NUCLEAR WASTE MANAGEMENT ORGANIZATION

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4-3 NATURAL AND ANTHROPOGENIC ANALOGUES – INSIGHTS FOR MANAGEMENT OF SPENT FUEL

EXECUTIVE SUMMARY

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Canada has from the beginning of commercial power production in the early 1970s up until the end of 2002 produced just over 30,000 tonnes of spent fuel expressed as the uranium content. This spent fuel is now being stored at reactor sites with approximately 26,000 tonnes of uranium in wet storage and 4,000 tonnes in dry storage. With continued nuclear power production this inventory will continue to build in the future. The relatively small quantity of spent fuel that is produced from nuclear power generation means that adequate storage space at Canadian reactor sites could likely be made available to safely store spent fuel for decades to come.

Even though spent fuel from CANDU reactors contains considerable residual fuel value that could be recovered by reprocessing or reconditioning the fuel, this option is not currently being considered by Canada for a number of economic and political reasons. Accordingly, at this point in time, spent fuel from Canada's CANDU reactors is considered as a "waste" material that requires long-term management. The Canadian NWMO has been given the task of evaluating and consulting with the Canadian public on the options that are available for the long-term management of these "waste" materials. Generically these options entail either long-term storage near or at surface or deep geologic disposal. With the first option, monitoring, surveillance and recovery would be relatively simple, initial capital costs would be low but maintenance and surveillance costs would be high. In the second generic option, recovery would be difficult and capital costs high but ongoing surveillance and operational costs relatively low. A hybrid of these could also exist wherein the spent fuel could be "stored" for an indefinite time within a deep geological repository type of environment. This option would involve the highest level of all costs but also keep both disposal and recovery options open. The long-term management of spent nuclear fuel presents the same types of generic issues that society has been dealing with in the management of other types of hazardous waste. The general principles for management of hazardous wastes involve first trying to treat the waste so as to detoxify it. If this is not possible then the waste may be "treated and contained" such that it is prevented from entering the environment at concentrations that may be detrimental.

Strategies being developed globally for the long-term management of spent nuclear fuel recognize the fact that spent nuclear fuel becomes less dangerous with time as a consequence of the radioactive decay of its constituent elements. The first step in management of spent fuel is to contain it in underwater storage where, in the first ten years, approximately 99.9% of the radioactivity in the spent fuel removed from Canadian (CANDU) power reactors decays. At this point, a couple of management options are available.

- The spent fuel may be reprocessed during which the highly radioactive elements are separated from the less radioactive uranium. The less radioactive materials will then have to be managed for the long term and the uranium and other fissile materials recycled back into new fuel.

- The spent fuel for economic and/or social and political reasons is not reprocessed. This is the current situation for spent fuel from Canadian nuclear reactors.

If a decision is made not to reprocess the spent fuel management this initial wet storage period is followed by decades of dry storage where a further 90% of the radioactivity decays. Following the first 100 years after removal from the reactor in which 99.99% of the radioactivity has decayed, decay continues at a slower rate, such that the spent fuel will have decayed after a period of approximately 100,000 years to a radioactivity level (expressed as Bq/g of fuel) that is approaching that in natural uranium minerals such as uraninite (expressed as Bq/g) which were extracted from the earth and from which the fuel was fabricated in the first place. Once the radioactivity has decayed to this level, the remaining radioactivity of the spent fuel changes little over geological time, supported by the decay of the natural uranium, which constitutes over 98% the mass of the spent fuel. This suggests that any long-term management strategy should involve an initial period of secure containment of the order of tens of thousands of years and a longer term phase lasting over geological time (hundreds of thousands to millions of years) where the residual natural uranium constituents of the spent fuel will eventually be allowed to reintegrate back into natural global geochemical cycles.

Because of the long management time frames involved in the management of spent reactor fuels and the lack of any "engineering" precedence for the behaviour of containment systems designed to last over many thousands of years the argument is sometimes raised that the behaviour of spent fuel management systems cannot be reliably predicted. One can, however, look to natural and anthropogenic (man made) analogues to provide insight into how spent fuel waste management systems and their component parts may behave over these long time periods. In the natural and archaeological environments, there are analogues for spent fuel as it comes from the reactor as well as for spent fuel after it has decayed to activity levels found in natural uranium minerals. There are also analogues for the materials that may be used in engineered containment systems, such as cement, iron, copper and the clays proposed to contain spent fuel on surface or seal a deep geological disposal site. Analogues are also present that can provide insights into how various radionuclides behave as they cycle through the natural environment.

This paper provides a short discussion of a number of natural and archaeological analogues that can assist in understanding many of the issues associated with the long-term management of spent fuel. Analogues in the sense that they are used in this discussion paper do not "prove" that any particular concept is safe, but they can provide insights and serve to "bound" issues that may be of concern in carrying out safety assessments. In a similar manner, the fact that spent fuel after a period of time has the same total radioactivity as the original uranium minerals from which it was made does not mean that a deep geological repository will behave exactly the same as a natural uranium ore body.

Despite their limitations, analogues are useful, in that they can provide valuable insights and can serve to “bound” certain issues and concepts to be addressed in the management of spent fuel. In this context, analogues have been studied as a part of the nuclear waste management programs in many countries around the world.