Radiation degrades nuclear waste-containing materials faster than expected

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Minerals intended to entrap nuclear waste for hundreds of thousands of years may be susceptible to structural breakdown within 1,400 years, a team from the University of Cambridge and the Pacific Northwest National Laboratory reported this week in the journal *Nature*.

The new study used nuclear magnetic resonance, or NMR, to show that the effects of radiation from plutonium incorporated into the mineral zircon rapidly degrades the mineral's crystal structure.

This could lead to swelling, loss of physical strength and possible cracking of the mineral as soon as 210 years, well before the radioactivity had decayed to safe levels, said lead author and Cambridge earth scientist Ian Farnan.

According to current thinking, highly radioactive substances could be rendered less mobile by combining them, before disposal, with glass or with a synthetic mineral at a very high temperature to form a crystal.

However, the crystal structure can only hold the radioactive elements for so long. Inside the crystal radioactive decay occurs, and tiny atomic fragments called alpha particles shoot away from the decaying nucleus, which recoils like a rifle, with both types repeatedly blasting the structure until it breaks down.

This may increase the likelihood for radioactive materials to leak, although co-author William J. Weber, a fellow at the Department of

Energy national laboratory in Richland, Wash., who made the samples used in the study, cautioned that this work did not address leakage, and researchers detected no cracking. Weber noted that the "amorphous," or structurally degraded, natural radiation-containing zircon can remain intact for millions of years and is one of the most durable materials on earth.

Some earth and materials scientists believe it is possible to create a structure that rebuilds itself after these "alpha events" so that it can contain the radioactive elements for much longer. The tests developed by the Cambridge and PNNL team would enable scientists to screen different mineral and synthetic forms for durability.

As well as making the storage of the waste safer, new storage methods guided by the NMR technique could offer significant savings for nations facing disposal of large amounts of radioactive material. Countries including the United States, Britain, France, Germany and Japan are all considering burying their nuclear waste stockpiles hundreds of meters beneath the earth's surface. Doing so necessitates selection of a site with sufficiently stringent geological features to withstand any potential leakage at a cost of billions of dollars. For example, there is an ongoing debate over the safety of the Yucca Mountain site in Nevada. A figure published in Science in 2005 put that project's cost at $57 billion.

"By working harder on the waste form before you started trying to engineer the repository or choose the site, you could make billions of dollars worth of savings and improve the overall safety," Farnan said.

"At the moment, we have very few methods of understanding how materials behave over the extremely long timescales we are talking about. Our new research is a step towards that.

"We would suggest that substantive efforts should be made to produce a waste form which is tougher and has a durability we are confident of, in a quantitative sense, before it is stored underground, and before anyone tried to engineer around it. This would have substantial benefits, particularly from a financial point of view."

PNNL senior scientist and nuclear magnetic resonance expert Herman Cho, who co-wrote the report, said: "When the samples were made in the 1980s, NMR was not in the thinking. NMR has enabled us to quantify and look at changes in the crystal structure as the radiation damage progresses.

"This method adds a valuable new perspective to research on radioactive waste forms. It has also raised the question: 'How adequate is our understanding of the long-term behavior of these materials?' Studies of other waste forms, such as glass, could benefit from this technique."

Source: Pacific Northwest National Laboratory

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