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Phosphorus Recovery from Incinerated Ash of Sewage Sludge by Heat Treatment

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Abstract: The phosphorus recovery from incinerated ash of sewage sludge by a heat treatment method was investigated. The incinerated ash of sewage sludge was mixed with sodium hydroxide or sodium carbonate, and treated at 750 °C to 900 °C in aerobic conditions. The phosphorus was successfully recovered as an alkali metal phosphate from the treated ash through water extraction. The recovery rate of the phosphorus reached about 74% to 78%. The optimal condition of the phosphorus recovery and composition of the recovered phosphorus was investigated.

Key word: Incinerated ash, sewage sludge, sodium hydroxide, sodium carbonate, phosphorus recovery.

1. Introduction

Sewage sludge contains significant amounts of phosphorus, and in order to recover phosphorus, some methods were investigated with the incinerated ash or charcoal of the sludge using acid [1] or alkal [2]. The phosphorus in the sludge is considered to exist in many forms of phosphate compounds ($AlPO_4$, $FePO_4$, $Ca_3(PO_4)_2$, etc.) [3]. In an acidic treatment, almost all of the phosphorus can be extracted, however, the recovered phosphorus contains high amounts of aluminum [4-6] which is considered to be inconvenient for the usage of the recovered phosphorus, and finding the usage is needed. On the contrary, the alkali treatment can possibly recover the phosphorus with the low content of aluminum, but the extraction rate is low because of low solubility of the $Ca_3(PO_4)_2$ component of the sludge in alkali conditions [7]. In order to obtain the high extraction rate through the alkali treatment, phosphorus extraction at high temperatures is regarded to be effective [8, 9]. We investigated phosphorus recovery from the charcoal of sewage sludge using NaOH [10] or Na_2CO_3 through the heat treatment of the incinerated ash of sewage sludge.

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2. Methods

2.1 Recovery Method

The ash of sewage sludge which was incinerated by an incinerator at 850 °C in anaerobic condition, was used. The chemical composition is shown in Table 1. As alkali materials, reagents of NaOH or Na_2CO_3 were used.

In the case of NaOH, the aqueous solution of the NaOH was mixed with the raw ash, and treated at an appropriate temperature (750 °C [11]) for 1 hour after drying at 105 °C. Later, in order to extract the alkali metal phosphate which is formed through the heat treatment, washing water was added to the treated mixture with S/L (solid/liquid) ratio 1:10, and filtrated using filter paper (5A, Toyo Roshi Kaisha, Ltd. Advantec). The phosphorus was recovered from the filtrate by drying at 105 °C as shown in Fig. 1. The case of Na_2CO_3, powder of the Na_2CO_3 was mixed with ash, and treated also at 900 °C [12] for 1 hour, later, washing water was added to the treated mixture, and the phosphorus was recovered the same as with the NaOH.

Table 1 Chemical composition of the ash.

Element	Na_2O	Al_2O_3	SiO_2	P_2O_5	CaO	Fe_2O_3	Others
Content (%)	1.0	6.9	31.3	18.0	14.5	18.3	10.0

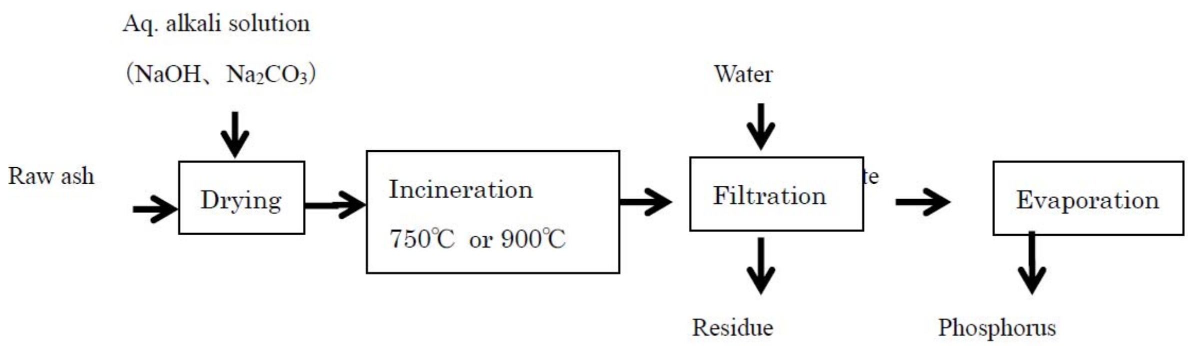

Fig. 1 Recovery method.

2.2 The Alkali Addition Rate

In order to decide an optimal addition rate of the alkali, 5 g of the raw ash was mixed with some concentrations of the aqueous solution of NaOH or the powder of Na_2CO_3. The mixture was dried at 105 °C, and treated at the temperature as mentioned, in aerobic conditions. To extract the phosphorus, water was added to the treated mixture, and was filtrated using filter paper. The phosphorus was recovered from the filtrate by drying at 105 °C as residue, and the chemical composition was examined using an X-ray analyzer (Rigaku Cooperation SPECTRO XEPOS). The phosphorus content of the residue was degreased by the extraction of the phosphorus, and the degreased amount of the phosphorus tended to be increased with the addition rate of the alkali. The degreasing rate of the phosphorus in the treated ash tends to flatter when the addition rate reached 2 g (in the case of NaOH, shown in Fig. 2) or 3 g (in the case of Na_2CO_3, shown in Fig. 3). From the result, we decided the optimal addition rate of the alkali for the phosphorus recovery was as follows.

The addition rate: 5 g of the ash to 3 g to 4 g of NaOH, and 5 g of Na_2CO_3.

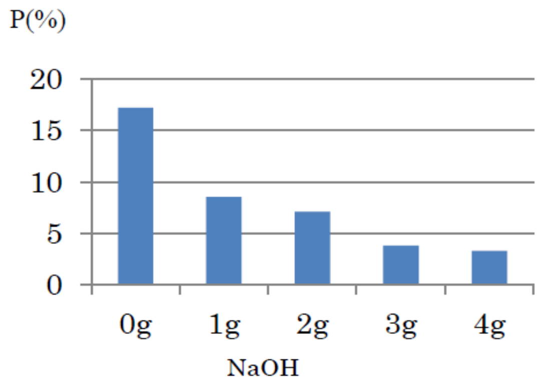

Fig. 2 The relation between the amount of phosphorus in the residue and the NaOH addition rate.

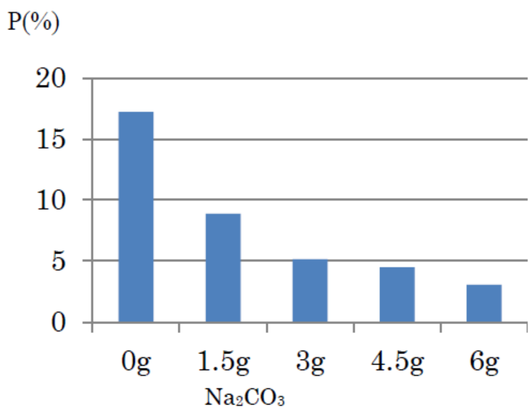

Fig. 3 The relation between the amount of phosphorus in the residue and the Na_2CO_3 addition rate.

3. Results and Discussion

In order to confirm the phosphorus recovery, the aq. solution of NaOH (6 g of NaOH mixed with 17 mL of water) was added to the 10 g of raw ash, and treated as described. Later, 200 mL of water was added to the treated mixture, and was filtrated using filter paper. The pH of the filtrate reached about 12. The possibility of Cr^{6+} formations through incineration or heat treatment is reported [13, 14]. In order to confirm the formation of the Cr^{6+} through this treatment, concentration of the Cr^{6+} was checked by a simple analysis (using the PACKTEST, KYORITSU Co. Ltd), 2 mg/L of the Cr^{6+} was detected. The filtrate and residue were dried for analysis at 105 °C, and recovered.

The same experiment was carried out using 10 g of the ash and 10 g of Na_2CO_3. The small amount of Cr^{6+} (0.5 mg/L) was found in the filtrate, and phosphorus or residue was recovered.

The amounts of the raw ash and recovered materials are shown in Table 2, and these materials were analyzed using an X-ray analyzer (as shown in Fig. 4). Almost all of the phosphorus was removed from the ash, and the recovery rate was calculated from the material balances and the compositional change as Eq. (1). The recovery rate is considered to be 78% (in the case of NaOH) or 74% (in the case of Na_2CO_3).

The recovered phosphorus is considered mainly to be a sodium phosphate from the chemical composition and previous researches, and contains a small amount of aluminum or silicon compounds.

In this treatment, almost the same amount of the treated ash will be remained, and finding the usage of the treated ash is a very important matter. The alkali metal aluminum silicate contained in the residue has a chemical composition like zeolite [15], and the residue is expected to have an ability like zeolite, however, further investigation will be needed in order to find a usage for them. The other matter, formation of the Cr^{6+} compounds was found, and elimination of them is necessary.

$$R = (1-P1 \times W1/P2 \times W2)\ 100 \quad (1)$$

R: Phosphorus recovery rate (%)

Table 2 The amount of the recovered materials (raw ash: 10 g).

Used alkali	Addition rate of the alkali	Amount of the treated ash	Amount of the recovered phosphorus
NaOH	6 g	11.6 g	8.2 g
Na_2CO_3	10 g	12.3 g	12.1 g

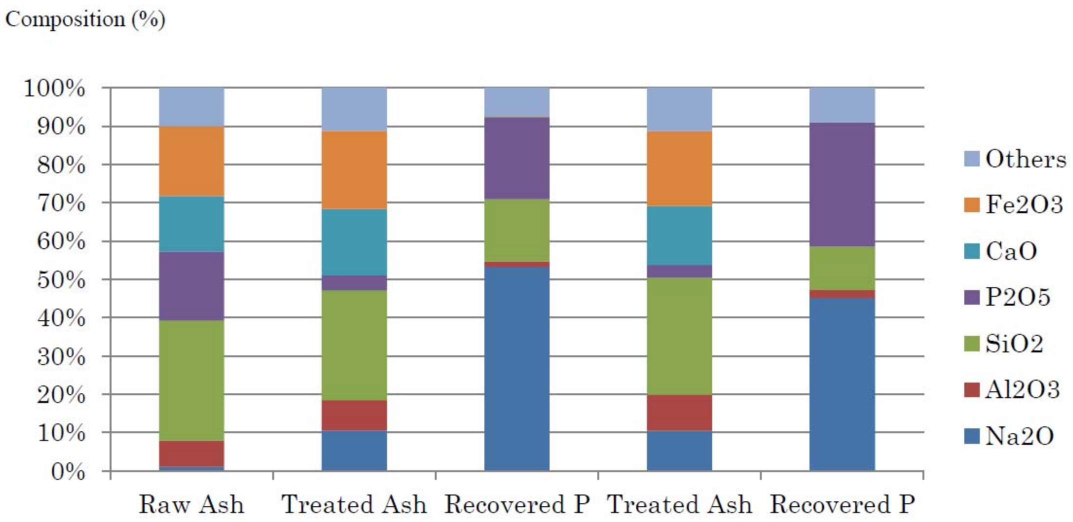

Fig. 4 The composition of the recovered materials.

P1: Phosphorus concentration of the treated ash
P2: Phosphorus concentration of the raw ash
W1: Amount of the treated ash
W2: Amount of the raw ash

4. Conclusion

Phosphorus was recovered from the ash of sewage sludge with a high recovery rate through heat treatment by the addition of alkali metal compounds. Almost all of the recovered phosphorus is considered to be alkali metal phosphate which can be used in many ways. However, much investigation will be needed to determine the best method for practical usage.

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