ABSTRACT

The aim of the current study is to evaluate the effectiveness of combined persulphate with hydrogen peroxide (S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−}/H\textsubscript{2}O\textsubscript{2}) oxidation as a post-treatment of biologically treated palm oil mill effluent (POME) for the first time in the literature. The removal efficiencies of chemical oxygen demand (COD), ammoniacal nitrogen (NH\textsubscript{3}-N), and suspended solids (SS) were 36.8%, 47.6%, and 90.6%, respectively, by S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−} oxidation alone under certain operation conditions (i.e., S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−}/C\textsubscript{0} = 0.82 g, pH 11, and contact time 20 min). Nevertheless, the combined process (S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−}/C\textsubscript{0}/H\textsubscript{2}O\textsubscript{2}) achieved 75.8% and 87.1% removals of NH\textsubscript{3}-N and SS, respectively, under 2.45/1.63 g/g H\textsubscript{2}O\textsubscript{2}/S\textsubscript{2}O\textsubscript{8}\textsuperscript{2−}/C\textsubscript{0}, pH 11, and 20 min oxidation. Moreover, 56.9% of COD was removed at pH 8.4.

INTRODUCTION

Oil palm plantations have been well developed in Malaysia since the 1870s. Malaysia so far has the second largest palm oil production globally (Green Palm 2015). In 2014, Malaysia generated around 20 million tonnes of crude palm oil, while for Indonesia around 30 million tonnes of crude palm oil was produced (SGS 2015). The oil palm species planted in Malaysia is called *Elaeis guineensis* Jacq. or African oil palm; each hectare of oil palm results in 10–35 tonnes of fresh fruit annually, and the economic life of an oil palm tree is around 20–25 years (Singh et al. 2010). During palm oil processing, biomass wastes such as palm press fibres, palm kernel shells, empty fruit bunches, and palm oil mill effluent (POME) are generated (Hassan et al. 2013). POME is the largest portion of waste generated from the palm oil industry: 28% by weight in relation to fresh fruit bunches (FFB) (Abdullah & Sulaiman 2013). POME is an intractable wastewater which is thick brown in appearance and has an unpleasant odour from palm oil extraction. POME discharge is normally as hot as 80–90°C an consists of water, oil and fine suspended solids (SS) (Liew et al. 2015). It is a form of colloidal suspension which is mainly yielded from hydrocyclone wastewater (4%), sterilizer wastewater (36%) and clarification wastewater (60%), accordingly (DOE 1999; Wu et al. 2010; Liew et al. 2015). POME is a non-toxic wastewater (Rupani et al. 2010) but it comprises nutrients such as nitrogen and phosphorous as well as other insignificant mineral constituents (Mohammed & Chong 2014) which can cause environmental problems and endanger aquatic life. Thus, around 85% of effluent treatment facilities in the oil palm industry have installed the ponding system (Ahmad & Krimly 2014). A series arrangement of anaerobic, facultative and aerobic open ponding is one of the conventional biological treatment systems for POME in Malaysia (Aris et al. 2008). However, the biologically treated POME (BIOTPOME) requires a post-treatment due to insufficient removal of colour and chemical oxygen demand (COD) prior to discharge into watercourses (Fadzil et al. 2013; Bashir et al. 2016). Successive amounts of organic and nutrient contents in term of COD will introduce eutrophication problems and further increase the amount of oxygen depleted in water (Fadzil et al. 2015). Advanced oxidation processes have recently been used to treat recalcitrant pollutant contained in water and soil. It involves the generation of highly reactive radicals and degradation of contaminants by
the oxidants. Persulphate ($S_2O_8^{2-}$) oxidation is an advanced chemical oxidation which utilizes $S_2O_8^{2-}$ anions as an oxidant. The oxidation-reduction potential for $S_2O_8^{2-}$ oxidation is shown as Equation (1) (Block et al. 2004).

$$S_2O_8^{2-} + 2H^+ + 2e^- \rightarrow 2HSO_4^-$$ (1)

$S_2O_8^{2-}$ can also produce highly reactive sulphate radical ($SO_4^{\bullet+}$) with 2.6 V redox potential through $S_2O_8^{2-}$ activation (Deng et al. 2014). $S_2O_8^{2-}$ can be activated by different agents such as heat, UV light and metal. Hydrogen peroxide ($H_2O_2$) is an oxidant which potentially functions as activator of $S_2O_8^{2-}$. In this dual oxidant system, the reactivity of peroxide in reduction of targeted organic substances collaborates with the improved stability of persulphate (Block et al. 2004). In the mechanism of $S_2O_8^{2-}$ activation, $SO_4^{\bullet+}$ and hydroxyl radical (OH$^\bullet$) are released and consumed through the initiation, propagation and termination reactions as shown in Equations (2)–(5) (Cronk 2008). The end product of oxidation, sulphate ion ($SO_4^{2-}$), is an inert salt and not harmful to the environment as it is not considered as a pollutant (Ahmadi et al. in press). However, the residual of sulphate ions can be removed following further aerobic and anaerobic treatment processes. Thabet et al. (2009) removed 91% of sulphate from leachate using anaerobic treatment reactor processes.

$NH_3$-$N$ would be oxidized into nitrogen compounds as shown in Equations (6) and (7) under presence of silver ions (Ali 2005).

Initiation:

$$Na_2S_2O_8 + \text{Activator} \rightarrow 2SO_4^{\bullet+} + 2Na^+$$ (2)

Propagation:

$$SO_4^{\bullet+} + H_2O \rightarrow OH^\bullet + HSO_4^-$$ (3)

Termination I:

$$SO_4^{\bullet+} + RH \rightarrow R^\bullet + HSO_4^-$$ (4)

Termination II:

$$OH^\bullet + RH \rightarrow R^\bullet + H_2O$$ (5)

where RH and R$^\bullet$ represent an organic matter and oxidized organic matter.

$$3S_2O_8^{2-} + 2NH_3 \rightarrow N_2 + 6SO_4^- + H^+$$ (6)

$$4S_2O_8^{2-} + NH_4^+ + 3H_2O \rightarrow NO_3^- + 8SO_4^- + 10H^+$$ (7)

In this study, $S_2O_8^{2-}$ oxidation alone and $H_2O_2$ activated persulphate ($S_2O_8^{2-}/H_2O_2$) oxidation were investigated for the removals of COD, $NH_3$-$N$ and SS from BIOTPOME for the first time. The pH, contact time and dosage of $S_2O_8^{2-}$ and $H_2O_2$ were the operational parameters used to achieve better removal efficiency of BIOTPOME.

MATERIALS AND METHODS

BIOTPOME sampling and sample characterization

The BIOTPOME sample was collected from Tian Siang Oil Mill (Air Kuning) Sdn. Bhd., Perak, Malaysia. The mill has been in commission since 2000 and the daily capacity of processing FFB has increased to 120 tons/hr. The samples were collected using 5.5 L clean and empty polypropylene containers and transported instantly to the environmental laboratory. The samples were preserved at 4 °C in order to minimize the possibility of biodegradation of sample and chemical reaction occurrence (APHA 2005). The initial characteristics of BIOTPOME were analysed and are presented in Table 1.

Experimental setup of $S_2O_8^{2-}$ and $S_2O_8^{2-}/H_2O_2$ oxidation system

Sample preserved under 4 °C was warmed to ambient temperature (27 °C) before starting the experiment. A 250 mL conical flask filled with 100 mL of sample was prepared...
for each experiment. The sample was placed on an orbital shaker (NB-101M) at shaking speed of 200 rpm under ambient temperature. The crystallized form of sodium persulphate (Na₂S₂O₈, ≥98%, Sigma-Aldrich) was utilized for S₂O₈⁻⁻ and S₂O₆²⁻⁻/H₂O₂ oxidation. A 30% H₂O₂ solution was employed after adding S₂O₆²⁻⁻ into sample in S₂O₈⁻⁻/H₂O₂ oxidation. For S₂O₈⁻⁻ oxidation, operational conditions involved were S₂O₈⁻⁻ dosage, pH and contact time. For S₂O₆²⁻⁻/H₂O₂ oxidation, the operational conditions were dosage ratios of H₂O₂:S₂O₆²⁻⁻, dosage concentration of H₂O₂:S₂O₈⁻⁻ and pH.

S₂O₆²⁻⁻ dosage was pre-determined in term of S₂O₈⁻⁻:COD₀ ratio (g/g). The S₂O₆²⁻⁻:COD₀ ratio was set to 4:1 and 1.32 g S₂O₆²⁻⁻ was required for 100 mL sample per 0.529 g initial COD (COD₀). The desired actual amount of powdered S₂O₆²⁻⁻ (Na₂S₂O₈) was 1.67 g with considering its purity by using Equation (8).

Na²⁺ + S₂O₆²⁻⁻ → Na₂S₂O₈

In S₂O₆²⁻⁻/H₂O₂ oxidation, the optimum dosage of S₂O₆²⁻⁻ found from S₂O₈⁻⁻ oxidation, 0.82 g, was applied constantly to find out the optimum ratio of H₂O₂:S₂O₆²⁻⁻ among 0.5:1.0–3.0:1.0. Based on the ratios, dosages of H₂O₂ used ranged between 0.41 g and 2.45 g. For the experiment of varying dosages, the optimum dosage ratio of 1.5:1.0 was fixed for varying dosages of H₂O₂ and S₂O₆²⁻⁻, and the dosages were adjusted in terms of H₂O₂/S₂O₆²⁻⁻ (0.61 g/0.41 g to 6.12 g/4.08 g).

For pH adjustment 5 M sodium hydroxide and 5 M hydrochloric acid were used. Different pH values (3–12) were examined in both S₂O₆²⁻⁻ (60 min; 200 rpm) and S₂O₆²⁻⁻/H₂O₂ oxidations (20 min; 200 rpm). For S₂O₆²⁻⁻/H₂O₂ oxidation, 2.45 g/1.63 g of H₂O₂/S₂O₆²⁻⁻ dosage obtained as optimum from the previous oxidation was fixed for the pH variation of S₂O₆²⁻⁻/H₂O₂ oxidation. The filtered samples were analysed after each run of experiment. All experiments were carried out in duplicate. Effectiveness of S₂O₆²⁻⁻ and S₂O₆²⁻⁻/H₂O₂ oxidation of BIOTPOME were studied in term of removal efficiencies of pH, COD, NH₃-N, colour and SS.

Analytical method

COD, NH₃-N, colour, SS and pH parameters were analysed before and after the oxidation treatment using Standard Methods for the Examination of Water and Wastewater (APHA 2005) and Hach Water Analysis Book (Hach 2005). NH₃-N concentration was determined by the Nessler method. Colour was examined by the spectrophotometric method – single wavelength method. The pH was measured using a digital pH meter. COD measurement of samples was carried out using the dichromate reactor digestion method (Hach Method 8000) while SS was tested by photometric method. Removal efficiencies of COD, NH₃-N, colour and SS were calculated as Equation (9):

Removal percentage(%) = \left[ \frac{C_i - C_f}{C_i} \right] \times 100 \quad (9)

where Cᵢ and Cᵢ represent the initial and final COD, NH₃-N or SS concentrations.

RESULTS AND DISCUSSION

BIOTPOME treatment: S₂O₈⁻⁻ oxidation

In S₂O₈⁻⁻ oxidation, the operational conditions of pH, contact time and S₂O₈⁻⁻ dosage were investigated in removing the contaminants of BIOTPOME such as COD, NH₃-N, colour and SS. All oxidation processes were carried out at shaking speed 200 rpm under ambient temperature.

Effect of pH adjustment

Different initial pHs (3, 5, 7, 9, 10, 11 and 12) were adjusted accordingly while S₂O₈⁻⁻ concentration was fixed at 1.32 g (S₂O₈⁻⁻:COD₀ = 4.0:1.0) before initiating the oxidation. Figure 1 shows the removal efficiencies of COD, NH₃-N, colour and SS in BIOTPOME under pH influence. The highest removal efficiency of S₂O₈⁻⁻ oxidation was achieved under alkali condition, pH 11, with 21.9% COD, 59.0% NH₃-N, and 87.8% SS. In terms of COD and colour, the

![Figure 1](https://iwaponline.com/wst/article-pdf/74/11/2675/457219/wst074112675.pdf)
removal percentages were decreased from pH 3 to pH 7 and rose again after pH 7 until pH 11; however, removal percentages of parameters at pH 12 were lowered compared to pH 11. For the parameters NH3-N and SS, the removals dropped slightly from pH 3 and started rising after pH 5, and the removal efficiencies at pH 12 eventually were also reduced compared to pH 11. It seems that alkali and acidic condition led to high removals on the parameters but lower removal efficiencies under neutral pH.

In S2O8^2− oxidation, releasing of free radicals through breakdown of persulphate (acid-catalysation) in acidic condition are shown in Equations (10) and (11) (Epold & Dulova 2013). Proton acts as catalyst to react with S2O8^2− anions and leads to the generation of sulphate radical (SO4^−). Under alkali condition, hydroxide (OH−) ions could be decomposed when S2O8^2− is activated under alkaline condition in order to generate OH* as Equation (12), resulting in a slight decrease in pH. This shows pH has significant influence on S2O8^2− oxidation. Another possible mechanism of formation of OH* according to Liang et al. (2007) is shown in Equation (13) but this reaction has a smaller reaction rate constant of <60 M−1 s−1 compared to Equation (12), 7×107 M−1 s−1. Among the radical formations, SO4^− is the predominant radical at acidic pH while OH* is the main radical at alkali pH (Zhao et al. 2016).

\[
\begin{align*}
S2O8^2− + H^+ & \rightarrow HS2O8^- \quad (10) \\
HS2O8^- & \rightarrow H^+ + SO4^− + SO4^{2−} \quad (11) \\
SO4^− + OH^- & \rightarrow SO4^{2−} + OH^* \quad (12) \\
SO4^− + H2O & \rightarrow SO4^{2−} + OH^* + H^+ \quad (13)
\end{align*}
\]

Effect of contact time

The concentration removals of COD, NH3-N, SS and colour were studied in different contact times (5, 10, 20, 40, 60, 120, 180 and 240 min) in S2O8^2− oxidation. The S2O8^2− dosage (1.32 g) was fixed by the ratio of S2O8^2− :COD0 = 4.0:1.0 as in the oxidation with previous pH adjustment. As shown in Figure 2, the optimum removal for SS, NH3-N and COD were 91.4%, 50.7% and 30.2% at 20 min. This may represent the free radicals attacking rapidly on BIOTPOME due to fast kinetic of those radicals (Cronk 2008). The COD removed was higher compared with the 221.9% of COD eliminated from previous operational condition, pH adjustment at 60 min. However, the removal of NH3-N at 20 min, 50.7%, was lower than NH3-N removed at 60 min, 59.0%, in the previous study of pH adjustment. In these conditions, S2O8^2− or radicals possibly attacked the organic compound rather than NH3-N. SS was also greatly removed with a range of 89.9% to 94.3%.

Effect of dosages of S2O8^2−

Figure 3 demonstrates the removal percentage of parameters of BIOTPOME with varied dosages of S2O8^2− (0.20–2.45 g) in relation to ratio of S2O8^2− :COD0 (0.5:1.0, 1.0:1.0, 2.0:1.0, 3.0:1.0, 4.0:1.0, 5.0:1.0 and 6.0:1.0). The optimum removal of parameters like SS, NH3-N and COD was 57.7%, 47.6% and 36.8% when ratio of S2O8^2− :COD0 = 2.0:1.0. By increasing S2O8^2− dosage higher than 2.0:1.0 of S2O8^2− :COD0 ratio, there was significant decrease on COD removal. COD removal ranged from 24.0% to 31.8% for S2O8^2− :COD0 = 3.0:1.0 to 6.0:1.0. Excessive amount of S2O8^2− may affect the treatment efficiency.
Sulphate ion, \( \text{SO}_4^{2-} \), formed from \( \text{S}_2\text{O}_8^{2-} \) can act as scavenger to attack oxidant and interminently reduce the decomposition rate of COD as in the study of degradation of trichloroethylene by \( \text{S}_2\text{O}_8^{2-} \) oxidation (Liang et al. 2007).

Table 2 shows the removal efficiencies for \( \text{S}_2\text{O}_8^{2-} \) oxidation of BIOTPOME. The removal efficiencies ranged from 21.9% to 36.8% for COD, 47.6% to 59.0% for NH\(_3\)–N, and 87.8% to 91.4% for SS. The pH values of samples rose to 10.5–10.6 after oxidation treatment. By adjusting the operational conditions to optimum, as \( \text{S}_2\text{O}_8^{2-}:\text{COD}_0 = 2 \), pH 11 and 20 min contact time, 36.8% COD, 47.6% NH\(_3\)–N, 57.7% colour and 90.6% SS removal efficiencies were achieved.

**\( \text{S}_2\text{O}_8^{2-} / \text{H}_2\text{O}_2 \) oxidation**

Hydrogen peroxide (\( \text{H}_2\text{O}_2 \)) was investigated and played an enhancement role in \( \text{S}_2\text{O}_8^{2-} \) oxidation for treating BIOTPOME. In the study, COD, NH\(_3\)–N and SS parameters were analysed before and after each experiment accordingly. The operational conditions of pH and dosages of \( \text{S}_2\text{O}_8^{2-} \) and \( \text{H}_2\text{O}_2 \) were also adjusted in the oxidation process under ambient temperature.

### Effect of dosage ratio of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \)

By fixing the optimum ratio of \( \text{S}_2\text{O}_8^{2-}:\text{COD}_0 = 2.0:1.0 \), the dosage ratios of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) were varied (0.5:1.0, 1.0:1.0, 1.5:1.0, 2.0:1.0, 2.5:1.0 and 3.0:1.0) for the oxidation of BIOTPOME under pH 8.4 within 20 minutes and the result is shown in Figure 4. The optimum removals of SS, NH\(_3\)–N and COD were 61.4%, 26.9% and 52.5% by using \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) dosage ratio of 1.5:1.0. When the lowest dosage ratio (0.5:1.0) was applied 53.4% SS, 11.1% NH\(_3\)–N and 32% COD removals were achieved. As dosage ratio increased, removal percentage of parameters were also increased. However, the removals of COD, NH\(_3\)–N and colour were decreased as the dosage ratio was increased over 1.5:1.0.

### Effect of dosage of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \)

The dosages of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) (g/g) were varied based on the optimum ratio of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) (1.5:1.0), as shown in Figure 5. Different dosages of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) (g/g: 0.61/0.41, 1.22/0.82, 2.45/1.63, 3.67/2.45, 4.89/3.26 and 6.12/4.08) in order to enhance the performance of \( \text{S}_2\text{O}_8^{2-} / \text{H}_2\text{O}_2 \) oxidation. The optimum parameter was obtained based on overall removals of parameters and the optimum dosage of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) determined was 2.45 g/1.63 g. SS, NH\(_3\)–N and COD removals were as high as 63.7%, 56.9% and 26%, respectively. By fixing the dosage ratio and varying the dosages of \( \text{S}_2\text{O}_8^{2-} \) and \( \text{H}_2\text{O}_2 \), the SS removal was increased gradually overall. When the dosage of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) was increased from 0.61 g/0.41 g to 2.45 g/1.63 g, COD removal was between 58.8% and 56.9%. The removal was decreased afterward when additional dosage of \( \text{H}_2\text{O}_2: \text{S}_2\text{O}_8^{2-} \) (g/g) was added. Removal efficiencies of SS and NH\(_3\)–N were increased gradually as dosages of \( \text{S}_2\text{O}_8^{2-} \) and \( \text{H}_2\text{O}_2 \) were increased.

As dosage of \( \text{H}_2\text{O}_2 \) increases, \( \text{H}_2\text{O}_2 \) and \( \text{SO}_4^{2-} \) may non-productively degrade and scavenge, respectively, and result in a quicker termination reaction because the free radicals will scavenge oxidants and oxidants may scavenge radicals too (Ko et al. 2012) as in Equations (14) and (15). Ko et al.
(2012) have also mentioned $S_2O_2^{2-}$ and $OH^*$ may react with each other although the reaction rate is slow.

$$\text{H}_2\text{O}_2 + \text{SO}_4^{2-} \rightarrow \text{SO}_4^{2-} + \text{HO}_2^- + \text{H}^+$$  \hspace{1cm} (14)

$$\text{SO}_4^{2-} + \text{HO}_2^- \rightarrow \text{SO}_2^{2-} + \text{H}^+ + \text{O}_2$$  \hspace{1cm} (15)

### Effect of pH adjustment

Different initial pHs (3, 5, 7, 8.4, 9, 10, 11 and 12) were also studied in $S_2O_2^{2-}/H_2O_2$ oxidation of BIOTPOME. Fixed variables of $S_2O_2^{2-}/\text{COD}_0 = 2.0:1.0$, dosage of $H_2O_2/S_2O_2^{2-}$ of 2.45 g/1.63 g and 20 minutes contact time were employed in the oxidation system. In Figure 6, the optimum pH for overall removals of parameters was 11; 87.1% SS, 75.8% NH$_3$-N and 35.8% COD were eliminated under pH 11. SS removal increased steeply as pH increased. The removal efficiencies of SS were 64.5% under acidic condition, pH 3. Colour removal of 90.5% and SS removal of 93.6% were also gained with initial pH of 12. The removal of NH$_3$-N was improved from 21% to 77.8% as pH increased, while the maximum removal of COD (53.2%) was achieved at pH 8.4.

Table 3 shows a summary of $S_2O_2^{2-}/H_2O_2$ oxidation. Through adjustment of the dosage ratios and dosages of $H_2O_2/S_2O_2^{2-}$ (g/g), removal efficiencies of COD, NH$_3$-N and SS were 52.5%–56.9%, 26%–26.9%, and 61.4%–63.7%, correspondingly, with the final pH values of 8.2. However, under adjustment of pH, COD removal was decreased and NH$_3$-N removal was increased sharply compared with COD and NH$_3$-N removals under varied dosages of $S_2O_2^{2-}$ and $H_2O_2$. In the studied conditions ($S_2O_2^{2-}/\text{COD}_0 = 2.0:1.0$, pH 11, 20 min contact time and $H_2O_2/S_2O_2^{2-}$ dosage of 2.45 g/1.63 g), the highest removal efficiencies of COD, NH$_3$-N and SS were 35.8%, 75.8% and 87.1%, respectively, at final pH of 10.1.

Although the optimum removal for ammonia and SS was achieved at pH 11, significant removal for COD was also achieved at pH 8.4. This finding is in agreement with Hilles et al. (2016a, 2016b) using $S_2O_2^{2-}/H_2O_2$ for concentrated landfill leachate treatments.

In the light of the above, operational cost for using $S_2O_2^{2-}/H_2O_2$ was calculated for kg COD removal. As the major cost of the treatment process is related to chemicals used, the operational costs were USD0.4/L 37% $H_2O_2$ and USD0.8/kg sodium persulfate ($NaS_2O_2^{2-}$), and about 4.98 kg
of persulfate and 5.2 L of 37% H2O2 are required to remove 1 kg COD (in 305 L of POME). Around USD6 is required to treat 303 L of POME using S2O2−8 /H2O2 oxidation process. Hilles et al. (2016a) reported USD10.7/kg COD removal using the same treatment process for landfill leachate.

CONCLUSIONS

In this study, S2O2−8 and S2O2−7/H2O2 oxidation were used for removing SS, NH3-N and COD from BIOTPOME. To the best of our knowledge, this is the first experimental study conducted to treat BIOTPOME via S2O2−8 and S2O2−7 /H2O2 oxidation. For S2O2−8 oxidation, 36.8% COD, 47.6% NH3-N and 90.6% SS were removed at the optimum operation conditions (S2O2−8 = 0.82 g, pH 11, and 20 min contact time). In S2O2−8/H2O2 oxidation, 35.8% COD, 75.8% NH3-N and 87.1% SS were achieved when operation conditions were S2O2−8 :COD0 = 2.0:1.0, H2O2/S2O2−8 = 2.45 g/1.63 g, pH 11 and 20 min contact time. The highest removal of COD was 56.9% when S2O2−8 :COD0 = 2.0:1.0 and 2.45 g/1.63 g of H2O2/S2O2−8 at pH 8.4 and 20 min contact time. High removal of COD could be obtained without adjusting pH while NH3-N was effectively removed at alkaline condition. Values of final COD and pH of S2O2−8 and S2O2−7 /H2O2 oxidation above the standard discharge limit and not suitable for release into the environment according to the industrial discharge standard for POME (DOE 1999). This study concluded that S2O2−8 and S2O2−7 /H2O2 oxidation were efficient to reduce certain parameters of BIOTPOME under certain operational conditions.

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