

Appendix G – Radiation and Worker/Public Safety



Special Use Permit Application

The Nuclear Regulatory Commission (“NRC”) strictly regulates the dose of radiation that may be received by mill workers and the general public. The Colorado Department of Public Health and Environment (“CDPHE”) is responsible for enforcing the NRC rules for uranium milling in Colorado. An important cornerstone of CDPHE’s Radiation Program is to keep radiation doses, on and off site, to levels that are “as low as reasonably achievable” (“ALARA”). To meet ALARA requirements, Energy Fuels Resources Corporation (“Energy Fuels”) will be required to implement strict radiation controls and monitoring throughout the Piñon Ridge Mill Facility (the “Project” or the “Facility”).

To provide a better understanding of the radiation controls that will be in place at the Facility, this appendix first provides a review of radiation and the various sources of radiation that people may be exposed to, both in daily lives and at a uranium mill site. This primer on radiation is then followed by a more detailed discussion of the sources of radiation at a uranium mill and the radiation protection measures and monitoring that will be implemented at the Facility. This appendix concludes with a short summary of the history of uranium mining and milling and explains how regulations and practices have changed over the years to become more protective of people working in the industry, as well as the general public.

Radiation

Radiation is energy given off by matter in the form of rays or high-speed particles. Radiation that originates from cosmic rays, radon in the air, naturally-occurring radioactive materials such as uranium, and other natural sources can damage plant, animal, and human cells. For low levels of radiation, the impacted cells may not be damaged or the damage may be repaired within the cell. However, a high radiation dose may cause physical damage within the cell or the cell may become cancerous. As the radiation dose increases, the potential for physical damage and illness increases.

Radioactivity is the number of atoms in the material that decay and release ionizing radiation in a given time period. The amount of energy deposited in living tissue by ionizing radiation is called the “dose” and is measured in millirems. On average, people living in Colorado receive a dose of about 450 millirems (“mrem”) each year from natural background radiation. Approximately two-thirds of this background dose originates from radon in the air with the remainder comprised of cosmic radiation, radioactive carbon and potassium contained within the body, and gamma radiation emitted by radioactive materials in the ground (i.e., radium, uranium, and thorium).

Under NRC regulations, mill workers are limited to an annual radiation exposure limit of 5,000 mrem/year. Most mill workers, however, receive a dose substantially less than 5,000 mrem/year. Today, the annual effective dose (i.e., incremental dose above background) received by a mill worker is typically less than 100 mrem/year.

The maximum exposure limit set by the NRC for the general public at the mill property line and beyond is 100 mrem/year above background. Adherence to this limit is verified through sampling and monitoring. Exposure at the nearest residence is expected to be 10 mrem/year or less. Given that the nearest downwind residents are located three to four miles east of the property, it is unlikely that an increase in radiation above background levels could be detected at these locations.



Special Use Permit Application

Exposure to radiation from other modern activities also occurs on a frequent basis. For example, a person typically receives an additional three mrem from a cross-country airline flight due to the higher exposure to cosmic rays at high altitudes. Obviously, airline pilots and stewards that fly on a regular basis are exposed to higher levels of radiation than the general public or even a typical person working in a modern uranium mill. A chest X-ray also imparts a dose of about three mrem while a lower pelvic gastrointestinal exam can provide a dose up to about 600 mrem. Use of radiation therapy to kill cancer cells and shrink tumors typically requires a dose of about 10 million mrems.

What constitutes a safe level of radiation? Unfortunately, that is dependent on the person and cannot be readily quantified. The above referenced exposure limits for mill workers and the general public have been set conservatively by regulatory agencies based on input from health professionals and numerous health studies. Energy Fuels must maintain radiation levels well below these regulatory limits.

Radiation Sources and Controls at a Uranium Mill

The three principal types of radiation found at a uranium mill are alpha particles, beta particles, and gamma rays. The potential health effects and the types of protection measures used for each type of radiation are described below.

Alpha Particles

Alpha particles are large, highly-charged particles emitted from the nucleus of elements such as uranium. Outside the human body, they are of little importance because alpha particles cannot penetrate the dead cells naturally present on the surface of our skin due to their large size and high electrical charge. One could even hold uranium in one's hands and not be affected by the alpha particles. However, if uranium is inhaled or ingested, the alpha particles emitted from the uranium can cause damage to the internal organs by depositing large amounts of energy into the absorbing tissue. For example, if a mill worker inhales uranium dust, the alpha particles from uranium deposits in the lung could damage the lung. Similarly, if uranium dust is ingested, alpha particles could potentially damage kidney cells or other organs as the uranium travels through the body.

Engineered controls, such as water sprays to suppress dust and ventilation systems with dust scrubbers to direct uranium dust away from workers, are used in uranium mills to minimize the radiation dose received by a worker. Secondary protective measures such as the use of respirators by mill workers may also be used to limit worker exposure. In addition, all employees are surveyed for the presence of radioactive materials on their person and clothing and are required to shower and change clothing if monitoring indicates the presence of radioactive material above strict regulatory levels.

The general public is protected from alpha particles by:

- dust collectors, scrubbers and other air pollution control devices installed on mill stacks;
- dust control measures (e.g., water sprays, dust suppressants) applied to the mill roads, ore stockpiles and tailings cells;
- washing and scanning of trucks and other equipment leaving the mill site; and
- permanently capping the tailings cells once they have reached capacity.



Special Use Permit Application

Beta Particles

Beta particles are another form of radiation. They are light particles and minimally charged. When absorbed by skin cells or by cells of internal organs, beta particles deposit small amounts of energy in the absorbing cells. In a uranium mill, the use of gloves and coveralls shield the mill worker from beta particles. Thus, beta particles in a mill produce minimal radiation dose to the mill workers from the radioactive materials inside the mill. Similarly, they do not represent a significant source of radiation exposure to the general public.

Gamma Rays

A third form of radiation is gamma rays. Gamma rays come from the nucleus of the decaying atoms and are the same as x-rays, which originate from medical instruments. Gamma rays can penetrate deeply into material and only deposit small amounts of energy into tissues. Typically gamma rays are present in uranium mills but at low levels. The highest gamma ray exposure levels in a uranium mill are usually from yellowcake that has been barreled for a year or more. As uranium decay products are formed in uranium oxide (“U₃O₈”) concentrate (called yellowcake), gammas are emitted; however, employees are excluded from these areas. Shielding is also used to protect workers from gamma rays.

The largest source of gamma rays outside of the immediate mill facility is the solid waste products disposed of in the tailings cells. These “tailings” are what remains at the “tail end” of the milling process. Gamma rays are emitted from the radioactive materials in the tailings but at low levels that readily dissipate in the atmosphere. Accordingly, the mill employees working in the vicinity of the tailings area receive relatively low doses from the gamma rays.

The yellowcake is shipped off site for further processing and eventual use by the nuclear power industry. The gamma rays from the yellowcake are shielded by 55-gallon sealed shipping drums and monitored for compliance with the U.S. Department of Transportation (“USDOT”) shipping regulations. At these levels of exposure, the radiation dose received by shippers and the public is very low. To guard against the consequences of a trucking accident involving a spill of yellowcake outside the truck, the USDOT requires that these carriers have emergency response plans in place with trained personnel available to respond in the event of a transportation accident.

Radiation Monitoring

Numerous monitoring systems will be present in the Piñon Ridge Mill Facility to identify potential radiation concerns and to verify that the work environment is safe. Area air monitors will be located throughout the mill to monitor the concentrations of uranium dust in the mill. Workers involved in potentially dusty operations will wear breathing-zone air monitors to monitor the air that they breathe. For those workers exposed to higher concentrations of uranium dust, urine samples will be collected and analyzed to determine the total uranium that has been inhaled and ingested. Those workers exposed to the highest levels of gamma radiation will wear gamma-monitoring badges, similar to what x-ray technicians and airline screeners wear. Other protections include regular power washing of equipment and vehicles, monitoring the amount of time workers are exposed to radiation, and implementation of good housekeeping and personal hygiene measures.



Special Use Permit Application

Energy Fuels selected the Piñon Ridge Mill site, in large part, because of its location. Not only is the mill located central to the uranium ore deposits on the Colorado Plateau, it is also relatively remote with the nearest residences located three to four miles away. Despite the large buffer area between the mill property and the closest residences, Energy Fuels must still meet regulatory limits for radiation dose at the property boundary. To verify compliance with these requirements, air monitoring stations have been established both on site and off site to measure radiation levels prior to, during, and after milling operations. Meteorological stations have also been installed to measure wind direction, wind speed, and other parameters. The meteorological data collected during pre-operations will be combined with emission data collected from the mill and tailings cells to predict radiation levels at the fence line of the property, at the nearest residence, and at communities within an 80-mile radius of the site. The later data will be used to maintain and verify compliance with regulatory standards during milling operations and closure activities.

Regulatory History

A significant number of people that worked in the uranium industry during the 1940s through the 1960s were exposed to high levels of radiation and radioactive dust that, in many cases, resulted in lung cancer. The 1990 Radiation Exposure Compensation Act was passed, in part, to provide compensation to uranium miners, millers, and ore transporters who contracted cancer or other specified diseases as a result of exposure to radiation. The uranium industry was not unlike other industries during that time period when chemicals and materials such as solvents, caustics, PCBs, and asbestos were used in manufacturing and construction without a full understanding of their health effects on exposed workers.

As understanding of the radiation health risks grew, so did the applicable regulations and the required protection measures for workers and the general public. State and federal regulations on permissible radiation levels were initially implemented in the late 1960s and early 1970s. Since that time, the rules have become increasingly strict with regard to radiation exposure and monitoring in all areas of the uranium industry starting with the mining, transporting and milling of uranium ore and continuing through to the generation of nuclear power.

Today, the Mine Safety and Health Administration (“MSHA”) requires adequate ventilation for underground uranium miners to reduce their exposure to radiation and radioactive materials to acceptable levels. The USDOT requires that ore shipments be covered, placarded, and monitored for gamma radioactivity levels at specified distances from the trailer. USDOT also requires that shipments of yellowcake be below their established radiation limits, packaged in leak-tight containers, and that the containers be free of any surface contamination. Similarly, as described above, the NRC and state radiation programs require that radiation doses at mill sites be reduced to levels that are ALARA through the use of modern technology and monitoring instruments.

