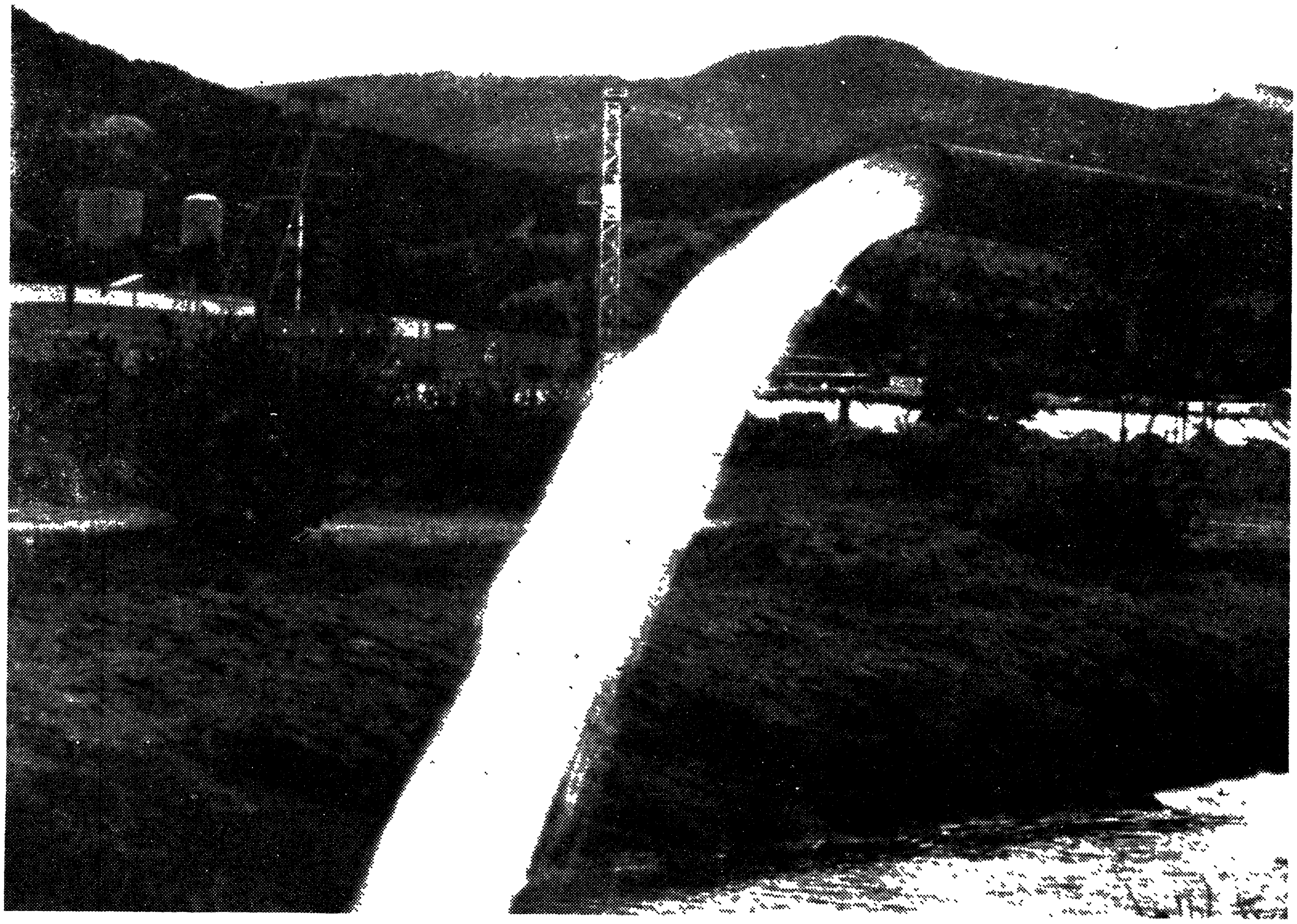
Uranium Mining & Milling
A Primer



Reprinted from: The Workbook,
Vol. IV, Nos. 6 & 7, Nov./Dec. 1979

PO Box 4524, Albuquerque, NM 87106

$1.25

Uranium Mining & Milling
A Primer

The coordinator for production of this article was **David Riccitiello**. Other contributors included **Paul Robinson, Alice Hector, Judy Luis, David Benavides**, and **Don Hancock.**

Every phase of the nuclear fuel cycle from mining, processing, and transportation, through utilization in nuclear reactors to reprocessing and waste disposal poses unique and unresolved problems. There are both important *technical* problems of controlling and containing the release of harmful material amounts of radioactivity and toxic elements from all phases of the fuel cycle, and *societal* problems related to the cultural, political and managerial impacts of every phase of the cycle.[1]

Both of these problems were recently demonstrated at the United Nuclear Churchrock mill in New Mexico where a combination of operating and design errors resulted in the failure of an earthern dam on July 16, 1979. The dam stored the highly acidic waste product of the mill, which included toxic radioactive materials (such as radium and thorium) and heavy metals (like selenium and molybdenum). The crack in the dam released over 100 million gallons of this liquid into the Rio Puerco, which is used by local Navajos for watering livestock and some drinking water. The spill has severely disrupted their lives and has created a great deal of concern over their future health, though effects will not become apparent for many years and will be impossible to precisely quantify. What is known is that contamination has spread at least 20 miles downstream to a depth of 30 feet – and some surface cleanup has been done even in Arizona.

With growing concern about reliable and unrestricted energy sources, and the growing controversy surrounding nuclear power, it is critical that people have a complete understanding of the ramifications of nuclear energy. This article aims to provide an overview of the "front end" (uranium is the fuel for present nuclear power plants) of the nuclear fuel cycle involving uranium mining and milling, including environmental and socioeconomic impacts, regulatory processes related to the uranium industry and opportunities for citizen action. The focus will be on New Mexico where over half of the U.S. uranium reserves have been found, but the information should be broadly applicable to most other regions where uranium development occurs.

What Is Uranium?

Uranium is a radioactive element, giving off small units of energy in the form of particles and electromagnetic waves during a process of decay. The rate of decay varies for each type of radioactive element and is measured in terms of "half-life." Half-life means that at the end of a specified time, half of a given amount of radioactive material will have changed to a decay product. The decay pattern of Uranium-238 is shown in figure 5. U-238, with a half-life of 4.5 billion years, decays to Thorium-234 by alpha emissions. Each element of the decay series is called a "daughter" product of Uranium-238. The decay pattern continues until Lead-206, a stable, non-radioactive element, is reached.[2]

Uranium occurs in very low concentrations of 0.1 to 2 percent in ore bodies with a current average ore grade of .15 percent.[3] This accounts for the large volumes of waste generated during mining and milling as over 99% of the ore remains after processing as mill tailings, which contain over 85% of the original radioactivity of the ore.

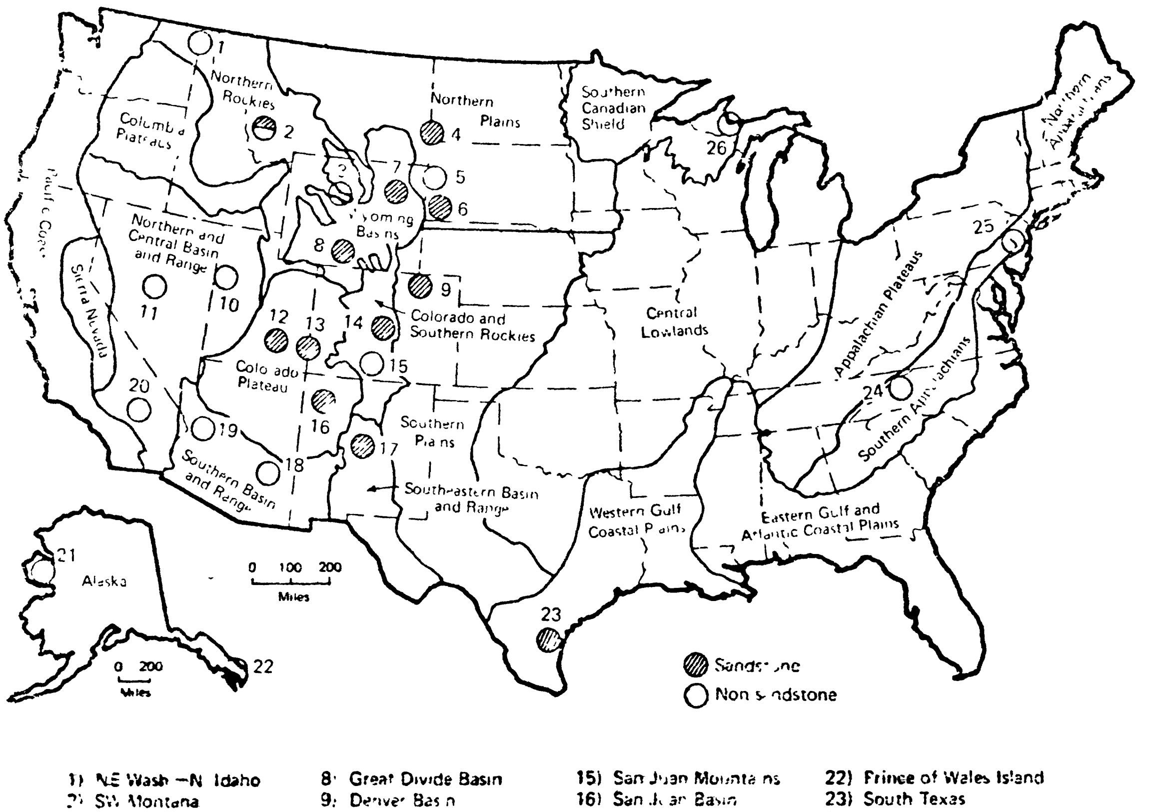
The production of uranium involves exploration, mining and milling. Each will be discussed before turning to the impacts and regulatory issues.

Uranium Exploration

Production begins with exploration for deposits of uranium-bearing ore. Geiger counters were traditionally used for locating deposits near the surface. Today, uranium companies drill test holes for deeper deposits and then geophysically analyze for the presence of uranium. Since most uranium near the surface has been identified, new discoveries are being found at greater depths. Both the Gulf-Mt. Taylor mine near San Mateo, New Mexico and the Phillips-Nose Rock mine near Crownpoint, New Mexico are sinking shafts of up to 3500 ft. below the surface, and Getty Oil and Mutsuibishi Oil are drilling over 4000 ft. near Chaco Canyon National Monument, NM.

Developmental drilling follows exploratory drilling and involves sinking holes at closer intervals than was done for exploration purposes. Exploration holes are 1000 ft. or more apart, while development holes can be down to 50 ft. across. The design of the mine and the cost estimates for removing the ore are based on the drilling samples which provide information about the ore quality, size, and depth. Operators usually conduct site surveys at the same time, providing data about soil conditions, archaeology, topography, hydrology, wildlife, vegetation, transportation, and available labor.[4] Information collected from developmental drilling and site surveys feeds into

Areas of significant exploration for uranium in 1977



1) NE Wash —N Idaho
2) SW Montana
3) Owl Creek Mountains
4) Williston Basin
5) Central Black Hills
6) Southern Black Hills
7) Powder River Basin
8) Great Divide Basin
9) Denver Basin
10) Thomas Range
11) Toiyabe Range
12) Henry Mountains
13) Paradox Basin
14) Tallahassee Creek
15) San Juan Mountains
16) San Juan Basin
17) Rio Grande Trench
18) Sierra Ancha
19) Date Creek
20) Mohave Desert
21) Seward Peninsula
22) Prince of Wales Island
23) South Texas
24) Grandfather Mountain
25) Reading Prong
26) N Michigan

Figure 1.

a more complete engineering and economic feasibility study.

In unexplored areas not commonly known to contain uranium ore, aerial reconnaissance is the most effective initial exploratory method. Since 1950, this method has been the basic tool for shallow ore identification. Air craft, flying a grid pattern at low altitudes, obtain radiation levels which indicate potential shallow ore deposits. Further exploration with ground instruments or drilling operations pinpoint uranium ore deposits.[5]

The known U.S. deposits are located in three major districts:

1) Colorado Plateau: Monument Valley, Grants Uranium Belt, Uravan.
2) Wyoming Basins: Power River, Gas Hills, Shirley Basin.
3) Texas Gulf Coast.

Mining Technology

Uranium miners use three basic types of technology: open-pit, underground, and in-situ. Open-pit and underground mining are the predominant technologies used, producing over 97% of U.S. uranium. The method used depends on the location of the ore and geologic conditions surrounding the ore deposit. Open-pit mining is used for shallow ore deposits, those less than about 300 ft. deep, underground mining is for deeper deposits and in-situ mining can be attempted when the ore deposit is deep and isolated by impervious geologic structures. In order of labor intensity, underground mining requires the most workers, followed by open-pit, then in-situ technologies.

Mine technology selection is based on detailed geologic, engineering, and economic studies; factors considered include ore body size, grade, location, depth, and host-rock characteristics.[6]

Open-pit Mining

Open-pit mining has been done at depths of "more than 500 ft.; but, usually below 300 ft., underground methods are preferred."[7] The mining of uranium with open-pit technologies can be performed at relatively greater depths than for most conventional fuel sources because of the greater value of refined uranium (yellowcake). Open-pit mining uses earth removing equipment such as bulldozers, backhoes, and diesel shovels.. The size and depth of the ore deposit determines the type of heavy equipment used.

The presence of ground water in open-pit mines is a major problem. To keep the floor surface workable, the water must be pumped and discharged to surface creeks and rivers. The pumping can have serious effects on (under) ground water availability and, if it is not properly treated, can result in the contamination of surface waters.

Underground Mining

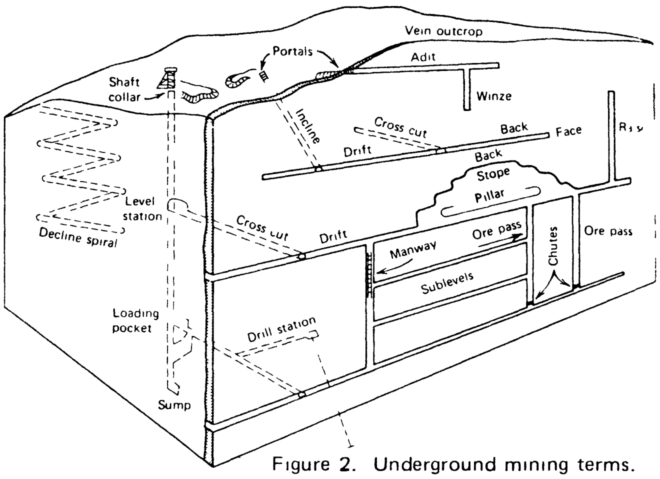


Figure 2. Underground mining terms. *Exploration & Mining Geology.*

About 70 percent of New Mexico's uranium production comes from underground mines. These mines require a concrete-lined shaft entry when deposits exceed 800 ft.[8] The roofs of the mines are supported with pillars (sections of the ore deposit not mined–see figure 2) or through backfill operations. Backfilling involves putting the waste product of the milling operation, tailings, back into the mine so that sections which were used for roof support can then be mined.

Miners continuously drive new tunnels until the ore deposit is depleted. Since rock strength is drastically reduced by the presence of ground water, pumps carry ground water from the ore body to the surface for release or use as mill process water. Mine dewatering rates range from 200 to 3,000 gallons or more per minute. The Gulf-Mt. Taylor mine discharges 6,000 gallons per minute now and may exceed 10,000 gallons per minute when in full operation by 1984. Such dewatering can lower the water table, reducing well water availability in rural communities.

A major health and technical problem in mines comes from the presence of radon gas, a uranium decay product. Inadequate mine ventilation results in radon gas accumulation which can seriously affect the health of miners. Most mines install some form of ventilation system such as fans to ensure that adequate amounts of fresh air are available and that radon gas levels do not exceed approved levels. However, periodic breakdowns in the systems cause radon concentrations to increase. Also, ventilation from the mines results in increased concentrations of radon gas in the general environment, posing a serious health hazard to individuals living in communities around the mines. Radon gas from mines is the largest routine release of radioactive material from the nuclear fuel cycle, exceeding 4510 Ci per reactor year.[9]

In-Situ Mining

In-situ mining technologies extract minerals while leaving the host rock in place. In-situ mining combines mining and milling into one step and results in significantly reduced radon emissions and tailings production. Solution mining is the most common form of in-situ used for uranium extraction. It involves pumping a leaching solution into the underground ore body, thereby dissolving the uranium into the leaching fluid. The uranium is precipitated from the solution through a series of steps after it is pumped to the surface.

The leaching solution is pumped into inflow wells and is withdrawn from the production wells. The process continues until the concentration of uranium in the leaching solution drops below a specified cut-off level indicating that the ore zone is sufficiently depleted.

Certain conditions must exist before solution mining of uranium can be used:[10]

1) the uranium ore must be in a horizontal bed which is isolated above and below by an impermeable geologic structure.

2) the direction and velocity of the area waterflow must be known.

3) the minerology of the uranium bearing ore must be known so that the proper leaching and precipitation process can be used.

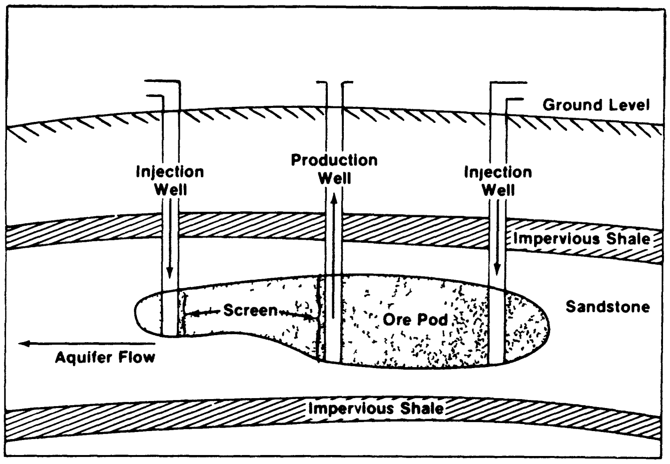


Figure 3. In-Situ Uranium Mining. *Exploration & Mining Geology.*

An advantage of in-situ mining is that it reduces the exposure of personnel to dangerous radioactive materials. However, unless the ore zone is completely isolated or restored completely, the injected leachate may be lost in underground fractures, resulting in the contamination of ground waters. Mobil has recently started the first in-situ uranium mine in New Mexico in the same layer that Crownpoint, New Mexico, uses for drinking water.

Milling Processes

The basic conventional mill process steps are ore crushing and grinding, ore leaching, uranium recovery from the leaching solution, and tailings disposal.

Mills blend ore to an average "run-of-the-mill" grade to efficiently remove the uranium. "Hard ores limit the capacity of the grinding [systems], slime interferes in ion exchange [leaching systems], and sandy ores settle too rapidly in pipelines causing plugging."[11] By blending the ores, the extremes can be eliminated allowing a more efficient process to be maintained. After blending, ore is crushed and ground to achieve an even particle size and is mixed with water to form a half liquid, half solid slurry. The ore slurry is pumped into a leaching system which is a series of tanks with agitators designed to remove the uranium oxide from the sands and slimes.

The leaching agent used for uranium extraction depends upon the chemical properties of the ore. A critical factor in leaching solution selection is the lime content of the ore. An acid solution is used when the ore has a low lime content and an alkaline solution is used when the lime content is high (12 percent or more). Most mills use a sulfuric acid leach solution.

After the ore has been processed through the leach circuit, the loaded liquid must be separated from the slimes and sands before entering the ion exchange or solvent extraction systems. The separation is achieved through a series of filtration, washing, or classifier devices. After the unwanted ore solids have been removed, ion exchange systems can then be used to concentrate the leached solution. Several stages of precipitation is needed to complete the separation of the uranium oxide. The final stages of the milling process include dewatering, drying, and packaging of the uranium precipitate (yellowcake). The end product will contain approximately 96% uranium oxide which is sealed and shipped in steel drums. One 55 gallon drum holds about 1,000 pounds of yellowcake.

The waste products of the milling process, tailings (the solid portion of the effluent) and liquors (the liquid portion containing unwanted dissolved elements and spent leaching solution), is normally stored on the mill site. The current practice of most operations is to store the tailings and liquors in above ground structures using earthern dams to contain the material. These structures do not guarantee the long-term isolation of the material from surface or ground waters or from wind erosion. The United Nuclear Churchrock facility did not even guarantee short-term isolation as the dam broke within two years after being licensed by the state.

Another disposal method used by some uranium operations on a piecemeal basis is backfill; the tailings are put back into the mine. This process has the advantage of removing the tailings from the surrounding landscape, but, if they are not treated for the removal of the heavy and radioactive metals, the groundwater can become contaminated. This degradation is possible because the process of crushing and grinding the ore makes the elements more mobile and soluble than when left undisturbed in the earth. Other disposal technologies are needed to reduce hazards associated with the mill wastes.

The following more detailed discussion of the impacts of uranium mining and milling serves to indicate the scope of the issues needing to be addressed regarding the public health, safety and welfare. While these impacts are primarily concentrated in uranium-producing areas, transportation of yellowcake and air and water pollution

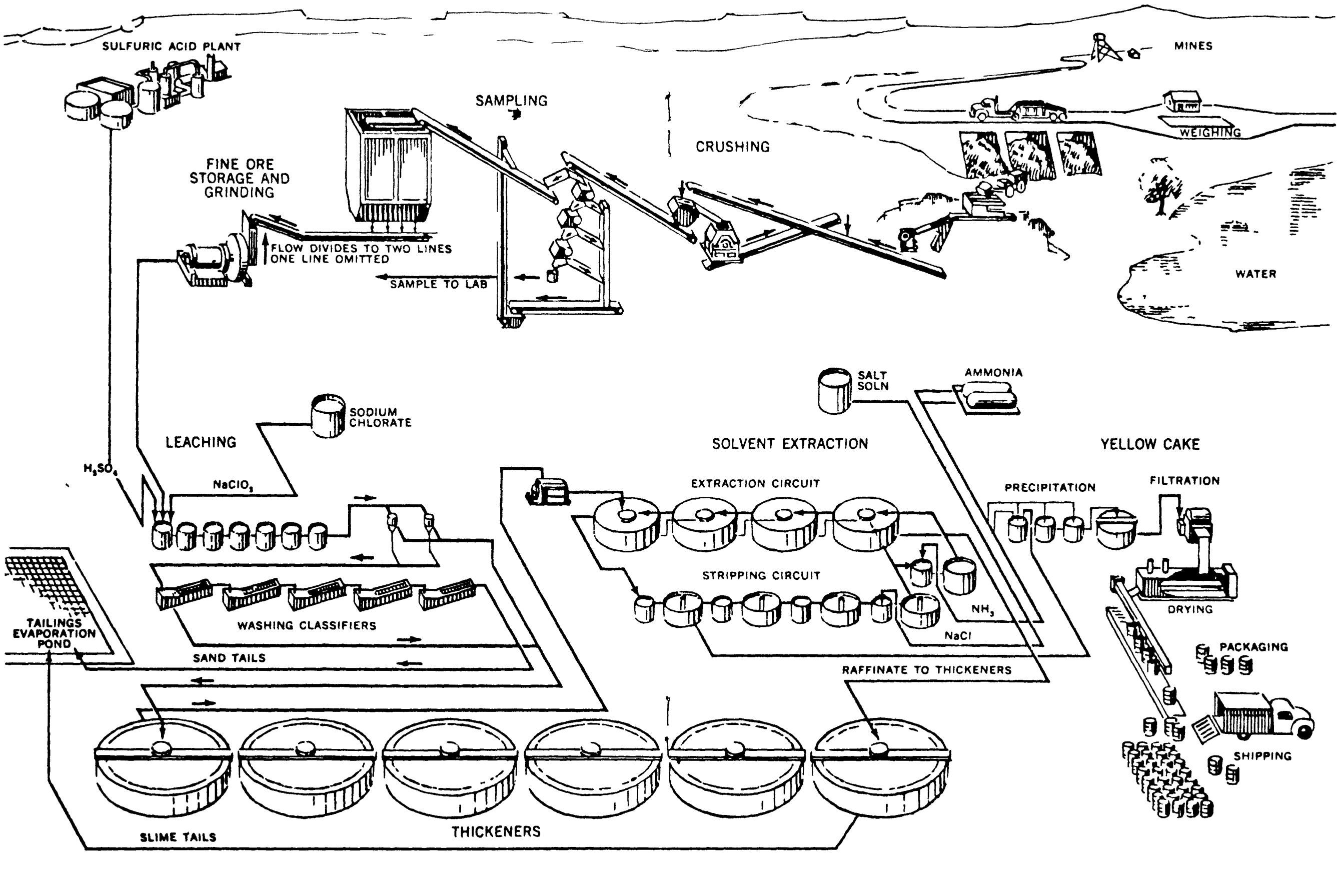


Figure 4. Schematic diagram of Kerr-McGee Uranium Mill.

affect millions of people across the nation.

Environmental Impacts

The mining and milling of uranium result in severe impacts on the human and physical environment. Releases of radioactive material to the environment present significant hazards to the public health. Exposure to pollutants can occur through:

1) the inhalation of radioactive materials as either a gas or as windblown particulate matter.
2) the ingestion of either contaminated food or water.
3) the exposure of the skin to radiation.

The soil and rock which cover the ore prior to mining protect the surface environment from the high levels of radiation emanating from the ore material. When the soil and rock are removed by mining operations, Radon-222, an alpha-emitting radioactive gas, escapes into the air. High levels of Radon-222 have been associated with an increased incidence of lung cancer among uranium miners. Emissions of gamma radiation from the mill operations present a risk to workers because they can affect the whole body, including the reproductive organs. Both genetic or multi-generational problems, which are usually manifested in subtle, chronic ailments, as well as cancers, can result from such exposure. The latter may have a 5-30 year latency period.

Ventilation shafts which remove radon gas from the uranium mines to reduce miners' exposure raise the general level of alpha radiation in the vicinity of the mine. Individuals living within about 4 km of the tailings piles are also at greater risk because radiation standards "could not be met."[12]

Victor Gilinsky, a Nuclear Regulatory Commission member, has said that because radon is a gas, "it is also possible for large populations thousands of miles from the source to be exposed, albeit to an extremely low dose."[13]

Even after mining operations cease, radon emissions continue from ore stockpiles, mine waste piles, vents, pit areas, mine shafts, and mill tailings for thousands of years unless they are adequately stabilized.[14]

Mill tailings pose the greatest long-term hazard from the mining and milling process. Eighty-five percent of the radioactivity in the original ore is present in the tailings in the form of unextracted uranium, radium, thorium, and other trace metals. In tailings, some of these radionuclides are found at 1000 times the normal levels in soils. Non-radioactive contaminants which are commonly found in high levels in tailings include arsenic, molybdenum, lead, and selenium. Selenium is concentrated by loco-weed and other plants in amounts toxic to cattle and sheep grazing in areas near uranium deposits.[15] Direct exposure to selenium can also make humans sick.

Rainwater running off tailings piles carries dissolved contaminants and causes surface erosion. Water-borne contaminants can reach surface, irrigation, and drinking water supplies or be deposited in the soil at great distances from the mill. Seepage from below tailings piles is a major source of ground water contamination.

Another mill tailings contaminant transport pathway is through the wind erosion of dry, exposed tailings. Particles suspended in the air can travel long distances.[16] Small particles are more likely to bypass respiratory filters and become deposited in the lung. Mining and milling operations also emit air-borne pollutants such as particulates, sulfur oxides, carbon monoxide, organics, and nitrogen oxides. The constant movement of heavy equipment over dirt roads results in elevated levels of suspended particles.[17]

Some plants, such as loco-weed, take up amounts of contaminants which are toxic to grazing livestock but which are not toxic to the plants. If the levels of contaminants are high in the soils, the potential for poisoning of livestock is great. Selenium, molybdenum, and radium have been found in high concentrations in plant tissues in areas of uranium mining and milling. Radium, because of its chemical similarity to calcium, tends to concentrate in the bones and teeth of mammals. Humans, consuming this livestock, will metabolize it in a similar fashion, increasing the chances of leukemia and bone cancer.

When uranium lies in a water bearing rock, the water must be pumped out before the ore can be removed. In New Mexico, high quality groundwater is removed, causing poorer quality aquifers to migrate into the depleted areas through the fractures in the rock layers or through unplugged drill holes. Dewatering also lowers water levels in surrounding domestic wells. Dried up wells have been reported in towns near existing uranium mines.

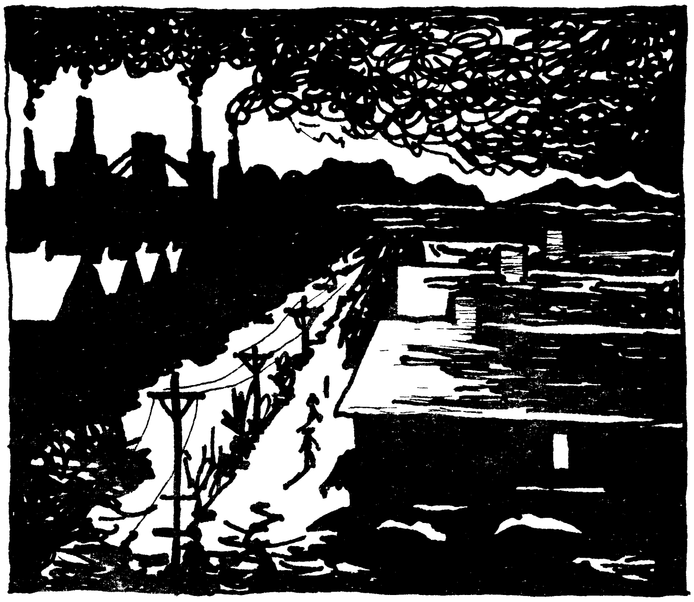
Socioeconomic Impacts

New Mexico possesses an enormous quantity of uranium reserves (539 million tons), all of which are located in the sparsely populated areas. The development pattern over the last 25 years has been characterized by outside populations moving to the small, mostly Indian and Spanish communities for the jobs, shrinking agricultural activities, and consolidating land and water control in the hands of a few corporations. Of the remaining land, most is controlled by the federal government through the Bureau of Land Management (BLM), the Forest Service (USFS), and the Bureau of Indian Affairs (BIA) or by the state. The result has been lost political and economic control by the native people of the region.[18]

This shift of economic and political power to individuals from outside the region has subjected the rural populations to cultural and economic pressures they cannot control. The promise of increased wealth or the political goal of energy independence has shifted the local economic base from one of relative self-sufficiency to a dependence on national economic factors.

The decision to construct a mine has wide ranging effects. In New Mexico, the social impacts on the Navajo, Pueblo, and Chicano people are more devastating than the environmental factors. "Mining requires its own army of workers and tends to draw on a mobile force of drillers, miners, heavy equipment operators, and engineers who are accustomed to following jobs around the country and world, if need be."[19] Mobile homes are the standard housing for most miners. The rapid influx of workers tends to over-crowd community services such as schools, sewers, water, and transportation systems. Conflict occurs when outsiders lack understanding or sensitivity for local traditions and life styles. Urbanization of land traditionally used for farming or lifestock, paving new roads and widening old ones to accomodate heavier traffic, stress on community services, and depletion of water supplies have very disruptive effects on the lives of long-term residents. When the people affected are traditional Navajo and Pueblo Indians, or rural Chicano people, the impacts become especially damaging because of the long time they have lived in the previously isolated area.

A recent report to the Governor of New Mexico predicts serious boomtown impacts in northwestern New Mexico as a result of energy development.[20] The report concludes that state and local governments will have extreme difficulty coping with various boomtown impacts. The study lists several changes which are likely to occur in towns affected by the boom:



1) the economic base of the community will become heavily dependent on the energy-based projects which are only temporary (usually no more than 25 years).

2) the community's need to provide public services and facilities will go far beyond its financial and managerial resources.

3) critically important public facilities, such as water and sewer systems, cannot be readily expanded to accomodate the growth.

4) a serious housing shortage will develop.

5) school classrooms will become inadequate to handle the additional students.

For most Navajos, livestock is the major asset and livelihood. It is important not only for survival, but it also plays a critical role in their traditional culture. Uranium production has produced serious harm to their livestock. Animals become sick and die after drinking the water discharged from the mines. The construction of access roads and drilling pads has destroyed valuable grazing areas. Because uranium exploration, mining, and milling activities diminish grazing activities, the Navajo culture and lifestyle is seriously impaired. Sacred sites such as Mt. Taylor and the Dalton Pass Spring have been damaged or destroyed by mining activities.[21]

As the NRC stated in the Draft Environmental Impact Statement for Uranium Milling (p. 21), of "the cumulative effects . . . that milling potentially has, the most significant are the socioeconomic ones."

Regulatory Process and Problems

In the U.S., there are four major types of land: federal domain lands, Indian land, state land, and private land. Each type of land comes under the jurisdiction of different state and federal agencies.

On federal domain land, the Mining Law of 1872 controls the development of uranium deposits. The law considers uranium a "hard rock mineral" and allows it to be mined without a permit or license. Individuals are allowed to enter public lands in order to develop "valuable" minerals. After a claim is filed, it can be patented, becoming the private property of the mining company. Timber and water on a claim can be used without charge and land adjacent to the mineral claim can be used for the construction of milling and other support facilities.[22] People with existing grazing leases on patented land lose their leases when the patent, or title to the land, is issued.

The mining law places little control on the activities of the mining company. There are no provisions for protecting the land during mining operations or for requiring reclamation. The law was originally designed to meet the demands of the "pick and shovel" technology in the development of valuable resources. The impact that modern mining operations have on the environment was not anticipated by the century-old mining law.[23]

On Indian lands mineral development is controlled by the Bureau of Indian Affairs. The granting of the leases has historically benefited the mining companies by charging minimal royalties for the extraction of the minerals. The mining operator is required to submit both exploratory and mining plans describing the area, the operation, adverse impacts, and also detailed reclamation plans and environmental protection measures during and after operations to the BIA and the United States Geological Survey (USGS). The operator also is required to file performance bonds to cover the costs of reclamation and must issue reports describing compliance with the exploration and mining plans.[24]

Though the law allows enforcement by the BIA and USGS, they lack the necessary equipment, personnel, and skills to adequately assess proposed plans to ensure compliance. The end result has been construction and operation of mines on Indian lands, producing serious negative impacts on the environment and inhibiting Indian self-determination efforts. Information used by agencies in assessing the adequacy of proposed mining plans is primarily provided by the operator and, therefore, supports the operator's position. Also, performance bonds do not guarantee that proper reclamation will take place because of inadequate estimates and escalating costs. In addition, in areas where the rainfall is below 10 inches per year, such as the arid regions in New Mexico, reclamation is almost impossible, resulting in "national sacrifice areas."[25]

On state land, uranium leases are obtained from the State Land Commission. Mining plans must be approved by the State Mining inspector. On private lands, mineral leases are obtained from the owner and no plans are required. Uranium mining and milling on state and private land simply remove, forever, additional land from the reserves available for grazing and other agricultural uses.

Several state agencies exercise jurisdiction over various phases of uranium mining and milling in New Mexico and other western states. Included are the Commissioner of Public Lands, the State Mine Inspector, the State Engineer's Office, and the Environmental Improvement Division of the Department of Health and Environment or similar agencies. The Commissioner of Public Lands is to provide for the management, care, control, and disposition of all state lands. The State Mine Inspector is responsible for mine safety and must investigate any mishaps in underground mines. The State Engineer claims jurisdiction over all waters in the state and determines the reliability of proposed structures to protect ground and surface waters from uranium activities. The Environmental Improvement Division and its board are charged with the responsibility of environmental management and protection by radiation protection and ground water control standards. The basic problem with the state's regulatory mechanisms is that they lack sufficient money and personnel to enforce state controls against corporate economics and political influence.[26]

Various Federal agencies have regulatory authority over aspects of uranium development. Radioactive contamination of the surface water and the air are major responsibilities of the

	Type of radioactive emission	Intensity of emission	Half-life	Decay rate Ci/gram	Biological half-time – vertebrates days	Target organ	Max. Permissible Conc. in Air – Soluble form pCi/l	MPC in H_2O – Soluble form pCi/l	Conc. found in typical uranium mill pCi/l	Max. Permissible Body Burden uci
Uranium^{238}	α	α, 4.3	4.5 x 10^9 y	3.4 x 10^{-7}	10-1,000	GI tract	3 x 10^{-3}	20,000	5,400	.4 whole body
Thorium^{234}	β, γ	β, 0.19	24.1 d	23,700	>1,000	GI tract	2	20,000	–	–
Protractinium^{234}	β, γ	β, 0.51	1.1 m	7.5 x 10^8	–	–	30	–	–	–
Uranium^{234}	α, γ	α, 4.86	2.5 x 10^5 y	.00626	10-1,000	GI tract	.02	30,000	–	–
Thorium^{230}	α, γ	α, 4.77	8 x 10^4 y	.02	>1,000	Bone	2 x 10^{-5}	2,000	150,000	–
Radium^{226}	α, γ	α, 4.78	1,620 y	1	>1,000	Bone	.003	30	400	0.1 bone
Radon^{222} (gas)	α, γ	α, 5.5	3.8 d	2.4 x 10^8	–	Lung	3	–	–	–
Polonium^{218}	α, β, γ	α, 6.0	3.05 m	2.9 x 10^8	–	Lung	2 x 10^{-5}	30	–	–
Lead^{214}	β, γ	β, 0.6	26.8 m	3.35 x 10^7	>1,000	Lung	30	–	–	–
Bismuth^{214}	α, β, γ	β, >1	19.7 m	4.5 x 10^7	1-10	Lung	30	–	–	–
Polonium^{214}	α	α, 7.68	.00016 s	3.4 x 10^{14}	–	Lung	2 x 10^{-5}	30	–	–
Lead^{210}	β, γ	β, 0.015	22 y	80	>1,000	Kidney	.004	100	400	–
Bismuth^{210}	β	β, 1.2	5 d	127,270	1-10	GI tract	.2	40,000	400	–
Polonium^{210}	α, γ	α, 5.3	140 d	4,545	–	Spleen	.02	700	400	–
Lead^{206}	stable	–	–	–	–	–	–	–	–	–

Figure 5.

Environmental Protection Agency. However, the agency has not issued standards to regulate radon and its daughters from uranium mining. Mining Safety and Health Administration controls the exposure of workers to radiation in underground mines, but has no authority above ground. Occupational Safety and Health Administration regulates exposure in the work place only if the operation comes under federal contracts. The U.S. Forest Service issues leases but lacks sufficient enforcement powers to ensure compliance. The USGS, BLM, and the USFS do not include performance standards for mining operations. The crossing of state and federal jurisdiction and the lack of a consistent regulatory process creates gaps and confusion to mitigating environmental impacts.[27]

The disposal of mill tailings is a prime example of the lack of adequate federal and state regulations. Contaminants from tailings include a number of radioactive elements and trace metals. The magnitude of the waste generated by the milling process creates formidable problems; 25 million tons were attributed to inactive tailings piles (those not presently growing) in 1978 and, by the year 2000, it is estimated that over 900 million tons of tailings will have accumulated.[28]

In 1979, the NRC issued proposed regulations under the 1978 Uranium Mill Tailings Act which include performance objectives designed to isolate the tailings from natural disturbances that result in the contamination of ground and surface waters and the air. However, a number of substantial problems remain. For existing or abandoned tailings piles, the new requirements do not present real solutions. Several currently operating mills are sited next to towns or on the edge of rivers or next to arroyos (intermittent water courses). Also, New Mexico, Colorado, Arizona, Washington and Texas are "agreement states," meaning that state agencies are to ensure compliance with NRC regulations or equivalent standards. Thus, over 50% of the nation's production comes from states whose enforcement agencies are understaffed and poorly equipped to handle the magnitude of the problems associated with tailings.

Surface water quality is primarily controlled by the Clean Water Act which is administered by the Federal Environmental Protection Agency and the state Environmental Improvement Division and enforced through the National Pollution Discharge Elimination System (NPDES) permits. NPDES permits apply only to point discharges of effluents (i.e. pipes, culverts). The state EID monitors compliance and the EPA takes enforcement action when a discharge violates the NPDES permit. The problem lies with the inability of the state to effectively monitor operations. Presently, six uranium companies are challenging the NPDES process in court saying their discharges are not to the "Waters of the United States" and thus are not subject to the Clean Water Act at all.

Ground water quality is controlled by the state EID which requires dischargers to provide a plan to avoid the contamination of underground waters that can reasonably expect foreseeable use. The problem with the enforcement of ground water quality standards is the difficulty in evaluating the effectiveness of proposed plans and in monitoring operations, and the lack of an enforcement mechanism.

In general, the regulatory weaknesses related to uranium operations are a result of:

1) inadequate enforcement provisions to guarantee compliance;

2) inadequate staffing to effectively evaluate, monitor, and ensure compliance;

3) insufficient coverage of significant pollutants such as radon;

4) inadequate performance standards to determine the effect of mining and milling activities;

5) gaps in state and federal jurisdictions; and

6) insufficient information on the effects of certain pollutants, such as radium and selenium, and on technologies such as in-situ mining and backfill.

Conclusion

This article summarizes many complex issues. Thus, we encourage readers to consult resources listed or to contact Southwest Research and Information Center for clarification or for additional information. In the future we will be preparing more detailed articles on the health effects, uranium companies, technology, local populations and economics, and legal constraints.

Additionally, many citizen organizations around the west are developing information about uranium development and getting people involved in the process. The following article lists a number of these groups.

* * *

ENDNOTES

[1] Union of Concerned Scientists, *The Nuclear Fuel Cycle*, The MIT Press, Cambridge, MA, 1975.

[2] E. C. Tsivoglou and R. L. O'Connell, *Waste Guide for the Uranium Milling Industry*, U.S. Dept. of HEW, Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, OH, 1962, pp. 3-11.

[3] Betty L. Perkins, *An Overview of the New Mexico Uranium Industry*, NM Energy and and Minerals Dept., Santa Fe, NM, January 1979, pp. 3-11.

[4] Webster and Stone, *Administrator's Guide for Siting and Operation of Uranium Mining and Milling Facilities*, U.S. Environmental Protection Agency, Denver, Colorado, May, 1978, pp. 3-1 – 3-10.

[5] D. A. Clark and S. Kerr, *State-of-the-Art: Uranium Mining, Milling, and Refining Industry*, Environmental Research Laboratories, Ada, OK, June, 1974, pp. 6-24.

[6] E. C. Tsivoglou and R. L. O'Connell, pp. 3-16.

[7] D. A. Clark and R. S. Kerr, p. 25.

[8] Ibid.

[9] Betty L. Perkins, p. 101.

[10] D. A. Clark and R. S. Kerr, p. 27.

[11] Ibid., p. 40.

[12] U.S. Nuclear Regulatory Commission, *Draft Generic Environmental Impact Statement on Uranium Milling*, NUREG-0511, April 1979, p. 4.

[13] Victor Gilinsky, Commissioner, U.S. NRC, "NRC Regulation of the Uranium Milling Industry: Problems and Prospects," May, 1978, p. 2.

[14] Betty L. Perkins, p. 101.

[15] D. R. Dreesen, "Uranium Mill Tailings: Environmental Implications," *LASL Mini-Review*, February, 1978, p. 2.

[16] Betty L. Perkins, p. 129.

[17] Ibid., p. 98.

[18] J. G. Jorgensen et al., *Native Americans and Energy Development*, Anthropology Resource Center, Cambridge, MA, 1978, p. 83.

[19] John A. Folk-Williams, "Uranium Mining on Navajo Land," *AKWESASNE Notes*, 1979, p. 15.

[20] ERB, *Managing the Boom*, Report to the Governor of NM, Santa Fe, NM, Sept., 1977, pp. 11-12.

[21] Walter Peshlakai, Sr., et al., vs. Charles Duncan, et al., Civil Action No. 78-2416, U.S. District Court for the District of Columbia, p. 26.

[22] Susan Bliss, *Summary of Environmental Statutes*, San Juan Basin Regional Uranium Study, Working Paper.ry, No. 13, February, 1979, p. 56.

[23] Sierra Club and Wilderness Society, "Hard Rock Mining on Public Lands Under a Century-Old Law," May, 1979, p. 4.

[24] J. B. Sorenson and K. L. Marston, *Uranium Mining and Milling and Environmental Protection: Mitigation of Regulating Problems*, San Juan Basin Regional Uranium Study, No. 35, p. 30.

[25] National Academy of Sciences, *Rehabilitation Potential of Western Coal Lands*, Ballinger Publishing Co., Cambridge, MA, 1974, see especially pp. 85-86.

[26] Mel Eisenstadt & Associates Inc., *Legal Infrastructure Related to Uranium Mining in the San Juan Basin*, San Juan Basin Regional Uranium Study, Dept. of Interior, Albq., NM, Working Paper No. 28, p. 77-11.

[27] J. B. Sorenson and K. L. Marston, p. 29.

[28] D. R. Dreesen, p. 1.

GLOSSARY

Aquifer – a geologic formation that contains sufficient saturated permeable material to yield a significant quantity of water to wells or springs.

Background radiation – includes all radiation from naturally occurring radioactive sources as well as human-made sources.

Checkerboard – an area in western New Mexico comprised of a mixture of federal, state, Indian, and private ownership and jurisdiction.

Curie – the unit describing the radioactivity of a sample of material. A curie (Ci) is equal to 37 billion (37 x 10^9) disintegrations per second.

Half life – the time in which half the atoms of a particular radioactive substance disintegrates to another nuclear form.

Daughter – a nuclide formed by the radioactive decay of another nuclide, which is this context is called the parent.

Food Chain – an arrangement of the organisms of an ecological community according to the order of predation in which each uses the next lower member as a food source.

Ionization – the process by which a neutral atom or molecule acquires a positive or negative charge.

Nuclide – any atom that exists for a measurable length of time. A radionuclide is the same as a radioactive nuclide, or a radioactive isotope.

Particulates – any liquid or solid particles suspended in or falling through an atmosphere.

Rad (Radiation Absorbed Dose) – amount of radiation absorbed by a given amount of tissue.

Rem (Roentgen Equivalent Man) – more precise measurement of the actual biological damage done in tissue.

Radiation – the process of emitting radiant energy in the form of waves or particles; a term which embraces electromagnetic waves (i.e. radiowaves, X-rays, gamma rays) and fast-moving particles (i.e. electrons, protons, neutrons) of all velocities.

Yellowcake – the yellowish product of the milling process containing a concentrated compound of uranium. Measured in its equivalent weight of U_3O_8.

URANIUM INFORMATIONAL RESOURCES
AVAILABLE FROM SRIC

PUBLICATIONS

New Mexico Uranium Inventory (By Wm. Paul Robinson)
$15.00 for non-profit organizations
$50.00 for profit-making organizations

LIBRARY BIBLIOGRAPHY

Listing of over 300 publications, over 500 magazine articles, and over 1,300 newspaper clippings in our Uranium Library. $10.00.

AUDIO VISUALS

New Mexico Uranium Industry --

1) Overview of technology and environmental impacts
2) Development on Indian land--aerial views
3) Impacts of mines and mills--aerial views
   (Each of the above includes script. For sale at $50.00 each or $15.00 rental fee.)
4) United Nuclear Churchrock Tailings Dam Break--some aerial views
   (Includes script. For sale at $25.00 or $10.00 rental fee.)

EXPERT TESTIMONY

Testimony Before the House of Representatives Committee on Interior and Insular Affairs, Subcommittee on Energy and the Environment, Hearings on the Causes and Implications of United Nuclear-Churchrock Tailing Dam Failure, Washington, D.C., October 1979. $1.00.

Testimony Before the Canadian Royal Commission of Inquiry into Uranium Mining, Vancouver, B.C., November 1979. $2.00.

Bokum Mill Application Comments, September 1978. $1.00.

Analysis of Mobil/TVA's Interim Mining and Reclamation Plan for Pilot Testing of Insitu Leaching at Crownpoint, McKinley County, New Mexico, June 1978. $2.00.

Plus others, available upon request.

OTHER GROUPS INVOLVED WITH URANIUM DEVELOPMENT ISSUES

Arizonans for a Better Environ.
1000 E. Apache Blvd.
Tempe, AZ 85281

Stop Uranium Now (SUN)
PO Box 772
Ojai, CA 93023
(805) 646-3832

Coalition Against Uran. Mining
2931 Piedmont Ave.
Berkeley, CA 94705

Colorado Open Space Council
Uranium Information Network
2239 E. Colfax
Denver, CO 80206
(303) 321-6588

Twin Rivers Citizens Assn.
PO Box 2932
Grand Junction, CO 81502

Citizens for Safe Tailings Man.
PO Box 2331
Durango, CO 81301
(303) 247-3471

Comm. on Mining & the Env.
PO Box 1692
Gold Hill
Boulder, CO 80302

Citizens for Safe Energy
309 Colorado
Pueblo, CO 81004
(303) 543-5340

Northern CO Resource Coun.
3630 W. Co. Rd. S
Ft. Collins, CO 80521
(303) 482-8290

Pikes Peak Justice & Peace
Committee
710 Prospect Lake Dr.
Colorado Springs, CO 80910
(303) 634-8740

Northern Rockies Action Group
9 Placer St.
Helena, MT 59601
(406) 442-6615

Headwaters Alliance
Box 494
Bonner, MT 59823

Northern Plains Resource Council
419 Stapleton Building
Billings, MT 59101
(406) 248-1154

Nevada Indian Environmental
Research Project
650 S. Rock Blvd., Ste. 11
Reno, NV 89502

La Colectiva
PO Box 723
El Rito, NM 87530
(505) 581-4454

La Raza Unida Party
General Delivery
La Madera, NM 87539

Concerned Citizens of Cerrillos
Box 7
Cerrillos, NM 87010
(505) 471-4169

Sandoval Environmental
Action Community
PO Box 1220
Bernalillo, NM 87004
(505) 867-2046

American Indian Environ. Coun.
Mt. Taylor Alliance
PO Box 7082
Albuquerque, NM 87194
(505) 268-9800

Florencia Land Rights
Coordinating Council
Box 1326
Loving, NM 88256

Dakota Resources Council
PO Box 254
Dickinson, ND 58601
(701) 227-1851

Radiation Information Council
907 N. 7th
Lakeview, OR 97630

Black Hills Energy Coalition
Box 8092
Rapid City, SD 57709
(605) 343-8006

Black Hills Alliance
PO Box 2508
Rapid City, SD 57709
(605) 342-5127

TX Mining Res. Comm.
PO Box 3472
Austin, TX 78764
(512) 258-6435

Southern Utah Resource Center
126 S. 1400 W
Cedar City, UT 89720

Southern Resource Council
PO Box 1100
Hurricane, UT 84737

VPIRG
26 State St.
Montpelier, VT 05602
(802) 223-5221

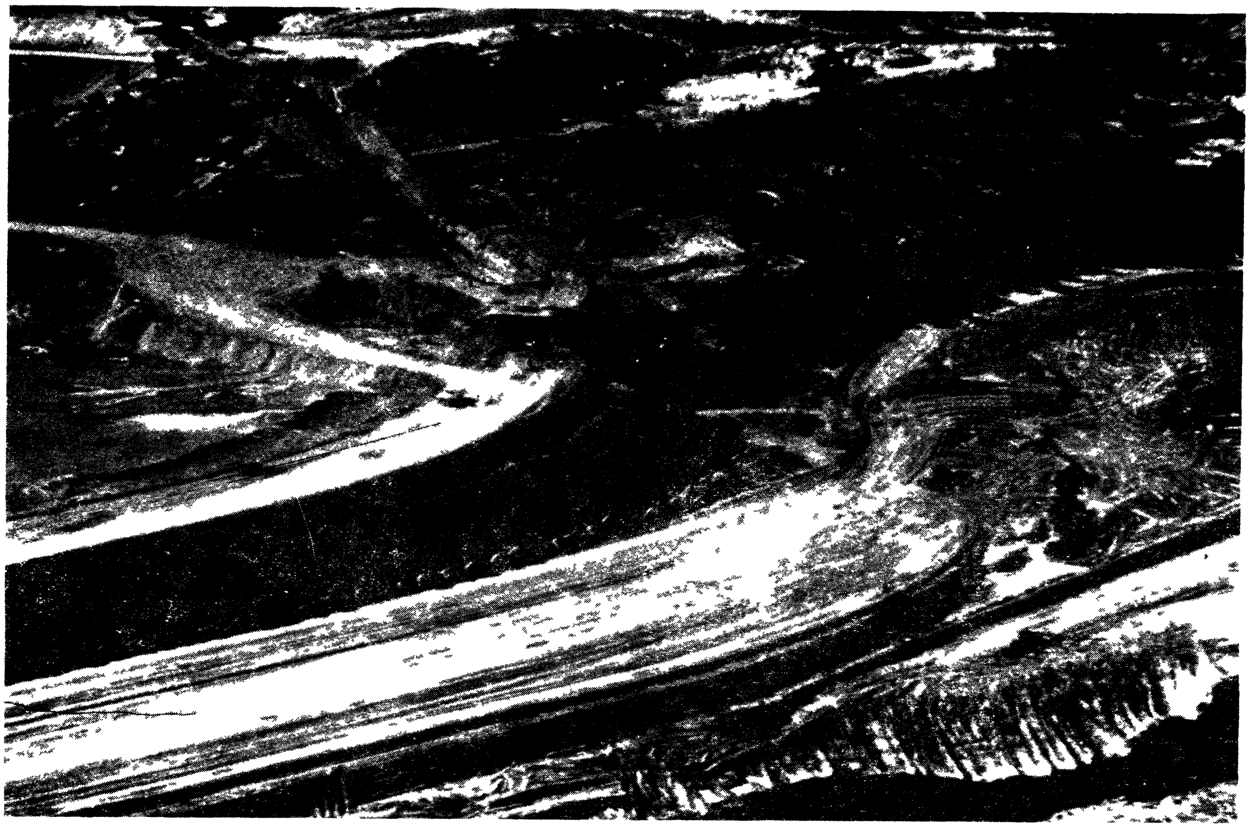
Center for Alt. Mining
Development Policy
731 State St.
Madison, WI 53703
(608) 256-6381

Wyoming Outdoor Council
Box 1365
Lander, WY 82520

Powder R. Basin Res. Council
214 S. 4th St.
Douglas, WY 82633
(307) 358-5558

Alliance Against Uran. Mining
c/o SPEC
3253 Heather St.
Vancouver, B.C. V5Z 3K4
CANADA

South Okanagan Envir. Coalition
Box 188
Penticton, B.C. V2A 6K3
CANADA



Above photo—The crack in the south end of the United Nuclear Churchrock uranium mill tailings dam. July, 1979. Photo by W. Paul Robinson

Cover photo—Old discharge point for Gulf-Mt. Taylor uranium mine. Mt. Taylor (Navajo holy mountain) in background. August, 1977. Photo by Wm. Paul Robinson.

Southwest Research and Information Center
P.O. Box 4524
Albuquerque, N.M. 87106
(505) 242-4766