaching operations were in operation within the U.S. As of 2014, five in-situ leaching sites were in operations and two conventional mills were in standby (not in operation). Should the mining and milling of uranium continue in the U.S.? Explain your answer.
   Answers may vary.

Activity 4: Uranium Mining Methods

Objectives:

Students will:

- Hypothesize and list the benefits and impacts of mining methods.
- Consider whether they would be for or against a particular mining method being used in their community.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- *Uranium Mining Methods Worksheet* (one per student, pair or group) and *Uranium Mining Methods Teacher Answer Key.*

Time

You may choose to have students complete the entire activity within one or two class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Ionizing radiation
- Radiation
- Radioactive atom
- Radium
- Radon
- Uranium
- Uranium mining
- Uranium milling

Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Explain that the U.S. uranium mining boom started in the mid-1940s. Once the U.S. built a stockpile of uranium in the 1970s, the mining industry slowed. Uranium mining is still in operation, but on a much smaller scale. The U.S. mining industry uses two distinct methods to extract uranium ore: physically removing the ore-bearing rock from the soil for processing or chemically dissolving uranium from the ore at the site.

3. Provide students with a *Uranium Mining Methods Worksheet* and review the directions. Students can form hypotheses based on their present knowledge or allow them to acess any available resources, such as the Internet, library or school books or individuals who may have insight on mining and environmental issues.

4. Conclude by having students share their responses. You can reference the *Uranium Mining Methods <u>Teacher Answer Key</u>*. Compile the "for" and "against" votes to see which method the class would be in most favor of, or if they would not want to allow mining in their community.

5. Optional activities or extensions: Have students:
   - Debate the pros and cons of the different mining methods.
   - Develop models or drawings that show the mining process and impacts on the earth, people and our environment.

Uranium Mining Methods Worksheet

Name: ______________________________ Date: ________________

Imagine that a company wants to mine uranium in your area. The company is trying to determine which of the three mining methods it wants to use based on considerations like:

- Other radioactive materials like radium and radon gas that can contaminate the environment and cause health concerns.
- Safe disposal or storage of the mining waste.
- The protection of the health of the workers, nearby community members and the environment.

For each mining method:

- Hypothesize and list the benefits and impacts each mining method may have on the local society, the economy and the environment.
- Check whether you might be for or against allowing the mining method in your area.

Underground mining involves digging and removing rock through a tunnel or opening the side of a hill or mountain. Miners must work underground in tunnels.

Benefits:

Impacts:

☐ For ☐ Against

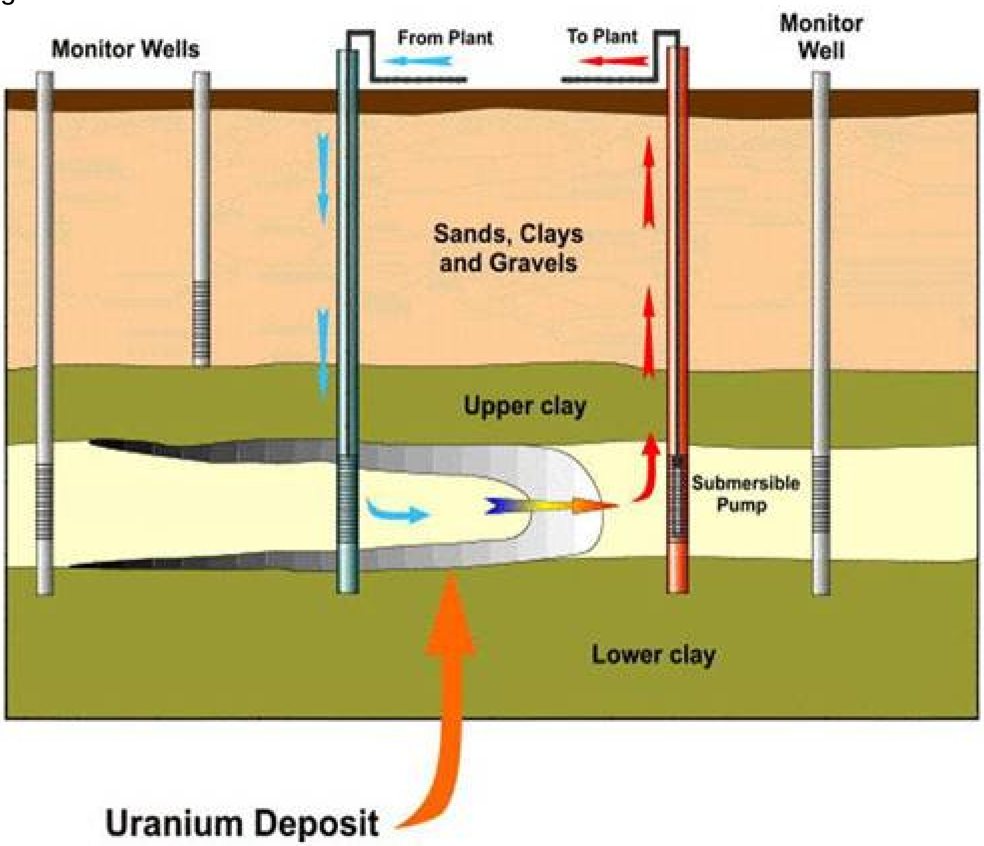
Open-pit mining involves stripping away or excavating the topsoil and rock that lie above the uranium ore

Benefits:

Impacts:

☐ For ☐ Against

In-situ leaching involves treating ore deep underground with chemicals to dissolve the uranium and then pumping the liquid to the surface. This method is feasible in deposits that are saturated and have high permeability. This method is the most common method used in the U.S. through wells.



Source: World Nuclear Association

Benefits:

Impacts:

☐ For ☐ Against

Uranium Mining Methods Teacher Answer Key

Mining Method	Benefits	Impacts
Underground mining	• **Provides jobs** • **Brings money to the local economy and may lead to improved local facilities and services** • **Permits mining operations to be largely out of sight** • **Allows for production in all kinds of weather conditions**	• **Produces safety and health hazards if unauthorized persons enter mines or fall in openings** • **Presents numerous safety and health risks for workers working underground** • **Releases radon and radioactive dust into the environment** • **Produces contaminated soil, water and tailings that can impact the surrounding soil, air and water if not managed properly**
Open-pit mining	• **Provides jobs** • **Brings money to the local economy and may lead to improved local facilities and services** • **Allows for high production of uranium that brings money to the company**	• **Produces safety and health hazards if unauthorized persons enter or fall in pits** • **Releases radon into the environment** • **Produces tailings/radioactive waste that can contaminate the soil, air and water**
In-situ leaching	• **Provides jobs** • **Brings money to the local economy and may lead to improved local facilities and services** • **Reduces risk of employee accidents and exposure to radiation** • **Costs less than other mining methods** • **Eliminates the concerns of open pits, radioactive dust and uranium mill tailings**	• **Risk of spills, leaks and contamination of groundwater and potential drinking water** • **Releases radon into the environment** • **Produces waste slurries and waste water that could contaminate the environment if not managed properly** • **Leaching chemicals may impact or contaminate groundwater, soil and rocks** • **Only feasible in deposits that are saturated and have high permeability**

Activity 5: Radiation Contamination and Exposure

Objectives:

Students will:

- Develop a radiation web or model to show how radiation can contaminate the environment, animals and people.
- Examine the three main exposure pathways: inhalation, ingestion and direct (external) exposure; and basic radiation protection measures.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- Art supplies for students; for example, paper or poster board, magazines, colored pencils and markers (optional for Step 4).
- Materials to create a watershed (optional for Step 4). Search for materials and directions online using keywords (build a watershed or crumpled paper watershed) or visit *Build Your Own Watershed*: water.epa.gov/learn/kids/drinkingwater/activity_grades_9-12_buildyourownwatershed.cfm.

Time

You may choose to have students complete the entire activity within one or two class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Direct exposure
- Exposure pathways
- Inhalation
- Ingestion
- Ionizing radiation
- Man-made radiation
- Natural (background) radiation
- Radioactive contamination
- Radon
- Uranium
- Uranium mining

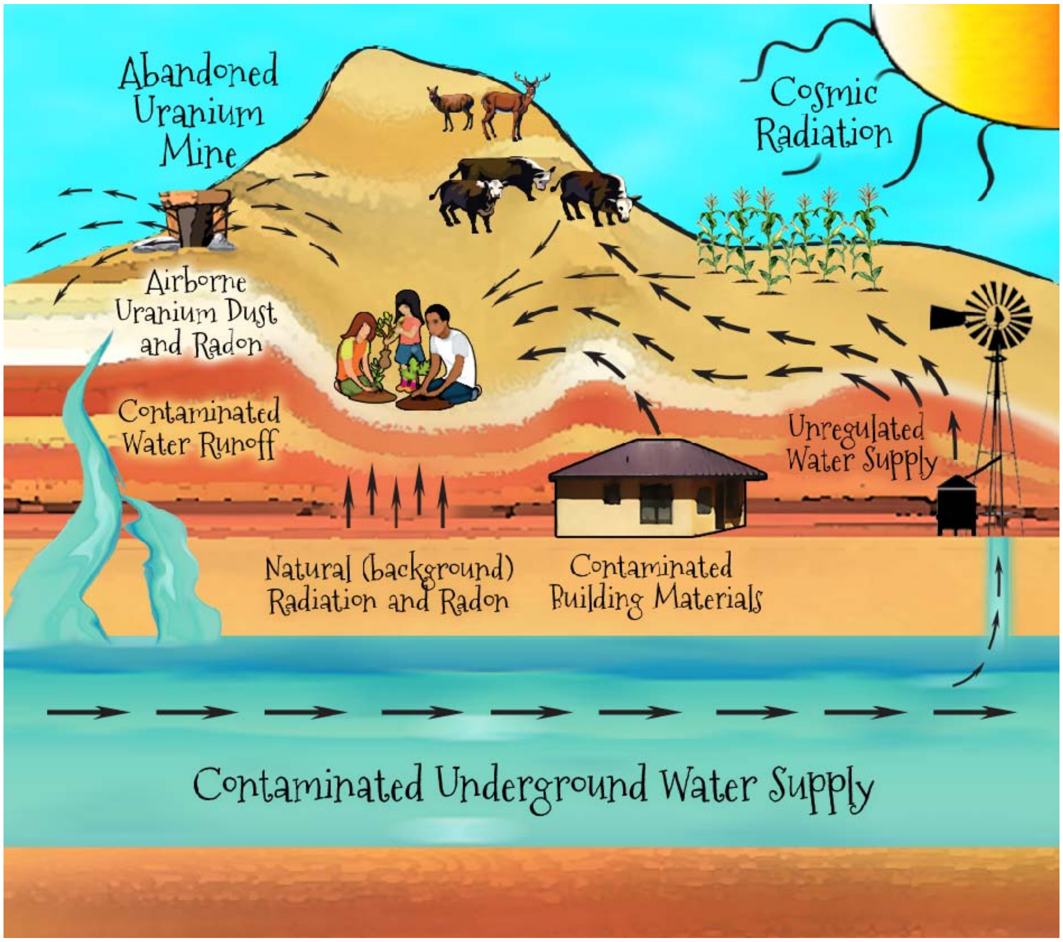
Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Explain that natural (background) radiation is all around us and has been present since the birth of this planet. However, many Native American and Alaska Native communities have been further exposed to radiation as a result of man-made activities including uranium mining and milling and nuclear testing. In the mid-1940s, with the dawn of the nuclear age, hundreds of uranium mines and dozens of mills were established and significant nuclear testing took place. Once the uranium supply exceeded the demand in the 1970s, uranium mines and mills began to shut down. Nuclear testing continued until 1992. Some of these mining, milling and testing sites were abandoned and not properly cleaned up. As a result, some Native American and Alaska Native communities are deeply impacted by contaminated soil, air, water and materials that were left behind.

3. Ask students how we might be exposed to radiation in contaminated soil, air, water and materials. Confirm or explain that routes of radiation exposure include direct or external exposure, inhalation and ingestion. We cannot see radiation, but if we are aware of radiation sources (such as abandoned mines and equipment, mine tailings, high radon levels, and contaminated water, soil and building materials) we can apply three basic radiation protection concepts to reduce our exposure to radiation:
   - Limiting *time* near a radiation source.
   - Increasing the *distance* from a radiation source.
   - *Shielding* by placing material or a barrier between a person and a radiation source.

4. Direct students to list, model or draw possible routes or pathways of exposure (direct or external exposure, inhalation and/or ingestion) to radioactive materials for uranium mining, milling, nuclear testing or nuclear waste. Students can also identify radiation exposure pathways for natural radiation sources or accidents (e.g., transportation accident that releases radioactive materials into the environment or a nuclear reactor meltdown).
   - List ways in which people may be exposed to radiation according to the three main pathways: direct or external exposure, inhalation and ingestion.
   - Create a watershed model to simulate how radioactive soil can dissolve and contaminate a common body of water that can serve as drinking water for people and animals or be used for watering plant food sources. Students can use a spray bottle to represent rain. Students can also use their breath or a small fan to model how materials can be blown into the air or into water sources.
   - Diagram exposure routes or pathways in the form of radiation webs (similar to the example provided on the following page) using paper and art supplies or electronic software to create their diagrams.



Radiation Web Example

5. Conclude by asking students to respond to the following questions orally or in writing:
   - What exposure pathways had you not considered before this activity?
   - How can you prevent or reduce your exposure to radiation based on the exposure pathways (direct exposure, inhalation and ingestion)? **Possible answers: Time, distance and shielding are three basic radiation protection measures. Other actions include testing radon and radiation levels in homes or buildings, taking action if the levels are high, using water from regulated water sources, and avoiding abandoned mining areas.**
   - Did this activity change your perceptions of or fears about radiation exposure? Explain.

6. Optional activities or extensions: Have students:
   - Investigate the working conditions of uranium miners in the mid-1900s and the protection measures required in mining operations today, or examine the life of the Inupiat Eskimos living in Point Hope, Alaska and how they were impacted by Edward Teller's Project Chariot.
   - Examine the health effects and risks associated with their exposure (or potential exposure) to radiation.
   - Develop a play or skit about their experiences. Record and share the performance.

Activity 6: Radiation Cleanup and Advocacy

Objectives

Students will:

- Investigate how people and the environment have been impacted by radiation-related events.
- Examine what cleanup and advocacy efforts have been, or need to be, completed related to these events.
- Identify advocacy efforts that they or others can implement.

Next Generation Science Standards

The concepts in this activity can be used to support the following science standard:

- ESS3. Earth and Human Activity.

Materials and Resources

- *Uranium: Teacher Background Information*.
- *Vocabulary Materials*.
- Internet-accessible computer and projector or student computers with Internet access.
- *Radiation Cleanup and Advocacy Worksheet* (one per student, pair or group).

Time

You may choose to have students complete the entire activity within one or two class periods. If time or computer access is limited, the activity can be introduced, completed outside of the class and concluded in another class period.

Vocabulary

- Ionizing radiation
- Nuclear energy
- Radiation exposure
- Uranium
- Uranium mining
- Uranium milling

Directions

1. Start with a vocabulary activity if students are not familiar with uranium and the vocabulary used in this activity.

2. Explain that uranium was primarily mined for nuclear weapons development in the 1940s and for both nuclear weapons and energy production following World War II. Nuclear testing was also conducted and the safe disposal of radioactive waste has been a consideration with the mining, testing and use of radioactive materials.

3. Investigate one of the following topics as a class or have students research the following topics to learn about events that took place during the uranium boom, the impact it has left on the people and the environment, and advocacy efforts and/or programs that may be in place to clean up the affected areas. Events that have occurred locally can also be selected as well as national events from the Highlights in Uranium History timeline found in the *Uranium: Teacher Background Information*.
   - *The Return of the Navajo Boy* is a documentary is based on a brother being reunited with his family. The family uses the documentary to raise awareness and campaign for the cleanup of abandoned uranium mines. Students can view the documentary trailer, webisodes or information online (www.navajoboy.com).
   - *The Firecracker Boys: H-Bombs, Inupiat Eskimos, and the Roots of the Environmental Movement* is a book by Dan O'Neill. The book is based on Edward Teller (the father of the hydrogen bomb) and his plan to detonate nuclear bombs off the coast of Cape Thompson in Alaska. Related information can be found online by searching "Project Chariot."
   - Bikini Atoll in the Marshall Islands is where the U.S. conducted nuclear weapons testing between 1946 and 1958. Books and movies are available about the people of Bikini Atoll.

4. Provide students with the *Radiation Cleanup and Advocacy Worksheet*. Direct students to complete the worksheet based on the topic they researched or based on radiation-related issues that may exist within their community, state or tribal nation. If the latter, investigate potential local, regional or state issues in advance and help guide students to resources, including people (e.g., advocates, environmental and health officials or staff, and regional Environmental Protection Agency (EPA) staff) that they may use to answer the questions. Consider inviting a speaker(s) to share information about local, regional or state issues and actions. Note that the U.S. Department of Energy and EPA have programs to clean up radioactive waste. The EPA's Superfund program is part of the government's effort to clean up areas contaminated by hazardous waste.

5. Conclude by asking students to share what they or their community can do. Education and advocacy are needed to ensure the proper clean up of radioactive waste and to prevent future generations from experiencing the impacts of elevated radiation levels.

6. Optional activities or extensions:
   - Encourage students to put their ideas into action by developing an advocacy project or campaign. Advocacy ideas may include:
     - Those identified by students on the *Radiation Cleanup and* Advocacy Worksheet.
     - Writing letters to tribal leaders or Congress prompting action on a uranium-related issue in their community or region.
     - Creating an informational or call to advocacy video.

- Creating a social media campaign to raise awareness.
- Creating informative and educational posters that can be displayed at school and in the community.

Radiation Cleanup and Advocacy Worksheet

Name: ______________________________ Date: __________________

Research and answer the questions.

1. What problems or concerns exist related to radiation and radioactive waste?

   ____

   ____

   ____

2. What has been done to address the concerns?

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3. What still needs to be done to address the concerns?

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4. What can I, my community or other communities do to raise awareness and action?

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Demolition and rebuilding of a contaminated home in the Navajo Nation.