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Open Access Journal of Waste Management & Xenobiotics
ISSN: 2640-2718

The Chemical Change of the Ash Components through Phosphorus Recovery of Dehydrated Sludge by Incineration using Alkali Metal Compounds

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Research Article
Volume 4 Issue 4
Received Date: October 29, 2021
Published Date: November 24, 2021
DOI: 10.23880/oajwx-16000168

Abstract

In order to recover phosphorus from the wastewater sludge, the dehydrated sludge was mixed with the reagent of NaOH, KOH or Na_2CO_3, and incinerated at 750 °C or 900 °C. Phosphorus in the incinerated ash of the sludge was dissolved by the addition of the hot water, and recovered by the evaporation of the extract. The recovered phosphorus was confirmed to be an alkali metal phosphate, and the recovery rate reached about 75% regardless in these reagents (NaOH, KOH or Na_2CO_3). The chemical change of the ash components were also found through phosphorus recovery.

Keywords: Water Sludge; Phosphorus Recovery; Incineration; Alkali

Introduction

Phosphorus is a very important element, and regarded to be one of the indispensable elements of life. However it distributes in a limited area of the world, and Japan is importing all of it from other nations, and finding the domestic sources are needed. A large amount of wastewater sludge is discharged through the construction of the wastewater treatment facility [1]. The water sludge contains a significant amount of phosphorus, and the phosphorus concentration in the sludge increases by the introduction of the advanced phosphorus removal technique [2]. However, a useful recycling technique is not established, and the phosphorus is discharged into the environment without utilization. In order to recover the phosphorus from the sludge, some kinds of the methods using alkali [3] or acid [4,5] are investigated. The acid treatment can recover the phosphorus with high performance [6]. However, the recovered phosphorus contains a lot of aluminum [7] and the usage is limited. On the other hand, with the alkali treatment, the recovered phosphorus contains small amounts of aluminum, but the recovery rate is low compared with the acid treatment [8]. We found that the phosphorus recovery rate became high by the treatment at high temperature [9,10]. However, how to use the heat source of the treatment is an important matter.

In Japan, almost all dehydrated sludge is already incinerated from the stand point of reducing the amount of the waste and also recover heat energy. Therefore, incineration of the water sludge which is mixed with alkali compounds, is considered to be a useful method for the phosphorus recovery. Based on this concept, the recovery experiment was carried out, and phosphorus was successively recovered [11]. In order to determine the mechanism of this reaction, we investigated the chemical state of the ash components which was converted through the phosphorus recovery.

Method

The dehydrated sludge (refer to as raw sludge) which was discharged at the Yokkaichi-City Waste Water Treatment Facility, was used. The aq. solution of the NaOH and KOH or powder of Na_2CO_3 was mixed with the raw sludge (water content 82%), and dried at 105°C for 24 hours. A basic matter is to determine the incineration method of the sludge. The raw sludge was mixed with the alkali compounds with finite ratio (Table 1) followed by incineration. A suitable instrument for the incineration is not provided, in order to make easy incineration of the sludge, the incineration was carried out in 2 steps.

In the first step, the dried sludge mentioned above was put into the evaporating dish (made of porcelain), and heated to about 500°C using an oven. The volatile organic components in the sludge were evaporated, and the sludge was changed to charcoal.

In the second step, the charcoal was incinerated at 750°C (NaOH , KOH) or 900°C (Na_2CO_3) using an electric furnace. These temperatures are considered best from former research [12]. The ash (refer to as generated ash) was generated by this treatment. As a reference, raw sludge was incinerated the same way without the addition of the alkali, and the ash of the raw sludge was prepared. The generated ash was mixed with hot water (about 90°C, solid/liquid mixing rate 1:10) to dissolve the phosphorus component in the ash, and was filtrated using the filter paper (Toyo Roshi Kaisha, LTD). The filtrate was concentrated by evaporation, and cooled at 5°C for one day. The phosphorus was recovered as a form of crystal from the cooled filtrate by separation using filter paper (Figure 1). On this occasion, significant amount of the alkali waste water remained. This waste water will possibly be reused as the alkali for the phosphorus recovery [13] but in this experiment reuse of the alkali waste water was not examined. The insoluble components in the generated ash were separated as the residue using filter paper. The proper mixing ratio of the raw sludge and the alkali compounds was decided as follows from the result of the previous research [14].

Sample	Amount of the raw sludge	Amount of the alkali	Incineration temperature （℃）
Sample 1	50g	NaOH 1g	750
Sample 2	50g	KOH 2g	750
Sample 3	50g	Na_2CO_3 2g	900

Table 1: Experimental Condition.

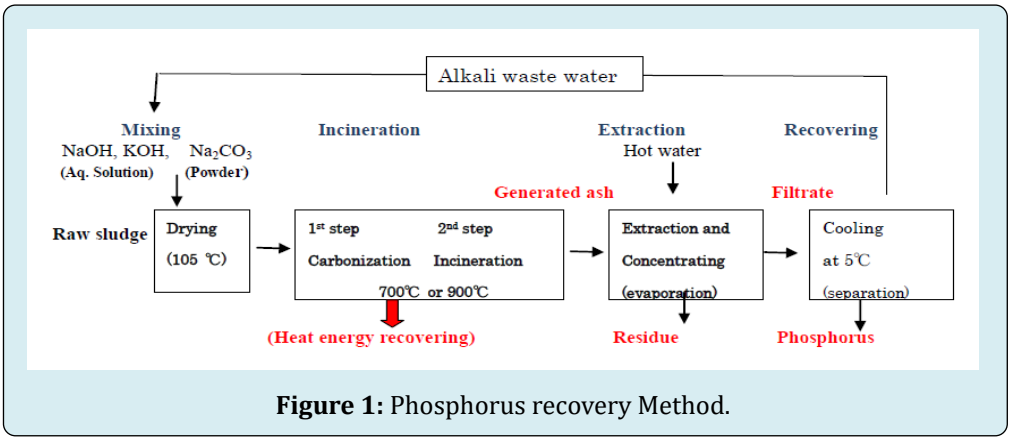

Figure 1: Phosphorus recovery Method.

Results and Discussions

Chemical Change of the Ash Components of the Sludge

50g of the raw sludge was mixed with each alkali metal compounds, and treated as shown in Table 1. The chemical compositions of the ash of raw sludge and the residue were analyzed using an Xray analyzer (Rigaku Cooperation SPECTRO XEPOS), and are shown in Figure 2. The phosphorus component in the residue was decreased, compared to the ash of raw sludge because of the phosphorus extraction. On the contrary, other components like Fe_3O_3, SiO_2, Al_2O_3 CaO were almost same. The component of Na_2O was increased by the case of the NaOH or Na_2CO_3, and K_2O was also increased by the case of the KOH. In order to identify the reaction through the phosphorus recovery, X-ray diffraction analysis was carried out on the ash of the raw sludge and the residue

using X-ray diffraction analyzer (Rigaku Cooperation). The X-ray diffraction spectrums are shown in Figures 3-5) The ash of the raw sludge, SiO_2 and Fe_2O_3 component was dominant, on the contrarily compounds made of Na, Al, Si or K, Al, Si were found in the residues. Some ash components like SiO_2, Al_2O_3 react with alkali metal compounds and form Zeolite, which is widely known [15]. It is considered that some kinds of chemical reactions happened like the one through the phosphorus recovery processes, and the reactions are enacting an important role.

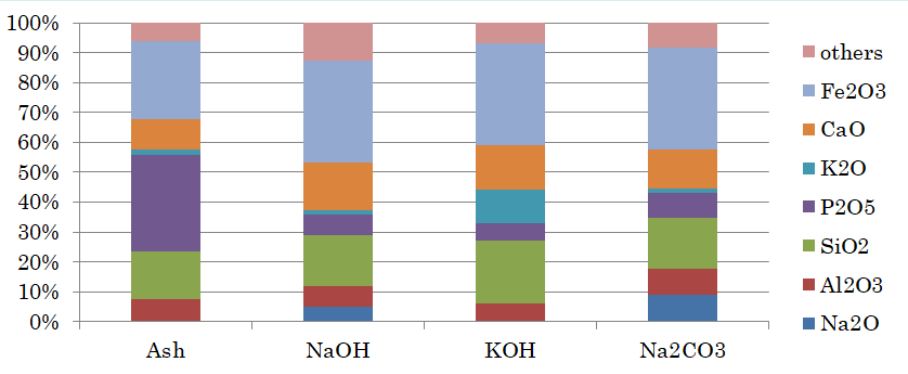

Figure 2: Chemical composition of the ash and residue of the basic experiment.
Ash; Ash of the raw sludge, NaOH; Residue mixed with NaOH,
KOH; Residue mixed with KOH.
Na_2CO_3; Residue mixed with Na_2CO_3.

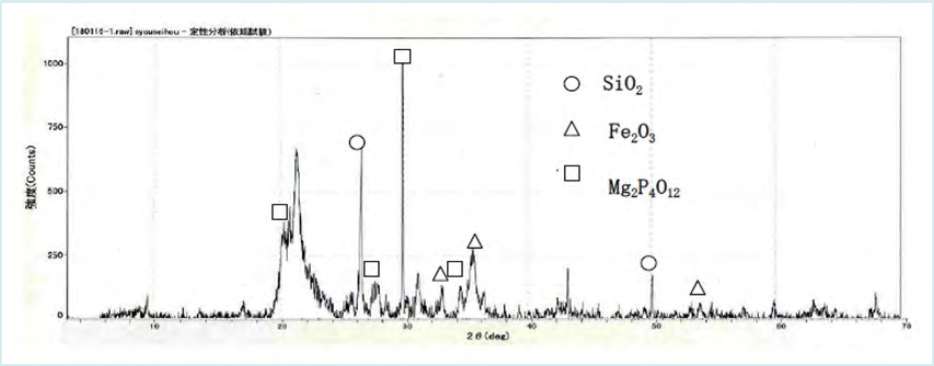

Figure 3: X-ray spectrum of the ash of the raw sludge.

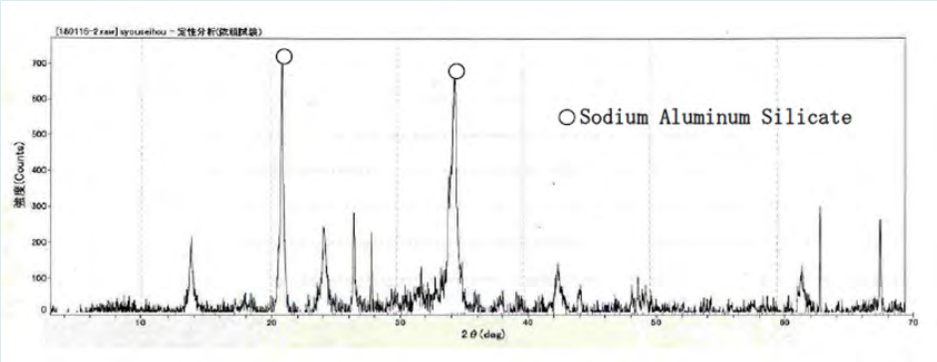

Figure 4: X-ray spectrum of the residue (NaOH).

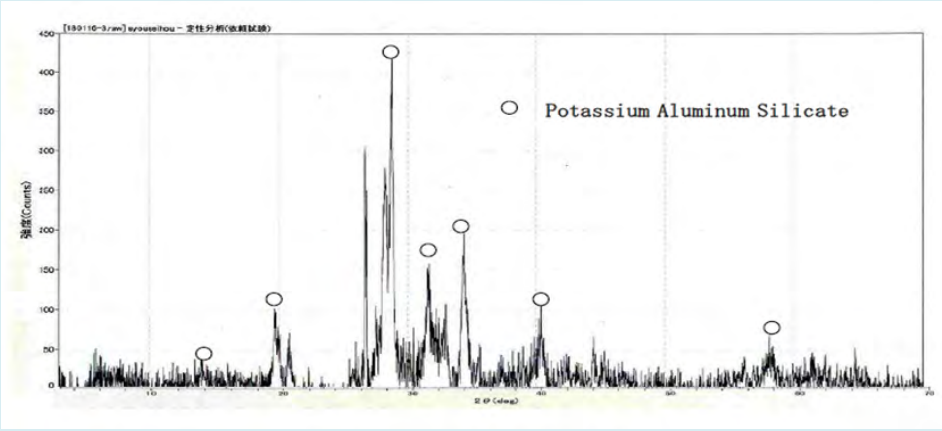

Figure 5: X-ray spectrum of the residue (KOH).

State of the Recovered Materials

In order to confirm the chemical state of the recovered phosphorus, 1100g of the sludge was also mixed with 22g of NaOH, and treated as mentioned above. The amounts of the recovered materials are shown in the Table 2. The phosphorus recovery rate reached 75% which is almost the same as in the previous research [14]. The recovered phosphorus was mainly composed of Na_2O and P_2O_5 (Figure 6), and confirmed to be made of Na_3PO_4 by the X-ray diffraction data (Figure 7). However, it contains more the Al_2O_3 component (18%) compared to the previous research, and in order to reduce the aluminum content, more investigations are needed.

Item	Raw sludge	NaOH	Generated ash	Extract	Residue	Phosphorus	P recovery rate
This experiment	1100g	22g	43	1000mL	19	26	75%
Previous research [14]	500g	10g	11.6g	500mL	8.5	7.7	74%

Table 2: The amounts of the recovered materials and recovery rate.

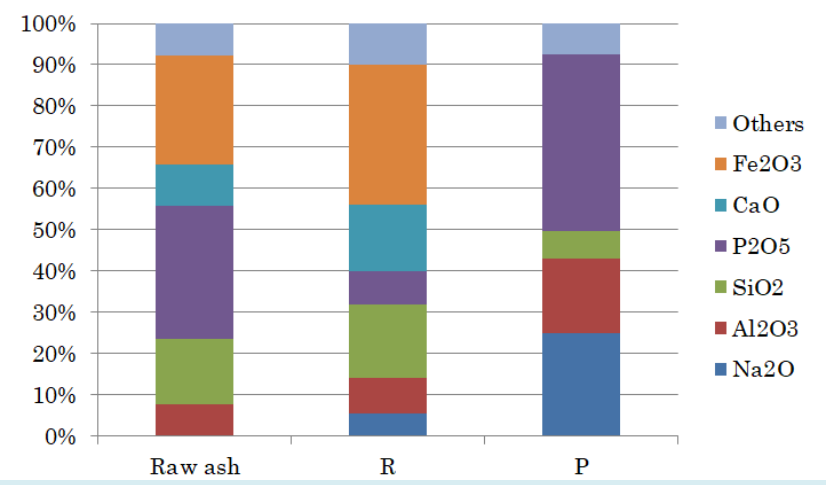

Figure 6: Chemical composition of the residue and recovered phosphorus
Remark; Raw ash: Ash of raw sludge, R: Residue, P: recovered phosphorus

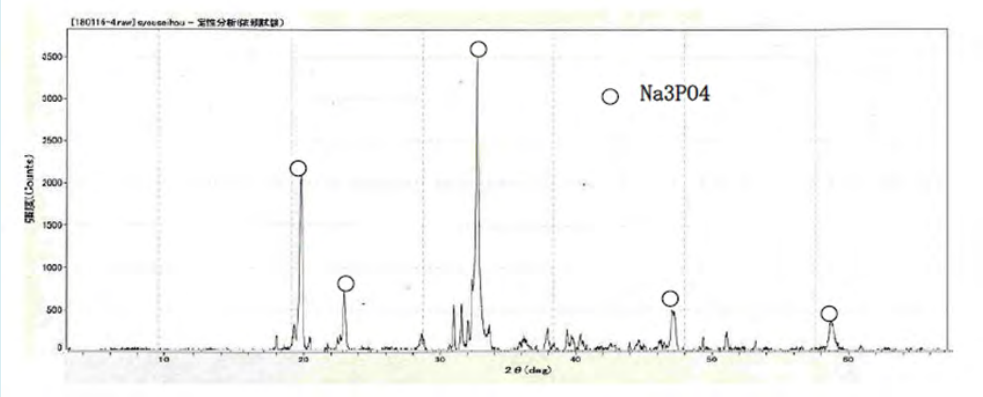

Figure 7: X-ray spectrum of the recovered phosphorus.

Conclusion

In order to improve the phosphorus recovery method of the sewage sludge, the dehydrated sewage sludge was mixed with alkali metal compounds, and incinerated at the 750°C or 900°C. Phosphorus was recovered by the extraction from the treated ash with the addition of water followed by concentration.

The recovery rate of the phosphorus reached about 75%, and recovered phosphorus was considered to be mainly made of alkali metal phosphate (considered to be sodium phosphate or potassium phosphate) which has many usages. The chemical state of the ash components were changed by the incineration. We considered that any kinds of reactions that have happened through the phosphorus recovery, and are considered to be enacting an important role. The phosphorus recovery from the dehydrated sludge is a simple and energy effective way, and considered to be useful. However, significant amounts of the residue (ash) is habitually discharged, and as the utilization of the ash components is an important matter, further investigation will be needed.

Acknowledgements

The authors express their appreciation to Dr. Shigeo Hayashi (Mie Prefectural Institute of Industrial Technology) for his assistance with the X-ray analysis, and also appreciation to Dr. Eric Bray (Professor of Yokkaichi University) for his advice on making the article and also express their appreciation to Mr. Kenji Takahashi for his assist on the experiment. The authors also express their appreciation to the Hinaga Wastewater Treatment Center (Yokkaichi City Government, Waterworks and Sewage Bureau) offering us the ash.

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