Report on In Situ Leach and Open-Pit Mining

Prepared for the Larimer County Commissioners
By
The Larimer County Environmental Advisory Board

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Executive Summary

The Larimer County Environmental Advisory Board was tasked by the County Commissioners to investigate the use of in-situ and open-pit mining operations for the extraction of uranium. Concern has been raised about the potential for such operations occurring near the county. To date, no applications have been submitted and no permitting processes have begun regarding the Centennial Project, although Powertech has submitted various documents to both Department of Natural Resources (DNR) and Colorado Department of Public Health and Environment (CDPHE) to be able to drill monitoring wells and overhaul some of the previous test bores on the Centennial site. No specific plans or precise information has been made available by the parties that have expressed interest in potential mining operations. Due to the early nature of the project and the request for a review prior to specific information becoming available, the EAB report focuses on uranium mining in a general sense and the risks that are associated with both in-situ and open pit mining.

Uranium mining has been conducted in Colorado for an extended period and active uranium mines are currently extracting ore in other counties. Larimer County had an active uranium mine, the Copper King mine, up from 1951 to 1953. The centennial mine would not be the first In situ leach (ISL) operation in northern Colorado, as Wyoming Mineral Corporation briefly conducted ISL operations in Weld County in the 1980s.

Uranium is not a highly radioactive mineral. The isotope used for energy production, U235, occurs at a rate of about 0.7% in uranium ore extracted from the earth. Uranium, like other heavy metals is toxic at sufficiently high doses, but unlike many other elements, the dosage for toxicity is rather large – on the order of grams.

The radioactive elements of radium and radon are both found in conjunction with uranium (both are the products of the radioactive decay of uranium). These elements are more radioactive than uranium. Radon occurs naturally as a gas and is easily wind dispersed. Radium occurs in very small quantities but is a serious environmental and public health issue.

A number of risks are identified with ISL operations. The environmental impact of these risks can affect the soil, air and water of the region. Water contamination is the most serious risk posed by ISL operations. The probabilities of any of these risks at a proposed site in Colorado remain unknown. Without baseline information regarding the operation geology and water quality, the EAB is unable to determine the chances that Larimer County will be adversely affected by the operation. There is a probability that the quality of ground water which supplies rural residences and agricultural businesses can be adversely affected. Most municipal water supplies for Larimer County are derived from water sheds to the west in the mountains and thus would have a very low chance of being affected by ISL operations.

Open pit mining operations present higher risks to the environment than ISL operations with the potential for serious land degradation and surface and ground water contamination as well as health impacts to mine workers, nearby residents and the ecosystem in whole. The minerals, such as selenium, released in such operations have been linked to deformities in birds.

Although the current permitting and regulation processes are extensive and requires monies to be set aside for remediation of any environmental damage, the end result is that the risks to the mining operators are strictly financial while the risks to the community are potentially financial, health and environmental with costs that may exceed any capabilities of the operations to rectify.

The effects of such operations, even if they have a relatively low risk of environmental degradation can damage the socioeconomic structure of the region. It is unclear what the short term or long term effects to the communities both socially and economically will be. Economic effects are not necessarily based on rational processes and can impact the region on a larger scale than the actual mining operations.

It is often the standard that entities other than the principle operators must show that harm will result in order for permitting to be halted. Given the seriousness of the potential risks (many of which appear to have low probabilities of occurring), the board would expect that those proposing the mining operation, provide a reasoned and scientifically based risk assessment of the operations as well as the risks of not mining, making public all data collected. The risks and the ability of the mine operator and local governments to address these risks should be weighed against the benefits that may be derived.

Introduction

The Environmental Advisory Board (EAB) of Larimer County was tasked by the Board of County Commissioners to investigate the mining processes that may be used at a proposed uranium mine in Weld County near the border with Larimer County. The two forms of mining that are discussed with respect to the Powertech Centennial Project are In Situ Leaching (ISL) and open-pit mining. Although at the time of completion of this report, Powertech has begun the permitting process, no detailed documents regarding the specifics of the Centennial Project were made available to the EAB.

This report is not exhaustive in nature. The EAB is a volunteer board and as such was limited in time and resources that could be devoted to the task. The board interviewed researchers with expertise in the subject, attended a symposium on the topic and read through a large body of primary literature on uranium mining in developing this report.

The EAB decided to investigate the methods of uranium extraction and to focus on the potential impacts of the process on the environment. The board recognizes that there are three main areas of impact: water, air and soil. Each of these is subject to risks due to mining operations and this report describes the known effects.

Although there has been much information presented regarding the proposed Centennial Project by a variety of interested parties, the EAB report is based on factual information. The scientific literature is somewhat limited in the analysis of ISL operations but a substantial literature of government reports provides a solid basis for understanding the issues regarding uranium mining and the impacts it may have to the environment of northern Colorado.

A Brief History of Uranium Mining

In Colorado, uranium was discovered in 1871 in Gilpin County and uranium oxide (later named carnotite) was discovered in Montrose County in 1881; but no major mining of uranium occurred in the 19th Century. Uranium was first actively sought in the 20th Century as a source of radium. Much of this mining occurred in the Uravan district in Montrose County. At about the same time production of vanadium started in Colorado and the carnotite ores also contained significant quantities of vanadium.

Not until the 1940s were uranium bearing ores actively mined for uranium, first as a source for weapons and later as fuel for reactors. Mining continued in Uravan and new sites were discovered across Colorado with the largest uranium deposit mined in Jefferson County. During this period uranium was mined in Larimer County near Red Feather Lakes at the Copper King mine. The EPA lists at least 25 other mines or occurrences of uranium in Larimer County. A confluence of factors led to the steep decline in the price of uranium in the 1980s and 1990s and the concomitant cessation of most mining operations in the state. The major production of uranium in Colorado has been via open pit and underground mines. Currently underground mining continues at the Sunday Mine in Montrose County. In situ mining of uranium began in the 1960s in Eastern Europe. In situ mining is currently used in Europe, Australia and in the U.S. in Texas, Nebraska and Wyoming. ISL extraction was briefly conducted in northern

Colorado near Grover, but the operation was halted apparently due to the low price of uranium at the time.

Uranium Mining

Uranium is extracted by three main processes, underground mining, open-pit mining and in situ leaching. Underground mining is not common currently. Underground mining prior to a complete understanding of the effects of radon, and improved techniques was associated with numerous cases of cancer in the miners. Underground mining would not be feasible for recovering uranium at the Centennial site. Both in situ and open-pit mining are apparently being considered for extracting uranium at the Centennial site and this report will describe both processes.

In Situ Leaching

The In-Situ Leaching (ISL) process involves the drilling of a series of wells into the aquifer containing the deposits. Often the aquifer that contains the deposits is below the aquifer that is used as a source for domestic, industrial and agricultural needs. In such cases it is very important that a sufficient low-permeability zone, such as a layer of shale, separate the production and drinking water aquifers (See Figure 1). A concentrated leaching solution (oxygen rich) called the lixiviant, is then pumped into the aquifer containing the deposits to oxidize, dissolve and mobilize the uranium minerals from the surrounding rock, so that the uranium concentration in the water increases and thus more uranium can be pumped back to the surface for extraction at a processing plant. The wells are divided into injection and extraction wells, and a number of extra wells are located outside the area where active pumping occurs to monitor any escape of the mining solutions. There are a variety of leaching solutions that can be used to dissolve the uranium, as well as numerous configurations for pumping and monitoring wells.

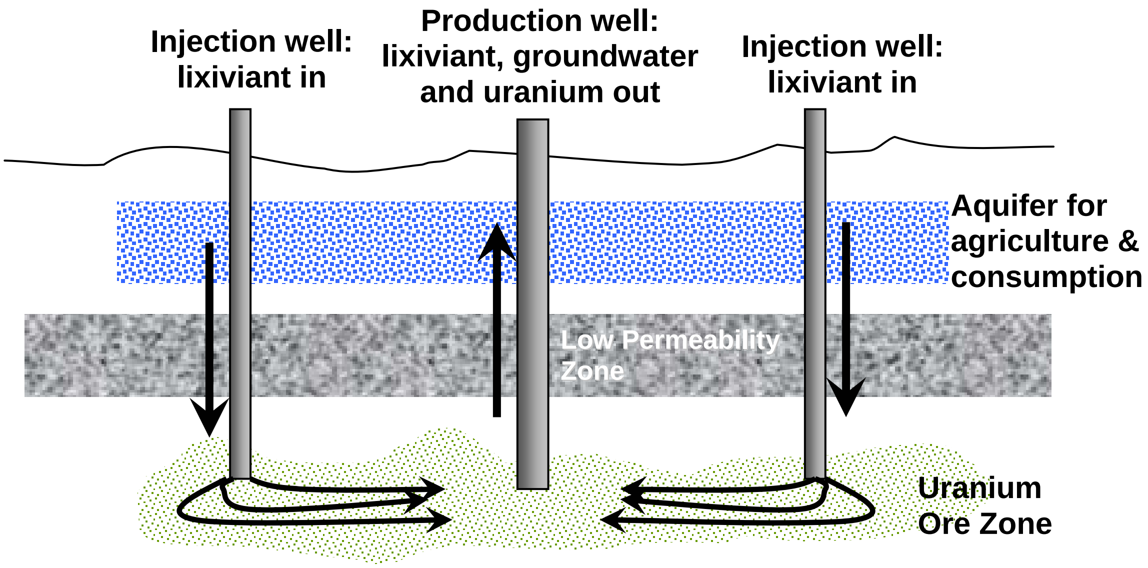

Figure 1: Schematic of ISL operations

Currently in the United States, all ISL uranium production is with alkaline leaching chemistry using carbon dioxide or sodium-carbonate and oxygen (lixiviant). The most common acid used in ISL is sulfuric acid. Acid leaching was only used once in the United States (in Wyoming) but is used in other countries.

One of the critical operational principles of any ISL mine is to control both the horizontal and vertical movement of leaching solutions within the groundwater area being mined. Not only is it important from an economic standpoint, but it is of importance for environmental protection so that the groundwater surrounding the mine site can continue to be used in the manner it was prior to ISL operations. An escape of leaching solutions, referred to as an *excursion*, and can result in contamination of soil, surface water or ground water. The main techniques used to prevent excursion are the engineering of groundwater bores to prevent leakage via the bore, and maintaining a negative pressure gradient on the injection wells relative to the production well. This means pumping out more water than the quantity of lixiviant injected into the ground.

The configuration of injection and extraction wells is also quite important for the successful control of the mining solutions. The main principle behind the patterns is that four (or six or twelve) injection wells surround one extraction well. A 5-spot pattern is thus square shaped, while a 7-spot pattern is hexagonal shaped.

ISL operations require a well designed groundwater monitoring system that can detect any excursion. It is intended that the wells are closely spaced so that any excursion of lixiviant will be detected by a monitoring well, detected by routine sampling and remedial action can be planned and undertaken. Monitoring wells need to be located with the uranium ore zone on order to detect horizontal excursions, and within any drinking water aquifers to detect vertical excursions into the domestic use aquifer.

After the pregnant (uranium rich) lixiviant is extracted from the ore zone, it is pumped to the processing plant, which is typically on the mine site. Here the uranium is extracted from the solutions using standard metallurgical techniques. The extracting solution is generally cycled through the well field, orebody and processing plant numerous times before being replaced by fresh lixiviant. The processing of pregnant lixiviant is very similar to standard uranium milling techniques.

Waste Stream

The ISL process leads to the formation of liquid and solid waste streams. These are produced from the bleed solutions, waste processing solutions, solid residues that build up due to the precipitation of minerals from the highly concentrated solutions involved, solid waste from the processing plant (such as contaminated clothing and equipment), and other normal wastes from industrial facilities. Due to the nature of ISL mining, quite large volumes of wastewater are created, which are often highly saline and contain toxic levels of heavy metals, process chemicals, and radionuclides. Excess ISL process water that is not re-injected is typically either directed to an evaporation pond, or injected into a deep disposal well to an aquifer below the uranium deposit and domestic aquifers.

Solid wastes are generally disposed of at an approved radioactive waste management site, or in an engineered facility on site. Since the ore body itself is not extracted, there are no tailings or residual rock material remaining in a large tailings dam. Treatment methods for the liquid waste incorporate strategies including biological treatment in wetlands, evaporation ponds, and reactive barriers. All of these strategies are designed to isolate the toxic waste into a solid sludge and to then dispose of the sludge recovered according to regulations. For the Centennial project, solar evaporation ponds would likely be used. These are shallow, lined ponds that allow for water to evaporate, condensing the waste.

Restoration

After the orebody has been mined, it is standard practice to restore the groundwater quality to pre-mining levels. Restoration is required by state regulations. There are several approaches to restoration, as seen in Table 1.

Table 1: Methods for restoring aquifers after ISL operations

Restoration Technique	Process	Impacts
Groundwater Sweep	Extraction of water from production wells to induce a flow of uncontaminated groundwater through the mined zone. Extracted water is treated the same as normal mining operations. Contaminated water is sent to evaporation ponds or is treated and discharged.	Requires substantial use of ground water. Is effective when the confining substrate allows leakage, potentially drawing down useable water supplies.
Forward Recirculation	Water is withdrawn via production wells, treated so that it meets required water quality and is reinjected via the injection wells.	Does not allow for removal of lixiviant or mobilized minerals that have escaped the mined aquifer (i.e. will not clean up an excusion).
Reverse Circulation	Treated water is injected via the production wells and extracted via the injection wells.	Similar effects to the forward circulation method.
Directional Groundwater Sweep	Contaminated water is pumped from a specific set of wells while treated water is injected into the aquifer outside of the boundaries of the mined area. Clean water is thus drawn into the contaminated portions of the aquifer.	While not requiring as much groundwater as the groundwater sweep method, additional groundwater is required for this technique.

The net effect is stabilization of minerals back into the geology and restoration or improvement in the post –mining water quality of the aquifer. Baseline groundwater quality data that were collected prior to initiation of the ISL mining are used to determine restoration standards. After an ISL mining project has been completed, the site is rehabilitated and returned to the former land use. All infrastructures are removed, such as buildings, roads, pipes, processing equipment etc. The remaining solid and liquid wastes are disposed of in radioactive waste facilities, and these sites are managed according to regulatory requirements.

Open Pit Mining

Open pit mining, also known as opencast or open-cut mining, is a type of surface mining that involves excavating earth, rock, and other material to uncover an orebody that lies close to the surface (typically such mines excavate to a depth of no more than 550 feet). The topsoil is removed and then the material between the topsoil and the orebody, the overburden, is removed. The overburden is generally low in radioactive elements, but is considered waste. The ratio of overburden to ore for uranium open-pit mines is 30:1 on average. The excavation of the overburden is completed in rectangular blocks in plain view called pits or strips. The pits are parallel and adjacent to each other with each strip of overburden and the mineral beneath extracted sequentially. The mining process moves the overburden laterally to the adjacent empty pit where the mineral has been extracted. This lateral movement is called casting or open-casting. The overburden is moved by heavy equipment, with the use of explosives to sometimes loosen the overburden. The uncovered mineral is excavated and hauled out of the pit to processing operations. Filling the adjacent empty pits with the overburden is systemic to the process and therefore is the foundation of land reclamation. The processed ore is known as tailings. Uranium strip-mine operations create large areas that require remediation. Large tailings ponds are created to contain the radioactive materials. Federal law requires the tailing ponds to be covered so that rainwater does not mix with the radioactive waste. These pond coverings may be eroded over time by water and wind, which could allow mobilization of radionuclides.

Reclamation / Restoration

Open pit mine reclamation and restoration begins prior to mining operations. Careful characterization of the surface slope, composition of the flora at the site and hydrological structure of the region is needed before operations begin. Often open pit waste rock and overburden is put back into the cut after mineral extraction. The decision to place overburden back into the mine is based on the presence of water and whether leaching will cause migration of radionuclides and heavy metals.

Generally, not all overburden can be returned to the pit. The standard technique to address the issue of exposed overburden and waste rock is to dry-cover the overburden and recontour the material.

The last steps for reclamation involve revegetation. The reseeding or replanting of the site helps control erosion and controls dust. Revegetation limits infiltration of precipitation into the disturbed rock and soil.

Risks

The question regarding environmental impacts largely hinges on the risks associated with the potential impacts and the probability of the impacts occurring. Some of the risks associated with these types of operations have been characterized and are discussed below. Some risks likely remain unknown. To determine the scale of potential impacts, a survey of the EPA list of superfund sites indicates that no ISL operations have yet generated problems that would require inclusion. A number of uranium milling operations, as a result of open-pit and hard rock mining, in New Mexico, Colorado and Utah have been declared superfund sites. ISL operations and milling share similarities in the drying process but differ substantially in the processing of the orebody to generate the yellowcake. Clean up at the mill sites has involved soils, surface water and ground water. The EPA lists one open pit uranium mine as a superfund site with surface and ground water contamination. Thus, in a worst case scenario, the risks to the environment of northern Colorado are serious. The board was not able to quantify the likelihood of such risks, but merely identify them. Any risk assessment should be based on sound science.

Waste production is directly linked to the risk of adverse environmental impacts in relation to both open pit and ISL uranium mining operations. Mining waste is regulated and management must comply with environmental laws. ISL mining has demonstrated to have far less waste production and risk than open pit operations. ISL mining is the operation of choice where feasible for extracting uranium. Human risks are greatest to miners in cave and open pit operations. Public risks are usually limited to affects of waste through contaminated water and/or soil and their propensity toward mobility and resulting exposure and uptake. Wastes associated with ISL operations include: drilling wastes, wastewater, wastewater sludge, lab wastes, produced water, leachate, liquids from the aquifer restoration, evaporates and refuse if radioactive. Radon levels increase where levels of radium 226 have become concentrated in solid wastes. Management strategies most frequently include solar evaporation or deep well injection for liquid wastes while solid materials may be buried onsite or transported to approved disposal sites/facilities. ISL operations minimize the production of all types of waste compared to open pit operations.

Of concern is the risk of water contamination. It should be noted that the aquifers used for ISL mining are not suitable for drinking water. The location of mineralized soil will by its very nature be contaminated with heavy metals and uranium, and unfit for use regardless of if any mining takes place. Thus the concern is that the aquifers used to for domestic, industrial and agricultural will become contaminated during the mining operations.

There are several ways that water can be contaminated. The first is when water migrates between aquifers. Communication and contamination can occur between aquifers above (shallow) or below (deep) the aquifer or site of interest and operation. Water (and contaminants) may migrate from one aquifer to another by damaged or disturbed geologic features, altered pressure gradients, advection, percolation, or intentional injection. Two of the most important variables to limit the risk of contamination between aquifers are ensuring that an adequate low-permeability zone separates the drinking water aquifer from the production aquifer, and that the injection and production wells are property sealed to prevent leakage between aquifers.

Groundwater is a major source of water for human consumption in many rural locations. Groundwater chemical characteristics are established as baseline reference prior to ISL operations and become reclamation standards for post operations restoration. The law requires that mining companies cleanup groundwater to the same or similar quality established by the baseline contaminant levels so that the groundwater may be used as it was prior to operations. There exists no obligation to improve the quality beyond prior levels. Use practices vary from site to site. ISL aquifer sites commonly do not have quality drinking water prior to or following mining operations and are not used for primary human needs. Chemical characteristics of groundwater are commonly altered by ISL mining activities due to uranium and other elements becoming mobilized for extraction or waste production and contamination during or after the operations. Some elements have appeared in greater concentration following stabilization of aquifers while others have been reduced as a result of the reclamation process. Analysis of groundwater for quality assessment after stabilization from the Crow Butte, Wyoming ISL revealed minor to moderate increases in concentrations of 13 of 33 contaminants and parameters evaluated including: alkalinity, arsenic, bicarbonate, calcium, iron, magnesium, molybdenum, nitrate and nitrite, potassium, radium 226, uranium, and vanadium. However, the concentration of 16 of the 33 contaminants were reduced including those for ammonium, barium, boron, cadmium, carbonate, chloride, copper, fluoride, lead, manganese, nickel, selenium, silica, sodium, sulfate, total dissolved solids, and zinc. The remaining two contaminants evaluated, chromium and mercury, were essentially at the same concentration. The pH was slightly lower but essentially the same (8.5 prior to 8.18 post - slightly basic) (NRC, 2007, Table 5). The same NRC report provides additional data from the Ruth, Wyoming Pilot R & D Study indicating similar effects to the groundwater quality when assessing 20 different contaminant levels and/or characteristics.

Surface spills from mining operations may also be a source of contamination of groundwater. For example, in the period from December 1999 to August 2007, the Smith Ranch ISL in Wyoming reported 37 spills or leaks with an average spill volume of 6,040 gallons. It may be possible that contaminated water is percolates downward and may contaminate groundwater in non-site shallow aquifers used for human consumption or food production. Percolation depth is a function of soil type and viscosity. For example clay soils are essentially impenetrable whereas, sandy-loamy soils percolate water downward very rapidly. Each site must be assessed for safety precautions to avoid and manage spills particularly if none minded aquifers are close to the surface.

Consequences

ISL operations can impact water, air and land resources. Research into the potential effects of excursions, surface spills, fugitive dust and other risks is not complete. Without scientific studies characterizing the scope of the impacts, a complete risk assessment is not available. The following sections discuss potential consequences of contamination from ISL operations.

Water

Potable water supplies derived from contaminated sources (aquifers or surface) pose threats to human and ecosystem health. The Safe Drinking Water Act establishes the Maximum Contaminate Levels (MCLs) for approximately 84 primary and 20 secondary contaminants. Sources used for municipal drinking water are monitored, evaluated, treated and quality is assured/required. Private wells that become contaminated may not be detected. Private citizens do not monitor and evaluate all water quality parameters, as do municipalities. Raw water commonly used in farming and agricultural production is not subject to the same evaluation, monitoring or standards as drinking water. Contaminants pose threats to health through increased concentration to dangerous levels. Exposure is through primary consumption of the contaminated water as well as secondary consumption through eating food stuffs / products exposed to contaminated water. The Agency for Toxic Substances and Disease Control (ATSDR), reported that toxicological assessment has determined contaminant levels associated with ISL operations may pose health threats. For example, the ISL Crow Butte water quality assessment revealed arsenic levels ranging from 0.002 mg/L prior to mining increased to 0.017 mg/L following stabilization. Research suggests risks from arsenic levels 0.01 to 0.1mg/L are associated with possible hepatic (liver) injury whereas concentrations as low as 0.0037 mg/L were associated with skin lesions. Pre and post selenium levels reduced from 0.003 mg/L to 0.002 mg/L however, levels greater than 0.002 mg/L have been associated with liver damage. Background levels of uranium ranged from 0.092 mg/L prior to operations increased to 1.73 mg/L post mining; levels as low as 0.05 mg/L are associated with kidney damage.

The ISL site evaluation must consider flora and fauna of the area and region, and both resident and migratory plant and animal species. Major impacts to ecosystems from ISL operations come from site disturbance via large ponds and/or pits onsite used to manage wastes as well as the solids produced from drilling and disturbing the geology related to operations. Management strategies inevitably concentrate contaminants that may become mobilized and adversely impact the ecosystems of the area.

Crops can be impacted by the drying up of these ponds which can result in particulate contamination that can result in dispersion of radionuclides. These radioactive particles can be deposit on crops, and can be consumed by animals.

Plants are impacted generally by the disturbance of operations such as in drilling aquifer access holes (hundreds or thousands), setting pipe, building structures, roadways, etc. ISL operations require large scale holding ponds for water that impact surface habitat. Flooding crop areas will destroy production and increase salinity of soils from solar evaporation of water. This will impact plant growth and limit use in future times. Limiting plant growth has the potential to increase air contamination in the future. Plant contact with contaminated water may transfer contaminants to the plant by adsorption or absorption. Contaminant may either “stick” to the surface of plants or be taken-up into the plant.

Domestic animals are impacted by operations as described above. Consumption of contaminated water can produce adverse health affects similar to those seen in other species including humans and are agent specific. Bioaccumulation or concentration of contaminants can also occur in disparate members of the local food web and this can affect species that are commonly consumed by humans thus imparting higher exposures of agents as in radionuclides concentrated by cattle and sheep.

The ecosystem in and around the ISL operations can be influenced by contamination from the operations. As with the agricultural processes, bioaccumulation of contaminants can increase as the minerals and radionuclides move through the food web. The local ecosystem will experience such bioaccumulation, but the region is also in a flyway for many bird species so the potential to affect other ecosystems linked by the migration and dispersal of animals is also an issue.

Air

Dust is inevitable in mining operations due to disturbance of the geology. Fugitive dust emissions are considerably less in ISL operations when compared to open pit mining. Disturbance of the site results from the operations described above. Mobilization of solids is dependant on wind patterns, barriers and methods used to suppress dust.

Radon levels have been increased where levels of radium 226 has become concentrated in solid wastes. This is a much greater problem in cave and tunnel mining where air circulation is minimized. ISL pit bottoms are common places for sediment/precipitate to concentrate. As solar evaporation of water concentrates solid materials, radionuclides decay and produce higher levels of radon. This is released to the atmosphere. Radon is dispersed easily in the atmosphere (which is why home basement mitigation systems vent directly to the outside) and the risks for radon exposure are limited to the immediate area around the operation.

Mining operations require the use of vehicles and other equipment that operates with fossil fuels. Increased traffic on rural roads could lead to congestion and further air pollution. Open-pit mining would require the use of heavy equipment, further increasing the local air pollution. This increase in air pollutants is not likely to be significant, although it should be noted that the proposed mining sites are within the EPA non-attainment area for the Denver Metro area.

Land / Soil

Land disturbance is significant but far less in ISL operations compared to open pit mining. Disturbances are described above and usually affect a large surface area at the mine site. For example, thousands of holes may be drilled and hundreds of acres may be used for wastewater ponds and pits. Most ISL sites create buffer zones by acquiring thousands of acres around the site of interest. Excursions of lixiviant, pregnant lixiviant, or wastewater all pose a risk to the soil of the mining site. The use of the soil near the operations for agricultural purposes either during operations or after the operations are complete could be impacted by such excursions.

Wildlife is impacted by site operations and disturbance of the ecosystem. The site evaluation must consider species that are both resident in the area and those that are migratory. It is suggested that most impacts are temporary and restoration permits a return and reestablishment of wildlife in time. Habitat fragmentation can occur with the construction of wellfields, roads constructed to support the mining and any fencing done during mining or during reclamation. This fragmentation affects the migration and dispersal of species. Of concern would be the impact on any endangered species (both plant and animal) that utilize the area affected by the mining.

Open-pit mining

ISL mining is considered to reduce environmental risks compared with open-pit mining. The wastes generated in open pit mining include protore, overburden, waste rock, drill cuttings and wastes, wastewater, treatment sludge, lab wastes, and pit water. Open pit mines may create increased runoff, wind and water erosion. Dewatering of the mine area can create groundwater depressions.

Ground and surface water can be pumped out of the region of the open-pit mine to facilitate access to the ore. After the mining is complete, the pumping is stopped and the pit can refill with ground and surface water. The mine water can be contaminated with metals, radioactive elements and dissolved solids. In some instances, the ground water takes on the chemical characteristics of the mine dewatering effluent. Mine water pumped out of the mine can be high in radionuclides and other metals.

The overburden and waste rock can become a source for acid runoff. This runoff can negatively impact surface and ground water downstream from the mine.

Greater volumes of airborne contaminants can occur with open pit mines with respect to ISL operations. The excavation processes, movement of heavy equipment, wind dispersion of overburden can create fugitive dust. This dust can contain heavy metals and other toxics. Generally, during mine operations water is sprayed on waste and overburden piles to reduce dust. Overburden and waste rock can release higher amounts of radon gas. Although it disperses quickly, radon can be a health risk to workers.

Clearly open-pit mining disturbs soils to a large extent. This type of mining operation can increase the radioactivity of the soil. Both radium and thorium concentrations have been shown to increase in some open-pit mines.

Baseline Data

It is important that any risk assessment be based on solid science, which in turn, must be grounded in data that describes the region. This information is also needed if ISl operations are conducted to determine the effectiveness of restoration and any remediation that would be necessary.

Baseline assessments of the geology of the aquifer must be carried out prior to operations to establish baseline restoration goals. The ISL process is intended to mobilize minerals. Pre-mining mineral level concentrations in the water must be determined prior to disturbing the hydrogeology of the site. Assessment and validation is incumbent on the individuals/company seeking access for mining operations and the agencies providing permits.

Likewise, water quality parameters must be established prior to disturbance of any aquifers to establish current quality and restoration goals.

Soil analysis must be performed to establish constituent make-up for the detection of change and/or concentration of contaminants posing health risks to the ecosystem and necessary clean-up strategies, technologies, and goals.

Evaluation of air quality and wind patterns must be performed to establish current quality and restoration goals and probabilities for offsite migration through fugitive dust emissions.

Conclusions

Mining operations carry with them the potential for significant environmental impacts. Water, soil and air contamination are all possible with the operations that may be conducted in Weld County. The probabilities associated with these impacts are not presently known. In the absence of sound scientific data, an acceptable risk assessment is not currently possible. Without a risk assessment, detailed project descriptions, or access to baseline data the EAB is unable to make recommendations regarding the Centennial Project at this time.

The effects of the Centennial Project extend beyond environmental impacts. There are potential public health and economic impacts as well. The economic impacts of the project may not be tied to actual risks but perceptions. In this case, regardless of the risks, the project may have a negative impact to the region. Other economic impacts may include additional jobs and tax revenue for the duration of the mining operations.

It is often the standard that entities other than the principle operators must show that harm will result in order for permitting to be halted. This approach, however, presupposes that the action is "innocent of harm until proven guilty" and places the burden of proof on those who usually have fewer resources to make their case. Given the seriousness of the potential risks (many of which appear to have low probabilities of occurring), the board would expect that those proposing the mining operation will provide the public with all of the data which they possess that could have any relevancy to the matter at hand and then use these data to propose a reasoned and scientifically based risk assessment of the operations. Without meeting this standard, it is impossible for the Board or the public to provide their informed consent or for the outcome to represent a just resolution. The risks (environmental, economic, health, and social) and the ability of the mine operator and local governments to avoid or mitigate these risks should be weighed against the benefits that may be derived from such an operation when determining whether the mine is acceptable for the region.

Regulatory requirements

Powertech is required to acquire federal, state and county permits on the Centennial Project in order to commence uranium mining activities. The Colorado Department of Public Health and Environment (CDPHE) has identified the following State and Federal Permits, Authorizations and Requirements that may be required for an in-situ uranium mining and milling operation. The list may change depending on the specific proposal for operation.

Colorado Department of Public Health and Environment:

Radiation Control:

1) Radioactive materials/uranium mill license. C.R.S. §25-11-101 et seq., 6 CCR 1007-1, Parts 1, 3, 4, 10, 17, 18. *Colorado's radiation control regulations are authorized through agreement with the U.S. Nuclear Regulatory Commission. In-situ mining of uranium ore is subject to licensing requirements due to the byproduct materials produced. The requirements include provisions regarding environmental assessment, financial assurance, operations, residuals management, worker and public safety and decommissioning.*

Water Quality:

1) Surface water discharge permit (if there will be a discharge to surface water). C.R.S. §25-8-501; 5 CCR 1002-61.
2) Storm water permit. 5 CCR 1002-61.
3) Ground water discharge permit (if the Division of Reclamation and Mining Services {DRMS} fails to provide adequate ground water quality protection). C.R.S. § 25-8-202(7); 5 CCR 1002-61.14. *Any radioactive materials license issued by DRMS would require containment of contaminated solutions within a defined aquifer area. If releases occur, a license requires corrective actions to be evaluated and implemented. Decommissioning requirements include*

decontamination of the mined zone and return to conditions consistent with groundwater standards, or pre-mining conditions.

Air Quality:

1) Air quality permit if there will be air emissions. C.R.S. §25-7-101 et seq. *The requirements for air emissions permits are evaluated when an applicant submits an Air Pollution Emission Notice (APEN) the Air Quality Control Division for review.*

Hazardous Materials and Waste Management:

1) Hazardous waste permit, if applicable. C.R.S. §25-15-101 et seq. *Permits are required if specified amounts of hazardous waste are generated or stored on the property.*
2) Solid waste certificate of designation, if applicable. C.R.S. §25-15-101 et seq. *A certificate of designation is required for onsite solid waste disposal activities.*

Department of Natural Resources

Division of Reclamation and Mining Services:

1) Reclamation permit. C.R.S. § 34-32-109. *The Rules and Regulations adopted by the Mined Land Reclamation Board contain performance standards for groundwater quality, drainage, post-mining use, wildlife and materials handling during the reclamation phase.*
2) Notice of Intent to Prospect. C.R.S. § 34-32-113. *A notice is required for exploration to define ore bodies, characterize groundwater and determine possible mining and refining methods.*

State Engineer's Office

1) Ground water permit. C.R.S. Title 37, Article 90.

US Environmental Protection Agency

1) Class I or Class III Underground Injection Control Permit. 42 U.S.C. §300h; 40 CFR §144.6, 147.301. *This program regulates waste disposal and injection wells used for in-situ uranium mining. Standards for wells pertain to construction methods, operating parameters such as injection volume and pressure, monitoring and reporting, well closure and abandonment procedures, and financial responsibility. Before injection can occur, an applicant must obtain an "aquifer exemption" from the EPA. An exemption can be issued only if the aquifer under consideration does not serve as a source of drinking water and cannot become one in the future due to its mineral, hydrocarbon or geothermal energy content.*

Weld County

1) Use by Special Review. Weld County Code, Chapter 23 (Zoning), Article II, Division 4. *The standards for use by special review require County review and approval to address issues related to compatibility with existing and planned uses in the neighborhood. The standards for approval include a requirement that adequate provisions for the protection of the health, safety and welfare of the neighborhood and County be made. Public hearings before the Planning Commission and County Commissioners must be held in*

Future Statutory Requirements

1) Bills Submitted for Consideration. *In January of 2008, a group of Northern Colorado lawmakers introduced two bills designed to protect public health and property values from uranium and other mining activities. House Bill 1161 would require mining companies to show they will restore groundwater aquifers to their pre-mining levels. House Bill 1165 would require mining companies to inform residents of mining activity taking place near them, and require local governments to protect local water sources from mining activities.*

Glossary of Terms

Aquifer – An aquifer is a geologic formation or a group of formations that contain sufficient water to permit extraction by wells or release through springs. Aquifer hydrogeology characteristics greatly affect water contaminant levels.

Arsenic – Arsenic is a metalloid exhibiting properties of both metals and non-metals. It may be present in combination with other compounds. Arsenic is present in nature and varies in concentration within the geology of soils. It is a known carcinogen and toxic agent. The primary target organs with chronic exposure include the skin, nervous system, liver and vascular system. High level ingestion (70 – 180 milligrams can be fatal to humans. Arsenic is found in our drinking water and food. It is estimated that the average daily intake (ADI) from food is 0.04 milligrams. For those with high seafood diets, the ADI may be as high as 0.02 milligrams. Current drinking water standards limit concentrations to 10 micrograms (.01 milligrams) per liter while most water sources are less than 5 micrograms (0.005 milligrams per liter in the US.

Extraction Well – A bore hole or well in an in situ well field through which pregnant lixiviant and ground water are drawn to the surface. Also known as a production well. Typically, an extraction well is surrounded by a number of injection wells.

Fold – Bending of rock layers due to slow sustained forces.

Food web – An ecological concept that relates species by which species consume others. Plants, which make their own food do not consume other organisms. Often, food webs are represented as simple food chains with a hierarchy, plants consumed by herbivores, which are consumed by predators and so on. Actual food webs are highly reticulated with various loops. Food webs are important for understanding the movement of elements (nutrients or toxic substances) from one part of an ecosystem to another.

Hard rock mining – Technique in which tunnels are dug and the ore is extracted from veins found underground. This technique generates less waste material but exposes miners to much higher radiation from the associated radon gas. The waste rock carries with it the possibility of subsequent leaching of toxic elements such as uranium, radium, selenium, or molybdenum into the groundwater.

In situ mining leaching – Mining technique, also known as in situ recovery or solution mining, in which holes are bored into the rock containing the mineral. Treated water is forced into a set of holes in order to dissolve the mineral. The water is treated either with sulfuric acid or sodium bicarbonate (sodium bicarbonate is currently used in the United States). The solution containing the mineral is brought to the surface via pumping from another set of holes. The dissolved mineral is then recovered from solution. The mineral-depleted water is then re-injected into the boreholes. This technique generates the least amount of rock waste but raises issues of contamination of useful aquifers by migration of water between aquifers from older drill holes. The region in Weld County where current mining interests are involved was explored in the 1970s with thousands of drill holes bored. Currently in situ mining is the main method used in the United States to extract uranium.

Injection Well – A bore hold or well in an in situ well field through which lixiviant enters the aquifer containing the orebody.

Isotope – An element can occur as different isotopes. The nucleus of an atom of a particular element contains the same number of protons but can contain different numbers of neutrons. These variants based on the number of neutrons are the isotopes of the element. The fewer the number of neutrons means the isotope is subject to more radioactive decay.

Open pit mining – Technique involves the removal of the rock and soil overburden to allow for the extraction of the mineral ore. Generally, this process involves a large amount of dust and extensive use of water is used to mitigate the dust. After the mineral is extracted, generally the area undergoes reclamation. This method also carries with it the possibility of subsequent leaching of toxic elements such as uranium, radium, selenium, or molybdenum into the groundwater.

Pregnant Solution - A solution containing lixiviant and the mineral targeted for extraction. Other minerals are often found in the solution having been mobilized by the lixiviant as well.

Protore – A mineral deposit that could become economically viable if prices change or technology for extraction improves.

Radiation – Energy in the form of waves or particles. It can be either ionizing or non-ionizing (heat, light, microwaves, radio waves). Three forms of ionizing radiation are alpha, beta and gamma. Alpha radiation is easily blocked and only when the source is internal can cellular damage occur (such as when Radon is inhaled, or when ingested, such as Polonium-210 poisoning). Beta radiation can penetrate tissue farther and can cause skin lesions at high exposures, or increased risk of cancers at lower exposures. Gamma radiation has the highest energy and can penetrate tissue readily and can increase the risk of certain cancers. Gamma radiation can cause DNA damage resulting in hereditary changes (in mammals, but such changes have not been documented in humans). As a radioactive element decays it changes to isotopes of different elements each releasing radiation until a final resting state is achieved (non-radioactive isotope). This sequence is the decay chain and the uranium decay chain releases alpha, beta and gamma radiation at various steps. Uranium decay occurs regardless of its location or any physical properties. Radon is an important decay product in the uranium decay chain. Uranium is naturally present in soil and water.

Radium – Radium is a naturally occurring radioactive element that assumes 16 different isotopes. The most common isotopes are radium 226, 224 and 228 used widely in medicine and industry. Radium forms when isotopes of uranium or thorium decay in the environment. Most radium (226) originates from the decay of the plentiful uranium (238). Radium 224 and 228 form when Thorium decays. Radium like uranium are naturally occuring and in the soil. Radium is a toxic element that targets the skeletal system causing bone cancer (osteogenic sarcoma).

Radon – A radioactive noble gas. The EPA lists radon as the second leading cause of lung cancer. Radon is a daughter element of uranium, that is, when uranium decays one of the elements it becomes is radon. Radon occurs naturally as a gas and as such is generally quickly dispersed in open air. Radon poses a serious health risk when it is allowed to concentrate. Radon can collect in subterranean areas without proper ventilation (mine shafts, basements, etc).

Reclamation – Reclamation standards and practices address environmental protection and stability post-mining operations including topsoil salvage and storage, surface and groundwater protection, stability of acreage exposed to wind and water erosion. These standards are established by the permitting agency and are meant to ensure recovery of the site. Standards are focused at surface mining impacts such as in open pit coal mining. The Surface Mining Control and Reclamation Act of 1977 created the Office of Surface Mining Reclamation and Enforcement within the Department of the Interior administered by the State of Colorado.

Remediation – Remediation is the cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a Superfund site, or uranium mine or extraction facility, including those included under the Uranium Mill Tailings Radiation Control Act (UMTRCA).

Selenium – Selenium is metal and an essential nutrient. It may be present in combination with other compounds. Selenium is present in nature and varies in concentration within the geology of soils. Deficiency causes cardiomyopathy (heart abnormality). The ADI is estimated at 0.02 milligram through food consumed. Selenium has low toxicity but may also be toxic at very high levels 100 – 100,000 times normal intake. Target organs include skin, hair, nails, and nervous system.

Tailings – Tailing are the solid material wastes (waste rock) from mining operations. Tailings are formed when the ore is extracted from the substrate. Uranium mining tailings, while generally low in radioactive elements can contain higher concentrations of contaminants including heavy metals. Open pit and tunnel mining produce large amount of tailings. Tailings reclamation are usually required by the permit process.

Uranium – Uranium is the heaviest naturally occurring element. It is found in low concentrations in water, rock and soil. Uranium is weakly radioactive, emitting alpha particles. Uranium occurs as several isotopes. The three most common are U-238 (99.28% of all naturally occurring Uranium), U-235 (0.71%) and U-234 (0.0054%).

Uranium is a heavy metal and as such is toxic to humans. The LD50 dosage for uranium is 29 grams in an average adult. Uranium, in large quantities, damages the kidneys. The CDC reports no radiological effects from naturally occurring uranium.

Yellowcake - a processed oxide of uranium, U_3O_8, extracted and concentrated from uranium ore: used as the raw material for commercial nuclear materials, esp. fuel elements in nuclear reactors.

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