Uranium Mining in Virginia – Can Downstream Drinking Water Sources be Impacted?

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Summary:

There is interest in the mining and milling of uranium ore reserves in Pittsylvania County, upstream of John H. Kerr Reservoir and Lake Gaston in southern Virginia. Because uranium ore is mostly present at relatively low concentrations in the United States, uranium mining and milling produces vast quantities of waste material known as tailings. These tailings retain about 85 percent of the original radioactivity for hundreds of thousands of years because of other radioactive materials, such as Radium and Thorium, which are not extracted during the uranium milling process. These radioactive materials can adversely affect public health if they are not confined properly or are released to the environment. In addition, uranium tailings contain other potentially hazardous substances such as arsenic, which can affect public health if they leach into groundwater or surface water.

Historically, the confinement of tailings has failed at a number of mines in the United States and elsewhere – some as a result of heavy rainfall – resulting in the release of radioactive sediments to downstream surface waters. Presently, uranium tailings are required to be stored in specially designed waste disposal facilities called containment cells or structures in compliance with Nuclear Regulatory Commission regulations.

There is concern that mining operations and a failure of the uranium ore tailing containment cells could result in the contamination of the downstream drinking water supply sources along the Banister River, Roanoke River, Kerr Reservoir, and Lake Gaston. Figure 1 shows the location of Pittsylvania County uranium ore deposits and properties with former uranium mining leases in relation to several downstream source water intakes, including the Lake Gaston intake for the City of Virginia Beach, which conveys water to the Southside Hampton Roads area.

Most uranium mines in the United States are located in western locations, which are more arid than Virginia. Virginia is subject to tropical storms and hurricanes, some of which have generated extreme flooding east of the Blue Ridge Mountains along a corridor that cuts a path through the uranium ore deposits in Pittsylvania County. In fact, two storms occurring in nearby Nelson and Madison Counties resulted in rainfall amounts almost as large as the Probable Maximum Precipitation (PMP, the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of the year). In addition, there were two more events that occurred in Charlotte and Page counties which were significant in nature.
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To better assess the impacts of a potential uranium containment failure, the City of Virginia Beach Department of Public Utilities has initiated a preliminary study of the likelihood of the degradation of the Lake Gaston water supply in the event of a containment cell failure. This white paper provides a brief background on uranium mining and milling, as well as the hazards these activities can pose to downstream water resources; describes Virginia’s climate, including the extent of near-PMP rainfall events in the vicinity of Pittsylvania County; and outlines the purpose of the City’s preliminary study.
Introduction:

Uranium is a radioactive material that naturally exists in soil, rock and water. Uranium oxide is the predominant form of uranium found in nature. Uranium decays very slowly and has a half life of billions of years\(^2\). There are two primary methods for mining uranium – conventional (open pit and underground) and unconventional (e.g., in-situ leaching). In open pit and underground mining, ore in solid form is removed from the ground and processed at a mill to extract the uranium. In-situ recovery involves leaving the ore where it is in the ground, and recovering the minerals from it by dissolving them and pumping the solution to the surface where uranium can be recovered. Consequently, there is little surface disturbance and no tailings or waste rock generated.

Because uranium ore in the United States is generally found at relatively low concentrations (0.05 to 0.3 percent)\(^3\), uranium mining is very volume-intensive when open pit and underground mining methods are used. Mined uranium ore is normally processed by first grinding it to a small, uniform particle size (this is called the milling process) and then treating it with chemical solutions to extract the uranium.

Tailings, the wastes from the milling (and extraction) processes, are stored in specially designed waste disposal facilities. Because the uranium content in the ore is very low, the majority of the ore extracted from the mine ends up as tailings. For example, to extract 1 pound of uranium, 1,000 pounds of uranium ore would be required (assuming 0.1 percent uranium concentration). The remaining 999 pounds of the material would be waste.

Uranium is used primarily for nuclear power. In the early 1980s, the price of uranium in the United States fell due to a reduced demand for nuclear power plants and the importing of uranium from other countries\(^4\). As a result, uranium mining operations were shut down or scaled back. However, U.S. uranium mining has revived since 2001 due to higher uranium prices.

Although most of the uranium was historically mined in the western part of the United States (such as Colorado, Utah, Wyoming, New Mexico, and Arizona)\(^5\), a large uranium reserve, estimated to be over 100 million pounds, was discovered in the Coles Hill site in Pittsylvania County, Virginia, about three decades ago. This reserve is large enough to supply the fuel to all nuclear reactors in the United States for two years\(^6\).

**Location of the Uranium Reserves in Pittsylvania County:**

The Coles Hill uranium reserves are situated in Pittsylvania County, in the Piedmont physiographic area of south-central Virginia (see map in Figure 2). The property is located northeast of the town of Chatham, Virginia and about 88 miles northwest of the Raleigh-Durham area of North Carolina.
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The Coles Hill area drains into Mill Creek. Approximately 1.4 miles east of Coles Hill, Mill Creek flows into Whitehorn Creek, which joins the Banister River soon afterward. The Banister River joins the Dan River and flows into John H. Kerr (Kerr) Reservoir, approximately 40 miles southeast of the Coles Hill area. The stream network in the project area is provided in Figure 3.

![Figure 2. Location of the Proposed Uranium Mining Site](image)

Kerr Reservoir was built by the U.S. Army Corps of Engineers primarily for flood control and hydropower generation. It has a 50,000-acre surface area and provides a variety of recreational amenities. Kerr Reservoir is located immediately upstream of Lake Gaston, which is approximately 35 miles long and covers over 20,000 acres. Kerr Reservoir provides 93 percent of Lake Gaston’s average inflow. Lake Gaston is a significant source for drinking water for the City of Virginia Beach and the Southside Hampton Roads area.

In January 1998, the City of Virginia Beach completed the Lake Gaston Water Supply Project. This project consists of an intake and pump station on the Pea Hill Creek tributary of Lake Gaston and 76 miles of 60-inch diameter pipe that can transfer water at a maximum rate of 60 million gallons per day from the lake to southeast Virginia for treatment and distribution to consumers in Norfolk, Chesapeake, and Virginia Beach.
Extreme Precipitation and Flooding Events in Virginia:

Virginia has a diverse climate. It is influenced by the Gulf Stream, the Appalachian and Blue Ridge Mountains, and a complex pattern of rivers and streams. Annual rainfall totals can reach over 60 inches in southwestern Virginia.

Climate and landscape features in Virginia produce much greater precipitation than the western part of the United States. For example, as shown in Figure 4, the average annual precipitation in the western part of the United States ranges from 5 to 15 inches (except along the Pacific coast and at higher elevations in Montana, Idaho, Wyoming, Utah and Colorado), as compared to an average annual precipitation of 30 to 80 inches in the eastern States. In addition, Figure 4 shows that an average annual rainfall depth of 40-inches would potentially be exceeded at a small fraction of all uranium locations in the western U.S., whereas in the eastern States all mining sites would likely receive this amount of precipitation.

Virginia’s climate differs dramatically from that of the western United States, where the majority of the nation’s uranium mines are located, as shown in Figure 5 (locations of uranium produced at phosphate mines are excluded). Figure 5 presents a compilation of data from rainfall atlases of the National Weather Service for rainfall depths over a 24-hour period with a
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1-percent chance of being exceeded in any given year. In general, the rainfall data are based on stations with more than 30 years of record.

Figure 4. Annual Average Precipitation in the U.S. [Linacre E., and Geerts, B. (1998)]

Maximum Precipitation in Virginia:

As a consequence of the topographic relief provided by the Blue Ridge Mountains and the subtropical moisture provided by the Gulf of Mexico and the Atlantic Ocean, the Piedmont region in Virginia just east of the Blue Ridge Mountains is subject to significant rainfall events. Additionally, this area experiences occasional tropical storms and hurricanes. Some of these have resulted in extreme flood events in the area. For example, in August 1969, the area near Tyro, located about 60 miles from the Pittsylvania uranium deposits, received up to 27 inches of rainfall during an 8-hour period as a result of Hurricane Camille9,10. Unofficial reports have indicated that the actual rainfall depth may have reached 31 inches or possibly higher11.

In Madison County on June 27, 1995, another extreme rainfall event occurred when a cold front stalled east of the Blue Ridge Mountains as a moist southerly tropical air mass met a
northerly polar air mass. As a result, very strong rainstorms generated up to 30 inches of rainfall in 14 hours or less near Graves Mill.\(^\text{12,13}\)

![Figure 5. Historic Rainfall Data (plotted as 1-percent, 24-hour rainfall frequency) versus Uranium Mining Locations\(^\text{8}\)](image)

These rainfall events in Nelson and Madison counties were very severe with approximately 27 inches of rainfall occurring over a 10-square-mile area. The events produced approximately 82 percent of the Probable Maximum Precipitation (PMP) of 33 inches for 12-hour duration over 10- square miles.\(^\text{14}\) A PMP is defined by the American Meteorological Society as the theoretically greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of the year. Figure 6 shows the proximity of Madison and Nelson counties to Pittsylvania County.

In fact, a string of at least 8 near-PMP storms have been recorded bordering the east side of the Blue Ridge Mountains from North Carolina to Maine (see Figure 8 for locations of near-PMP events)\(^\text{15}\). The Coles Hill uranium deposits in Pittsylvania County are also located on the eastern boundary of the Blue Ridge Mountains.

**Extreme Flooding in Virginia:**

Extreme flood events are defined by the United States Geological Survey (USGS) as flows of 100 to 300 cubic feet per second (cfs) per square mile for small watersheds (30 to 1,000 square miles) and 50 to 100 cfs per square mile for large watersheds (1,000 to 3,000 square miles). The USGS has collected stream flow data at 23,000 gages across the country; the locations of these gages are shown in Figure 7.
For the contiguous 48-States, other than those on the west coast, extreme flooding occurs mostly in the southeast quadrant (south of the 40th parallel and east of the 100th meridian), as illustrated in Figure 8. Moisture for the precipitation that fuels these events is provided by the warm waters of the Gulf of Mexico and the Atlantic Ocean. One area of intense flooding includes the central Midwest and the lower Mississippi Valley, which includes eastern Kansas; Oklahoma; eastern Texas; Missouri; Arkansas; Louisiana; Mississippi; and western Tennessee and Alabama.

Another area prone to extreme flooding events is the eastern ridge of the Appalachian/Blue Ridge Mountain chain from Georgia to Massachusetts, including a distinct concentration of flooding events in Virginia. The USGS determined that these regions are prone to extreme flooding because the topography provided by mountain ranges and escarpments can rapidly lift moisture-laden air into the cooler upper atmosphere.
Figure 7. USGS Gaging Stations on Streams and Rivers throughout the U.S. and Puerto Rico

Figure 8. USGS Gages Where Largest Peak Discharges Exceeded Extreme Flood Criteria and Locations of Gages that Recorded Near-PMP Events
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The average stream flow for watersheds in Virginia and adjacent States is approximately 1.0 cfs per square mile. Figure 8 shows the locations where recorded stream flows were 50 to 300 times greater than the average normalized stream flow in Virginia. A flood frequency analysis of the seven USGS gages within the Coles Hill area (with a minimum of 30 years of record) revealed that flows defined by the USGS as extreme flooding events correspond to flows that would be expected to have a return frequency that ranges from 1- to 0.2-percent chance of being exceeded in a given year, depending on location.

Landslide Potential:

In addition to extreme flooding events, southwestern Virginia also has the potential for landslides and debris flows. Susceptibility to landslides is defined by the USGS as the probable degree of response of areal rocks and soils to cutting, loading of slopes, or high precipitation. The landslide incidence and susceptibility for the eastern part of the United States is shown in Figure 9\textsuperscript{17}. As illustrated, the area where former uranium mining leases are located (which include the Coles Hill uranium reserves) is classified by the U.S. Geological Survey as “High Incidence” or “High Incidence and moderate susceptibility” for landslides. Although the landslide map is highly generalized and may not represent actual local conditions\textsuperscript{18}, changes in existing conditions and extreme precipitation in the vicinity of uranium reserves in Virginia could cause landslides.

Need to Evaluate Potential Impacts of Uranium Mine Tailings on Drinking Water Supply:

Hazards of Uranium Tailings:

Uranium ore, waste, and tailings contain a mixture of materials that have the potential to adversely impact human health and the environment. Mining and milling remove potentially hazardous constituents in the ore from relatively stable underground locations and convert them to fine particles and sludge, which become more susceptible to spreading throughout the environment.

Uranium is both radioactive and a chemical toxin. As long as it remains outside of the body, uranium poses little health hazard. Exposure to high levels of uranium can cause kidney disease. It is not known to cause cancer, but can decay into other radioactive materials that may\textsuperscript{19}. Radium, a decay product of uranium, is dangerous when ingested and may increase the risks for bone, liver and breast cancer\textsuperscript{20}. 
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The uranium tailings contain constituents similar to the ore. Due to limitations in uranium extraction technology, not all of the uranium in the ore can be extracted. Therefore, the tailings also contain 5 to 10 percent of the uranium initially present in the ore\(^1\). In addition, the sludge contains heavy metals, such as arsenic, as well as chemical reagents used during the milling process. Uranium mill tailings also contain nearly all of the decay products of uranium including radium, which decays to produce radon gas\(^2\). Uranium mill tailings retain 85 percent of the radioactivity of the ore\(^1\).

When people breathe air containing radon, it increases their risk of developing lung cancer. Radon gas can diffuse from the containment areas into the atmosphere, where it can be inhaled, and small particles can be blown from the piles to locations where they can be inhaled or ingested. The dispersal of tailings by wind, water, or leaching can carry radioactive and other toxic materials to surface or ground water that may be used for drinking water\(^2\).
Potential for Failure of Containment Structures and Downstream Contamination of Rivers and Reservoirs:

Open pit and underground uranium mining techniques produce large amounts of solid waste. For example, for ore with a uranium concentration of 0.1 percent, 99.9 percent of the ore is left over as sludge mixed with the chemical agents used to extract the uranium. The leftover sludge (tailings) is typically stored in containment impoundments designed for the proper handling of the waste. The volume of the tailings produced by a mine throughout its operational life can be significant. Using the Coles Hill reserves as an example, if 100 million pounds of uranium were mined (assuming a 0.1-percent concentration of uranium in the ore), the combined tailings would require the storage volume of an area approximately 1 mile long, 1 mile wide, and 30 feet deep (excluding necessary containment cell structures).

Historically, a number of tailings containment structures have failed in the United States and elsewhere, resulting in the release of dissolved and particulate radioactive materials to downstream surface waters\(^{23}\). Containment structure failures continued to happen through 2009. Although there were a variety of reasons for these failures, such as seepage, structural defects, earthquakes, and foundation settlement, most of the failures world-wide were caused by heavy rain, which caused contamination downstream and human fatalities.

Based on climatic and geologic conditions surrounding the uranium reserves in the Lake Gaston watershed, the City of Virginia Beach is concerned that mining operations and uranium ore tailings could result in the contamination of Lake Gaston, a critical water supply source to the Southside Hampton Roads area (see Figure 1 for proximity of the proposed uranium mine and downstream drinking water sources).

In an effort to address this concern, the City of Virginia Beach Department of Public Utilities has initiated a preliminary study of the potential for uranium mining to degrade the water quality of the Lake Gaston water supply. The preliminary study will determine the potential for radioactive sediments to reach Kerr Reservoir if a containment failure were to occur.
REFERENCES:

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