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Feasibility of using natural fishbone apatite on removal of Pb from municipal solid waste incineration (MSWI) fly ash

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Abstract

Fishbone, a common waste generated in coastal areas, especially from the fish processing industry, is known as the natural resource of hydroxyapatite (HAP). Researchers have investigated the removal of heavy metals from the contaminated environments based on the exchange capacity of Ca in HAP with heavy metal ions, while there are limited numbers of researches on the effect of natural HAP on municipal solid waste incineration (MSWI) residues. This work is an attempt to ascertain the feasibility of fishbone used for stabilizing Pb in lime-treated MSWI fly ash via leaching process. Lime-treated MSWI fly ash and ground fishbone of Japanese horse mackerel (aji in Japanese) were used during the whole experiment. The result from X-ray fluorescence on fly ash indicated that Ca and Cl are the two main elements, and Zn and Pb take the first two places among heavy metals. Based on X-ray diffractometry analysis, HAP is the only mineral phase in aji fishbone. The effects of fishbone on Pb immobilization of fly ash under different fishbone doses and various contact times were investigated by batch leaching test at room temperature, and Pb concentration in leachates was measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES). Different fishbone/fly ash ratios were examined; 0 (control group), 5%, 10%, 15%, and 20% (test groups) by weight, and the tests were run for different periods; 3, 6, 24, and 72 h. The results indicated that higher dosage of fishbone and longer contact time were more effective for Pb sequestration from the leachate and the highest removal efficiency of Pb in leachate under the given conditions reached to 24.76% after 72 h leaching process at fishbone dosage of 20%. Although the effectivity of fishbone on Pb removal was not as expected, the preliminary experiments provided promising results regarding the possibility of using low-cost waste fishbone as an environmental-friendly alternate for the stabilization of Pb in MSWI fly ash.

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1. Introduction

Fishbone is a common waste generated in coastal areas, especially from the fish processing industry. For such communities, fish waste management is becoming a pressing issue, because there is a large amount of fishbone waste daily exhausted[1]. This type of waste needs to be managed properly in a short period of time in order to avoid environmental risks due to the rapid corruptibility of the organic fractions[2]. As a kind of bio-waste, treated fishbone and other fish waste have been utilized in food industry, biogas production and other fields[3]. Fishbone is also known as the natural resource of P and Ca, and actually is the natural supply of hydroxyapatite (HAP), whose Ca possesses the exchange capacity with heavy metal ions[4–6]. The mechanism was assumed as a dissolution-precipitation mechanism (Eq.1 and 2). Metal ions are referred to the divalent ones including Pb[7,8]:

$$Ca_5(PO_4)_3OH + H_2O \rightarrow 5Ca^{2+}(aq) + 3PO_4^{3-}(aq) + 2OH^-(aq) \quad (1)$$

$$5M^{2+}(aq) + 3PO_4^{3-}(aq) + 2OH^-(aq) \rightarrow M_5(PO_4)_3OH + H_2O \quad (2)$$

Where M^{2+} is a divalent metal.

In recent decades, some researchers focused on the application of fishbone for the immobilization of heavy metals in contaminated environments with emphasis on the effectiveness of fishbone on decreasing the concentration of heavy metals[9–11]. These researches were mainly conducted[12,13] using standard metal solutions or in low metal concentrations[14,15] under a relatively controlled condition. The problem of heavy metal contamination does not only occur in aqueous environments, but also in solid waste management field.

An enormous amount of municipal solid waste is generated every year, and incineration treatment is adopted as a common technology in many countries in order to effectively reduce the volume and mass of solid waste and to generate electricity[16]. Bottom ash and fly ash are the main residues from the incineration of municipal solid waste, and fly ash is classified as a hazardous waste due to containing much higher concentration of leachable heavy metals than that of bottom ash[17]. Many technologies are employed for inhibiting the environmental risk brought by fly ash during its disposal, like sintering[18], vitrification[19], transforming into a harmless material by a combination of chemical and thermal processes[20] or immobilizing through a solidification by cement, and so on. But some of these technologies are very costly or may not be technically viable in some countries. Accordingly, the exploration and development of low-cost and more environmental-friendly techniques should also be considered.

Therefore, the possibility of using fishbone for immobilizing Pb in municipal solid waste incineration (MSWI) fly ash was taken into account in the present research. Instead of using standard metal solutions, this work was an attempt to ascertain the potential of natural fishbone apatite on the immobilization of Pb in lime-treated MSWI fly ash via leaching process, in which the relationship between Pb removal efficiency and fishbone dosage or contact time was investigated. Additional experimental scenarios are underway to evaluate the capacity of fishbone for the immobilization of toxic heavy metals and to examine the effect of other parameters on the interaction of fishbone with MSWI fly ash.

2. Material and methods

2.1. Sample collection and preparation

Lime-treated MSWI fly ash was obtained from an incineration plant (K) in Japan. The sample used in this study was collected from the air pollution control system. The original fly ash sample was in dry state, the moisture content of which was 1.5-2% tested in an oven at 105 ºC for 24 h. Thus, the original samples were directly used in the