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# INVESTIGATION ON NEUTRALIZING AGENTS FOR PALM OIL MILL EFFLUENT (POME)

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**Abstract:** Proper treatment of palm oil mill effluent (POME) is necessary to sustain the progress of palm oil industry in Sri Lanka. A case study was conducted to improve existing wastewater treatment system in a palm oil factory located in Galle district. The system consists of a neutralization tank, anaerobic ponds followed by anaerobic biogas digesters. Lime has been used to neutralize before sending to ponds for biological treatment. However, this treatment did not bring optimum pH for microbial action in anaerobic ponds. Therefore, performance of lime, caustic soda, iron lathe shavings and boiler ash from the same factory were studied for pH adjustment. A lab scale leaching bed with boiler ash was tested as it is freely available. Total carbon and total nitrogen in effluent were also measured. It was found that the $Ca(OH)_2$ availability in commercially available lime was 31% and less effective. The effective dosage of caustic soda to obtain neutral pH was 5 kg/m3 thus lead to high cost. Iron lathe shavings and boiler ash of palm oil mill were effective and economically feasible in balancing pH. The boiler ash has shown significant effect in pH neutralization with the rate of 60 g/l with 4 days hydraulic retention time. Leaching bed with an ash layer shows an acceptable performance.

**Keywords:** Palm Oil Mill Effluent (POME) Neutralization; Lime; Boiler ash; pH

## 1. Introduction

The palm oil industry has grown tremendously in the recent past and accounted for the largest percentage of oil and fats production in the world in 2011.The oil palm gives the highest yield of oil per unit area compared to any other oil crops and produces two distinct oils; palm oil and palm kernel oil, both are very popular in the world trade (Ji, 2013).

The process of palm oil production involves a number of stages from sterilization of the Fresh Fruit Bunch (FFB) to the digestion, threshing and clarification of the oil. At each processing phase a different form of waste is produced. In general, all wastes from the palm industry are termed as Palm Oil Mill Wastes (POMW) (Embrandiri, Ibrahim, & Singh, 2013).

Palm Oil Mill Effluent (POME) is the largest Palm Oil industry by-product, a colloidal suspension containing 95-96% water and it is thick, brownish in color, liquid with a discharged temperature of between 80-90 0C, being fairly acidic with a pH value of 4.0-5.0 (Otti et al 2014).

Raw Palm Oil Mill Effluent (POME) can be considered as one of the highest industrial polluting sources having BOD, COD and TDS values as high as 26,000, 67,000 and 72,000 mg/l respectively. (Weerasekara, 2015).The characteristics of POME depend on the quality of the raw material and the production processes (Iwuagwu & Ugwuanyi, 2014)

POME contains soluble materials that are injurious to the environment. Such soluble materials may be gases such as CH4, SO2, NH4, halogens or soluble liquids or solids which contain ions of either organic or inorganic origin and with their concentration above the threshold value (Igwe & Onyegbado, 2007). The palm oil industry contributes 83% of the total pollution in west African countries; the situation is probably similar in other palm

oil producing countries and so raised the need to look at the impact of palm oil wastes (especially the effluent) on the environment (Palm Oil Milling - The Impact, 2011). POME has to be treated before discharge into the environment.

Biological methods are practiced for treatment of POME. The microbial community in biological treatments are sensitive to pH changes and methanogens are affected to a greater extend. Optimum pH for microbial growth is between 6.8 and 7.2 while pH lower than 4 and higher than 9.5 are not tolerable. Several cases of reactor failure reported in studies of wastewater treatment are due to accumulation of high volatile fatty acid concentration, causing a drop in pH, which inhibited methanogenesis.

To control the level of volatile fatty acids in the system, alkalinity has to be maintained by recirculation of treated effluent to the digester or addition of lime and bicarbonate salt (Poh & Chong, 2009). However, addition of lime to neutralize the acidic condition of POME, did not bring optimum pH for microbial action in anaerobic ponds. Therefore, performance of lime was tested in addition, potential of caustic soda, iron lathe shavings and boiler ash from the same factory were studied for pH adjustment.

## 2. Materials and Methods

### 2.1. Experimental Location

The study was carried out at a palm oil mill, in Galle during the period of August to November 2015. Existing wastewater treatment system consists of cooling & oil recovery tanks, neutralization tank, open anaerobic ponds, Biogas plant with closed anaerobic digesters, facultative ponds, and scum collection ponds. Palm oil mill effluent has the temperature of almost 100°C, once it is discharged from the outlet and the temperature is reduced up to 61.1°C when it is pumped to the first cooling tank. In the neutralization stage, the temperature of the POME is 50.1°C.

### 2.2. Neutralization of POME

**Effectiveness of lime**

Initially a test was conducted to determine the $Ca(OH)_2$ % available in lime used by the mill for neutralization. Samples of lime were collected from mill and 1g of lime was weighed and mixed with 100 ml of distilled water. Then 5 ml of the mixture was taken and diluted up to 25 ml by distilled water. Following the same steps three replicates of 25 ml of lime solution were prepared. They were separately titrated with 0.01 M HCl with Phenolphthalein as the indicator.

Then lime was fired in the muffle furnace at 550°C for 20 minutes. Three replicates of solution with fired lime were prepared by following the same procedure. They were titrated separately with 0.01M HCl.

Then five samples of 50 ml wastewater were treated with five different dosages of lime including control, 2, 4, 6, 8 g/l. The pH variation with the time was recorded in each sample using a pH meter.

**Caustic soda**

Samples of 50 ml of palm oil mill effluent were treated with several dosages of caustic soda, 0 (control), 1, 2, 3, 4, 5 g/l. The pH variation over time was measured by using a pH meter.

**Iron lathe shavings**

Samples of 500 ml of palm oil mill effluent were treated with 50 g of iron lathe shavings. The pH was measured for consecutive four days. Then the iron particles were removed in the fourth day and pH was measured for two more days.

**Palm oil mill boiler ash**

Boiler ash which is produced in the palm oil mill was collected and sieved from a 2 mm sieve. Part of boiler ash was also fired in the muffle furnace at 550°C for 20 minutes.

Wastewater samples of 50 ml were treated separately with raw ash and fired ash with the dosages of 20, 40 and 60 g/l with a control sample. Then, pH was monitored with time.

**Coconut leaf ash**

Coconut leaves were kept in muffle furnace at 550°C for 20 minutes to obtain ash. Then

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three 50 ml samples of palm oil mill effluent were treated with coconut leaf ash dosages of 10, 16 and 20 g/l. The pH was measured and recorded for these samples and for a control sample.

### 2.3. Designing the Wash Bed of Boiler Ash

Wash bed was designed with length, width and height as 50 cm, 33 cm and 30 cm, respectively. A gravel layer of 10 cm height was used at the bottom. Boiler ash collected from the mill was filled as the middle layer up to a height of 7 cm. Then river sand was placed for 3 cm depth. Inlet pipes were set at the bottom and outlet was set a height of 24 cm from the bottom. Pipes with 2 cm diameter were used for both inlet and outlet (Figure 2.1).

Effluent was sent through the system at a flow rate of 480-780 ml/h. Initial pH of entering POME and final pH of leaving POME were measured four times per day and recorded for four consecutive days.

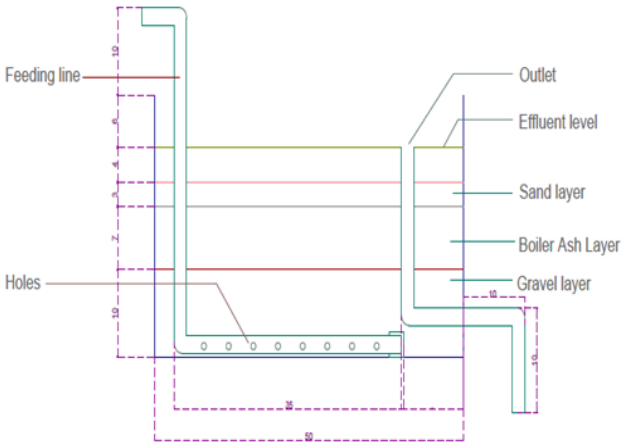


Fig. 2.1: Wash bed of boiler ash

## 3. Results and Discussion

### 3.1 Existing Wastewater Treatment System

The layout and the flow paths of the treatment system is shown in figure 3.1.The first three tanks are used as cooling and waste oil recovery tanks and the fourth one is a neutralizing tank. Then the POME is pumped into a secondary oil recovery tank. After that, the effluent is sent through two open ponds. Finally it is treated in five biogas digesters in a series and sent through settling tanks.

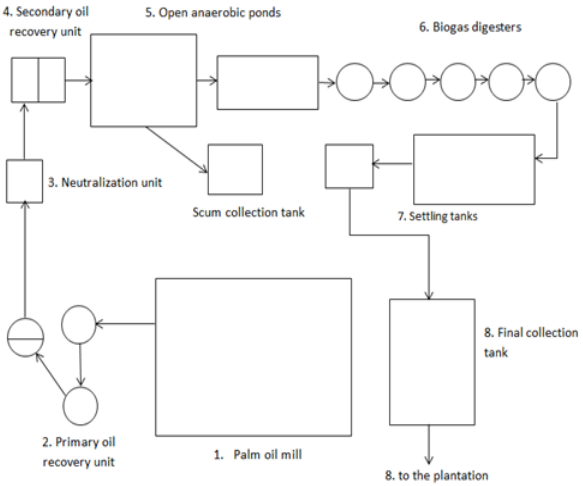


Fig. 3.1: Arrangement of treatment units

### Variation of pH and Temperature

Figure 3.2 and 3.3 illustrates the pH and temperature variation along the pond series. In the pond 1, pH is 5.15 and it is increasing slightly until the 3rd pond and again decreased to 5.05 in the pond 4. At this pH, optimum microbial activity cannot be expected in all these ponds as the microbes require almost neutral pH value. In the Pond 1, the average temperature is around 45 °C and it reduces to 36°C when the effluent reach end of pond series. In the pond 1, microbial activity cannot be expected.

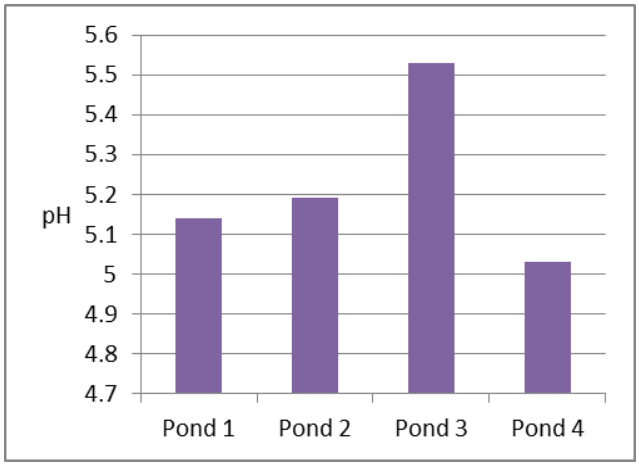


Fig. 3.2: pH variation of the palm oil mill effluent treatment ponds

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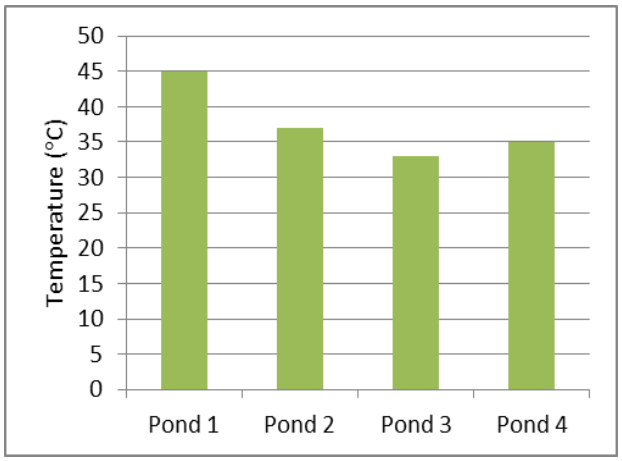


Fig. 3.3: Temperature variation of the palm oil mill effluent treatment ponds

### 3.2 pH Balancing of POME

#### $Ca(OH)_2$ content of commercial lime

The average $Ca(OH)_2$ availability of raw lime collected from the palm oil mill and after proper burning of the same lime were 31.4% and 70.6%, respectively. Therefore, lime has to be re-fired before using or the mixing rate has to be increased until it is effective to bring the pH to neutral. Particularly, if the mixing rate is to be increased, it will add Rs.40, 000 extra costs per month. Therefore, it is advisable to find a better source of lime. When lime has long time exposure to atmosphere $CaCO_{3(s)}$ is formed according to the following equation.

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)} \quad \text{Eq 01}$$

Once it is fired, convert back to $CaO_{(s)}$ by releasing $CO_2$ and when dissolved in water forms $Ca(OH)_{2(aq)}$ as follows,

$$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_{2(g)} \quad \text{Eq 02}$$

$$CaO_{(s)} + H_2O_{(s)} \longrightarrow Ca(OH)_{2(aq)} \quad \text{Eq 03}$$

The less availability could be either due to reverse of the firing reaction or improper firing.

#### Effectiveness of caustic soda

The figure 3.4 illustrates the pH variation of POME samples treated with different dosages of caustic soda. A concentration of 5 g/l has shown a significant effect. The variation of pH at the 6th and 7th days shows the stabilizing effect as they overlap each other. Although, it is effective to add caustic soda at a rate of 5 kg/$m^3$, it will add a cost of Rs.342, 000 per month. At the same time, a trend of scum formation has also shown similar to lime application.

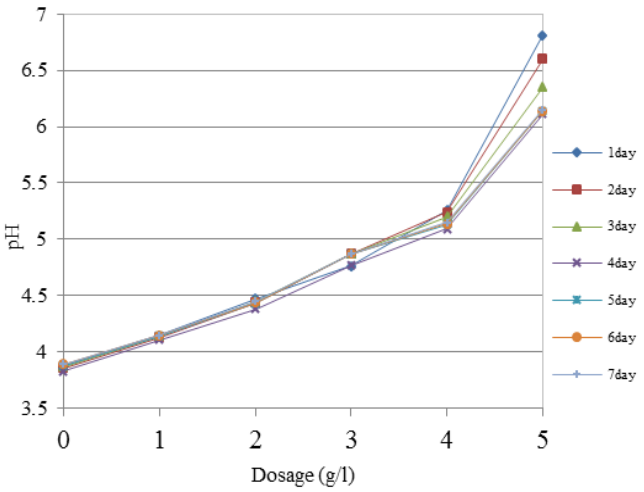


Fig. 3.4: pH variation of POME treated with Caustic Soda

#### Effectiveness of iron lathe shavings

As shown in the figure 3.5, pH has increased until the 4th day. After removing the lathe shavings on the 4th day, pH starts to decrease. This increase in pH can be clearly observed when it is compared with the control. As it is reported (Madaki & Seng, 2013), POME contains comparatively high Nitrogen content as 750 mg/l. This nitrate can react with iron as shown below.

$$NO^{3-}_{(aq)} + 8Fe^{+}_{(aq)} + 18H_2O_{(l)} \rightarrow 3NH^{3}_{(aq)} + 8Fe^{3+}_{(aq)} + 27OH^{-}_{(aq)} \quad \text{Eq 04}$$

This is a redox reaction by which $Fe^{+}$ is oxidized to $Fe^{3+}$ while reducing $NO^{3-}$ in to $NH_3$. Resultant $OH^-$ ions are responsible for pH reduction of POME.

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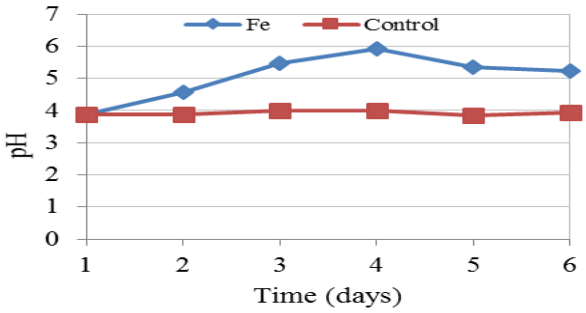


Fig. 3.5: pH variation of POME treated with iron lathe shavings

**Effectiveness of boiler ash**

Boiler ash of palm oil mill contains $K_2O$, MgO, CaO and Silica. Once these oxides dissolved in water, they reacts with water as follows and form hydroxyl ions,

$$K_2O_{(s)} + H_2O_{(l)} \longrightarrow KOH_{(aq)} \quad \text{Eq 05}$$

$$MgO_{(s)} + H_2O_{(l)} \longrightarrow Mg(OH)_{2(aq)} \quad \text{Eq 06}$$

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)} \quad \text{Eq 07}$$

Figure 3.6 shows the results of the treatment of POME with boiler ash. According to the results, boiler ash is also effective in neutralizing POME up to pH 6.56 in four days retention time at a dosage of 60 g/l.

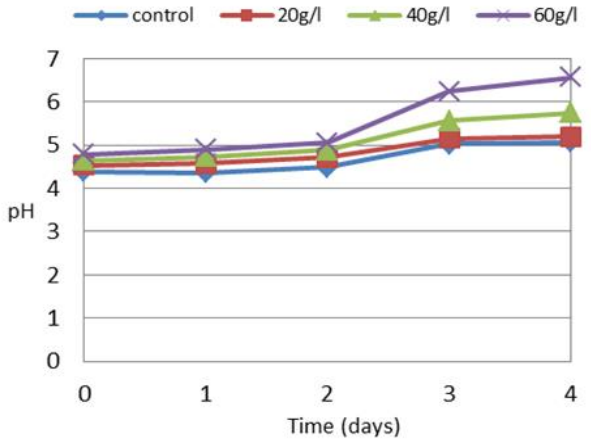


Fig. 3.6: pH variation of POME treated with boiler ash

POME was treated with coconut leaf ash to compare the performance with boiler ash. As shown in figure 3.7 it is apparent that the treatment is less effective in comparison to boiler ash treatment.

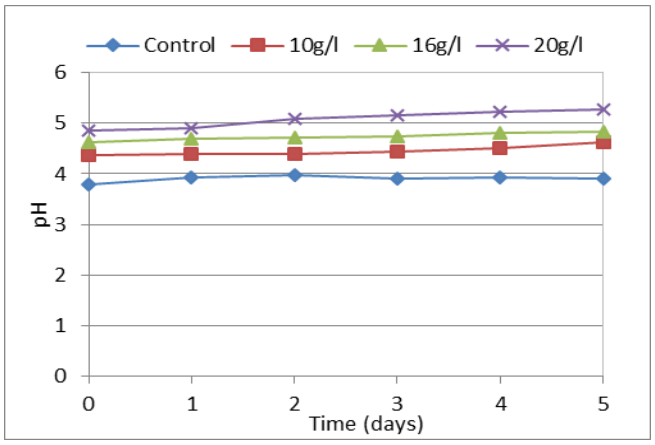


Fig. 3.7: pH variation of POME treated with Coconut leaf ash

**3.3 Neutralization Wash Bed with boiler ash**

Results obtained by sending POME through a boiler ash incorporated wash bed are shown in figures 3.8, 3.9, 3.10 and 3.11 for different days and time. According to the results of the boiler ash, it is a very effective neutralization agent for POME without adding any cost to the mill.

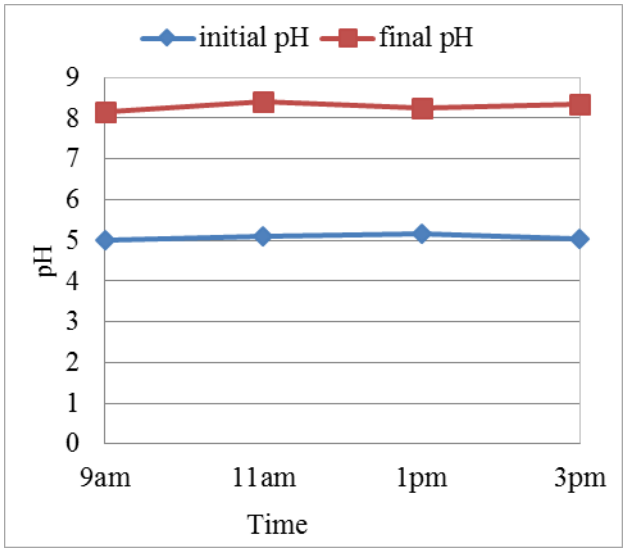


Fig. 3.8: pH variation of raw POME and treated POME with wash bed Day-1

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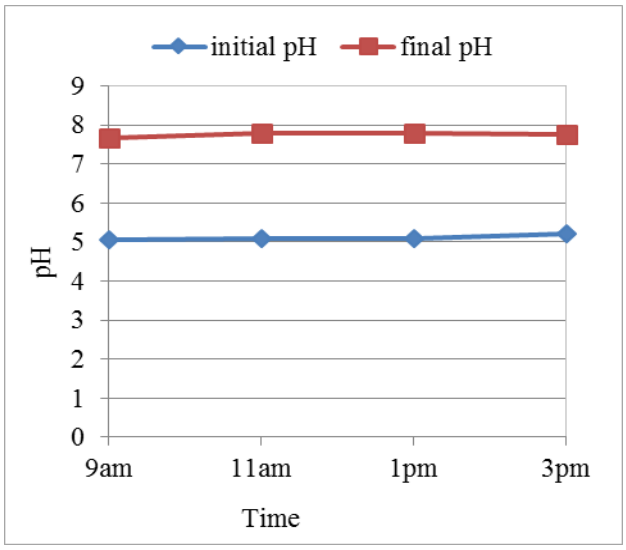


Fig. 3.9: pH variation of raw POME and treated POME with wash bed Day-2

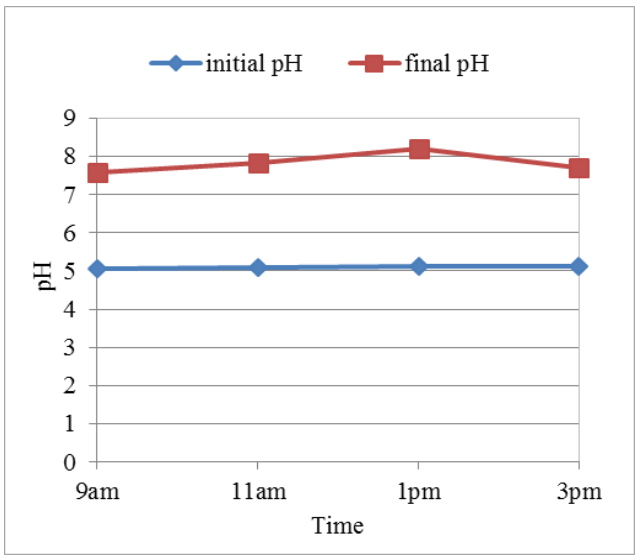


Fig. 3.10: pH variation of raw POME and treated POME with wash bed Day-3

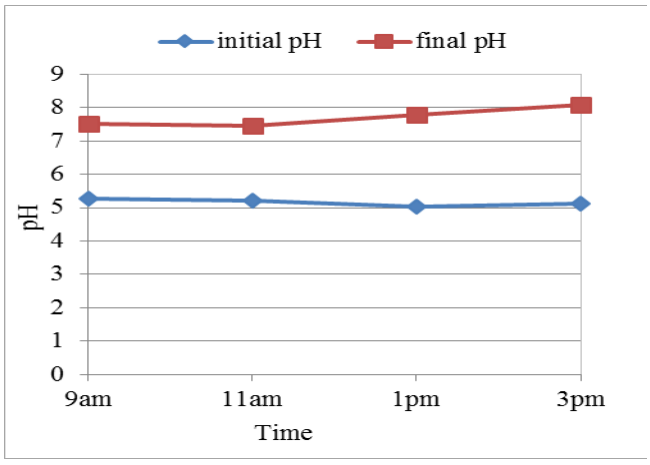


Fig. 3.11: pH variation of raw POME and treated POME with wash bed Day-4

## 4. Conclusions

The pH of POME is 5.05 after cooling and needs neutralization. Commercially available lime used by the oil mill is less effective as a neutralizing agent due to the relatively low availability of $Ca(OH)_2$. The concentration could be increased from 31.4% to 70.6 % by proper burning of that lime. Although the effective dosage of caustic soda to obtain a neutral pH was 5 $kg/m^3$, it is expensive. According to the findings, ash discarded from boiler in the palm oil mill and iron lathe shavings (commercial waste iron) can be used for pH balancing of POME. The boiler ash has shown significant effect in pH balancing with the rate of 60 g/l with a 4 days hydraulic retention time. A leaching bed with an ash layer shows an acceptable performance in pH balancing of POME.

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