Lessons Learned from Radioactive Waste Storage and Disposal Facilities

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INTRODUCTION

The safety of radioactive waste disposal facilities and the decommissioning of complex sites may be predicated on the performance of engineered and natural barriers. For assessing the safety of a waste disposal facility or a decommissioned site, a performance assessment or similar analysis is often completed. The analysis is typically based on a site conceptual model that is developed from site characterization information, observations, and, in many cases, expert judgment.

Because waste disposal facilities are sited, constructed, monitored, and maintained, a fair amount of data has been generated at a variety of sites in a variety of natural systems. This paper provides select examples of lessons learned from the observations developed from the monitoring of various radioactive waste facilities (storage and disposal), and discusses the implications for modeling of future waste disposal facilities that are yet to be constructed or for the development of dose assessments for the release of decommissioning sites.

LESSONS LEARNED

Monitoring has been and continues to be performed at a variety of different facilities for the disposal of radioactive waste. These include facilities for the disposal of commercial low-level waste (LLW), reprocessing wastes, and uranium mill tailings. Many of the lessons learned and problems encountered provide a unique opportunity to improve future designs of waste disposal facilities, to improve dose modeling for decommissioning sites, and to be proactive in identifying future problems. Typically, an initial conceptual model was developed and the siting and design of the disposal facility was based on the conceptual model. After facility construction and operation, monitoring data was collected and evaluated. In many cases the monitoring data did not comport with the original site conceptual model, leading to additional investigation and changes to the site conceptual model and modifications to the design of the facility.

The following cases are discussed: commercial LLW disposal facilities; uranium mill tailings disposal facilities; and reprocessing waste storage and disposal facilities.

Commercial Low-Level Waste Disposal Facilities

Currently there are three operating commercial LLW facilities: Barnwell SC, Hanford WA, and Clive UT. There are a number of commercial LLW facilities that are no longer in operation. These facilities were sited and operated in a broad range of environmental settings, ranging from semi-arid to humid and cold to temperate. The original conceptual model for Hanford and Clive assumed that infiltration to the waste could be limited due to the semi-arid environmental conditions and that the transport of radionuclides from the waste would be slow due to limited recharge to underlying aquifers. To date, these conceptual models have not been invalidated at these sites. The disposal concept at Barnwell was based on utilizing a low permeability clay formation to limit water contact with the waste and to limit transport from the disposal facility. Limiting water ingress to the waste in the humid environment has proven more challenging than originally thought, necessitating a number of successful proactive changes to the design.

Similar to Hanford and Clive, the disposal facility at Beatty NV was based on a conceptual model that assumed very low infiltration to the waste and very long transport times to the water table through a deep unsaturated zone. The Beatty facility is one of the few that have been closed, monitored, and maintained. After tritium was observed at great depths below the facility, an extensive investigation was completed [1]. It is believed that liquid waste was improperly disposed of in the facility resulting in rapid transport to the aquifer below, possibly enhanced by fast pathways. Additionally, the original closure cap was a relatively simple design. Monitoring identified fissures that formed in the cap, possibly due to the combined effects of a seismic event and erosion processes. The design was modified to add a more robust rip rap cover to prevent future erosion and cap deterioration. The commercial LLW disposal facilities at West Valley and Maxey Flats were conceptually based on placing the waste in a low-permeability near-surface formation. Precipitation at each site is moderately high. Each site experienced problems with disposal trenches accumulating water. At West Valley, transport was observed to occur laterally at the top of a higher permeability alluvial and weathered layer rather than vertically through the low permeability unweathered clay layer [2]. Additional barriers were used to modify the original design to solve the water management problems. These observations are summarized in Table I.

Uranium Mill Tailing Disposal Facilities

Monitoring at disposal facilities for uranium mill tailing facilities has yielded important lessons. At a number of facilities, even in environments with relatively low precipitation, the hydraulic conductivity of resistive barriers was found to have not been achieved in the field, regardless of success in the laboratory (e.g., Shiprock NM, Lakeview OR) [3, 4]. Extensive research has been completed on evapotranspiration-type covers, resulting in considerable success at semi-arid locations. However, changes in the plant communities combined with variability in weather patterns (especially with rapid snowmelt), have resulted in some infiltration. At the Burrell PA disposal facility, plant encroachment occurred in the closure cap much more rapidly than expected, resulting in significant cost to remove the vegetation. A risk assessment was completed that determined the plant encroachment did not impact safety and over the long-term may actually be beneficial [5].

Reprocessing Waste Storage and Disposal Facilities

At reprocessing waste storage facilities at Hanford and Idaho, releases from spills or leaks have been observed to travel through thick unsaturated zones much more rapidly than originally anticipated. In each case the rapid transport is believed to be a result of heterogeneity and fast pathways in the geologic system as well as the chemical composition of the released waste that may have modified the retention of radionuclides by the geochemical system. In addition, at each location recharge had been found to significantly exceed ambient values due to the disruption of natural materials during facility construction and the presence of man-made sources of recharge. At tank waste storage systems in Idaho and West Valley, below-grade concrete vaults in the unsaturated zone have been observed to transmit significant quantities of infiltration as a result of storm events and variability in weather conditions.

DISCUSSION

Table I provides a summary of observations from a variety of waste storage and disposal facilities, including the original conceptual assumptions and the implications for future modeling. A few main points can be derived from Table I, including:

- Water management at humid sites designed to take advantage of low-permeability formations has proven challenging.
- Disruption of near-surface materials can result in infiltration much higher than would be anticipated for ambient conditions.
- Variability in climatic conditions, especially events that may happen on short time scales, can greatly impact the amount of water contacting waste.
- The chemical composition of waste may impact the geologic retention of radionuclides.
- The combined effects of processes and events needs to be considered in predictive modeling.

CONCLUSION

The observations developed from the monitoring and maintenance of waste disposal and storage facilities provide valuable lessons learned for the design and modeling of future waste disposal facilities and the decommissioning of complex sites.

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TABLE I. Observations from Waste Storage and Disposal Facilities

Site	**Original Conceptual Model**	**Observations**	**Implications**
Hanford - LLW	Low infiltration, slow transport.	In agreement with conceptual model.	None
Clive - LLW	Low infiltration, slow transport.	In agreement with conceptual model.	None
Barnwell - LLW	Low permeability formation with cap will limit water contact and waste release.	Water management initially challenging.	Difficult to prevent 'bath-tub' processes at humid sites in low-permeability formations.
West Valley – LLW Maxey Flats - LLW	Low permeability formation will limit transport to slow vertical migration.	Trenches filled with water, migration occurred primarily horizontally much more rapidly than anticipated.	Modeling needs to consider high-permeability pathways and if they may be active.
Shiprock and Lakeview – Mill Tailings	Low-permeability cap can prevent water contact with the waste.	Hydraulic conductivity achieved in the laboratory was not achieved in the field.	Field-scale properties may not agree with lab-scale properties.
Burrell – Mill Tailings	Vegetation will gradually impact closure cover.	Vegetation rapidly grew in closure cap.	Timing of natural processes for revegetation are difficult to estimate.
Hanford and Idaho – Reprocessing Waste Storage	Thick unsaturated zone will greatly slow transport. Infiltration will be limited in semi-arid environment.	Disruption of near-surface materials can result in much larger infiltration than ambient conditions. Geologic heterogeneity and fast pathways can shorten travel times.	Infiltration estimates need to consider mans influence. Geologic variability should be considered in developing travel time estimates.
Hanford and Idaho – Reprocessing Waste Storage	Concrete vaults would limit water contact with storage tanks.	Variability in climatic conditions combined with discrete features of the engineered vaults resulted in transmission of substantial amounts of infiltration.	Modeling needs to consider discrete pathways and temporal variability at an adequate scale.