PERFORMANCE TESTING OF HIGH SPECIFIC ACTIVITY WASTE FORMS PER 10 CFR PART 61[a]

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ABSTRACT

The Low-Level Waste Data Base Development - EPICOR-II Resin/Liner Investigation Program of the U.S. Nuclear Regulatory Commission (NRC) is obtaining information on radioactive waste by means of NRC-prescribed tests in a disposal environment. This paper describes the resin solidification task of that program and includes the current test status and results.

INTRODUCTION

The March 28, 1979 accident at Unit 2 of the Three Mile Island Nuclear Power Station (TMI-2) released approximately 2,120,000 L (560,000 gal.) of contaminated water to the Auxiliary and Fuel Handling Buildings. The water was decontaminated using a three-stage demineralization system called EPICOR-II, containing organic and inorganic ion exchange media. The first stage of the system was designated the prefilter. Fifty EPICOR-II prefilters with high concentrations of radionuclides were transported from TMI-2 to the Idaho National Engineering Laboratory (INEL) for storage before final disposal at the commercial disposal facility in the State of Washington. EG&G Idaho, Inc. is examining materials from several of those prefilters under the Low-Level Waste Data Base Development - EPICOR-II Resin/Liner Investigation Program funded by the U.S. Nuclear Regulatory Commission (NRC). An unusual feature of this investigation is the use of commercial grade, ion exchange resins that have been loaded with over five times the radioactivity normally seen in a commercial application, dramatically increasing the total radiation dose to the resins.

The investigation is divided into four tasks which address different aspects of waste disposal, as discussed in the program plan (1). Those include investigating: (a) resin degradation, (b) resin solidification, (c) field testing, and (d) liner integrity. Resin solidification studies are being conducted at the INEL, with emphasis placed on evaluating the requirements of 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," (2) using the methods specified in the "Branch Technical Position on Waste Form" (3) (TP) of the NRC Office of Nuclear Materials Safety and Safeguards. The INEL resin solidification studies are using resins removed from EPICOR-II prefilters PF-7 and -24, as described in papers at Waste Management '86 (4,5) and at the American Nuclear Society (ANS) International Meeting on Low-, Intermediate-, and High Level Waste Management and Decontamination and Decommissioning 1986 (6). Several interim, annual and NUREG reports are also available (7-16). This paper describes the task undertaken to investigate resin solidification and gives the status and results of the work to date.

WASTE FORM FABRICATION

EPICOR-II Prefilter Wastes - Highly loaded ion exchange resin wastes were obtained from EPICOR-II prefilters PF-7 and -24. PF-7 contains three types of synthetic organic ion exchange resins; phenolic cation, strong acid cation, and strong base anion. PF-24 contains two types; strong acid cation and strong base anion, as well as inorganic zeolite. The ion exchange media were layered in the prefilters. Resin wastes were obtained from the prefilters in a coring operation, during which a coring tool was inserted vertically through the resin layers, closed, and withdrawn, thereby removing a representative portion of the waste.

Solidification Agents - Two types of solidification agents (binders) were used in preparing waste forms for the resin solidification task; Portland Type I-II cement and vinyl ester-styrene (VES).[b]

Formulation Development Studies - Formulation development studies (5-7) were conducted based on previous work (17-19), using unirradiated, simulated EPICOR-II prefilter wastes supplied by EPICOR, Inc. The unirradiated resins were representative of the ion exchange media in PF-7 and -24 and were used in the proper ratios to simulate the actual EPICOR-II wastes (20,21). Those studies were conducted to determine appropriate formulations for solidifying the actual prefilter wastes.

Solidification of EPICOR-II Prefilter Wastes - EPICOR-II prefilter wastes were homogenized by mixing them in 19 L buckets for 10 min, using a low speed dough mixer. That operation was performed in a hot cell. After homogenization, individual samples (approximately 20 g each) of PF-7 and -24 resin wastes were removed from the hot cell to determine water and activity contents. Water content measurements were obtained, using ASTM D2187-77 (22), with 5-g subsamples of resin. Then water was added to measured quantities of the actual EPICOR-II wastes to prepare

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b. VES is a proprietary, thermosetting polymer solidification agent of the Dow Chemical Co., Midland, MI.

decanted resins for solidification. Reference 6 gives the water content and grams of dry resin/gram decanted waste, as determined for both the simulated and actual EPICOR-II wastes.

Aliquots (0.1 to 0.3 g each) of dried EPICOR-II resin wastes were analyzed by gamma spectroscopy and Sr-90 analysis to determine the radionuclide contents. The resins contained Cs-134, -137, and Sr-90. The average resin activities are given in Table I. The radionuclide content data were used to calculate the radionuclide contents of the waste forms for leachability testing.

Four batches of cement waste forms were prepared, two batches for each waste type (PF-7 and -24). Four batches of VES waste forms were prepared, also two batches for each waste type. Table II gives the formulations used for the cement batches, and Table III gives those for the VES batches. A total of 267 waste forms was prepared. This total includes 136 cement waste forms (72 containing prefilter PF-7 waste and 64 with PF-24 waste) and 131 VES waste forms (71 containing PF-7 waste and 60 with PF-24 waste).

Radioactive EPICOR-II waste forms were prepared in a hot cell, using specially designed, remotely operated solidification equipment (Fig. 1). For each batch prepared, 36 vials were filled. Sufficient mixture was added to each vial to produce waste forms with an average height of 7.6 ± 0.6 cm. Snap-on lids were placed on the vials after filling, and the waste forms were cured at approximately 20°C.

TABLE I

Activity Content of EPICOR-II Resin Wastes

Waste Type	Nuclide	Activity Content[a] $\pm 1\sigma$ (Ci/g dry resin)
PF-7	Cs-134	7.73 E-05 ± 2.83 E-07
	Cs-137	1.17 E-03 ± 9.90 E-05
	Sr-90	6.92 E-05 ± 7.21 E-06
PF-24	Cs-134	3.30 E-04 ± 5.80 E-05
	Cs-137	4.99 E-03 ± 3.04 E-04
	Sr-90	1.18 E-05 ± 6.36 E-07

a. Cs-134 and -137, as of Sept. 20, 1983; Sr-90, as of Oct. 25, 1983.

TABLE III

Formulations for Vinyl Ester-Styrene Waste Form Batches Containing EPICOR-II Wastes

		Formulation Weight Percentage[a]			
Batch	Waste Type	As-Received Waste	Added Water	Decanted Waste[b] Total	Vinyl Ester-Styrene
D1	PF-7	40.9	20.3	61.3	38.7
D1A	PF-7	38.9	22.6	61.5	38.5
D2	PF-24	43.1	18.3	61.4	38.6
D2A	PF-24	34.9	14.9	49.8	50.2

a. Does not include catalyst and promoter, which constitutes a total of approximately 1 wt%.

b. Decanted waste total is the as-received waste plus added water.

All waste forms were weighed. Contact gamma dose measurements also were obtained (5) for each waste form within its preparation vial. Those measurements were obtained at the mid-height of the waste form, with the center of the ion chamber located approximately 3.2 cm from the side of the waste form.

WASTE FORM TESTING

Baseline/qualification testing of radioactive EPICOR-II waste forms was conducted to determine the following; (a) presence of any free-standing liquid, (b) as-prepared compressive strength, and (c) homogeneity. Environmental tests were conducted to determine; (a) thermal stability, (b) leachability, (c) immersion stability, (d) radiation stability, (e) leachability after irradiation, and (f) biodegradability. The tests were conducted to determine the adequacy of test procedures specified in the TP. Note that leachability after irradiation testing is not required by the TP.

Baseline/Qualification Tests - Baseline/qualification tests were performed on eight cement and eight VES waste forms. Four of the cement waste forms contained prefilter PF-7 waste, and four contained PF-24 waste. Similarly, half the VES waste forms contained PF-7 waste, and the remainder PF-24 waste.

TABLE II

Formulations for Portland Cement Waste Form Batches Containing EPICOR-II Wastes

	Formulation Weight Percentage					
Batch	Waste Type	As-Received Waste	Added Water	Decanted Waste Total[a]	Portland Type I-II Cement	Additional Water
C1	PF-7	15.6	8.5	24.1	62.7	13.2
C1A	PF-7	15.6	8.5	24.1	62.7	13.2
C2A	PF-24	16.8	7.1	24.0	62.5	13.5
C2B	PF-24	16.5	7.1	23.6	61.4	15.1

a. Decanted waste total is the as-received waste plus added water.

Fig. 1. Photograph of the remotely operated equipment used to produce Portland cement and vinyl ester-styrene waste forms incorporating actual EPICOR-II ion exchange resin wastes.

Because of the high radionuclide contents of the waste forms, those and subsequent tests were performed in a manner that limited both radiation exposure to personnel and contamination of the test environment (see Fig. 2).

Free-standing liquid determinations were made with the method of ANS 55.1 (23). The lid of each preparation vial was removed, and the waste form inspected to determine if free-standing liquid was present on its top surface. A pointed plunger then was inserted through the bottom of the vial to push the waste form out, and the waste form and vial were inspected for presence of any free-standing liquid.

Compression testing (Fig. 2) was conducted in accordance with ASTM C39-72 (24). The waste forms were capped using a sulfur base mortar and compression tested using an Instron Model TTCLM1-4 Tension/Compression Tester, operated at a crosshead speed of 1.27 mm/min. The cure-times of waste forms that were compression tested ranged from 30 to 49 days.

The compressive strength data and visual observations of the waste forms after failure were used to determine homogeneity of the waste forms.

Environmental Tests - Eight Portland cement and eight VES waste forms were used to perform all except two of the environmental tests. Of the eight waste forms in each group, four contained PF-7 waste and another four contained PF-24 waste. The exceptions to these numbers were the leachability after irradiation testing (for which 8 waste forms were used) and biodegradability testing (for which 20 waste forms were used - 10 cement and 10 VES).

Thermal Stability - Sixteen EPICOR-II waste forms were selected for thermal stability testing. They included eight cement waste forms (4 containing PF-7 waste and 4 with PF-24 waste) and eight VES waste forms (4 with PF-7 waste and 4 with PF-24 waste). The cure time of the waste forms tested was approximately 17 months. Thermal stability testing was conducted in accordance with Sections 5.4.1 through 5.4.4 of ASTM B553-79 (25). That procedure specifies a maximum temperature limit of 60°C and a minimum temperature limit of -40°C (details given in Refs. 5, 6, 8 and 11). The waste forms were exposed to 30 complete thermal cycles.

The waste forms (in their preparation vials) were double bagged in individual "zip lock" type polyethylene bags to prevent spread of radioactive contamination. Eight waste forms each were placed in a larger "zip lock" type polyethylene bag and placed on a plastic tray. The tray containing the eight waste forms also was placed in a polyethylene bag. The bag containing the second set of eight waste forms also contained a dummy cement waste form and a dummy VES waste form, each containing an axial thermocouple. The thermocouples were used to determine how long the waste forms were at the desired temperatures.

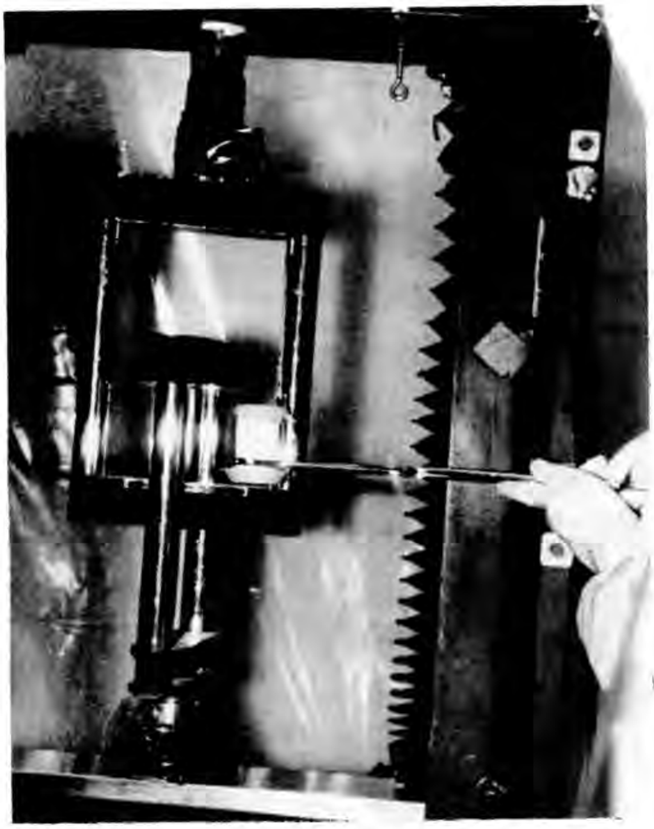

Fig. 2. Photograph of an EPICOR-II waste form being placed in the Instron compression testing machine.

[Note that equilibration to the test temperatures (as opposed to exposure to the test temperatures) represents the most restrictive interpretation of the test method.]

After thermal cycling, the waste forms were removed from the polyethylene bags and preparation vials. Compression testing was conducted, as described earlier, using ASTM C39-72.

Leachability - Sixteen waste forms were selected for leachability testing, including eight cement waste forms and eight VES waste forms. Four of each type of waste form contained PF-7 waste, and four contained PF-24 waste. The elapsed time between preparation of the waste forms and leachability testing was approximately 20 months. The test was conducted in accordance with the procedures of ANS 16.1 (26).

The 16 waste forms were removed from their preparation vials, then weighed and measured (dimensionally). They were placed in individual Teflon netting "baskets," which were suspended from the lids of leachant containers. The leachant containers (Fig. 3) consisted of wide-mouthed, polyethylene bottles, 2 liters in volume, with screw-top lids (details on testing given in Refs. 5, 6, 9 and 11). After leachability testing, the 16 waste forms were compression-tested under the immersion testing procedure.

Immersion Stability - Part of the leachability testing procedure served as the immersion portion of this test procedure, using the same 16 waste forms. The waste forms were capped with a sulfur base mortar and compression-tested, using ASTM C39-72, as described previously.

Fig. 3. Photograph of EPICOR-II waste forms in the leachate containers during leachability testing. (Note the lead brick shielding required to reduce radiation exposure to personnel.)

Radiation Stability - Sixteen waste forms (8 cement and 8 VES) were subjected to gamma irradiation for the radiation stability test. Four of the waste forms prepared from each binder contained PF-7 waste, and four contained PF-24 waste. The elapsed time between preparation of waste forms and gamma irradiation was 26 months.

The 16 waste forms were irradiated in the fuel storage pool of the Gamma Irradiation Facility at the Advanced Test Reactor of the INEL. A total intended gamma irradiation dose of 5×10^8 R was selected for all waste forms; this was based on the maximum expected accumulated dose. During the irradiation procedure, the positioning equipment in the Gamma Irradiation Facility failed, and the cement waste forms received an actual, average gamma irradiation dose of 5.2×10^8 R; the VES waste forms received 4.3×10^8 R. After gamma irradiation, the waste forms were placed in a storage cask (Fig. 4) to await compression testing. Two months later, compression testing was accomplished, using the ASTM C39-72 procedure, described previously.

Leachability After Irradiation - Eight waste forms were selected for leachability after irradiation testing, including four cement and four VES waste forms. Two of each waste form type contained PF-7 waste, and two contained PF-24 waste. Those waste forms were irradiated with the *radiation* stability waste forms described in the previous paragraphs. The average gamma dose was 5.4×10^3 R for Portland cement waste forms and 5.3×10^3 R for VES waste forms. The elapsed time between preparation and irradiation was 26 months; leachability testing was initiated approximately five months after irradiation. Leachability testing was conducted in accordance with the procedures of ANS 16.1 described in previous paragraphs. Note that leachability after irradiation testing is not required by the Technical Position (3). However, since the activity inventory

Fig. 4. Photograph showing an EPICOR-II waste form being placed in a plastic bag after the gamma irradiation portion of the irradiation stability testing. (Note the anti-contamination precautions taken by the technician.)

and thus the maximum accumulated irradiation dose for these waste forms was high, experiments were conducted to determine what effect gamma irradiation may have on the release of radionuclides in leaching.

Biodegradability - The Technical Position (3) indicates that waste forms should be tested for resistance to biodegradation in accordance with both ASTM G21, "Determining Resistance of Synthetic Polymeric Materials to Fungi" (27) and ASTM G22, "Determining Resistance of Plastics to Bacteria." (28) Initial work was conducted, exposing unirradiated waste forms (powdered, wafered, and whole) to both fungi and bacteria. Subsequent work was conducted per ASTM G21 and G22, using irradiated, whole waste forms. Twenty waste forms (10 cement and 10 VES) were subjected to biodegradability testing. Five waste forms prepared from each binder contained PF-7 waste, and five contained PF-24 waste. Two of each type of waste form prepared from each binder (8 total) were exposed to fungi, and two of each (8 total) were exposed to bacteria. The four remaining waste forms were placed in nutrient agar and used as control specimens. Following the procedures recommended in the TP, those waste forms which supported growth were rinsed in methanol, dried, and retested.

RESULTS

Baseline/Qualification Tests - The Technical Position (TP) (3) states that ". . . specimens should have less than 0.5 percent by volume of the waste specimen as free liquids as measured using the method described in ANS 55.1." During the baseline/qualification tests, no free-standing liquid was observed on any of the waste forms.

Data from compression testing of waste forms are given in Table IV. The average compressive strengths for Portland cement and VES waste forms containing the same waste type (PF-7 or -24) are approximately equal. Waste forms containing PF-24 waste (organic resin with zeolite) exhibited a higher average compressive strength (25,000 kPa) than those prepared with PF-7 waste (20,200 kPa). The compressive strengths of all the waste forms tested exceeded the 350 kPa minimum strength required by the TP. The high compressive strengths and the appearance of the waste forms after failure indicated that the waste forms were homogeneous.

The baseline/qualification tests indicated that both Portland cement and VES waste forms containing resin wastes from PF-7 and -24 met the requirements specified in the TP for free-standing liquid, compressive strength, and homogeneity. The testing and results obtained also confirmed the general applicability of the test methods specified.

Thermal Stability - Thermal instability of waste forms usually results from repeated or alternate freezing and thawing of chemically uncombined water during storage and transport. Degradation of the waste forms is caused by expansion of the water upon freezing with thermal instability evident after thawing. However, no such degradation was noted in testing.

Average compression test data are given in Table IV for the thermally cycled waste forms. The TP requires that waste forms should have compressive strengths greater than 350 kPa, after thermal cycling. All thermally cycled waste forms had

TABLE IV

Compressive Strengths of EPICOR-II Waste Forms

		Compressive Strength $\pm 1\sigma$ (kPa)			
Binder	Waste Type	As-Prepared	Thermal Cycled	Immersion Tested	Radiation Stability
PC	PF-7	20,200 ± 3,300	32,700 ± 600	20,400 ± 5,400	25,100 ± 9,900
PC	PF-24	25,000 ± 5,000	39,100 ± 4,500	26,600 ± 8,300	22,800 ± 11,800
VES	PF-7	20,000 ± 1,000	19,100 ± 2,300	19,100 ± 2,000	13,300 ± 3,900
VES	PF-24	24,700 ± 1,300	28,000 ± 500	22,600 ± 2,200	16,700 ± 5,600

PC = Portland Type I-II cement
VES = vinyl ester-styrene

compressive strengths ranging from 16,800 to 43,600 kPa. The procedure of ASTM C39-72 was applicable for determining compressive strengths of the waste forms after thermal cycling.

Leachability - The test procedures and calculation of leachability indexes, as specified by ANS 16.1, were applicable for determining leachability of the waste forms. Average data from the leachability test are given in Table V for Cs-134 and -137. The leachability of cement waste forms (cumulative activity release range of 2.2 to 9.1%) generally was higher than that of comparable VES waste forms (cumulative activity release range of 0.03 to 6.5%) in the same leachate, as indicated by the lower leachability indexes for the cement waste forms. Both cement and VES waste forms containing PF-7 waste exhibited higher leachability than those containing PF-24 waste. The use of sea water as the leachate resulted in higher leachability than using demineralized water. The Cs-137 and -134 leachability indexes, confidence ranges and correlation coefficients are comparable for individual waste forms. The leachability index is decreasing with time for the Portland cement waste forms (as indicated by the negative correlation coefficient) and increasing with time for the vinyl ester-styrene waste forms. The cement and VES waste forms containing wastes from PF-7 and -24 were found to be resistant to leaching. All waste forms tested have leachability indexes greater than 6, as required by the TP.

Immersion Stability - Immersion of waste forms was conducted satisfactorily as part of the leachability test. The waste forms then were compression-tested to determine if their compressive strengths had been degraded by immersion. Compressive strength data for immersion-tested waste forms are given in Table IV. All immersion-tested waste forms exhibited compressive strengths far in excess of the 350 kPa required by the TP. The ASTM C39-72 test procedure was applicable for determining compressive strengths of the waste forms.

Radiation Stability - The total gamma irradiation dose received by the waste forms was larger than the total beta plus gamma self-irradiation dose that the waste forms would have received by the end of 300 years. [The calculated self-irradiation doses to infinity ranged from 2.9×10^8 R for cement waste forms containing PF-24 waste to 4.2×10^8 R for VES waste forms containing PF-7 waste.]

Compression test data for radiation stability specimens are listed in Table IV. All specimens had compressive strengths from 9400 to 35,000 kPa, far in excess of the 350 kPa required by the TP. The compressive strengths of vinyl ester-styrene waste forms decreased by more than 30% as a result of gamma irradiation; the Portland cement waste forms did not appear significantly affected. Results from this work demonstrate that radiation stability testing procedures as specified by the TP are generally applicable.

Leachability After Irradiation - Leachability of the irradiated waste forms was calculated in the manner detailed in ANS 16.1. Leachability index data are shown in Table VI for Cs-134 and Cs-137. That table also lists average leachability indexes for unirradiated waste forms. All leachability indexes are above the value of 6 recommended by the Technical Position; cumulative activity releases ranged from 0.3 to 11.9%. These data suggest that Portland cement waste forms are relatively unaffected by gamma irradiation (the average leachability index is 10.2 for unirradiated Portland cement waste forms and 10.1 for waste forms irradiated to 5.4×10^8 R). However, the leachability in demineralized water of the Portland cement waste form containing PF-7 waste increased with gamma

TABLE V

Average Cesium-134 and -137 Leachability from EPICOR-II Waste Forms

				Leachability		
Binder	Waste Type	Radionuclide	Leachate	Index	Confidence Range	Correlation Coefficient
PC	PF-7	Cs-134	DI	10.3	9.3-10.8	-0.50
PC	PF-7	Cs-134	SW	9.6	9.0-10.2	-0.73
PC	PF-7	Cs-137	DI	10.3	9.1-11.4	-0.40
PC	PF-7	Cs-137	SW	9.5	8.9-10.1	-0.73
PC	PF-24	Cs-134	DI	10.6	10.1-11.1	-0.10
PC	PF-24	Cs-134	SW	10.4	10.2-10.7	-0.44
PC	PF-24	Cs-137	DI	10.4	10.0-10.8	-0.25
PC	PF-24	Cs-137	SW	10.3	10.1-10.6	-0.15
VES	PF-7	Cs-134	DI	12.4	11.3-13.4	0.80
VES	PF-7	Cs-134	SW	9.4	8.5-10.4	0.55
VES	PF-7	Cs-137	DI	12.2	11.1-13.3	0.80
VES	PF-7	Cs-137	SW	9.3	8.3-10.2	0.54
VES	PF-24	Cs-134	DI	14.0	13.6-14.4	0.56
VES	PF-24	Cs-134	SW	10.9	10.5-11.3	0.26
VES	PF-24	Cs-137	DI	13.8	13.5-14.3	0.68
VES	PF-24	Cs-137	SW	10.7	10.4-11.2	0.29

PC = Portland Type I-II cement
VES = vinyl ester-styrene
DI = demineralized water
SW = synthetic sea water

TABLE VI

Effect of Gamma Irradiation on the Leachability Index

Binder	Waste Type	Leachant	Gamma Dose, rad	Leachability Index Cs-134	Leachability Index Cs-137
PC	PF-7	DI	0	10.3	10.3
PC	PF-7	DI	5.3 E+08	9.4	9.3
PC	PF-24	DI	0	10.6	10.4
PC	PF-24	DI	5.4 E+08	10.0	9.9
PC	PF-7	SW	0	9.6	9.5
PC	PF-7	SW	5.3 E+08	10.0	9.9
PC	PF-24	SW	0	10.4	10.3
PC	PF-24	SW	5.4 E+08	10.9	10.8
VES	PF-7	DI	0	12.4	12.2
VES	PF-7	DI	5.7 E+08	9.8	9.7
VES	PF-24	DI	0	14.0	13.8
VES	PF-24	DI	4.9 E+08	12.3	12.2
VES	PF-7	SW	0	9.4	9.3
VES	PF-7	SW	5.7 E+08	8.8	8.7
VES	PF-24	SW	0	10.9	10.7
VES	PF-24	SW	4.9 E+08	10.0	9.8

PC = Portland Type I-II cement
VES = vinyl ester-styrene
DI = demineralized water
SW = synthetic sea water

irradiation (leachability index decreased). Decreased leachability of Portland cement waste forms in sea water was noted also.

The largest gamma irradiation effects were noted for vinyl ester-styrene waste forms. Leachability was increased significantly in these waste forms as a result of gamma irradiation, especially those that contained PF-7 waste and those that were leached in demineralized water. The explanation for this behavior was not determined, although, because of its organic structure, vinyl ester-styrene is expected to be more susceptible to radiation damage than Portland cement. This also was seen in radiation stability studies, where the compression strength of vinyl ester-styrene waste forms decreased significantly. Similarly, gamma irradiation might be expected to affect radionuclide retention by the ion exchange resins in PF-7 waste (all organic resins) more than in PF-24 waste (organic resin with inorganic zeolite). Note that formulations used for solidification of EPICOR-II wastes have low waste loadings relative to commercial practice in order to ensure waste form integrity during testing (and may as a result over-estimate the conservatism of commercial products). Consequently, degradation of leachability indexes induced by gamma irradiation, particularly in vinyl ester-styrene waste forms, could result in leachability indexes below the value of 6 recommended by the Technical Position for commercial products.

Biodegradability - ASTM G21 and G22 procedures were used to test biodegradability. The cement waste forms gave no indication of being affected by, or offering support for, growth of the applied species of fungi and bacteria. However, Portland cement waste forms placed in nutrient-rich media did not chemically or radiologically prevent the growth of fungi. Thus, while the waste forms did not support microbial growth, neither did they prevent it.

The VES waste forms supported fungal growth (Fig. 5), but not bacterial. Tests with unirradiated, powdered, or wafered material showed that fungi would grow on the growth media surrounding the material, and a close visual inspection showed fungal growth on at least 10 to 30% of the waste form surface. Whole, irradiated VES waste forms had fungal growth on the surrounding media, but close inspection of the waste form surfaces was not possible with available facilities, because of the high radiation levels. The VES waste forms were cleaned using methyl alcohol and retested; those waste forms were found to continue to support fungal growth.

Portland cement waste forms are not affected by plastic degrading fungi or bacteria, while the VES waste forms apparently support fungal growth. Long-term effects of microbial growth cannot be determined using the ASTM G21 and G22 tests.

RECOMMENDATIONS

It is recommended that:

The thermal stability test procedure require that waste forms be sealed in containers immediately after preparation and throughout thermal cycling to prevent evaporative water

Fig. 5. Photograph of a VES waste form containing PF-7 wastes exposed to fungi in an agar-filled Petri dish during biodegradability testing.

loss. Thermocouples should be used during testing to monitor centerline temperatures of the waste forms.

- The Technical Position (3) state more positively whether other fluid(s) in addition to demineralized water are required for immersion testing.
- Though the methodology of ASTM G21 and G22 is applicable to biodegradation potential testing of waste form materials, longer exposure times and use of microbes known to attack Portland cement would make these methods more useful in determining biodegradability of actual waste forms.

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