A Fresh Look at Greater Confinement Boreholes for Greater-Than-Class C Low-Level Radioactive Waste Disposal

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ABSTRACT

The United States Federal government has responsibility for disposal of low-level radioactive waste (LLW) with concentrations of radionuclides that exceed limits established by the United States Nuclear Regulatory Commission (NRC) for Class C LLW. Since Greater-Than-Class-C (GTCC) LLW is from activities licensed by NRC or NRC Agreement States, a disposal facility by law must be licensed by NRC. The United States (U.S.) Department of Energy (DOE) has the responsibility to site, design, construct, operate, decommission, and provide long-term care for GTCC LLW disposal facilities. On May 11, 2005, DOE issued an advance notice of intent to begin preparation of an Environmental Impact Statement (EIS) for GTCC LLW disposal. Since the initiation of the EIS, analysis has focused on compiling the inventory of commercial GTCC LLW and DOE GTCC-like wastes, reviewing disposal technologies, and other preliminary studies. One of the promising disposal technologies being considered is intermediate depth greater confinement boreholes. Greater confinement boreholes have been used effectively to safely dispose of long-lived radioactive waste at the Nevada Test Site (NTS). The DOE took a fresh look at global experiences with the use of greater confinement borehole disposal, including current considerations being given for future applications in the U.S., and concluded that the U.S. is positioned to benefit from international collaboration on borehole disposal technology, and could ultimately become a pilot project, if the technology is selected.

INTRODUCTION

The Low-Level Radioactive Waste Policy Amendments Act of 1985 (LLRWPAA), 42 United States Code [USC] 2021, as amended, assigned the U.S. Federal Government the responsibility for disposing of GTCC LLW generated by activities licensed by NRC or Agreement States. GTCC LLW is LLW generated by activities licensed by the NRC or NRC Agreement States that exceeds the maximum concentration limits of radionuclides established by NRC for Class

[1] Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. (SAND2006-5095A

C LLW. GTCC LLW is the most "difficult" class of LLW to manage in the U.S. and there has never been a licensed disposal facility for GTCC LLW.

As part of the responsibilities assigned to the DOE in the LLRWPAA, DOE has begun the EIS process for development of a disposal capability for GTCC LLW. Until recently, there has been very little progress in implementing this responsibility. However, national security concerns over the potential for disused radioactive sealed sources (a subset of GTCC LLW) to be used for malevolent purposes have renewed focus on GTCC disposal [1]. DOE's Office of Disposal Operations is responsible for leading the EIS, with technical analysis provided by Sandia National Laboratories and National Environmental Policy Act (NEPA) analysis provided by Argonne National Laboratory.

On May 11, 2005, DOE issued an advance notice of intent to begin preparation of an EIS for GTCC LLW disposal. In addition to seeking early comments from interested parties, DOE announced that some DOE GTCC-like waste that does not currently have a disposition path may be included in the EIS. Since the initiation of the EIS, the analysis has focused on compiling an inventory of commercial GTCC LLW and DOE GTCC-like wastes, reviewing disposal technologies, and other preliminary studies. In July 2005, DOE sought expressions of interest from the commercial sector and received feedback from several entities. In August 2006, DOE issued a report to Congress on the estimated cost and proposed schedule to complete an EIS and record of decision for the disposal of GTCC LLW.

TYPES AND QUANTITIES OF GTCC LLW AND DOE GTCC-LIKE WASTE

NRC classifies LLW in three categories based on the presence and specific activity of particular long- and short-lived radionuclides. These categories of LLW, referred to as Class A, Class B, and Class C LLW are defined in Title 10, Code of Federal Regulations, Part 61.55 (10 CFR 61.55). Tables 1 and 2 from 10 CFR 61.55 are used to determine waste categories. Waste that is referred to as "Greater-Than-Class-C" LLW exceeds the maximum concentration limits of radionuclides established by NRC for Class C LLW.

For the EIS, GTCC LLW is being divided into three types: sealed sources (includes radioisotope thermoelectric generators [RTGs]), activated metals, and other miscellaneous waste (e.g., contaminated equipment and process waste). A sealed source is radioactive material that is permanently sealed in a small capsule or closely bonded in a solid form. They are commonly used to treat cancer, sterilize medical products, and detect flaws in pipeline welds. Commonly used radionuclides in GTCC sealed sources include: Cs-137, Am-241, and Pu-238. RTGs are devices typically containing very large sealed sources, which use thermocouples to convert heat decay into electricity for use in remote locations. The most commonly used radionuclides in RTGs are Sr-90 and Pu-238.

Activated metals are primarily generated by nuclear reactors during normal operations and become waste during facility decommissioning. The waste consists of components internal to the reactor that have become radioactive from exposure to a neutron flux. The bulk of the total activity in the activated metals initially is from the short-lived radionuclides Co-60 and Fe-55, which do not have Class C LLW limits as defined in 10 CFR 61.55. The high concentrations of

the longer-lived radionuclides, such as Ni-63, Ni-59 and Nb-94, in the activated metals are responsible for the material resulting in GTCC LLW. There are 104 operating commercial nuclear reactors in the U.S. and an additional 28 that have been shut down or have been decommissioned.

Other GTCC waste includes equipment such as decommissioning material and process wastes from industrial research and development firms, fuel fabrication and irradiation research laboratories, research nuclear reactors, and sealed source manufactures. These wastes include both short-lived (e.g., Cs-137) and/or long-lived radionuclides (e.g., Am-241).

DOE GTCC-like waste includes sealed sources, activated metals, and other miscellaneous waste generated by DOE activities that has characteristics similar to GTCC LLW and does not have an identified disposal path. Most of this waste consists of transuranic waste that may have originated from non-defense activities and therefore may not be authorized for disposal at the Waste Isolation Pilot Plant under the Waste Isolation Pilot Plant Land Withdrawal Act of 1992.

DOE expects to complete a final report on the estimated quantity and activity of GTCC LLW and DOE GTCC-like waste in 2006, for the purposes of analysis in the EIS. Based on a draft report, it is estimated that there is approximately 2,200 cubic meters of GTCC LLW with an approximate activity of 10 million TBq (270 million curies). Most of this waste is comprised of activated metals from the decommissioning of commercial reactors, and is not projected to be generated until after the year 2035. The preliminary estimate of current and projected DOE GTCC-like waste through 2035 is on the order of 2,500 cubic meters, with an approximate activity of 7.8 million terabecquerels (TBq) (210 million curies). Simplistically, GTCC LLW occupies low volumes and has high specific activities. To better appreciate the magnitude of the volume of GTCC LLW and GTCC-like waste requiring disposal by 2035, the total volume of GTCC requiring disposal in the next 30 years (~4,700 cubic meters) is less than 10 percent of the volume of LLW disposed of at the DOE/National Nuclear Security Administration's NTS (51,283 cubic meters) in fiscal year 2005. The GTCC LLW and GTCC-like volume and activity estimates are subject to certain technical assumptions and uncertainties, and may be subject to change as DOE finalizes its inventory report.

GREATER THAN CLASS C LOW-LEVEL WASTE DISPOSAL

Under NRC regulations (10 CFR 61), Class A, Class B, and Class C LLW can be disposed of in a near-surface disposal facility licensed by NRC or an Agreement State. The NRC regulations (10 CFR 61.2) define a near-surface disposal facility as "a land disposal facility in which radioactive waste is disposed of in or within the upper 30 meters (98.4 feet) of the earth's surface." The NRC regulations at 10 CFR 61.55(a)(2)(iv) state that GTCC waste is generally not acceptable for near-surface disposal and require that the waste be disposed of in a geologic repository as defined by 10 CFR Part 60 or 63, unless proposals for an alternate method of disposal are approved by NRC. However, the NRC regulations (10 CFR 61.7 (b)(5)) acknowledge that "There may be some instances where waste with concentrations greater than permitted for Class C would be acceptable for near-surface disposal with special processing or design."

Because NRC regulations allow for alternative disposal methods to be considered, DOE is considering a wide range of disposal options during the ongoing EIS process. These options include disposal of GTCC LLW in an enhanced near-surface disposal facility, intermediate depth borehole disposal facility, and a geologic repository facility. Different methods of disposal will be evaluated for each of the different waste types (e.g., activated metals, sealed sources) based on physical, radiological, or other technical considerations. For example, GTCC LLW containing transuranic radionuclides with long-half lives may require greater (longer-term) isolation to protect inadvertent human intruders; whereas GTCC LLW containing short half-lives may require lesser (shorter-term) isolation to protect inadvertent human intruders. DOE may also consider quantities and time periods when wastes would be generated and require disposal.

BOREHOLE TECHNOLOGY AS A DISPOSAL CONCEPT

An Intermediate Depth Borehole Disposal facility (IDBD) would use drilled or augered shafts for placing GTCC LLW at least 30 meters below the land surface, although the actual depth would depend on site conditions. The augered shafts could be on the order of 0.3 to 4 meters in diameter and the waste disposal zone could be tens of meters thick. An engineered barrier could be used to deflect inadvertent drilling into the wastes. Some of the potential advantages of an IDBD facility [2] are:

- Boreholes offer the potential for safe and long term isolation of wastes;
- Augered holes are amenable to intermittent or low-volume operations, such as may be the case with GTCC LLW inventories;
- The drilling technology is globally available;
- Inadvertent human intrusion is unlikely because the depth of burial eliminates all types of inadvertent human intrusion except human intrusion by well-drilling;
- The small “footprint” greatly reduces the probability of inadvertent human intrusion by well-drilling;
- Because of the small footprint, a relatively small intruder barrier can be used to protect a relatively large volume of waste;
- Boreholes are easily co-located with existing or other planned disposal facilities; and
- Boreholes are cost effective means for intermediate-depth disposal.

For protection of the inadvertent human intruder from Class C LLW, the NRC uses a combination of waste disposal limits (10 CFR 61.55) and depth of burial *or* 500-year intruder barriers (10 CFR 61.52(a)(2)). There is no upper limit on the activity of waste that qualifies as GTCC LLW, and the intruder must be protected by intruder barriers and disposal limits per borehole. The NRC defines an intruder barrier as sufficient depth of cover or engineered structures that provide equivalent protection to the inadvertent intruder (10 CFR 61.2). If a case can be made that the IDBD eliminates all inadvertent human intrusion vectors, except accidental drilling and subsequent exposure through exposure to drill cuttings, then perhaps an engineered structure, such as a drilling deflector, may be considered to prevent the inadvertent human intruder from being exposed to wastes buried deeper than 30 meters.

The NRC made the following statements which support the possibility of intermediate-depth borehole disposal of GTCC LLW [3]:

> *If DOE chooses to develop one or more intermediate disposal facilities, the Commission anticipates that the acceptability of the facilities would be evaluated in the light of the particular circumstances, considering for example the existing performance objectives of 10 CFR Part 61 and any generally applicable environmental radiation protection standards that might have been established by the U.S. Environmental Protection Agency. Technical criteria to implement performance objectives and environmental standards would be developed by the Commission after DOE had selected a specific disposal technology and decided to pursue development of an intermediate facility…*
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> *It is the Commission's view that intermediate [depth borehole] disposal facilities may never be available. In this event, a repository would be the only type of facility generally capable of providing safe disposal for GTCC wastes. At the same time, the Commission wishes to avoid foreclosing possible use of intermediate [depth] disposal facilities by the DOE.*

Because of the potential advantages, particularly to small amounts of GTCC LLW, and the possible regulatory acceptance, the IDBD option will be analyzed in the EIS process. The EIS will likely consider an IDBD sited on both an existing Federal site and at a commercial site. Feedback to the request for expressions of interest indicates there is interest in the commercial sector. This raises the possibility that an IDBD could be implemented at a commercial facility. However, it is far too early in the EIS process to know the specific alternatives that will be analyzed and how any specific alternative will fare.

USE OF BOREHOLE TECHNOLOGY FOR DISPOSAL IN THE UNITED STATES

Radioactive waste has been successfully disposed in boreholes by the DOE in the U.S. at the NTS and at the Los Alamos National Laboratory. With wastes being placed as deep as 36 meters below the ground surface, the boreholes in Nevada are comparable to those being considered in the IDBD concept and the experience gained is relevant to the EIS.

The Area 5 Radioactive Waste Management Site at the DOE/National Nuclear Security Administration's NTS includes 13 greater-confinement-disposal (GCD) boreholes [4]. Nine of the boreholes were used for disposal, which began in 1983 and continued until 1989. The boreholes range from 3 to 3.6 meters in diameter, and extend to a depth of 36 meters. The boreholes are unlined, except for the upper 3 meters which are cased with a corrugated steel culvert. Waste packages were placed in the boreholes from the bottom to approximately 21 meters from the surface, and when closed were backfilled with gravelly sand native to the location. Figure 1 presents a cross-section of a GCD borehole as implemented at the NTS. Limited amounts of high-activity LLW and classified transuranic waste were disposed in the facility. Four of the boreholes contain Pu-239-bearing, classified transuranic waste from nuclear-weapons-related events. The non-transuranic waste includes high-specific-activity tritium, sealed sources, and RTGs.

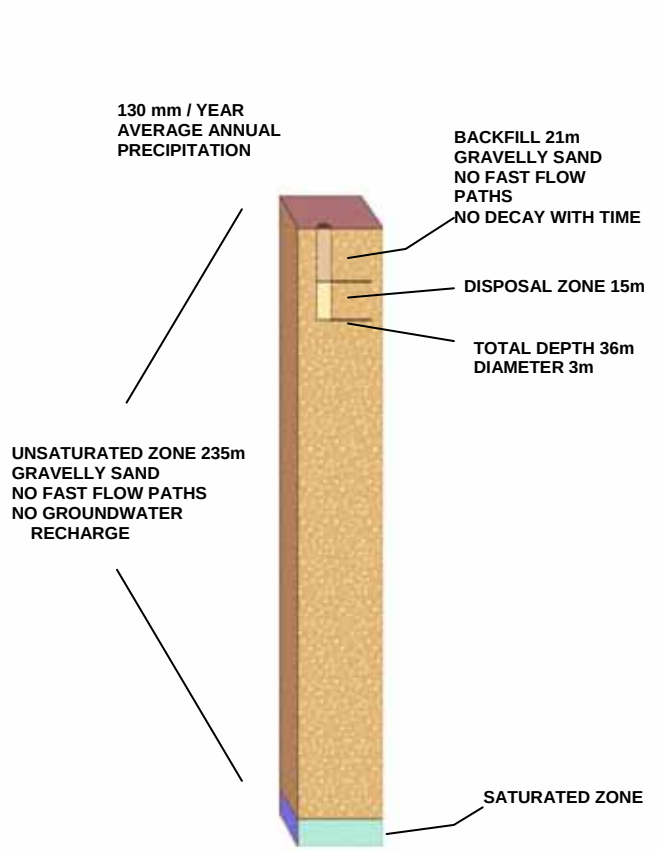

Fig. 1. Cross-section of a GCD Borehole

Because of regulatory concerns expressed by the State of Nevada, the GCD boreholes have not been used for waste disposal since 1989. The NTS facility falls under the self-regulatory authority of DOE as per the Atomic Energy Act of 1954, as amended. DOE commissioned a performance assessment by Sandia National Laboratories of the transuranic waste disposed in this facility. The performance assessment [5] was reviewed and accepted by a Federal Review Group in 2001 as meeting the regulatory standards found in the Environmental Protection Agency (EPA) regulations (40 CFR 191) for disposal of transuranic waste.[6] Therefore, DOE not only has directly relevant operational experience, but also experience in building a safety case using EPA standards for safe disposal of long-lived wastes.

Material Disposal Area G at the DOE/National Nuclear Security Administration's Los Alamos National Laboratory includes over 180 vertical shafts used for disposal of LLW.[7, 8] Disposal of waste began in 1956 and continued until 1987. Shafts are up to 20 meters deep and range in diameter from 0.5 to 5 meters. Shafts are filled with 10 to 12 tiers of tightly packed generally

higher-activity waste and special waste forms that require additional confinement from that provided in disposal pits. Filled shafts were backfilled with crushed tuff rock and plugged with a meter of concrete with the surface shaped to form a dome.

INTERNATIONAL CONSIDERATION OF BOREHOLE DISPOSAL

The United States is one of 42 Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (Joint Convention). In May 2006, the Second Review Meeting of the Parties to the Joint Convention occurred in Vienna, Austria. This meeting culminated a 30-month process, during which each Contracting Party prepared a National Report, reviewed the National Report prepared by the other Contracting Parties, and responded to questions from the other Contracting Parties as a result of their review of the U.S. National Report. The National Reports provide a synopsis of radioactive waste management and represent most of the nations with nuclear power programs in the world today.

These reports reveal that all Contracting Parties are storing some disused sealed sources and/or other radioactive waste. Many of the reports are publicly available on the Internet[2]. One third of the Contracting Parties have no disposal facilities for LLW or disused sealed sources. The use of boreholes for disposal of radioactive waste currently is very limited.

The published National Reports prepared for the Second Review Meeting of the Parties to the Joint Convention reveal some information on borehole disposal. The U.S. National Report describes the GCD facility at NTS, which has not been used since 1989.[9] The Russian Federation and several other nations formerly part of the Soviet Union have “radon”-type near-surface disposal facilities for disused sealed sources with boreholes typically 5 to 6 meters deep. The safety bases for many of these older facilities are being reassessed under modern standards, and several nations consider these near-surface boreholes to be storage rather than disposal facilities.[10] Hungary has a radon type facility with 36 disposal “wells” at a depth of 6 meters at the Püspökszilány repository.[11] The wells are used for interim storage or disposal of spent sealed sources and by-products from Co-60 source production. Germany reported eight containers of sealed sources “intermediately stored” in a borehole within the Morsleben repository (ERAM) prior to 1998, for which a decommissioning application is pending to declare this as disposed.[12] The Mount Walton East Intractable Disposal Facility is a near-surface repository operating in Western Australia, including 40-meter deep boreholes, for chemical and radiological waste disposal. Australia specifically mentions borehole disposal as a disposal option being taken into account in their development of a strategy for radioactive waste management.[13] Although it is evident that most nations are still in the early stages and facing difficult future decisions on new disposal facilities, it is not clear why more nations, particularly those many with small amounts of radioactive waste, are not acknowledging borehole disposal as a potential disposal option. Borehole disposal facilities may offer

[2] Publicly available National Reports prepared for the Second Review Meeting of the Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management are available on the International Atomic Energy Agency Internet web site at: http://www-ns.iaea.org/conventions/waste-jointconvention.htm.

attractive disposal options to many nations, particularly those with limited volumes of waste, e.g., only sealed sources from nuclear applications.

INTERNATIONAL BOREHOLE DISPOSAL PROJECT

The International Atomic Energy Agency (IAEA) is providing ongoing technical assistance to help Member States safely dispose of small quantities of sealed sources.[2] Many African nations could benefit from access to a disposal facility for their disused sealed sources. Working with South Africa, the IAEA is assessing the technical feasibility and economic viability of a disposal system called BOSS (BOrehole disposal of Sealed Sources). The IAEA's BOSS provides both technology and safety assessment support to Member States. The technology design would utilize small-diameter (0.14 to 0.26 meters) boreholes with depths ranging from 30 to 100 meters, coupled with engineered, stainless steel disposal capsules and containers.[14] To provide assistance with the safety assessment portion of the BOSS disposal system, the IAEA is developing a "*Generic Post-Closure Safety Assessment for Borehole Disposal Facilities.*" It is hoped that the Generic Safety Assessment can be used as the vehicle for demonstrating long-term safety, where it is verified that the actual site-specific conditions do not deviate from the envelope of expected conditions simulated in the Generic Safety Assessment. Portions of the technical assistance project were completed and subject to an international peer review in 2005. The outcome was a determination that the concept provides a safe, economic, and practical means of disposal for disused radioactive sealed sources. The IAEA is actively looking for candidate nations to implement the various phases of the concept resulting in completion of a borehole disposal facility. According to IAEA, several nations in Africa, Middle East, South East Asia and Latin America are exploring the possible options for disposal of sealed sources and are investigating the applicability of this approach for their small inventories. The IAEA may consider providing assistance in the future for the implementation of the concept by a Member State or group of Member States.

The U.S. is generally very supportive of IAEA activities, including those relating to waste safety and waste technology. Progress on the BOSS program and on sealed source recovery and disposal is being watched with interest. The IAEA very likely would look favorably on a proposal to implement an intermediate-depth borehole-disposal system in the U.S. for GTCC LLW or other LLW.

CONCLUSION

The DOE has taken steps to formally begin the EIS process leading to selection of an option to dispose of GTCC LLW. Studies are ongoing that will inform the public process that lies ahead. Disposal of GTCC LLW in intermediate-depth boreholes is one of the promising alternatives being considered. The technology has several potential advantages, and the NRC is on record supporting the possibility.

The U.S. has past experience in operating borehole disposal facilities for radioactive waste, and has successfully completed a performance assessment for transuranic waste disposal at one of the facilities against the EPA disposal standard. Notwithstanding, the regulations and process for licensing an IDBD facility have not been fully defined by the NRC.

Several other nations have or are considering borehole disposal facilities. Contracting Parties to the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management have an excellent forum for review of existing and planned disposal facilities and sharing of experience. The IAEA has developed and is very actively seeking Member States to implement their internationally-reviewed BOSS concept.

Because of the above-stated facts, the U.S. is uniquely positioned to benefit from international collaboration on borehole disposal technology.

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