Environmental Impacts of Uranium Mining  
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This lesson would be appropriate to incorporate within a high school earth science unit or subunit on the Earth systems/spheres, rocks and minerals, alternative energy, or groundwater contamination, or within an environmental or physical science class.

**Rationale:**
Uranium mining and the resulting environmental impacts of such mining is important for students to have an understanding of since increasing the use of nuclear power as a U.S. energy source is a recent issue in the current presidential race. Both candidates, Obama and McCain, believe that nuclear energy is part of the solution to the recent climate change concern (Reuters, 2008). While one major concern of developing new nuclear power plants is the disposal of nuclear waste produced by their operation, little mention is made as to the environmental impact of the uranium ore mining, which is the fuel necessary to run the desired power plants. These should both be of concern to the general public since the operation of Yucca Mountain, a hazardous waste disposal site, may never open due to opposition and potential environment risks, and that parts of our country are still recovering from the effects of past uranium mining expeditions.

**Michigan High School Earth Science Content Standards:**
E2.1C - Explain, using specific examples, how a change in one system affects other Earth systems.
E2.2B - Identify differences in the origin and use of renewable and nonrenewable sources of energy.
E2.4A - Describe renewable and nonrenewable sources of energy for human consumption, compare their effects on the environment, and include overall costs and benefits.

**Lesson Timeframe:**
One 70-minute class period (based on a trimester schedule)

**Objectives:**
Students will be able to:
1. Discuss some environmental impacts and concerns associated with uranium mining.
2. Use the Earth System Science Analysis Model to describe how uranium mining can impact other Earth systems/spheres.
3. Research and describe environmental impacts and regulation of mining in the State of Michigan.

**Previous Instruction:** Prior to this lesson, students should have knowledge about nuclear power as an alternative energy source. They should have some understanding as to how a nuclear power plant operates, and the advantages and disadvantages of harnessing nuclear power. Students should also be able to compare the advantages and disadvantages of nuclear power to those of other energy sources such as hydroelectric, wind and coal. Since uranium is the fuel for nuclear power students should understand that uranium is mined from the earth just as metal ores and coal are extracted.

Students should already have been introduced to the Earth System Science Analysis Model and be able to apply it to natural and anthropogenic events.
Safety: No safety concerns.

Materials: Moab UMTRA Project fact sheet, Earth System Science Analysis Model handout, Computer access or printed information from the National Park Service website on Abandoned Mineral Lands, access to excerpt from the World Nuclear Association on wastes from mining and milling uranium

*All materials referenced below and accessible via the Internet.

Background information/Notes: (to be presented to students as lecture or notes)

_Uranium Mining in Utah and Colorado_
The Paradox Basin that runs through southwestern Colorado and southeastern Utah includes major uranium ore deposits. These deposits have been mined for radium, vanadium (used in steel production), and then mainly for uranium starting in 1947. In the 1950’s and 60’s most uranium mining was conducted in response to the production of nuclear weapons in the United States. Then in the 1970’s and 80’s most uranium mining provided fuel for the nuclear power plants that had been constructed around the country. Since 1947, the uranium-bearing rocks of the Paradox Basin have produced approximately 188 million pounds of uranium ore, which represents about 21 percent of the domestic ore production. The uranium producing mines closed down in the late 1990’s due to declining prices and demand. Profitable ore deposits still exist in the Paradox Basin that could be mined if the demand and interest for such deposits is renewed (Chenoweth).

_Environmental Impacts of Uranium Mining_
The environmental impacts of uranium ore mining are similar to those related to metallic ore mining. Radioactivity associated with uranium ore requires special management in addition to the general environmental controls and regulations associated with any mine. The uranium itself has a low level of radioactivity (comparable to granite) and most of the other radioactive material associated with ore end up in the tailings (sold waste products from the mining and milling of the ore). Water and air pollution from the tailings are factors to consider when mining.

_Hazardous Waste Management_
In 1976 the federal government begin the management of hazardous waste with the passage of the Resource Conservation and Recovery Act (RCRA). RCRA was designed to identify hazardous wastes and their life cycles. The Act identifies hazardous wastes in terms of the following categories:
- materials that are highly toxic to people and other living things (ie. radioactive waste)
- wastes that may explode or ignite when exposed to air
- wastes that are extremely corrosive
- wastes that are otherwise unstable

After determining that a number of waste disposal sites presented hazards, Congress passed the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), which created a fund (called Superfund) to clean up the worst abandoned hazardous chemical waste disposal sites known in the country. The Environmental Protection Agency (EPA) develops the list of Superfund sites. A number of sites have been treated while some others are still in the process, and there are even others that are simply contained until better disposal or
remediation processes are developed (Keller, 1999)

Lesson:
1. Students will take notes on the uranium mining, the history of uranium ore mining in the Paradox Basin, and the formation of RCRA and CERCLA, see background information above. (15 minutes)
2. Students will then read the following excerpt taken from the World Nuclear Association on wastes from mining and milling uranium: (10 minutes)

Wastes From Mining & Milling
In most respects, conventional mining of uranium is the same as mining any other metalliferous ore, and well-established environmental constraints apply in order to avoid any off-site pollution. From open cut mining, there are substantial volumes of barren rock and overburden waste. These are placed near the pit and either used in rehabilitation or shaped and revegetated where they are. At Ranger mine, the development of the first orebody involved a waste to ore ratio of slightly over 2:1.
However, uranium minerals are always associated with more radioactive elements such as radium and radon in the ore. Therefore, although uranium itself is not very radioactive, the ore which is mined, especially if it is very high-grade such as in some Canadian mines, is handled with some care, for occupational health and safety reasons. Mining methods, tailings and run-off management and land rehabilitation are subject to Government regulation and inspection. For instance in Australia the new Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing was published in 2005. It is simpler than its two predecessors (on health & wastes) and moves away from undue prescription to performance-based and audited regulatory approach.
Mining operations are undertaken under relevant national health and radiation protection codes of practice. These set strict health standards for exposure to gamma radiation and radon gas. Standards apply to both workers and members of the public.
Tailings & Radon - Solid waste products from the milling operation are tailings. They comprise most of the original ore and they contain most of the radioactivity in it. In particular they contain all the radium present in the original ore. At an underground mine they may be first cycloned to separate the coarse fraction which is used for underground fill. The balance is pumped as a slurry to a tailings dam, which may be a worked-out pit as at Ranger and McClean Lake.
When radium undergoes natural radioactive decay one of the products is radon gas. Because radon and its decay products (daughters) are radioactive and because the tailings are now on the surface, measures are taken to minimise the emission of radon gas. During the operational life of a mine the material in the tailings dam is often kept covered by water to reduce surface radioactivity and radon emission (though with lower-grade ores neither pose a hazard at these levels).
On completion of the mining operation, it is normal for the tailings dam to be covered with some two metres of clay and topsoil to reduce radiation levels to near those normally experienced in the region of the orebody, and for a vegetation cover to be established. At Ranger and Jabiru in North Australia, tailings will be returned underground, as was done at the now-rehabilitated Nabarlek mine. In Canada, ore treatment is often remote from the mine that the new ore comes from, and tailings are emplaced in mined out pits wherever possible, and engineered dams otherwise.
The radon gas emanates from the rock and tailings as the radium or thorium decays. It then decays itself to (solid) radon daughters, which are significantly alpha radioactive (About 95% of the radioactivity in the ore is from the U-238 decay series, totalling about 450 kBq/kg in ore with 0.3% U3O8 (eg from Ranger). The U-238 series has 14 radioactive isotopes in secular equilibrium, thus each represents about 32 kBq/kg (irrespective of the mass proportion). When the ore is processed, the U-238 and the very much smaller masses of U-234 (and U-235) are removed. The balance becomes tailings, and at this point has about 85% of its original intrinsic radioactivity.
However, with the removal of most U-238, the following two short-lived decay products (Th-234 & Pa-234) soon disappear, leaving the tailings with a little over 70% of the radio-activity of the original ore after several months. The controlling long lived isotope then becomes Th-230 which decays with a half life of 77,000 years to radium-226 followed by radon-222).
Radon occurs in most rocks and traces of it are in the air we all breathe. However, at high concentrations it is a health hazard.

3. Teacher will then ask students to offer up a few main points discussed in the excerpt to
add to their lecture notes. (5 minutes)

4. Students will read about the UMTRA Project and jot down notes from the project fact sheet. Teacher will supplement fact sheet with notes and pictures taken of the UMTRA Site. (15 minutes)

5. Students will apply the Earth System Science Analysis Model to the UMTRA Project. This assignment will be collected and graded. If students do not finish this in class, they are to complete it for homework as well. (20 minutes)

6. For homework students will access the National Park Service website or read a handout from the site regarding Abandoned Mineral Lands (AML). Students will need to summarize information about AML. This summary will be collected for a grade in the following class period. (5 minutes to pass out and/or discuss homework assignment)

Assessment:
Teacher will collect and grade the Earth System Science Analysis Model that students prepared based on the UMTRA Project in Moab, Utah.

Teacher will also collect and grade the homework assignment/summary on abandoned mineral lands.

As an optional extended assignment, students can research Copper Mining in Michigan and write a one page, typed report outlining the environmental impacts and regulations associated with mining in the State of Michigan.

References:


