Lifetime Predictions of Toxic and Radioactive Waste Disposal and Remediation Schemes

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Over the past few centuries, technological and societal advances have resulted in explosive growth of a human population with increasing material appetites, creating a world in which resources are clearly limited, energy and materials utilization have global environmental and political impacts, and geohazards (earthquakes, volcanic eruptions, tsunamis, landslides, etc.) affect ever-growing numbers of people. One of the Grand Challenges for geochemists in the 21st Century will be to contribute to the transformation of geoscience from a largely observational and explanatory science, into a science that is capable of making reliable predictions at levels of accuracy and over time scales that are useful in formulating public policy and even personal decisions, such as where to live, how to avoid calamity, and how to accommodate the limitations of a finite Earth. Designing safe disposal and remediation strategies for wastes from mining and energy production is clearly an arena in which geochemical experiments, theories and models will play a pivotal role.

Toward that end, the authors organized what turned out to be a highly successful and well-attended symposium, with the same title as this article, at this year's 15th V.M. Goldschmidt Conference, May 20-25, in Moscow, Idaho (GCA, v.69, no.10S, p. A408-430, 2005). Forty six presenters from countries throughout the world participated in the two-day event, which featured three keynote and sixteen invited talks and posters, including six student presentations. Participation was greatly aided by the generous sponsorship of: the U.S. Department of Energy's Office of Civilian Radioactive Waste Management - Science, Technology and International (OST&I) program; The Electric Power Research Institute's High Level Waste Repository Issue Resolution program; and UT-Battelle, LLC. Their sponsorship also subsidized a pre-conference field trip (Figures 1-6) to the Yucca Mountain High Level Nuclear Waste Repository Site (May 18,19, 2005), lead by Wesolowski, Zhongbo Yu (University of Nevada, Las Vegas), Abe Van Luik (U.S. DOE) and John Stuckless (U.S. Geological Survey).

Nuclear power production epitomizes the need for predictive geoscience (Ewing, 2004). Current global carbon emissions of ~7 Gt/y, largely from fossil fuel consumption, are expected to grow and result in a variety of global effects, including acid rain, toxic smog, and *hypothetically,* sea level rise and increased frequency and severity of adverse weather conditions. One of the most reliable and sufficiently large alternative sources of energy is nuclear power, which currently provides about 17% of the world's electricity, equivalent to a reduction in carbon emissions of ~0.5 Gt/y. The U.S. currently consumes ~40% of the world's fossil fuel production, but generates only about 20% of its own electricity from nuclear plants. Many view the lack of a licensed repository for spent nuclear fuel as an impediment to increased power production form this source in the U.S., and Yucca Mountain is the only site being considered at this time.

The licensing issue hinges on DOE’s ability to present a credible case before the Nuclear Regulatory Commission that releases of radionuclides from the repository will not pose a threat to the accessible environment. This case is being built by using a performance assessment model that incorporates a thermochemical reaction-transport code (EQ3/6) containing experimental and theoretical developments in aqueous geochemistry and fluid rock interactions, hydrogeological models that combine both the chemical and physical aspects of fluid and heat transport through porous and fractured media, geohazard and climate change models, and information gleaned from natural analogs. The previous regulatory period of 10,000 years was set aside by a federal court in July 2004, and the EPA must now establish a revised standard, including a regulatory period that, if it were to follow the recommendation of the National Academy of Sciences, could extend out to “peak dose”, which might be several hundred-thousand years in the future.

Yucca Mountain has a statutory capacity that only marginally exceeds the current U.S. inventory of commercial spent fuel, stored on site at power plants throughout the country. Some analysts suggest that, in order to have a significant impact on global carbon emissions, worldwide nuclear and other carbon-neutral energy sources would have to increase tenfold by 2050. If this increase came entirely from electrical power plants using the once-through nuclear fuel cycle, about 3,500 new 1-GW plants would be needed, which would generate enough spent fuel to fill a Yucca Mountain-sized repository every year. Though this extreme scenario is not likely to unfold, it seems inevitable that we need to further develop this source of energy. However, the public must be assured that the operation of new nuclear power plants and the management of the wastes generated from their operation can be made acceptably safe.

The Yucca Mountain field trip provided an excellent opportunity for a diverse cross section of engineers and geoscientists to gain a clearer perspective on the nature of issues related to this particular type of repository. The Goldschmidt symposium not only brought together a similarly broad cross section of scientists and engineers, but provided a forum for comparing and contrasting different repository designs being considered throughout the world, different methods of assessing their performance characteristics, and the surprisingly broad array of geochemical inputs needed in order to succeed in this Grand Challenge.

Reference Cited:

R.C. Ewing, Environmental Impact of the Nuclear Fuel Cycle”, in (R. Giere and P. Stille, Eds.) *Energy, Waste and the Environment: a Geochemical Perspective,* The Geological Society of London, London, pp. 7-23 (2004).