Development of a Dimensionless Number to Assess Risk for LLW Disposal Facilities - 14585

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ABSTRACT

The Department of Energy (DOE) operates a number of near surface disposal facilities (NSDFs) for Low Level Radioactive Waste (LLW), and for each facility a performance assessment (PA) is conducted to demonstrate that regulatory performance requirements are met. Within the PA, risk from disposed waste is evaluated using a conceptual model with four sections: source term (radionuclides available to the environment), environmental transport pathways (movement of radionuclides through the environment), exposure routes (how an individual becomes exposed to radionuclides), and receptors (dose from radionuclides to the individual). This paper will discuss the development of a dimensionless number as a screening parameter that takes into account risk drivers for the source term within the facility.

INTRODUCTION

Disposal of US government LLW by the DOE is governed by a set of performance objectives defined within DOE Order 435.1 under the self-regulating authority given to DOE by Congress in the Atomic Energy Act of 1954 [1]. Within the accompanying manual 435.1 M, a set of performance objectives are presented that define limits of release of radionuclides from a NSDF in terms of an annual dose to a member of the public at the boundary of the facility (100 m.) [2]. In order to demonstrate compliance with these performance objectives, a PA is conducted for the NSDF to establish a maximum inventory of radionuclides that can be disposed within the facility that would still meet the performance objectives, typically represented as an activity per unit volume, over several important time steps during the lifetime of the facility [3]. A conceptual model is developed to calculate the release of waste from the NSDF (source term), movement of the waste through the environment (fate and transport), how a member of the public is exposed to the waste (exposure routes), and finally the dose to this individual. Calculations are done with the use of a number of different modeling software packages.

A similar way to characterize the performance of a NSDF is to consider the facility as a system with three components. Facility cover and bottom layer(s) represent the *engineered component*; waste composition, form, and package represent the *disposal component*; and environmental features including precipitation and hydrogeology represent the *site component*. Parameters from each component are linked and affect the overall performance of the NSDF in an integrated manner. Much focus is placed on characterizing site parameters, especially hydrogeology and geochemistry, in order to increase accuracy and reduce uncertainty within environmental transport pathway models. However, once radionuclides leave a NSDF, there are limited actions that can be taken to control hazards associated with their movement through the environment. Improving assessment methodology of the source term is, therefore, useful in characterizing and reducing facility risk, as there is the ability to affect waste conditions before, during, and after disposal.

Screening Tools

Modeling of NSDF engineered performance and subsequent contaminant movement through the environment is a complex challenge for even the best characterized site. Examples include missing or incomplete data on waste parameters, uncertainty in subsurface geology, and uncertainty in cover degradation rates. Often simplifying assumptions are incorporated into the contaminant modeling to compensate for uncertainty in parameters, provide additional conservatism to the model, reduce the needed computing power, and to build confidence in the bounding nature of the modeling results.

A number of different models have been employed by DOE site disposal groups with varying degrees of complexity for use as both waste screening tools and overall facility performance [4]. Relatively simple models such as GWSCREEN [5] and MEPAS [6] analytically model transport of contaminants in one-dimension within the unsaturated zone. Increasing in complexity is Disposal Unit Source Term Model (DUST) [7], a one-dimensional solution to the advection-dispersion equation in the unsaturated zone using finite-difference, and Mixing Cell Model (MCM) [4], which solves for one-dimensional waste transport by dividing the subsurface into a series of well-mixed compartments. At the upper end of the complexity scale are models that approximate fluid and waste flow and transport from non-linear partial differential equations in three dimensions, such as the PORFLOW code used at Savannah River [8].

However, as mentioned in the previous section, transport through the environment is only one portion of the overall performance of a NSDF. The waste available to the environment at the disposal facility boundaries (source term), the fractional release of radionuclides from the disposed waste forms, and the movement of that waste throughout the disposal facility can impact both the peak concentration of a given radionuclide at the site boundary and time of that peak arrival. Conservative assumptions are often made about the source term from a lack of long-term data on degradation of waste forms and waste packages under varying (e.g. site-specific) environments. This often results in an estimation of the source term that is larger than the actual amount. In some cases no credit is taken for waste form and waste package robustness, and all waste is assumed to be available to the environment beginning at the end of the institutional control period. While bounding, a source term much higher than actually present can have significant influence on the calculated risk of the waste and on the disposal facility, such as requiring more robust engineered barriers or decreasing disposal limits per facility, thus requiring construction of more disposal units.

Source Term Dimensionless Parameter

Research is being conducted at Vanderbilt on the development of a dimensionless parameter to use as a screening tool to assess source term risk. Dimensionless numbers are employed throughout engineering to represent ratios or products of dimensioned parameters that when combined provide quick insight into a complex system. A common example is the Reynolds Number, a ratio of inertial and viscous forces of a fluid that conveys information on the flow regime of that fluid. Walton et al. have already proposed an approach for relating movement of radionuclides in groundwater to natural site parameters and source term in order to screen for key transport processes when there is a lack of site characterization data [9].

The proposed source term dimensionless parameter seeks to relate facility loading (waste composition, waste form, and waste package) to the performance of engineered barriers (infiltration through a cover system). At present a generic facility model is being constructed, using the Engineered Trenches at Savannah River E-Area as a basis of comparison. Still in development, the model assumes that the disposal facility will contain waste within a standardized waste package (metal box) stacked four boxes high, with the box properties based on the Savannah River B-25 box. This type of waste package is being considered since it is relatively robust and currently used in LLW disposal. Randomized failure estimates for waste packages will be accomplished using a Monti Carlo method. Waste package corrosion rates and site environmental characteristics will also be based on parameters found at Savannah River. Event trees will be incorporated to help identify the main risk drivers for the generic facility.

CONCLUSION

The development of a dimensionless parameter to assess LLW source terms has the potential to be used to estimate environmental hazards posed by disposed waste under varying performance scenarios and at different periods during the lifespan of a NSDF. The driving goal of this research is the creation of a screening parameter that uses the dimensionless parameter to show combinations of waste and facility parameters that could drive or reduce performance risk for the NSDF. The information can then be used to direct further investigation of specific performance scenarios to better understand sources of risk drivers, adjust waste acceptance criteria (WAC), or improve the engineered barriers.

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