Site Characterization and Remedial Design for Surface Impoundments Containing Technologically Enhanced, Naturally Occurring Radioactive Material (TENORM)

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Background/Objectives. Aluminum sulfate (alum) was historically produced by processing bauxite ore. Bauxite is considered naturally occurring radioactive materials (NORM) and typically contains radionuclides in the uranium-238 and thorium-232 decay chains. The manufacturing process generated “alum process residuals” (APR) that consist of a dry, light grey, inorganic silt-sized material, with the consistency of sludge. The alum production process tends to concentrate the radionuclides in the APR, which meets the definition of technologically enhanced NORM (TENORM) as defined by the Health Physics Society (2009). A chemical company produced alum over a period of more than 50 years at facility in Washington State. The facility included an unlined, uncovered surface impoundment covering approximately 6.1 acres. The impoundment, which is up to 19 feet deep, contains approximately 130,000 cubic yards of APR. The site owner was interested in in-place closure of the APR impoundment by placing an engineered protective cap over the APR to isolate it from future potential direct contact with human or ecological receptors and comply with regulatory standards.

Approach/Activities. A radiological site characterization was conducted to assess the concentrations of radionuclides in the APR and underlying native soil, and to support the results of long-term groundwater monitoring from perimeter wells. Sixteen borings were advanced through the APR and into the underlying native soil. APR and soil samples were analyzed for uranium-238 and thorium-232 decay chain isotopes. To support the APR cap design, modeling using the radiochemistry data and other available site characteristics was performed, using the RESidual RADioactivity (RESRAD) model version 7.2, developed at the Argonne National Laboratory for the United States Department of Energy (DOE 2001). The RESRAD model calculates the annual radiation dose from residual radionuclides over a specified time period (default duration is 1,000 years). The general annual radiation dose limit received by a member of the general public from residual radioactive material is 25 mrem per year. The results of the modeling were used to estimate the minimum required thickness of a soil cap over a range of conditions.

Results/Lessons Learned. Our experience at similar sites has shown that APR tightly binds radionuclides and an aggressive sample preparation method is required to fully extract the radionuclides of concern (ROCs) from the sample matrix. Accordingly, standard laboratory practices of ball-milling the samples to a fine powder followed by acid extraction do not adequately extract the ROCs and can bias results low by a factor of 10 when analyzed using standard methods for the analysis of radionuclides. Instead, the samples were prepared using a persulfate fusion process. The individual ROC concentrations detected in APR samples ranged over one order of magnitude, up to approximately 70 to 80 picocuries per gram (pCi/g). Concentrations in local background soil were typically lower by an order of magnitude and nearly identical to the concentration in soil immediately beneath the APR, confirming that the ROCs in the APR are relatively immobile. RESRAD model outputs indicated that a 2-foot-thick clay soil cap would adequately reduce the radiation dose to achieve the 25-mrem-per-year standard, and would be effective for 1,000 years. The capping option is preferred because it offers enormous cost savings relative to excavation and offsite disposal of APR.