Manufacture of KJRR Cement Waste Form for Enhancement of Cesium Leaching Resistance

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1. Introduction

KAERI has a plan to build KRJJ (Ki-Jang Research Reactor) in Ki-Jang, Busan by 2022. It is important to safely dispose of low and intermediate level liquid radioactive waste from operation of the research reactor. One of the efficient ways to treat liquid radioactive waste is cement solidification. The cement solidification is more simple and efficient than other solidification method, but has relatively lower leaching resistance. Therefore, this study focused on the development of cement solidification for an enhancement of cesium leaching resistance. We used loess to improve the cesium leaching resistance of KJRR cement form containing KJRR simulated liquid waste (Loess KJRR cement waste form). A leaching test was carried out using KJRR simulated liquid waste containing 3 g/L of cesium for 90 days. KJRR cement waste form containing loess showed cesium leaching resistance was 21.1% higher than KJRR cement form without loess (KJRR cement waste form).

2. Methods and Results

2.1 Materials

Portland cement and loess were purchased from SSangyong and Greenbio respectively. NaCl, Na_2SO_4 and CsCl were purchased from Sigma-Aldrich (Mo, USA). All other chemicals used are of analytical or research grade.

2.2 KJRR simulated liquid waste

The KJRR (Ki-Jang Research Reactor) simulated liquid waste constituents are as follows: Na_2SO_4 106.53 g/L, NaCl 64.28 g/L, and Cs^+ 3 g/L [1].

2.3 Manufacture of KJRR cement waste form

The KJRR cement waste form were simulated in accordance with the Korean Industrial Standard (KS-L-5109) [2]. The mechanical mixer was purchased from Jl-206 (Jeil Precision, Korea). KJRR cement waste forms were made to find the optimal mixing rate (W/C, W: water, C: cement) from 0.4 to 1.3 (Fig. 1a). The KJRR cement waste forms were made by W/C 0.7 considering
the result of the workability test (Fig. 1b). And we added loess to improve the cesium leaching resistance of KJRR cement (S/C, S: loess, C: cement) from 1, 5 and 10wt.% (Fig. 1c). And KJRR cement was solidified while curing at room temperature with relative humidity of 40 to 60% for 28 days. After 28 days, the uniformity of KJRR cement waste form was visually confirmed.

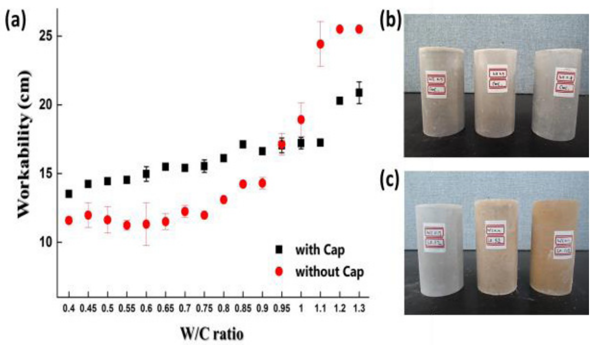

Fig. 1. (a) Workability of KJRR cement waste form according to W/C ratio (b) KJRR cement waste form (c) Loess KJRR cement waste form.

2.4 Characterization of KJRR cement waste form

The component of KJRR cement waste form was analyzed using SEM-EDS. As shown in Table 1, it can be seen that (Fe, Al, Si) ions, which are the main components of loess, increase with the loess content of KJRR cement waste form.

Table 1. Weight percent (wt. %) of loess elements according to loess contents of KJRR cement waste form

Elements	Loess	KJRR (Without Loess)	KJRR (Loess 5%)	KJRR (Loess 10%)
O	48.84	42.19	36.64	43.64
Al	17.87	1.57	2.30	3.00
Si	24.69	6.50	6.66	7.96
Ca	0.41	37.25	40.84	30.43
Fe	7.62	1.57	3.90	4.24

2.5 Leaching test of KJRR cement waste form

As shown in Fig 2. We analyzed pH and electronic conductivity of KJRR cement waste form with a leaching time. It was confirmed that the pH and Eh increased with loess content of KJRR cement waste form.

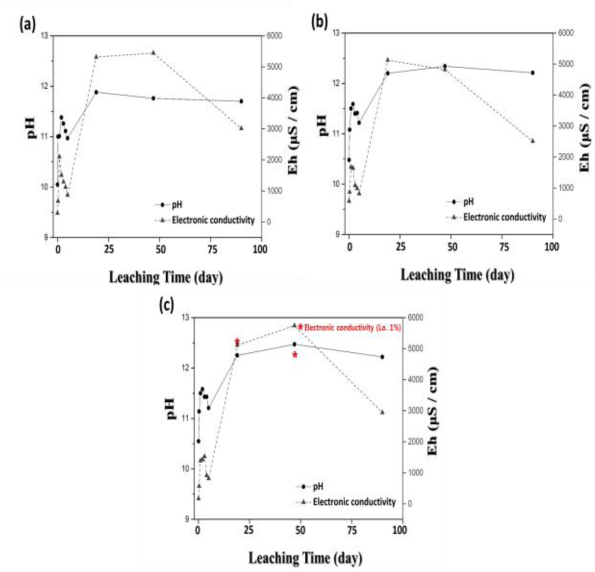

Fig. 2. pH and electronic conductivity with a leaching time (a) control, (b) Loess in KJRR cement waste form (S/C 1.0 wt.%) and (c) (S/C 10 wt.%).

The cumulative fraction leached (CFL) of cesium according to the change of loess content was calculated using the ANS 16.1 test method from USA. The leaching resistance was determined by considering the degree of cesium ions leached during the leaching test, and the cumulative fraction leach was defined as the equation below [3]

$$CFL = \frac{\sum A_i}{A_0} \quad \textbf{(1)}$$

A_i= Cumulative leaching amount of material A during the leaching interval

A_0= Initial content (g) of the material A

It was confirmed that KJRR cement waste form containing loess was lower Cs^+ leaching rate than control sample(KJRR cement waste form, without loess) (Fig. 3).

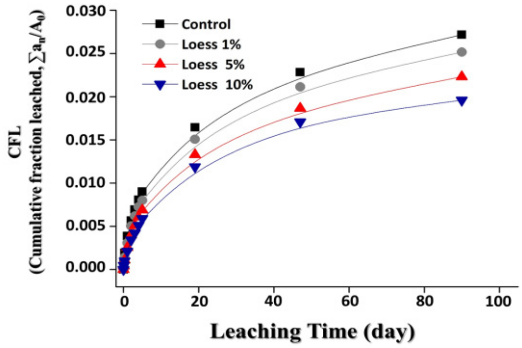

Fig. 3. Cumulative fraction of Cs^+ leached in loess KJRR cement waste form.

3. Conclusions

In this study, we made a KJRR cement waste form with KJRR simulated liquid waste. In addition, we used loess to improve the cesium leaching resistance of KJRR cement waste form. We proved based on SEM-EDS spectrum analysis that loess was successfully isolated with the KJRR cement waste form. A leaching test was carried out using simulated KJRR liquid waste containing 3 g/L of cesium. Loess KJRR cement waste form achieved a cesium leaching resistance 21.1% higher than the control value. In addition, all experimental groups were satisfied with acceptance criteria of the final disposal facility such as the compressive strength and leaching rate.

REFERENCES

[1] J.S. Shon, et al., “Treatment and Disposability of Intermediate Level Liquid Radwastes generated by Fisson Moly Production”, Proc. of the Korean Radioactive Waste Society, 15 (2017).

[2] W.H. Jang, et al., "A Study on Operating Range of Cement Solidification for Final Disposal of Radioactive Soil”, Journal of Korea Society of Waste Management, 34 (2017).

[3] Y.J. Lee, et al., “Characterization of Cement Waste Form for Final Disposal of Decommissioned Concrete Waste”, Journal of Nuclear Fuel Cycle and Waste Technology, 11 (2013).