QA:NIA
DT# 43676
CB 4/20/2005

MOL.20050718.0099

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Spent Nuclear Fuel: Research Needs

R.C. EWING[1]

[1]University of Michigan, Dept. of Geological Sciences and Dept. of Nuclear Engineering & Radiological Sciences, Ann Arbor, MI, USA, rodewing@umich.edu

In 2005, the global inventory of spent nuclear fuel (SNF) is approximately 175,000 metric tonnes (slightly less than one third is in the USA) (Ewing, 2004). Most of this SNF is still at 236 nuclear power stations where it was originally generated in 36 different countries. In the USA, the inventory in 2010 will be 61,800 metric tonnes of heavy metal (tHM) with a total activity of 32.6 GCi. The USA presently has an open nuclear fuel cycle (without reprocessing) with ultimate disposal at the proposed geologic repository at Yucca Mountain. The SNF represents >95% of the radioactivity. Thus, a major challenge of successful geologic disposal of radioactive waste is to understand the long-term behavior of SNF.

SNF is essentially UO_2 with minor impurities, mainly the fission product (3%) and transuranium elements (1%). The precise radionuclide inventory and physical state of the fuel depend on its irradiation and thermal history. Three critical parameters change dramatically during the first 10,000 years in the repository: 1.) the thermal output will decrease to < 0.1%; 2.) the radioactivity will decrease to < 0.01%; 3.) the inventory of radiotoxic nuclides will change. Beyond 10,000 years radionuclides of major importance under oxidizing conditions include: ^{239}Pu, ^{237}Np, ^{129}I and ^{99}Tc. Less problematic elements include: ^{241}Am, ^{79}Se and ^{36}Cl. These elements exist in a variety of chemical forms: incorporated into the UO_2 structure, as separate phases in inclusions and at grain boundaries. Corrosion under oxidizing conditions leads to the formation of a variety of U(VI)-phases. An understanding of their long-term behavior requires an improved knowledge of their structures, thermochemical parameters, solubilities, substituion mechanisms for trace radionuclides, surface properties and the kinetics of dissolution/precipitation reactions. Natural uranium deposits, such as the Oklo natural reactors, also provide important data. This paper reviews recent research on these topics, and its relation to the properties of SNF.

References

Ewing, R.C. (2004) Environmental impact of the nuclear fuel cycle. In *Energy, Waste, and the Envirohnment: A Geochemical Perspective*, Geological Society, London, Special Publications, 236, 7-23.