Fissile Mass and Concentration Limits on Criticality in the Engineered and Geologic Barrier for a Repository in Salt or Argillite/Clay

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Abstract

As with other nuclear facilities, the possibility of sufficient fissile mass and concentration causing a self-sustained neutron chain reaction (critical event or "criticality") is of potential interest in a repository for radioactive waste disposal. The focus here is on the rationale used after repository closure, when humans are no longer present. This paper describes the fissile mass and concentration necessary for a critical event to occur outside a package containing commercial or defense-related spent nuclear fuel or transuranic waste disposed in a generic salt or argillite/clay repository. The criticality limits are based on modeling mixtures of water, salt, argillite, rust, and fissile material using neutron/photon transport computational codes. Several idealized depositional configurations of fissile material in the host rock are analyzed: homogeneous spheres and heterogeneous arrangements of plate fractures in regular arrays. Generally, deposition of large masses and concentrations are required for criticality to occur in the configurations analyzed, especially, for fissile material low in ^{235}U enrichment derived from commercial spent nuclear fuel. Homogeneous mixtures are usually more reactive for fissile material at high enrichments. Conversely, heterogeneous configurations are often more reactive at low enrichments. However, unlike engineered systems, heterogeneous configurations are not always more reactive at low enrichments because the relationship between the porosity of the fractures and matrix also strongly influences the results. The neutronic limits developed here are used in combination with geochemical constraints on fissile deposition in the engineered or natural geologic barrier to show that a critical event is not credible outside the container.

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