EXAMINATION PLAN FOR THE SOILS AND LOW-LEVEL RADIOACTIVE WASTE FORMS OF THE NRC FIELD TESTING LYSIMETERS

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ABSTRACT

The Field Lysimeter Investigations: Low-Level Waste Data Base Development Program is obtaining information on the performance of radioactive waste forms. These experiments were recently shut down and have been examined in accordance with a detailed waste form and soil sampling plan. Ion-exchange resins from a commercial nuclear power station were solidified into waste forms using portland cement and vinyl ester-styrene. These waste forms were tested to (a) obtain information on performance of waste forms in typical disposal environments, (b) compare field results with bench leach studies, (c) develop a low-level waste data base for use in performance assessment source term calculations, and (d) apply the DUST computer code to compare predicted cumulative release to actual field data. The program, funded by the Nuclear Regulatory Commission (NRC), includes observed radionuclide releases from waste forms at two test sites over 10 years of successful operation. The lysimeter is a useful experimental device that is providing source term data and can be used to determine waste form stability. Lysimeters are ideal systems for obtaining actual field test data because, when properly designed and operated, they can be used to isolate soil and waste systems under actual environmental conditions. Such conditions cannot be duplicated by standard laboratory testing.

The purpose of this paper is to present the experimental plan for the examination of the waste forms and soils of the two lysimeter arrays, which have now been shut down. During this examination, it is planned to characterize the waste forms after removal from the lysimeter and to compare those findings to the original characterizations. Vertical soil cores have been taken from the soil columns and will be analyzed with radiochemistry to define movement of radionuclides after release from the waste forms. A comparison is made of the DUST-predicted releases to those previously determined and reported from the lysimeter leachate analyses. That comparison uses new partition coefficients \( K_d \) recently obtained from laboratory analysis of the lysimeter soils and sand. Those DUST code results also will be compared to actual radionuclide movements through the soil columns as determined from soil core analysis.

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INTRODUCTION

This paper presents the experimental plan for the examination of the waste forms and soils from two field lysimeter arrays. While results of this program have been presented at previous Low-Level Radioactive Waste Management Conferences, this paper gives an update of the study, which includes discussion of some results of the examination of the soils from the lysimeters after experiment shutdown and exhumation. During the examination, the waste forms are being characterized, and these results compared to the original characterizations, thus providing the basis for a material balance of the radionuclides present. Vertical cores were taken from the soil columns and are being analyzed by radiochemistry to determine movement of radionuclides after release from the waste forms. A comparison is made of the DUST code predicted releases to releases previously determined and reported from the lysimeter leachate analyses. That comparison uses new distribution coefficients (Kd) recently obtained from laboratory analysis of the lysimeter soils and sand.

The U.S. Nuclear Regulatory Commission (NRC) has enacted regulations that link low-level radioactive waste (LLW) acceptance criteria to the long-term satisfactory performance of the waste. Under Code of Federal Regulations (CFR) 10, Part 61, "Licensing Requirements for Land Disposal of Radioactive Wastes," commercially generated LLW is classified as Class A, B, C, or Greater Than Class C. Wastes classified as either Class B or Class C must be stabilized for a minimum of 300 years. To verify the 300-year stability of waste forms, the NRC originally specified the use of short-term standardized tests with the intention that such tests would provide information relevant to near-surface disposal performance objectives. Those tests were initially published in the NRC Branch "Technical Position on Waste Form" and have been revised in Revision 1 of the Technical Position. A central requirement for disposing LLW is the need for a detailed understanding of the waste form behavior. That is necessary because the radionuclide source is the driving force behind the site performance. A major requirement in any site licensing is the site performance assessment, which is used to evaluate whether or not a proposed disposal site will meet performance objectives. The performance of the buried waste form has a direct bearing on the outcome of the performance assessment.
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The objective of the Field Lysimeter Investigations: Low-Level Waste Data Base Development Program is to compare the results of short-term laboratory leach testing, performed earlier by the INEEL, with actual leaching in the field. This program, funded by the NRC, operated lysimeters for over 10 years to obtain information on the performance of radioactive waste forms in a disposal environment and to investigate waste form stability per requirements of 10 CFR 61. The experiment measured the releases of radionuclides and chemical species from the waste forms and the subsequent transport through soil columns to sampling locations within the lysimeters. This study was developed to field test waste forms composed of solidified ion-exchange resin materials from EPICOR-II\textsuperscript{a} prefilters used in the cleanup of Unit 2 of the Three Mile Island Nuclear Power Station.\textsuperscript{4} Those wastes are significant because they are nuclear-grade ion-exchange media with high loadings of radionuclides.

EXPERIMENT DESCRIPTION

Wastes used in the experiment include a mixture of highly loaded, nuclear-grade, synthetic, organic ion-exchange resins from EPICOR-II prefILTER PF-7 and a mixture of organic-exchange resins and an inorganic zeolite from prefilter PF-24. Solidification agents employed to produce the 4.8 x 7.6-cm cylindrical waste forms used in the study were portland type I-II cement and DOW vinyl ester-styrene (VES). Seven of the waste forms were stacked end-to-end and inserted into each lysimeter to provide a 1-L volume. The PF-7 waste contained 89\% of the radionuclide activity as Cs-137, while PF-24 contained 94\% Cs-137. The PF-7 waste also contained 5\% Sr-90, and PF-24 contained 1\% Sr-90. There were also measurable amounts of Cs-134, Co-60, and Sb-125 found in those wastes. Details on waste form descriptions, formulations, and characterization are given in References 4 and 5.

Ten lysimeters were used in this study: five at Oak Ridge National Laboratory (ORNL) in Tennessee and five at Argonne National Laboratory-East (ANL-E) in Illinois. The lysimeters were designed to be self-contained units that will be disposed at the termination of the study. Each lysimeter is a 0.91 x 3.12-m right-circular cylinder divided into an upper compartment.

\textsuperscript{a} References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendations, or favoring by the United States Government or any agency thereof.
that contained fill material, waste forms, and instrumentation, and a lower compartment for collecting leachate (Figure 1). Four lysimeters at each site were filled with soil; a fifth, used as a control, was filled with inert silica oxide sand. The lysimeters at ANL-E contained soil indigenous to the site, while the ORNL lysimeters contained soil taken from Savannah River Laboratory in South Carolina. The soil columns were 2.21 m deep.

Instrumentation in each lysimeter included moisture cup soil-water samplers and soil moisture/temperature probes. The probes were connected to an onsite data acquisition system (DAS), which also collected data from a field meteorological station located at each site. Porous cup soil-water samplers and the leachate collection compartment comprised the water sampling components of each lysimeter (Figure 1). Incoming precipitation moved downward through the soil column to the waste form, then on to cups 3 and 1, and finally to the leachate collector at the bottom. Radial movement of releases were detected in cups 5, 4, and 2 with vertical releases observed in cups 3 and 1. Samples of moisture were withdrawn from the cups and the collector. Lysimeter design, installation, instrumentation, and data acquisition are explained in Reference 6, as well as a listing of waste form and fill material types. Monitoring of the lysimeters at ANL-E and ORNL began with the collection of liquid samples in September 1985 (3 months from the time of placement) and continued through shutdown in October 1995 with sample collection on approximately a quarterly basis. Samples of liquids were taken from locations near the waste forms and from the leachate collectors to track the migration of radionuclides, primarily Cs-137. The water samples were analyzed for Sr-90 and gamma-producing nuclides. Soil moisture and temperature at three elevations in each lysimeter, along with a complete weather history, were recorded on a continuing basis by the DAS.

RESULTS AND DISCUSSION

Weather and Leachate Radionuclide Data

Precipitation, air temperature, wind speed, and relative humidity were recorded continuously by the ANL-E and ORNL DAS during the experiment. The cumulative volume of leachate from the lysimeters since the initiation of field work, and examples of the lysimeter soil temperature and moisture data from ANL-E and ORNL are found in Reference 7.
To pump

Access tube

Typical sample numbering of cores

1 1/2" Core #1

Pump line

Horizon 2

3" Waste form core #2

Core #12

Core #13

Horizon 4

River stone filter

Leachate collector

Lysimeter sampling - isometric view

Ground level

Horizon 1

1 1/2" Cores #4 & #7

1 1/2" Cores #3 & #6

1 1/2" Core #5

Horizon 3

Filter cloth

Screen

Core #11

Core #10

Figure 1. Isometric drawing showing the lysimeter experiment, cores, and samples.
Reference 7 gives data on the cumulative amounts of nuclides as determined in water samples obtained from ANL-E and ORNL leachate collectors. That data show that not all nuclides consistently appeared in the water obtained from the moisture cups or the leachate collectors. The nuclide that appeared with the most regularity at both sites was Sr-90. Recovery of Sr-90 in number 3 cups and the leachate collectors indicated a varied waste form performance (Table 1). Recovery of Sr-90 in the ORNL cups was comparable for those lysimeters containing the cement waste forms and one of the two containing VES waste forms. However, the cups at ANL-E recovered much more Sr-90 from the VES waste forms compared to the cement waste forms. These data indicate that releases from the cement waste forms were generally less than from VES waste forms.

Table 2 is a comparison of cumulative fractional releases from field testing EPICOR-II waste forms in lysimeters to releases from bench-leach-testing similar waste forms as reported in References 5 and 8. Releases observed in the lysimeter were at least two orders of magnitude less for Sr-90 and at least five orders of magnitude less for Cs-137 in soil. Release of Sr-90 in the sand-filled lysimeter was only one or two orders of magnitude less than bench test results.

**Lysimeter Waste Form and Soil Core Sampling**

The primary objective of the recently completed waste form and soil sampling was to obtain the waste forms from all of the five lysimeters at each site in cylindrical cores. Secondary objectives were to extract soil cores, soil microbial samples, selected moisture cups, filter fabric samples, and filter support stone samples. Seven cores were to be taken per lysimeter, one for the waste form and six for soils. Four soil grab samples, one filter cloth cut sample, and one filter support rock grab sample per lysimeter were planned. Moisture cup numbers 1 and 3 from each lysimeter also were to be collected. All waste form cores were successfully taken at both sites and have been shipped to the INEEL for detailed examination. Nearly all soil cores were taken at ANL-E, while only soil cores number 1 and sample 1 of cores number 2 were taken thus far at ORNL. Samples of filter cloth, filter support rock, and moisture cups 1 and 3 were obtained only from the ANL-E control lysimeter.
Table 1. Percent release of Sr-90 and Cs-137 per lysimeter in moisture cups and leachate water through July 1995.\(^7\)

<table>
<thead>
<tr>
<th>Lysimeter Number</th>
<th>Solidification Agent</th>
<th>Percent Total Inventory</th>
<th>Percent Total Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Moisture Cups</td>
<td>Leachate Water</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ANL-E</td>
<td>ORNL</td>
</tr>
<tr>
<td>1</td>
<td>Cement</td>
<td>1.4E-4</td>
<td>9.7E-4</td>
</tr>
<tr>
<td>2</td>
<td>Cement</td>
<td>4.4E-4</td>
<td>7.8E-4</td>
</tr>
<tr>
<td>3</td>
<td>VES</td>
<td>69.4E-4</td>
<td>13.0E-4</td>
</tr>
<tr>
<td>4</td>
<td>VES</td>
<td>14.7E-4</td>
<td>3.3E-4</td>
</tr>
<tr>
<td>5</td>
<td>Cement</td>
<td>2.7E-4</td>
<td>8.8E-4</td>
</tr>
</tbody>
</table>

a. Percent released is essentially equal to zero.

Table 2. Cumulative fractional releases from lysimeter field testing compared to those from bench leach testing.\(^5,7,8\)

<table>
<thead>
<tr>
<th>Test Type and Location</th>
<th>Ion-Exchange Resin Prefilter Number</th>
<th>Waste Form Solidification Agent</th>
<th>Radionuclide of Interest</th>
<th>Cumulative Fractional Release</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DW(^a)</td>
<td>Seawater</td>
<td>Soil</td>
<td>Sand</td>
</tr>
<tr>
<td>Bench, INEEL</td>
<td>7</td>
<td>Cement(^b)</td>
<td>Sr-90</td>
<td>7.8E-2</td>
</tr>
<tr>
<td>Field, ANL-E</td>
<td>7</td>
<td>Cement(^b)</td>
<td>Sr-90</td>
<td>7.8E-2</td>
</tr>
<tr>
<td>Field, ANL-E</td>
<td>7</td>
<td>VES(^b)</td>
<td>Sr-90</td>
<td>7.8E-2</td>
</tr>
<tr>
<td>Field, ORNL</td>
<td>7</td>
<td>Cement(^b)</td>
<td>Sr-90</td>
<td>7.8E-2</td>
</tr>
</tbody>
</table>

a. Demineralized water.

b. Waste form samples were irradiated before test.
A diagram of the sample locations and sizes is shown in Figure 1, and Table 3 lists the cores and samples to be taken. The waste form cores (number 2) are 7.5 cm in diameter and about 58.5 cm long and extend from horizon 2 to 3. That length contains all seven waste form samples. The soil cores and microbial soil samples are 3.3 cm in diameter and are various lengths. All were taken with coring tools made up of 25-cm segments. Cores number 1 were taken with a 75-cm top segment, then a 25-cm bottom segment. Cores #3 and 4 were taken with a 50-cm top segment, then a 25-cm bottom segment. All other cores were taken to full depth with multiple segments. The microbial soil samples were also taken with the 3.3-cm diameter tool using one segment. All cores were contained in plastic, cylindrical core tool liners that were closed with plastic caps on the ends. Radial and vertical position of the coring tools was controlled during coring operations by use of special guide plates and bushings. The coring tools and tips were specifically designed for this task by Art's Manufacturing and Supply of American Falls, Idaho. The INEEL designed the special guide fixture system.

Table 3. Core and other samples.

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>Number of Samples/Makeup</th>
<th>Sample Length (cm)</th>
<th>Planned Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core number 1</td>
<td>8</td>
<td>12.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 2</td>
<td>1</td>
<td>54.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 3</td>
<td>1</td>
<td>4.0</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 4</td>
<td>4</td>
<td>12.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 5</td>
<td>1</td>
<td>7.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 6</td>
<td>5</td>
<td>6.3</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 7</td>
<td>1</td>
<td>7.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 7</td>
<td>3</td>
<td>12.5</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Sample number 8</td>
<td>Filter cloth</td>
<td>NA</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Sample number 9</td>
<td>Rock</td>
<td>NA</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Core number 10</td>
<td>Soil</td>
<td>25</td>
<td>Archival</td>
</tr>
<tr>
<td>Core number 11</td>
<td>Soil</td>
<td>25</td>
<td>Microbial</td>
</tr>
<tr>
<td>Core number 12</td>
<td>Soil</td>
<td>25</td>
<td>Microbial</td>
</tr>
<tr>
<td>Core number 13</td>
<td>Soil</td>
<td>25</td>
<td>Microbial</td>
</tr>
<tr>
<td>Sample number 14</td>
<td>Soil</td>
<td>NA</td>
<td>Microbial</td>
</tr>
<tr>
<td>Sample number 15</td>
<td>Waste form scraping</td>
<td>NA</td>
<td>Microbial</td>
</tr>
<tr>
<td>Sample number 16</td>
<td>Moisture cup 3</td>
<td>NA</td>
<td>Radionuclide</td>
</tr>
<tr>
<td>Sample number 17</td>
<td>Moisture cup 1</td>
<td>NA</td>
<td>Archival</td>
</tr>
</tbody>
</table>
Waste form characterization, which is in progress at this time at the INEEL, will include full-length gamma scanning of each seven-sample waste form and radiochemical analysis of segments of selected samples from each waste form. These analyses are designed to identify the remaining waste form radionuclide inventory. Waste form physical condition will be determined by visual examination, weighing, and compressive testing. Three soil subsamples will be taken adjacent to the waste forms in each waste form core. The soil cores will be segmented to 6.3-cm samples for those taken below the waste forms, and 12.5-cm samples for those alongside and above the waste forms. Representative 10-g subsamples will be taken from those soil samples. Those subsamples will be radiochemically analyzed for nuclide content by ANL-E, as will the filter cloth, filter support stone, and moisture cups. These resulting data will then be used to determine radionuclide material balance within each lysimeter, radionuclide pathways through the soil columns, and radionuclide holdup factors of the various components of each lysimeter system. Soil grab samples and three additional soil subsamples taken adjacent to the waste forms as well as three swipes from each waste form surface will be examined for microbial activity, which may then be related to waste form physical condition by examination of the waste form surface.

Gamma measurements of soil samples made during coring have provided preliminary indications of Cs-137 movement within the soil columns. Examination of the soil samples at ANL-E showed that Cs-137 was found in one or more of all cored locations of the four soil lysimeters. That indicates radionuclide movement downward, upward, and radially, with dispersion apparent in all ANL-E soil lysimeters. All cores #1 at ORNL contained some Cs-137. At least one measured over 20,000 disintegrations per minute, an indication of upward migration. It is assumed that Sr-90 has also moved out from the waste forms at least as far in all directions as the cesium. This assumption is based on the measured movement of strontium versus cesium in the lysimeter leachate waters as previously noted.

**Partition Coefficients of Lysimeter Fill Material**

Partition coefficients for Cs-137 and Sr-90 were measured in the laboratory for the lysimeter fill materials. Batch methods were used. Table 4 lists the $K_a$ values for ANL-E and ORNL soils and silica sands. While the sorption isotherms reported were not linear over the
test range, for the low concentrations of radionuclides observed in the lysimeter leachates, the coefficients may be treated as linear.

**SOURCE TERM MODELING OF LYSIMETER RELEASES**

The Disposal Unit Source Term (DUST) code\textsuperscript{10} has been used to model the release of the radionuclides Cs-137 and Sr-90 from the lysimeter waste forms. DUST is a one-dimensional code that accounts for container performance and waste form leaching (including diffusion-controlled release). Transport can be modeled through finite differences or by a multi-cell mixing cascade approach. The finite difference method was used in the simulations reported in this paper because it is more general than the mixing cell approach and permits modeling of dispersive transport. Use of these lysimeter data in the DUST code was examined in detail in a paper presented at WM '93\textsuperscript{11} and was studied more recently in References 7 and 12. Radiochemical analysis is not complete on the soil cores; therefore, no comparison is made.

The releases of Cs-137 and Sr-90 from portland type I-II cement located in the inert, sand-filled lysimeters 5 at ORNL and ANL-E were chosen because releases from other lysimeters were substantially lower; therefore, the data were not yet sufficient to model. At ANL-E, lysimeter 5 contained resin waste from PF-7 solidified in portland cement; at ORNL, lysimeter 5 contained resin waste from PF-24, which was also solidified in cement (Table 1). Diffusion coefficient values measured in laboratory testing of these waste forms were 9.6E-10 cm\textsuperscript{2}/s for Sr-90 in cement and 6.0E-10 cm\textsuperscript{2}/s for Cs-137 in cement.\textsuperscript{13} The Darcy velocities ranged from 2.96E-6 cm/s at ANL-E to 4.3E-6 cm/s at ORNL.\textsuperscript{7} The soil bulk density values were 1.55 g/cm\textsuperscript{3} at ANL-E and 1.60 g/cm\textsuperscript{3} at ORNL.\textsuperscript{6} In lysimeter 5 at both sites, the average moisture content was calculated to be 21% from values found in

<table>
<thead>
<tr>
<th>Material</th>
<th>Cesium $K_d$ (cm\textsuperscript{3}/g)</th>
<th>Strontium $K_d$ (cm\textsuperscript{3}/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANL-E soil</td>
<td>390</td>
<td>81</td>
</tr>
<tr>
<td>ORNL soil</td>
<td>37</td>
<td>20 - 40</td>
</tr>
<tr>
<td>ANL-E sand</td>
<td>55</td>
<td>6.4</td>
</tr>
<tr>
<td>ORNL sand</td>
<td>40</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Table 4. Linear $K_d$ values for cesium and strontium in lysimeter materials.
Reference 7. The partition or distribution coefficients were measured for Sr-90 and Cs-137 and are presented in Table 4.9 The dispersion coefficients have not been measured; therefore, they were estimated based on data in References 14 and 15 and by fitting the model predictions to the data. The cumulative activity collected in the lysimeter leachate water over the first 10 years of operation of the experiment, which was used to make comparisons to the DUST code predictions, represented cumulative fractional releases of about 0.0018 and 0.00023 of the Sr-90 in lysimeter 5 at ORNL and ANL-E, respectively (Table 1). The "best-fit" parameters for four different waste form release and nuclide transport models for Sr-90 are displayed in Table 5.

The three waste form release models using ORNL data all limit the total 10-year release from the waste form to about $10^7$ pCi, which was two orders of magnitude less than the release predicted on the base case parameters ($D_{wf} = 9.6E-10$ cm$^2$/s). The best-fit diffusion coefficient was four orders of magnitude below the laboratory-measured value. This low release rate was used to match the data because of the relatively fast transport time that occurred when using the base case $K_d$ values. The best-fit transport parameter, $K_d = 36$, was about the same as the laboratory-measured value of 37 and was much larger than the best-fit value found previously based on 8 years of data ($K_d = 24$). After collecting the additional 2 years of data, it became clear that the previous best fit was too low. Figure 2 (top) displays the predicted cumulative release of the four different scenarios and compares them to the measured data. All of them predicted the cumulative release over 10 years to within 20% of the measured value. This was the result of the fitting procedure used to select the appropriate release parameters. The transport model curve does not compare well to the other curves.

Table 5. Best-fit parameters for release of Sr-90 from lysimeters 5 at ORNL and ANL-E.

<table>
<thead>
<tr>
<th>Model</th>
<th>Parameter</th>
<th>ORNL</th>
<th>ANL-E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diffusion-controlled release</td>
<td>Waste form diffusion coefficient (cm$^2$/s)</td>
<td>$D_{wf} = 5E-14$</td>
<td>$D_{wf} = 1E-15$</td>
</tr>
<tr>
<td>Uniform release</td>
<td>Uniform fractional release rate (yr$^{-1}$)</td>
<td>4E-4</td>
<td>1.3E-4</td>
</tr>
<tr>
<td>Solubility limited</td>
<td>Solubility limit (pCi/L)</td>
<td>1,260</td>
<td>1,680</td>
</tr>
<tr>
<td>Transport limited</td>
<td>Partition coefficient (cm$^3$/g)</td>
<td>$K_d = 36$</td>
<td>$K_d = 36$</td>
</tr>
<tr>
<td></td>
<td>Dispersion coefficient (cm)</td>
<td>Disp = 7.5</td>
<td>Disp = 8</td>
</tr>
</tbody>
</table>
Figure 2. Comparison of measured and DUST-predicted cumulative Sr-90 released.
The best-fit parameters for ANL-E lysimeter 5 differ from those found at ORNL lysimeter 5. The waste form diffusion coefficient and fractional release rate were lower than at ORNL. The ANL-E waste form best-fit diffusion coefficient, 1E-15 cm²/s, was a factor of 50 lower than the best-fit value found for the ORNL data and almost six orders of magnitude lower than the laboratory-measured value. The solubility limit was slightly higher than found at ORNL because of the lower water flow rates found at ANL-E. The Kₐ of 36 was within the range of the laboratory-measured partition coefficient. In Figure 2 (bottom), the cumulative release based on the solubility limited release model tracked the measured value the best. The uniform and diffusion-controlled waste form release models also followed the trends in the measured data reasonably well. The high Kₐ model showed a much different shaped curve than the data or any of the other models.

CONCLUSIONS

The radionuclide that has appeared with most regularity at both sites is Sr-90, although Cs-137 was observed regularly in the leachate of all ORNL lysimeters. The data indicate that portland cement and VES waste forms had comparable releases of Sr-90 to leachate passing through the lysimeter.

The waste form and soil sampling is developing important data on radionuclide movement from the waste forms into and through the soil columns. Gamma measurements of core samples indicate Cs-137 movement in all directions from the waste forms. Waste form and soil coring will provide more detail on waste form releases and release patterns to better define the radionuclide movement in the lysimeters.

DUST-predicted cumulative releases of Sr-90 from both ORNL and ANL-E lysimeters 5, which were plotted over 10 years of data collection, showed a reasonable fit to the field data. The accuracy of the DUST modeling study was limited, however, by the small amount of radionuclide releases to leachate.

Data provided by these lysimeter experiments have been shown to be useful in computing many parameters used as input to performance assessment codes. The utility of this reliable
source of data will be enhanced by application of radionuclide movement data from soil
taking to source term models such as DUST.

ACKNOWLEDGMENTS

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