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Compatibility of Packaging Components with Simulant Mixed Waste*

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INTRODUCTION

The purpose of hazardous and radioactive materials packaging is to enable these materials to be transported without posing a threat to the health or property of the general public. To achieve this aim, regulations in the United States have been written establishing general design requirements for such packagings. While no regulations have been written specifically for mixed waste packaging, regulations for the constituents of mixed wastes, i.e., hazardous and radioactive substances, have been codified by the U.S. Department of Transportation (U.S. DOT, 49 CFR 173) and the U.S. Nuclear Regulatory Commission (NRC, 10 CFR 71). Based on these national requirements, a Chemical Compatibility Testing Program was developed in the Transportation Systems Department at Sandia National Laboratories (SNL). The program provides a basis to assure any regulatory body that the issue of packaging material compatibility towards hazardous and radioactive materials has been addressed.

In this paper, we present the results of the second phase of this testing program. The first phase screened five liner materials and six seal materials towards four simulant mixed wastes. This phase involved the comprehensive testing of five candidate liner materials to an aqueous Hanford Tank simulant mixed waste. The comprehensive testing protocol involved exposing the respective materials a matrix of four gamma radiation doses (~1, 3, 6, and 40 kGy), three temperatures (18, 50, and 60°C), and four exposure times (7, 14, 28, and 180 days). Following their exposure to these combinations of conditions, the materials were evaluated by measuring five material properties. These properties were specific gravity, dimensional changes, hardness, stress cracking, and mechanical properties.

EXPERIMENTAL

Materials

The selected materials were five plastics having known chemical resistance to a large number of classes of chemicals. The plastics were high-density polyethylene (HDPE), cross-linked polyethylene (XLPE), polypropylene (PP), fluorocarbon (Kel-F™), and polytetrafluoroethylene (Teflon).

Simulant Preparation

The simulant mixed waste form used in this testing phase was an aqueous alkaline simulant Hanford Tank waste. It was prepared by dissolving 179 g (2.10 moles) of sodium nitrate and 50 g (0.73 moles) sodium nitrite in deionized water (600 mL) using a 4-L beaker. After these salts had completely dissolved, 82 g (2.05 moles) sodium hydroxide was added under stirring and slight heating using a magnetic stirrer. To this hot (~70°C) stirred solution, 17 g (0.107 moles) cesium chloride and 16 g (0.0952 moles) strontium chloride were added. Finally, 32 g (0.301 moles) of sodium carbonate was added to the solution. To the resulting mixture was added another 400 mL of deionized water to bring the total volume of water used to 1 L. After cooling to near ambient temperature, the stirred mixture was stored in Amber Glass Bottles.

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Sample Preparation

Standardized test methods were used to cut, condition, and test the materials. The geometry of the material samples was specified by the test method. The samples were cut using an expulsion press and dies manufactured by Testing Machines Inc., Amityville, NY. The use of the press and dies permitted the cutting of multiple samples of uniform dimensions. When attempting to cut out the harder materials such as HDPE, PP, and Kel-F with the expulsion press, considerable difficulty was encountered requiring machining to specifications. The individual samples were visually checked to assure that none had nicks or other imperfections prior to their use. As recommended by ASTM D618, the plastics were conditioned at a standard temperature of 23°C and relative humidity of 50% for at least 24 hours prior to the testing process.

Sample Irradiation

The above mentioned samples were exposed to gamma radiation from an underwater ^{60}Co source at SNL. These samples were loaded into a metal basket in the same configuration as was used to condition the samples, i.e., the samples were stacked atop each other and separated by a metal spiral. The basket was then inserted into a water-tight stainless steel canister (volume ~4 L). The canister was sealed and lowered into the pool to a depth of 6 feet, purged with slow steady flow (~ 30 mL/min) of dry air, and allowed to come to thermal equilibrium at either ambient, 50, or 60°C. Once thermal equilibrium was obtained, the canister was lowered into its irradiation location in the pool and the exposure time was started to obtain the desired radiation dosage. The highest dose rate available at the Low Intensity Cobalt Array (LICA) Facility was ~2 kGy/hr. Thus for irradiations where a gamma-ray dose of 1.43 kGy was required, the samples were exposed for approximately 0.75 hours. For doses of ~3, 6, and 40 kGy, the corresponding longer exposure times were needed. After the samples received the calculated radiation dosage, the canister was removed from the pool and the samples were again placed in the conditioning chambers.

Sample Exposure to Chemicals

The general exposure protocol for all tests involved placing specimens of each plastic material into a container (cell), and exposing them to the specific testing conditions. Care was taken to ensure that sufficient simulant waste was present to expose the entire surface area of all the samples. After adding the liquid simulant waste, the plastic lid was attached to the jar and tightened. The cells were placed in the respective enviromental chambers maintained at 18, 50, and 60°C. The cells were kept in these environmental chambers for 7, 14, 28, and 180 days.

DISCUSSION

The material properties that should be evaluated to assess the suitability of potential liner materials in mixed waste packaging designs are mass, dimensional and density changes, hardness, modulus of elasticity, tensile strength, elongation, and stress cracking in polyethylene materials. Since the measurement of <u>all</u> these material properties was expected to be costly and time-consuming, screening tests with relatively severe exposure conditions such as high temperatures and high radiation levels were implemented to quickly reduce the number of possible materials for full evaluation. The screening criteria used were density changes for liners and vapor transport rates for elastomers. From this screening study, it was found that all of the selected liner materials had passed the screening criteria in the aqueous simulant mixed waste. This then resulted in the testing of five materials that were exposed to a matrix of four radiation doses, three temperatures, and four times in the simulant waste. These parameters were evaluated using standardized test methods such as those developed by the American Society for Testing and Materials (ASTM). For specific gravity changes, ASTM D792 was used. In evaluating dimensional changes, ASTM D471 was used. For hardness changes, ASTM D2240 was used. In evaluating stress cracking in polyethylene materials, ASTM D1693 was used. Finally, for evaluating tensile property changes, ASTM D638 was used.

RESULTS

Before describing the results of the analyses to date, it should be mentioned that a complete data analyses of all testing performed to date has not been completed. The principle reason for this is that a number of the 180-day experiments are still in progress. Until all experiments are completed, it is not possible to fully understand the implications of these studies. In Figure 1, we present the results of four measurements, specific gravity changes, dimensional changes (volume changes), hardness changes, and tensile strength changes.

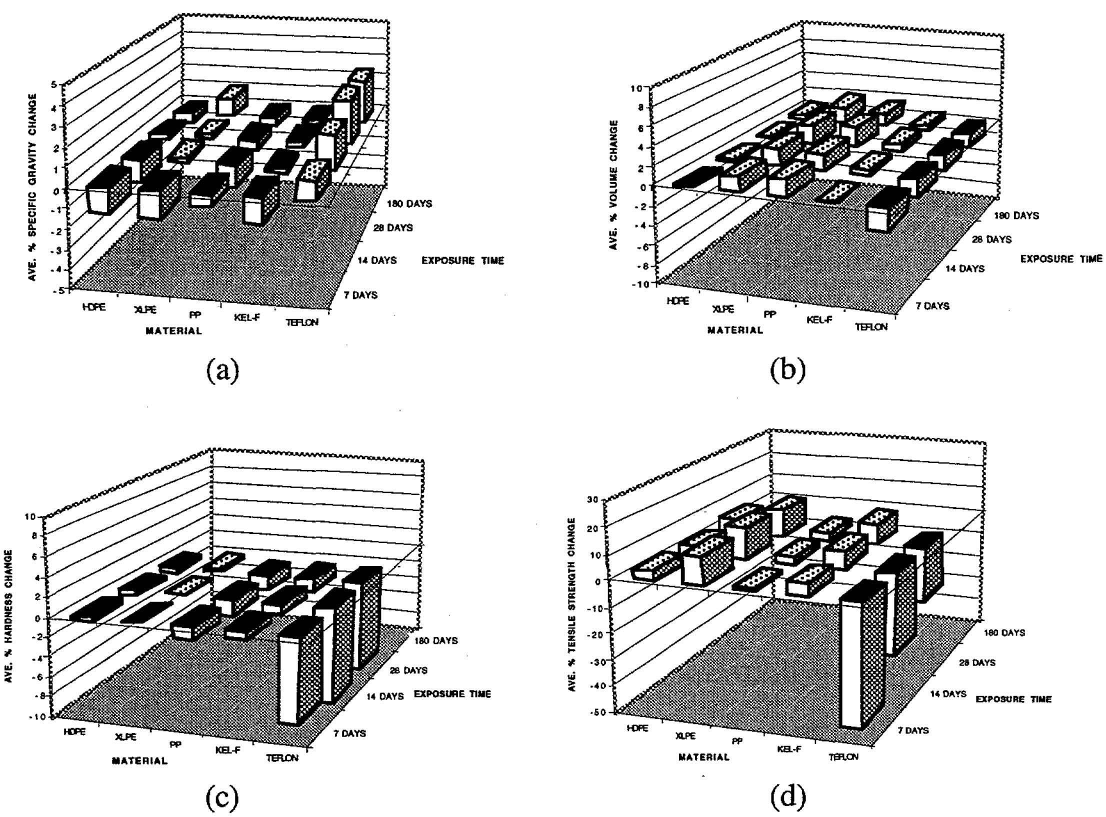

Figure 1. Comprehensive testing results of five liner materials after exposure to ~40 kGy of gamma radiation and the aqueous simulant waste at 60°C (a) specific gravity changes, (b) dimensional changes, (c) hardness changes and (d) tensile strength changes. Note: 180 day data currently being obtained for hardness and tensile strength changes.

Based on the limited results presented here, it is worthwhile to attempt to identify the one material which displayed the greatest compatibility towards the simulant mixed waste under these conditions. In order to accomplish this, a ranking scheme was developed. By identifying the material which had the best test performance under each test condition and assigning an arbitrary value of one, suming these four test values gave a overall value. That material with the lowest value was most compatible. Using this very simplistic approach, the fluorocarbon Kel-F™ was identified as the material which is most compatible with this simulant mixed waste under these conditions. Interestingly, Teflon was found to be the least compatible material.

CONCLUSIONS

We have developed a chemical compatibility program for the evaluation of plastic packaging components which may be incorporated in packaging for transporting mixed waste forms. From the limited data analyses performed to date in this study, we have identified the fluorocarbon Kel-F™ as having the greatest chemical compatibility after having been exposed to 40 kGy gamma radiation followed by exposure to the Hanford Tank simulant mixed waste at 60°C. The most striking observation from this study was the poor performance of Teflon under these conditions.

DISCLAIMER