Chapter 8
Alkaline Leaching of Phosphate from Sewage Sludge Ash

Ken-ichi Sonoda

Abstract The alkaline technology has been applied to phosphate (P_i) recovery from sewage sludge ash (SSA) at wastewater treatment plants (WWTP). P_i is extracted from mono-incinerated sewage sludge with NaOH and recovered from the leachate using chemical precipitation with $Ca(OH)_2$. Approximately 30–40% of P_i could be recovered from SSA as calcium P_i while minimizing the leaching of toxic heavy metals at high pH. The recovered P product can be recycled as a fertilizing material for agriculture.

Keywords Alkaline leaching · Calcium phosphate · Sewage sludge ash · Phosphate fertilizer

8.1 Introduction

Phosphorus (P) needs to be removed from sewage to control eutrophication in natural bodies of water. The P removed from sewage ultimately ends up in sewage sludge at wastewater treatment plants (WWTP). Dewatered sewage sludge is often mono-incinerated to reduce its volume and to recover energy at WWTP. This allows phosphate (P_i) to be concentrated in the sewage sludge ash (SSA). Since SSA has a high P content, typically ranging from 20 to 30 wt% P_2O_5, it is becoming increasingly a priority target for P recovery in the wastewater treatment sector.

In Japan, about 300 incinerators are operating at WWTP. Together, they have a capacity of incinerating c. 25,000 t/year (tons per year) of dewatered sludge, generating c. 33,000 t/year of SSA. Approximately 70% of the SSA has been accepted by the recycling sector, mainly the cement industry in Japan. However, since P_i can cause a detrimental effect on the cement quality, it is becoming a nuisance issue for the cement industry to accept P_i-rich SSA from the wastewater treatment sector. Hence, it is critical to develop an alternative technology option that

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enables the valorization of ever-increasing P_i-rich SSA. In this chapter, the alkaline P leaching technology to recycle P from SSA to farmland will be described.

8.2 Alkaline P_i Leaching Technology

Figure 8.1 shows a schematic diagram of P_i recovery from SSA using the alkaline leaching technology (Yanase 2009). In the alkaline leaching process, ash is mixed with 1.0 M NaOH solution to extract P_i (PO_4^{3-}). The P_i-rich leachate is separated from the rest (de-phosphorus ash) by mechanical dewatering. P_i is recovered as calcium phosphate ($Ca_3(PO_4)_2$) by the addition of $Ca(OH)_2$ to the leachate in the precipitation process. The phenomenological reaction for P_i leaching and precipitation may be given by:

$$P_2O_5 + 6OH^- \rightarrow 2PO_4^{3-} + 3H_2O \quad (8.1)$$

$$2PO_4^{3-} + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6OH^- \quad (8.2)$$

After the precipitation process, the slurry is subjected to mechanical dewatering to recover P_i. The high-pH rejected liquor is returned to the P_i extraction process. This is effective in saving the chemical costs for P_i recovery from SSA.

Figure 8.2 shows the full-scale process for P_i recovery from SSA using the alkaline leaching technology (Moriya 2009). Ash, which is collected by a dust collector of the incineration system, is fed to the P_i leaching tank through a buffer ash hopper. SSA is then mixed with 1.0 M NaOH solution at temperature of 50–70 °C for about 30 min of gentle mixing. NaOH is dissolved in hot water, which is prepared using waste heat energy of the exhaust gas from the mono-incinerator. Although the tem-

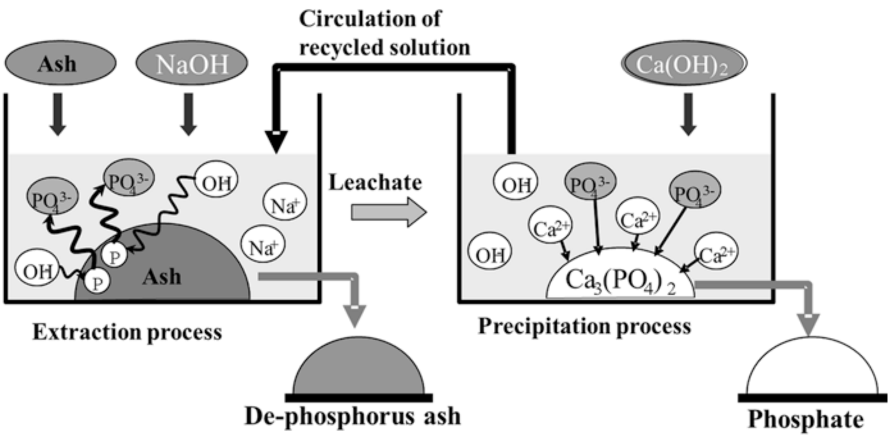


Fig. 8.1 A schematic diagram of P_i recovery from SSA using the alkaline leaching technology

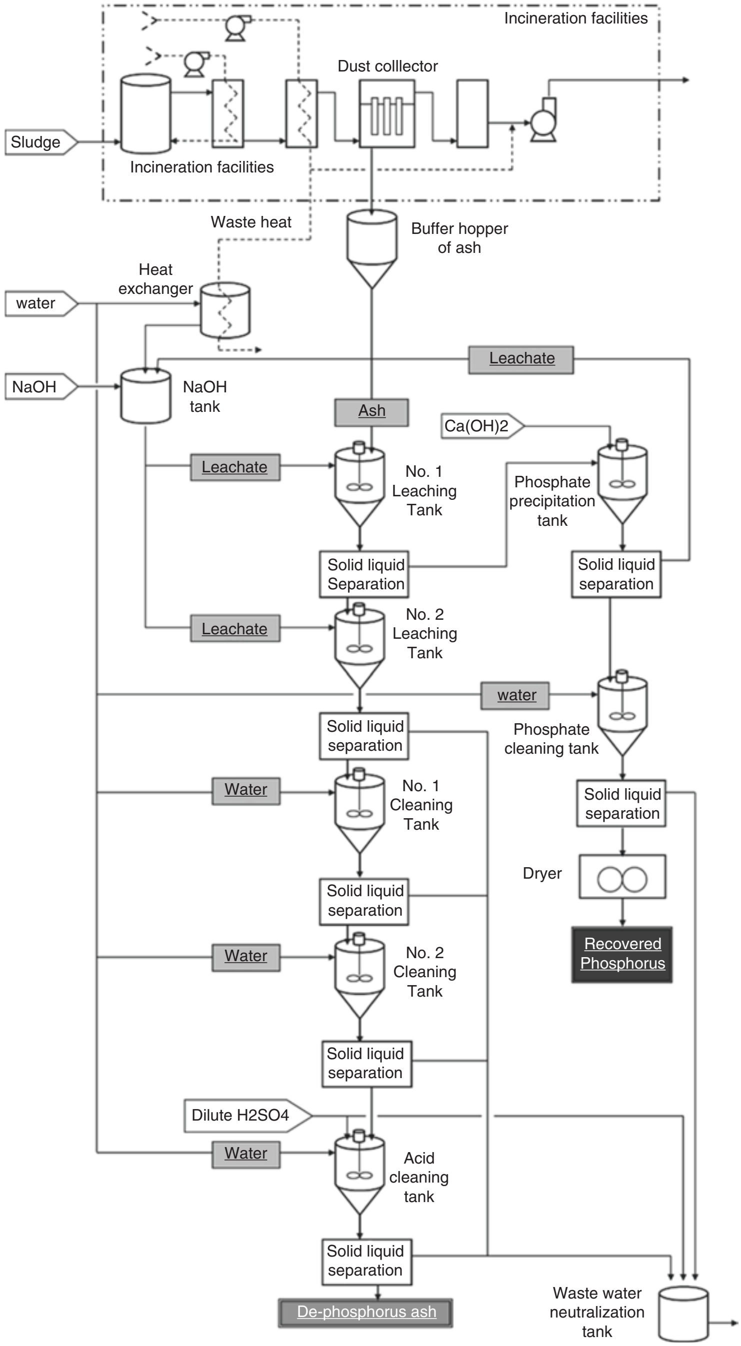


Fig. 8.2 Process flow of alkaline leaching of phosphate from SSA

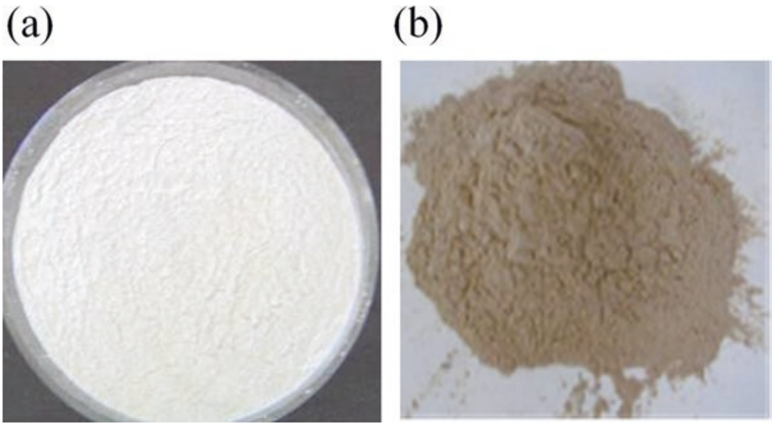
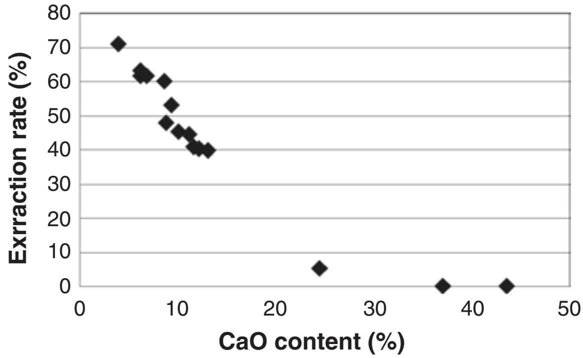


Fig. 8.3 Recovered P_i product (**a**) and de-phosphorus ash (**b**)

Fig. 8.4 The relationship between the CaO content of SSA and the rate of P_i leaching



perature required for P_i leaching is about 50–70 °C, the heat energy can be supplied by the waste heat from the incinerator, thereby saving the energy costs.

In the P_i leaching tank, the concentration of slurry is kept around 8–10%. In case that the P_i content in SSA is high, the P_i leaching step can be repeated to increase the amount of P_i leached. After leaching P_i, the mixture is subjected to mechanical solid-liquid separation. Then the P_i-rich liquor is sent to P_i precipitation tank where $Ca(OH)_2$ is fed at Ca/P molar ratio of 1–1.5. The mixture is slowly stirred for about 6–18 h to gradually dissolve $Ca(OH)_2$ and to generate calcium P_i as precipitates.

Calcium P_i precipitates are recovered by mechanical dewatering, washed with water, dried, and stored for shipping (Fig. 8.3a). To reduce the chemical cost, high-pH rejected water is returned to the NaOH tank for NaOH recycling. The solid material remaining after P_i leaching is washed two times with water and finally with dilute H_2SO_4 at pH of 4.5–5.5 to remove toxic heavy metals. The resulting solid (de-phosphorus ash, Fig. 8.3b), which meets the environmental quality standard for soil in Japan, can be used for cement, asphalt filler, and roadbed.

The alkaline leaching technology can recover approximately 30–60% of P_i from SSA in the form of calcium P_i. Importantly, the rate of P_i leaching from SSA is strongly dependent on the CaO content of SSA. Figure 8.4 shows the relationship between the CaO content in SSA and the rate of P_i leaching in the alkaline extraction step (Moriya 2009). There is a clear relationship between them. The alkaline P_i leaching becomes difficult when the CaO content of SSA exceeds 20%. Hence, if lime is used for sludge dewatering, the alkaline leaching technology is not a suitable option for P_i recovery from SSA.

8.3 Recovered Products

The weight of recovered P product is about 30–50% of SSA on a dry weight basis. The typical composition of recovered P product is shown in Table 8.1 (Yanase 2009). The total P content of recovered product is about 30% P_2O_5, most of which is citric acid-soluble P. The levels of toxic substances such as As, Cd, and Se are much lower than their regulation levels for by-product P_i fertilizer in Japan. Since the main component of recovered product is calcium P_i, it can also be used as a substitute for P_i rock in a variety of technical applications.

The alkaline P_i leaching process generates about 0.75 tons of de-phosphorus ash from each ton of SSA treated. De-phosphorus ash is a microporous material whose average particle size is typically about 50% smaller than that of SSA. Therefore, the specific surface area of de-phosphorus ash is about one order of magnitude larger than that of SSA. As mentioned before, de-phosphorus ash meets the environmental quality standard for soil in Japan so that it can be used for cement, asphalt filler, and roadbed. The stable sale of recovered P product and de-phosphorus ash is critical to bring economic benefits to WWTP. However, fertilizer companies do not accept recovered P product unless it brings some economic benefits to their business. The expanded use of this technology requires further reduction of the cost of chemicals required for P_i leaching and recovery.

Table 8.1 The typical composition of recovered P_i product

Main components				Toxic substances		
Total P	C-P[a]	Ca	Al	As	Cd	Se
[% P_2O_5]	[% P_2O_5]	[%CaO]	[% Al_2O_3]	[mg/kg]	[mg/kg]	[mg/kg]
29.8	29.2	45.1	4.40	21.4	1.4	6.1

[a]Citric acid-soluble P

8.4 Conclusions

The alkaline leaching technology can be applied to P_i recovery from sewage sludge ash at wastewater treatment plants. Approximately 30–40% of P_i could be recovered from sewage sludge ash as calcium phosphate while preventing toxic heavy metals from leaching at high pH. The rate of alkaline P_i leaching from SSA is strongly dependent on the CaO content of SSA. The alkaline P_i leaching technology is suited for P_i recovery from SSA having a low CaO content. Recovered P product can be used as a fertilizing material for agriculture, while the rest is usable for cement, asphalt filler, and roadbed after being washed with a dilute acid solution.

References

Moriya Y (2009) Phosphorus recovery technology from sewage sludge ash. J Resour Environ 45(6):35–39. (in Japanese)

Yanase T (2009) Phosphorus recovery and detoxification system from sewage sludge ash. J Earth Environ 40(4):72–73. (in Japanese)