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Derivation of Thermal Treatment Process Conditions for Volume Reduction of Dry Active Waste

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1. Introduction

The generation of radioactive waste is increasing due to the life extension of nuclear power plants and the additional operation of new nuclear power plants. A large amount of dry active wastes(DAWs) is generated in the process of operation and maintenance of nuclear power plants, accounting for about 69 % of the total waste[1]. Therefore, it is necessary to develop a technology that reduces the volume of DAWs and secures the stability of disposal. Thermal treatment such as combustion is the most effective way to reduce the amount of DAWs.

DAWs have a chemically complex composition due to the development of new materials. Therefore, the applicable alternative incineration technology must be different. Hazardous wastes are excluded from the thermal treatment process because they may release hazardous substances(dioxin, furan, acid, gas, and harmful heavy metals etc.) into the environment. Therefore, for the application of this technology, it is very important to accurately find the physicochemical characteristics of DAWs generated from actual nuclear power plants.

In this study, the physicochemical properties of each DAWs were analyzed for the design of a customized thermal treatment process. Then, we derived the thermal treatment conditions for several representative samples.

2. Methods

2.1. Amount of DAWs & selection of samples

Based on domestic and international literature, we investigated the weight ratio of waste for each type of DAWs. A representative sample applied to the thermal treatment process was selected based on the weight ratio of each DAWs type. Next, to verify the actual waste, we investigated the purchase specifications of each domestic nuclear power plant(Kori, Saeul, Wolsong, Hanul, Hanbit).

2.2. Analysis of physicochemical properties of DAWs

For underground disposal, it is important to stabilize the ash condition after thermal treatment. This means that stabilization is due to the physicochemical properties of each DAWs. Therefore, the design of stabilization processes should be based on quantitative analysis of physicochemical properties.

Element analysis(EA) was conducted to confirm the composition of organic elements of 14 samples. Next, a 'Proximate Analysis' was conducted to analyze the Moisture, ash, Volatile Matter, and Fixed Carbon by applying specific temperatures and conditions to the sample. Proximate analysis was performed on 12 samples(excludes PVC vinyl sheets and shoe covers containing halogen elements). The change in weight of the sample before and after the thermal treatment was compared.

2.3. Thermal treatment process design by type of DAWs

TG/DTA analysis was performed to derive the thermal treatment conditions for each DAWs. For each DAWs, thermal decomposition is confirmed by temperature rising at a constant speed in nitrogen or air atmosphere, and the weight change at this time is measured.

3. Results

It was found that 88.5 % of the total DAWs were cotton, vinyl, and paper. Among the various DAWs, it was confirmed that the proportion of decontaminated paper was the highest at about 22.5 %. Gloves, protective clothing, socks, shoes cover used to prevent contamination by workers accounted for about 70.0 % of the waste weight ratio. Based on these results, representative samples were selected as shown in Table 1.

Table 1. Specifications for samples by DAWs

Type	Waste weight ratio(%)	Waste weight ratio(%)
Paper	Decontamination paper	22.44
	Wiper towel	0.22
Cotton	Protective clothing	9.77
	headwear, gowns etc.	3.12
	Cotton gloves	10.87
	Socks	10.19
Vinyl	Plastic bags	4.20
	Vinyl sheets	12.11
	Shoes cover	15.62
Plastics	Reagent bottles	1.22
Rubber	Latex gloves	9.72
	Rubber shoes	0.52

As a result of analyzing the composition of organic elements in the sample(Table 2), it was confirmed that most of them consisted of C, H, and O, and N was included only in the case of nylon gloves. Sulfur was detected only in latex gloves. It was also found that PVC vinyl and Shoe covers contain a large amount of Cl, a halogen element.

Table 2. Results of Element Analysis

Sample name	C(%)	H(%)	N(%)	S(%)	O(%)	Cl(%)
Decontamination paper	41.14	6.00	0.09	-	45.66	0.03
Wiper towel	41.78	6.16	0.03	-	46.31	0.03
Protective clothing	54.93	4.91	0.10	0.00	36.23	0.04
Protective gowns	41.12	5.99	0.10	-	44.71	0.01
Socks	47.16	5.64	0.17	-	41.99	0.05
Nylon gloves	62.82	12.13	9.87	0.00	14.57	0.00
Cotton gloves	42.14	6.29	0.08	0.00	46.52	0.03
PVC sheets	50.31	6.79	0.00	-	5.88	33.00
Shoes cover	37.09	3.54	0.00	-	24.08	13.00
General waste bags	84.59	14.47	0.09	-	0.69	0.04
Dust suit	65.38	10.40	0.25	-	9.86	0.01
Sticky Mats	82.72	13.83	0.08	-	2.75	0.01
Reagent bottles	85.84	14.61	0.07	-	0.18	0.01
Latex gloves	69.77	0.00	0.00	2.23	17.10	0.01

The results of the Proximate Analysis are shown in Table 3. After the thermal treatment, it was confirmed that 10 samples were almost lost(Ash ratio ≤ 1.3 %). This can be seen as a result of the decomposition of organic compounds to produce volatile species during the thermal treatment process. On the other hand, it was confirmed that a relatively large amount of thermal treatment products remained in dust suit and latex gloves(Ash ratio ≤ 14.0 %). This is considered to be due to the inorganic compound contained in the sample[4].

Table 3. Results of the Proximate Analysis

Sample name	Moisture (%)	Volatile (%)	Ash (%)	Fixed Carbon(%)
Decontamination paper	6.22	82.50	1.02	10.26
Wiper towel	6.36	83.96	0.18	9.50
Protective clothing	3.70	83.77	0.55	11.99
Protective gowns	7.67	82.33	0.14	9.86
Socks	3.98	83.67	0.89	11.45
Nylon gloves	2.41	97.24	0.27	0.08
Cotton gloves	5.01	86.76	0.32	7.91
General waste bags	0.01	98.69	1.28	0.02
Dust suit	0.11	86.04	13.83	0.02
Sticky Mats	0.00	99.59	0.52	0.02
Reagent bottles	0.00	100.00	0.00	0.00
Latex gloves	0.22	85.96	13.71	0.11

The temperature with the highest efficiency of thermal decomposition was derived for cotton gloves and latex gloves(with large differences in ash ratio after thermal treatment). Cotton is found to have the efficiency of the highest thermal decomposition at about 435°C after it begins thermal decomposition at 300°C. On the other hand, latex gloves showed the efficiency of the highest thermal decomposition at about 385℃.

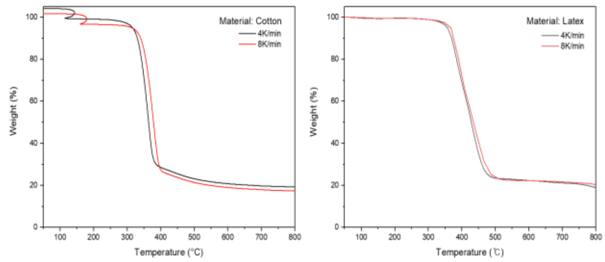

Fig. 1. Thermogravimetric Analysis(TGA) curves for cotton and latex under different heating rates

4. Conclusions

Thermal treatment was performed on actual waste for volume reduction and stable disposal of DAWs. Most of the samples were found to disappear during the thermal treatment process, except dust suit clothing and latex gloves. TG/DTA analysis results, the thermal treatment process conditions for cotton and latex gloves could be optimized to 435°C and 385°C. In the future, we plan to conduct TG/DTA analysis with other DAWs to derive the thermal treatment temperature. In the future, we plan to analyze the hazardous substances generated during thermal treatment and confirm the stability of the technology.

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