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ESTIMATING RADIONUCLIDE RELEASES FROM LOW-LEVEL RADIOACTIVE WASTES

Michael F. Weber
U.S. Nuclear Regulatory Commission
Washington, D.C., U.S.A.

ABSTRACT

Performance assessments of low-level radioactive waste (LLW) disposal facilities are particularly sensitive to assumed radionuclide source terms and release models. The U.S. Nuclear Regulatory Commission (NRC) is currently evaluating alternative approaches for estimating radionuclide releases from LLW. As part of a more comprehensive performance assessment methodology, the NRC is developing source term models to estimate radionuclide releases for safety assessments of LLW disposal facilities. These models range from simple, empirical approaches to more complex models that attempt to simulate the processes of leaching, dissolution, sorption, corrosion, diffusion, and advection. Preliminary results indicate that relatively simple, deterministic approaches are preferable provided that they can be demonstrated to be reasonably conservative. The NRC staff intends to select an approach for estimating radionuclide releases that provides demonstrably conservative estimates and sufficient flexibility to consider releases on a facility-specific basis.

RESUME

Les estimations de la performance des installations destinées au traitement des résidus faiblement radioactifs (abbréviation US: LLW, pour "Low-Level Waste") sont particulièrement sensibles aux modèles de simulation du dégagement et aux termes présumés de la source des radionuclides. Actuellement, la Commission Régulatrice Nucléaire Américaine (U.S. Nuclear Regulatory Commission: NRC) étudie d'autres méthodes pour estimer les dégagements de radionuclides émanant des LLW. C'est dans l'ensemble d'un plus grand programme d'étude de la méthodologie destinée à estimer cette performance que le personnel du NRC s'applique à développer des modeles concernant les termes de la source afin d'estimer les dégagements de radionuclides en vue de définir la sécurité des usines de traitement de LLW. Ces modèles partent des méthodes simples et empirique jusqu'à des modèles plus complexes qui tentent de simuler les processus de filtration, dissolution, adsorption, corrosion, diffusion et advection. Les résultats préliminaires indiquent que des méthods simples et déterminstiques sont préférables tant qu'il est possible de démontrer qu'elles sont raisonnablement conservatrices. Le personnel de la NRC a l'intention de sélectionner une méthode pour estimer les dégagements des radionuclides qui puiss fournir des evaluations conservatrices et une suopless suffisante pour pouvoir être modifiée pour chaque installation.

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INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is responsible for regulating the disposal of commercial low-level radioactive waste (LLW) in the United States. NRC's regulations in 10 CFR Part 61 provide a comprehensive set of licensing requirements for land disposal of LLW. These regulations provide several performance objectives, including one that requires license applicants to demonstrate that concentrations of radioactive materials that may be released to the general environment will not exceed appropriate dose limits [1].

To demonstrate compliance with this performance objective, license applicants need to assess the performance of proposed LLW disposal facilities. Such assessments should consider any significant pathway of radionuclide release, transport, and exposure to humans [2]. The NRC staff considers the groundwater transport pathway as one of the most significant pathways resulting in potential human exposure to radionuclides released from LLW disposal facilities [3]. In addition to evaluating the environmental transport of radionuclides after they reach the groundwater, a realistic performance assessment of a LLW disposal facility should include an evaluation of the release of radionuclides from the waste form as the source term for the transport evaluation.

The processes and conditions that control radionuclide releases from LLW are among the poorest understood components of performance assessments of LLW disposal facilities. Although a substantial amount of source term modeling and experimental studies have been performed, these studies have not significantly reduced uncertainties associated with the estimation of radionuclide releases from LLW [4]. Nevertheless, such estimates are essential to performance assessments of LLW disposal facilities. Previous performance assessments have either assumed radionuclide releases a priori or utilized extremely simple models to estimate radionuclide releases. These approaches, however, do not provide demonstrably conservative or best estimates of radionuclide releases. In addition, such approaches do not provide sufficient flexibility to account for enhanced radionuclide containment by engineered barriers and stabilized waste forms. Therefore, additional effort is warranted to improve current performance assessment capabilities to estimate radionuclide releases from LLW disposal facilities.

After a brief review of previous efforts to estimate radionuclide releases from LLW, this paper describes several approaches being considered by NRC and its contractors for estimating radionuclide releases from the waste form into the disposal unit. The paper briefly reviews the diverse characteristics of LLW streams in the United States and suggests that this diversity currently precludes complicated approaches for estimating radionuclide releases. Based on this information, the paper presents an approach and computer code entitled RELEASE that the NRC staff is currently evaluating. The paper concludes by describing planned future work to test and refine the capabilities of RELEASE and alternative approaches.

PREVIOUS WORK

The relative importance of radionuclide release estimates in performance assessment for LLW disposal facilities has been recognized for many years [5]. Without releases of radionuclides into the aqueous phase, groundwater and surface water pathways would not be significant in considering the performance of LLW disposal facilities. In recognition of the importance of radionuclide releases from LLW, numerous attempts have been made to minimize or eliminate the releases from certain types of LLW [6]. However, these attempts have only been partially successful because they have not been able to quantify the small, but finite release rates of the radionuclides over the long periods of concern. In addition, not all types of LLW can be stabi''zed and treated to minimize the release of radionuclides.

Considerable effort has also been invested in development of standard laboratory leaching tests to screen waste form characteristics and demonstrate their suitability for disposal [7-10]. The validity of extrapolating the results from these tests to estimate radionuclide releases in actual LLW disposal facilities has not been demonstrated. In addition, the technical community has not been able to select a standard leaching test to represent the full range of environmental and waste conditions anticipated at LLW disposal facilities. Thus, the principal utility of the laboratory testing has been to screen waste form characteristics and expand the data base about radionuclide releases rather than to estimate long-term radionuclide release rates. This data base has supported the development and validation of empirical and phenomenological models for estimating radionuclide releases.

Previous investigators have also pursued development of computer models to estimate long-term releases of radionuclides from LLW. For example, NRC developed an empirically-based generic approach in the Impacts Methodology used to support the development of 10 CFR Part 61. The source term algorithm of the comprehensive Impacts Methodology was developed based on the best information about radionuclide releases available when NRC promulgated these regulations in 1982. The algorithm employs an integer-based approach to calculate a waste form and package barrier factor, which is a multiplier in the overall equation used to estimate radionuclide concentrations in the environment. The source term algorithm of the Impacts Methodology accounts for leachability (i.e., waste form), chelating agents, waste segregation, and the accessibility of radionuclides embedded in activated metals [11]. This approach, however, does not attempt to estimate radionuclide releases by explicitly simulating any of the processes or phenomena that may control radionuclide releases (e.g., advection, diffusion, solubility, sorption). Instead, the approach provides release estimates based on simple empirical relationships and radionuclide concentrations observed in leachate at two commercial LLW disposal facilities: West Valley, New York, and Maxey Flats, Kentucky.

More recent approaches have attempted to simulate the processes and phenomena that control radionuclide releases from LLW [12-14]. For example, Reference 14 develops an evaluation methodology that explicitly simulates moisture migration and groundwater flow in and near the LLW, as well as transfer of the radionuclides into the aqueous phase, degradation of waste packages, and transport of radionuclides after they are released. Under contract to the NRC, this effort should continue for the next couple of years and develop an approach to simulate the processes that significantly affect release and near-field transport of radionuclides at LLW disposal facilities. Such complicated analytical approaches, however, may not be compatible with the amounts and types of information that are available for LLW disposal facilities. Therefore, implementation of relatively complicated approaches for source estimation may be precluded by data limitations.

DIVERSITY OF LLW

The release of radionuclides from LLW is controlled at least in part by the characteristics of the waste. Thus, it is important to assess the relative amounts and characteristics of LLW expected to be received at LLW disposal facilities. Figure 1 compares typical radionuclide concentrations in untreated, high-volume waste streams in the United States. This figure illustrates the diversity of waste characteristics in terms of radionuclide types and concentrations. It is important to recognize that the figure provides information on only a few radionuclides, whereas LLW may contain many other radionuclides. It is also important to recognize that radionuclide concentrations are often lower in the large volume LLW streams than in smaller volume waste streams. For example, typical radionuclide concentrations in decontamination resins may be orders of magnitude greater than concentrations in the large volume waste streams depicted in Figure 1. Further, these concentrations reflect average concentrations in "typical" waste streams. Actual radionuclide concentrations may vary considerably as a function of many parameters, including generation process, operational cycle, age of facility, fuel burn-up, housekeeping practices, waste treatment, and age of waste. The diversity of radionuclide concentrations is only one factor that complicates development and use of approaches for estimating radionuclide releases from LLW. Although the diverse characteristics of LLW complicates analysis of radionuclide releases, careful record-keeping of the characteristics of the waste in disposal units is essential to the development of defensible source term models.

In addition to radionuclide concentrations, radionuclide releases from LLW may depend upon many other variables, including composition and characteristics of the waste form, leachant residence times, and the physico-chemical characteristics of the leachant. For example, if the percolation rate of water through the waste is slow, release of radionuclides from the waste may be dominated by diffusion. However, if the flow rates are very slow, radionuclide concentrations in the leachate may be constrained by solubility limits. Alternatively, if percolation rates are relatively rapid, then release of the radionuclides may be controlled by the dissolution rate of the waste form [15]. Table I summarizes the factors that are known or suspected to affect the release of radionuclides from LLW [4]. Given the current limitations of analytical approaches for estimating radionuclide releases from LLW, these complications currently preclude explicit simulation of all of the processes or phenomena that may be important in quantifying the releases. Therefore, approaches to estimate the releases should rely on relatively simple and conservative analyses that attempt to approximate the results of release processes rather than on complicated algorithms derived from fundamental equations (e.g., complicated multi-dimensional flow modeling coupled with geochemical equilibria and speciation modeling).

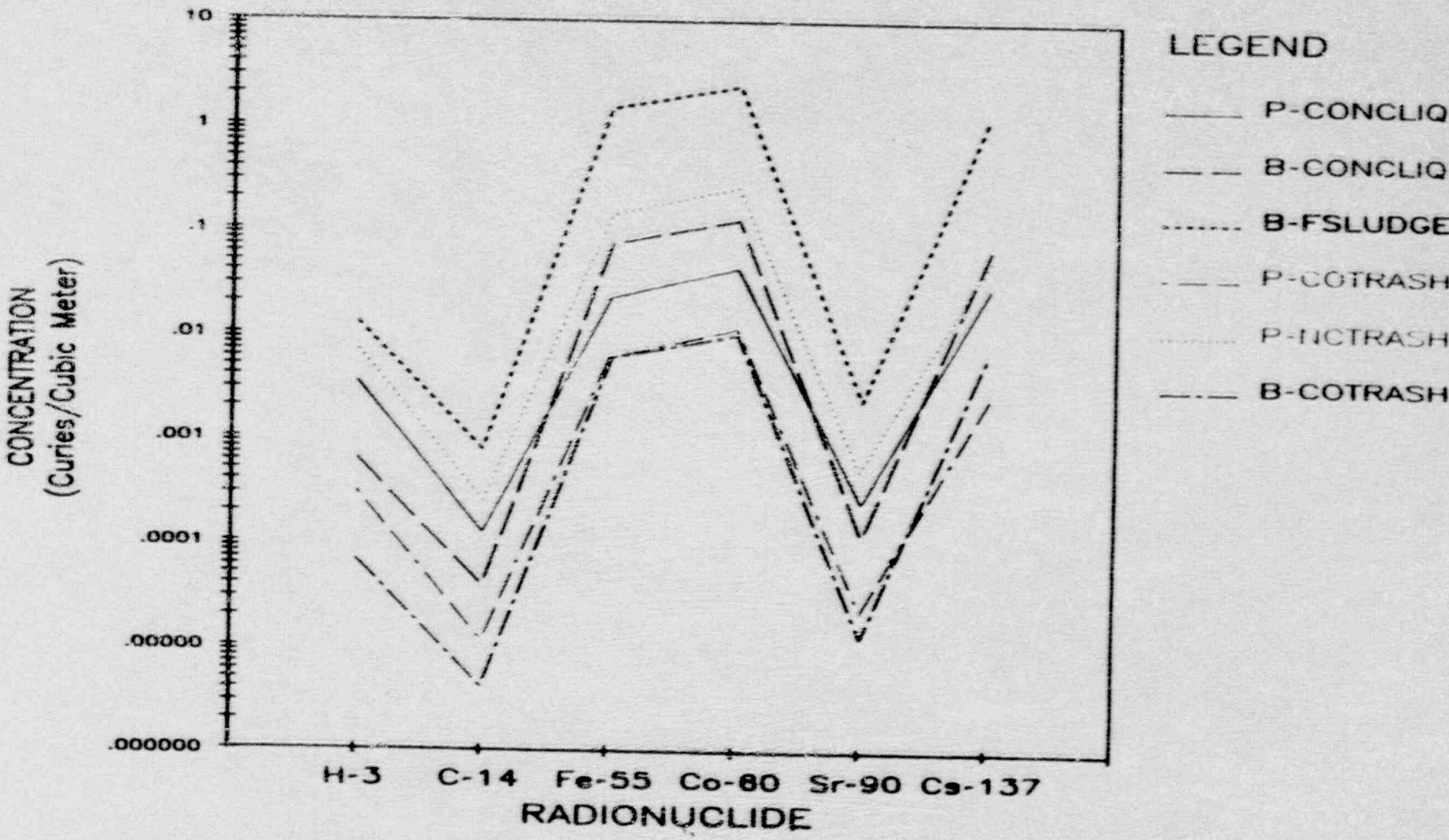

Figure 1. Typical radionuclide concentrations in high-volume low-level radioactive waste streams. P=Pressurized Water Reactor, B=Boiling Water Reactor, CONCLIQ=Concentrated Liquid Waste, FSLUDGE=Filter Sludge, COTRASH=Compressible Trash, NCTRASH=Non-compressible Trash (Based on Ref. 18).

Table I. Factors that may influence the release of radionuclides from LLW (Modified from Table 1.1, pg. 2, of Ref. 4).

System Factors	Radionuclide Factors
Temperature	Radionuclide
Pressure	Solubility
Radiation field	Solid speciation and form
Leachant resident time	Atomic radius
Leachant contact	Physical state
Ratio of waste form surface area to leachant volume	
Waste Form Factors	**Leachant Factors**
Composition	Leachant composition
Surface characteristics	Complexing agents
Effective diffusivity	pH and Eh
Corrosion rate	Percolation rate
Porosity	Biologic activity
Structural integrity	
Curing time	
Mixing ratio (waste/matrix and matrix/water)	
Biodegradation	

RELEASE

This paper focuses on a source term release approach and computer code entitled RELEASE. RELEASE is being developed and assessed by NRC staff along with other alternative approaches, including site-specific application of the source term algorithm of the Impacts Methodology [11] and a diffusion-limited approach developed by investigators at Brookhaven National Laboratory for estimating releases from LLW [12]. The objective of the NRC staff evaluation is to select a preferred approach or set of approaches for estimating radionuclide releases from LLW.

The RELEASE approach has been incorporated into a computer program of the same name, which was written by the author in advanced BASIC for execution on a personal computer. RELEASE interactively queries the user for input information and calculates incremental and cumulative fractional releases of individual radionuclides and annual releases in curies. The author is currently revising RELEASE to enhance its computational efficiency and user options. This section briefly reviews RELEASE's analytical approach, input requirements, and output characteristics, and compares the performance of RELEASE with other source term estimation approaches for a sample problem.

Analytical Approach

RELEASE is intended for site-specific application using the characteristics of the waste, disposal facility, and disposal environment. RELEASE provides limited flexibility to consider engineered barriers and other types of disposal facility enhancements intended to improve LLW isolation.

The analytical approach used in RELEASE assumes that radionuclide releases from LLW are dominated by rinsing of surface contamination from LLW trash and diffusion of radionuclides out of solidified waste forms. In addition, RELEASE approximates radionuclide releases from activated metals. RELEASE combines these processes to estimate total releases of a given radionuclide from individual LLW disposal units. The equations used in RELEASE to describe these processes were developed based on laboratory experiments and field observations at several LLW disposal facilities in the United States [4].

The analytical approach used in RELEASE is based on several fundamental assumptions. RELEASE assumes that (1) advective release of radionuclides from LLW trash can be represented by a rinsing model, (2) radionuclide releases from solidified wastes (e.g., cementitious or bituminous waste forms) are controlled by diffusion through the solid matrix, and (3) releases of radionuclides from activated metals can be approximated as a constant fraction of the diffusional releases. RELEASE also assumes that no liquid or gaseous wastes are included in the disposal units and that wastes do not degrade to form liquid or gaseous wastes other than leachate within the disposal unit. In addition, RELEASE does not explicitly simulate corrosion of waste packages or activated metal components. Further, RELEASE does not consider biodegradation of the LLW or secondary release mechansims, such as gaseous tritium transport with subsequent deposition in the unsaturated zone and transport into the saturated zone. The equations used in RELEASE were developed in References 4, 12, and 14.

The rinse model was developed in Reference 14 by Brookhaven National Laboratory to simulate releases of radionuclides from surface-contaminated trash in carbon steel drums at the Sheffield LLW disposal facility. The model is intended to simulate the mixing of leachant that occurs within a waste package after the package has been initially breached by corrosion or mechanical failure, but while the waste package still limits the exposed surface area of the waste. Thus, mixing occurs in a finite volume that is dependent upon the sum of the volumes of the individual waste packages. For each infiltration event during the year, RELEASE assumes that the wetting front propagates through the waste and displaces a finite volume of leachate from the waste packages. The rinse model is only appropriate if most of the radionuclide releases occur during the lifetime of the waste packages. Once the waste packages fail completely, advection of radionuclides through the bulk waste may dominate over the simple mixing process within individual waste packages. Therefore, the rinse model in RELEASE is best suited for estimating releases from unstabilized, low activity trash containing relatively short-lived radionuclides.

Based on the equations derived in References 4 and 14 for the rinse model, radionuclide releases from LLW trash may be approximated as follows:

$An = XZ(1-Z)^{(n-1)}$, where An = activity release per cycle,
n = number of rinse cycle,
Z = ratio between the rinse volume [L] and standing bath volume [L], and
X = source activity corrected for radioactive decay = $X(\exp(-Lt))$,
where X = initial activity,
L = decay constant [1/T], and
t = age of waste [T].

RELEASE assumes that each infiltration event results in a constant displacement of mixed leachate from all waste packages. In addition, the model also assumes that the radionuclides are contained in the trash as surface contamination. Thus, each infiltration event releases an ever decreasing incremental release of the radionuclide; RELEASE sums these incremental releases to approximate the annual activity release rate.

RELEASE does not incorporate the "tilt" factor discussed in the original rinse model [14]. The tilt factor was originally used to decrease the annual releases proportional to the cosine of the angle of the long axis of the waste packages with respect to the vertical. Because of uncertainty about waste package configuration in disposal units, the reduction of releases by the tilt factor does not appear to provide conservative estimates of radionuclide releases and is, therefore, not included in RELEASE. RELEASE conservatively assumes that all waste packages are vertically oriented, which maximizes the rinse volume per infiltration cycle.

In addition to estimating radionuclide releases from unstabilized LLW trash, RELEASE can be used to estimate releases from stabilized LLW that has been solidified. As previously discussed, RELEASE assumes that releases from solidified wastes are dominated by diffusion of the radionuclides through the waste matrix. Once they reach the outer surface of the waste form, RELEASE assumes that they are instantaneously released into the leachant. RELEASE partially accounts for containment by waste packages by assuming that radionuclide releases are proportional to the exposed surface area of the waste, which increases as a function of time. Unlike the rinse model, however, the diffusion model in RELEASE does not account for alternating wetting-drying cycles. Such cycling has been shown to increase releases of certain radionuclides under specific conditions [12]. Future testing of the RELEASE approach will include evaluation of the need to consider wet-dry cycling in estimating radionuclide releases.

The equation used in RELEASE to estimate radionuclide releases via diffusion is developed in Reference 14 and may be summarized as:

$CFR = (A/S)(C_1X + C_2X)$, where CFR = cumulative fractional release,

$A = S + \sqrt{Kt}$, where
- A = surface area function,
- S = initially exposed surface area [L],
- K = container area constant, and
- t = leaching time [T],

S = surface area of waste form [L],

$X = (S/V)(\sqrt{Dt})$, where
- V = waste form volume [L],
- D = effective diffusivity [L/T], and

$C_1 = 1.3441$ and $C_2 = -0.4416$.

This equation is based on a quadratic power series fit for the solution to the infinite plane sheet diffusion equation as used in ANS Standard 16.1 [8, 14].

The incremental fractional release rates may be calculated as

$$IFR = (CFR(t) - CFR(t-1))(\exp(-Lt'))$$, where L = radioactive decay constant [1/T], and t' = time since emplacement of waste.

The decay corrected CFR's are then calculated by summing the IFR's; incremental releases are calculated by multiplying the IFR's by the initial activity of the radionuclide in the waste. In the original reference [14], t' was assumed to be significantly greater than t because leaching only occurs during a small fraction of the total time (t') since emplacement of the waste. However, RELEASE invokes the conservative assumption that leaching time equals time since emplacement. Although it may be possible to estimate t on a site-specific basis using complicated moisture migration modeling within the waste, the uncertainties associated with predicting moisture migration in a highly heterogenous disposal unit may preclude such estimates. Therefore, RELEASE assumes that radionuclide diffusion through the waste matrix begins upon emplacement of the LLW in the disposal unit.

RELEASE also estimates releases from activated metals in the LLW by multiplying the IFR's for solidified waste by the initial activity contained in the activated metals and by a constant ratio of 0.01. Although the rates of radionuclide release from activated metals are not well understood, most approaches assume that these rates are controlled by the corrosion rate of the activated metal components. These rates are generally low because the components are constructed out of corrosion resistant metals. Many of the activated metal components are composed of high-alloy materials (materials with a high non-ferrous metallic component). The radionuclides contained within the activated metal components are gradually released as the metal matrix slowly corrodes.

Corrosion of these materials occurs at low rates such as 7.3E-6 g/cm/yr for high allow stainless steels [11, 16, and 18]. Although release rates based on metal corrosion are a function of geometry of the metallic component, these rates are generally lower than those estimated for solidified wastes using RELEASE. Thus, RELEASE estimates radionuclide releases from activated metals by multiplying the diffusion-dominated release rates by a constant factor of 0.01 to account for the slower rate of radionuclide release from activiated metals.

The author has incorporated several features in RELEASE to consider the increased isolation of LLW provided by engineered barriers. For example, covers that minimize infiltration into the waste in conventional trenches can be considered by reducing rinse volume. Special waste packages intended to contain the waste and minimize its contact with leachant can be considered by delaying initial release time and reducing or eliminating the initial surface area. RELEASE can also consider structural components such as concrete vaults and monoliths by delaying the initial release time and reducing rinse volumes. Further, these barriers may provide additional protection by containing leachate after radionuclides are released from the LLW and before the leachate is released to the general environment. Selection of these input parameters should be based on accelerated leach and durability testing in the laboratory; field observations of actual waste form, waste package, and disposal unit performance; and information on the reliability of engineered components such as waste packages.

Input Requirements and Output Characteristics

Users enter a variety of input data into RELEASE in response to a series of interactive queries. The input requirements are listed in Table II. The input requirements have been minimized so that RELEASE can be effectively implemented in assessing potential LLW disposal sites given the types and amounts of information available for the sites.

Based on input supplied by the user, RELEASE estimates radionuclide releases from the waste form into the disposal unit in terms of incremental and cumulative fractional releases and annual activity releases. RELEASE provides separate output for releases from LLW trash, solified waste, and activated metals. The releases are then summed to estimate the annual activity releases into individual disposal units. These estimated releases may then be used as the radionuclide source term for evaluations of transport out of the disposal units and into the surrounding environment.

Table II. Input Requirements for RELEASE

Input Type	Units
Radionuclide name	--
Decay constant	1/yr
Site name/unit number	--
Initial activity	Ci
Fraction of activity in trash	--
Fraction of activity in activated metals	--
Time of first pit/crack	yr
Total volume of waste packages	m
Rinse volume per cycle	m
Initial surface area	m
Total surface area of solidified waste	m
Effective diffusivity	cm/s

Comparison of Results

Figure 2 compares releases of cesium-137 from a hypothetical LLW disposal unit estimated using RELEASE and four other computer codes. Two of the codes, IMPACTS and DIFFUSE, are based on alternative approaches [11 and 12] for estimating source term releases and were written by the author as computer programs in BASIC to support the comparison of the approaches. The "IMPACTS" model is basically the submodel used in NRC's generic rational for 10 CFR Part 61 and is based on the algorithm used by the Impacts Analysis Methodology to calculate the waste form and package barrier factor [11]. The "DIFFUSE" model solves the infinite sheet diffusion-limited release model [12]. The

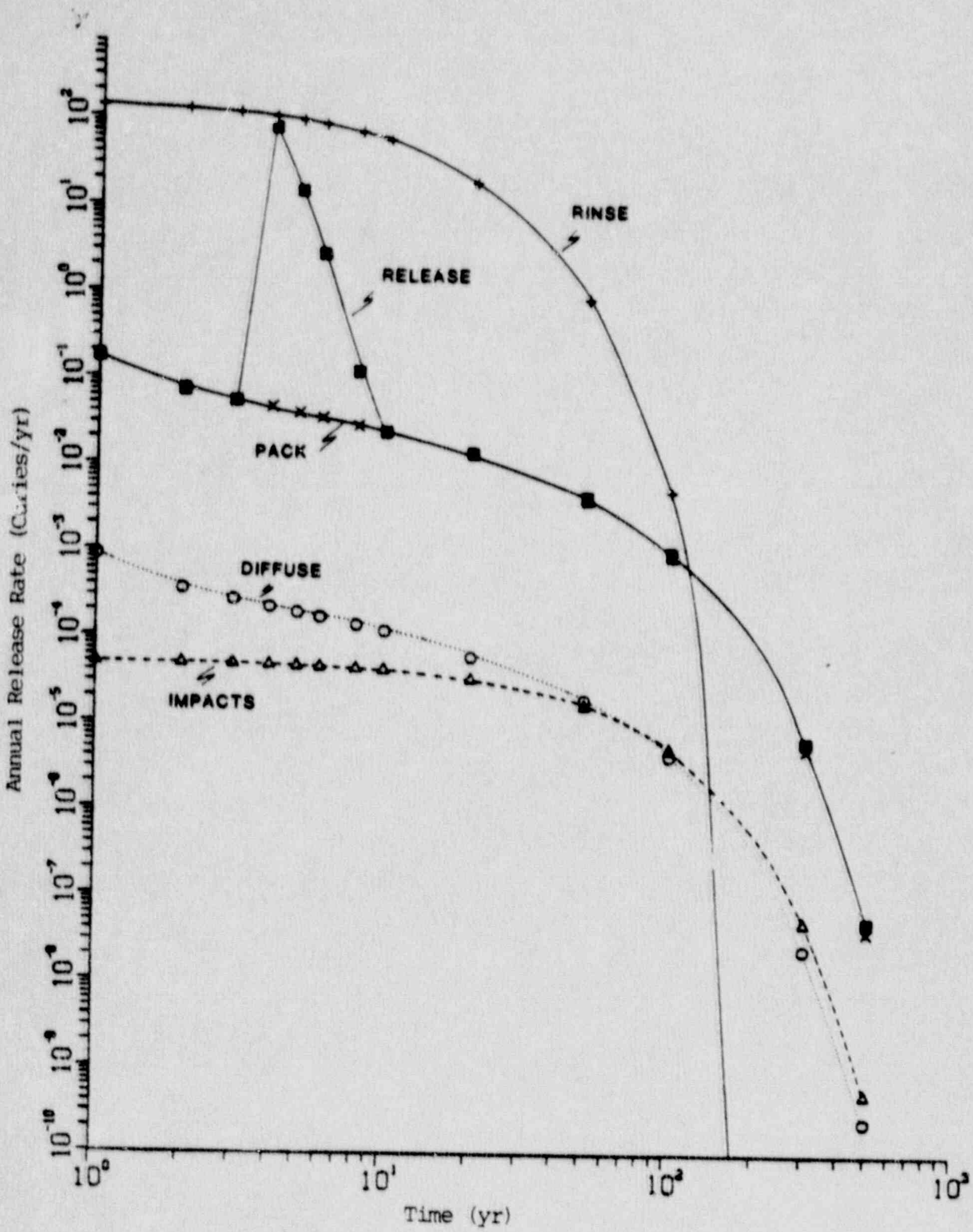

Figure 2. Estimated releases of Cesium-137 from a hypothetical LLW disposal unit. See text for discussion of models RELEASE, RINSE, PACK, DIFFUSE, and IMPACTS.

last two models listed in Figure 2 are the "RINSE" and "PACK" (diffusion-limited) submodels that have been incorporated in RELEASE. Their results have been included in the figure to assess the relative release contribution from LLW trash and solidified waste for the sample problem. The input information for RINSE and PACK has been modified from that for the sample problem to represent all waste as LLW trash for the RINSE model and as solidified LLW for the PACK model. These modifications account for the large differences in the estimated releases between RINSE, PACK, and RELEASE.

Figure 2 indicates that RELEASE provides relatively conservative estimates of radionuclide releases compared with the other models. The RINSE model provided the most conservative estimates, as expected, because it assumes that the entire radionuclide inventory is contained in the LLW as surface contamination. This approach is clearly conservative if much of the cesium-137 inventory is contained in solidified waste forms and is not readily accessible. Release estimates from RINSE decrease below the other estimates after 100 years because most of the waste activity has already been released. The IMPACTS model provides the lowest estimated source term releases for the first 100 years. It is important to recognize that the radionuclide releases estimated by IMPACTS for the sample problem are not necessarily representative of the results of generic applications of the Impacts Analysis Methodology. Although the source term releases estimated by IMPACTS are lower than the estimates from the other models, the relative conservatism of the Impacts Analysis Methodology is influenced by conservatisms introduced by such components as disposal unit design and performance, and environmental transport. The comparison of releases in Figure 2 does not account for these components because the models described only estimate releases from the waste form into the disposal unit.

FUTURE WORK

The RELEASE model described in this paper is being developed and tested by the NRC staff to provide necessary capabilities for estimating or bounding radionuclide releases from LLW. RELEASE represents one of several alternative approaches that are currently being evaluated by the NRC staff. Although preliminary comparisons of the performance of RELEASE with other approaches indicates that RELEASE may provide relatively conservative estimates, additional work is necessary to determine whether RELEASE provides radionuclide release estimates that are adequate and defensible in reviewing license applications for LLW disposal. Ongoing NRC studies of commercial LLW disposal facilities may provide information about actual releases of radionuclides that may be compared with releases estimated using RELEASE, IMPACTS, and other models. For example, NRC staff and contractors are developing transport models for the inactive, commercial LLW disposal facility at Sheffield, Illinois, which may be useful in estimating actual releases by inverse modeling. These estimates could then be used in calibrating and validating RELEASE and other approaches for estimating radionuclide releases from LLW. Further evaluation of the performance of RELEASE and other approaches is warranted to ensure that the approaches provide reasonably conservative or best estimates of radionuclide releases that are consistent with observations of radionuclide releases from LLW.

The purpose of the staff's evaluation is to select a preferred approach that can be integrated into a comprehensive performance assessment methodology for LLW disposal facilities. In the future, the NRC staff may propose such an approach in regulatory guidance or as part of standard review procedures for LLW disposal license applications.

Prior to selection or rejection of RELEASE as an estimation approach, the NRC staff will further assess the performance of RELEASE to evaluate its capacity to provide reasonably conservative or best estimates of radionuclide releases from LLW based on reasonable input information. In particular, the staff intends to compare the estimates from RELEASE with laboratory and field measurements of releases from LLW. The staff also intends to evaluate alternative and more rigorous approaches to assess the release of radionuclides from activated metal components, which comprise most of the projected activity in LLW in the United States. Further, the staff intends to assess the importance of processes that RELEASE does not currently consider such as biodegradation and wet/dry cycling. The goal of these assessments is to enhance the capabilities of RELEASE or alternative approaches to provide reasonably conservative or best estimates of radionuclide releases from LLW.

SUMMARY

Estimation of the source term for radionuclide releases to the environment is required to assess long-term performance of disposal facilities for LLW. The processes and phenomena that control radionuclide releases from LLW are relatively poorly understood. The diversity of waste, facility, and environmental characteristics that influence radionuclide releases currently preclude use of complicated approaches to estimate releases. Simple approaches that can be demonstrated to provide reasonably conservative estimates are, therefore, preferable to more complicated approaches. Based on laboratory leach tests and actual performance of LLW disposal units, the NRC staff and its contractors have developed an approach for for estimating radionuclide releases. This approach has been developed into a computer code entitled RELEASE. The NRC staff is currently assessing the capability of RELEASE to provide reasonably conservative or best estimates of radionuclide releases from LLW. Preliminary comparison of results from RELEASE with two other approaches indicates that RELEASE can provide relatively conservative estimates of radionuclide releases. Prior to selection of a preferred approach for estimating radionuclide releases, the NRC staff intend to further evaluate the performance and capabilities of RELEASE and other approaches.

The author wishes to express his appreciation for NRC staff and contractor support of this effort. Because of the preliminary nature of the work described in this paper, the conclusions provided above are those of the author and do not necessarily represent those of the U.S. Nuclear Regulatory Commission or its staff.

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