Physicochemical Properties of Wastewater from Palm Oil Mill Secondary Effluent (POMSE) for Water Evaluation Quality

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Abstract. Effluent from palm oil mills is one of the main sources of pollution that seriously affects the physicochemical parameters in water bodies. Palm oil mill effluent (POME) is a potential hazard to the general environment. Regularly monitoring effluent is important to ensure industry compliance with effluent quality limits based on national and international regulations to safeguard human life, aquatic organisms, and other living organisms. This research focused on analyzing the physicochemical parameters of wastewater palm oil mill secondary effluent (POMSE) from palm oil mills in Rokan Hulu, Riau. The assessed physicochemical parameters included pH, chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), total nitrogen, oil and fat, turbidity, and odor. The results indicated significant differences in characteristics in some of the observed parameters. Our findings were: pH (6.03−8.42); BOD (36.7−2,136.0 mg/L); COD (26.33−4,753.00 mg/L); TSS (30-5,438 mg/L); total nitrogen (361-830 mg/L); oil and fat (4−23 mg/L). The physicochemical characteristics of the effluent in the last treatment pond before being discharged through the liquid waste sewage have met the wastewater standards of the palm oil industry.

1 Introduction

The palm oil industry in Indonesia has made significant development in recent years. The palm oil industry development is marked by the high production of crude palm oil (CPO), which reached 48.2 million tons in 2021 [1]. This development is very positive for the economy as a foreign exchange earner but also has a considerable risk of environmental pollution. Palm oil processing in the palm oil industry produces five times greater waste than the raw material. Even though it is not toxic, palm oil industry waste produces high organic waste that is dangerous when discharged directly into the land or the river because it has high levels of BOD, COD, TSS, oil and fat, total nitrogen, and pH. Previous research reported that physicochemical characteristics of palm oil mill effluent had level of BOD (25,545 mg/L),

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COD (55,775 mg/L), Total Suspended Solid (18,479 mg/L), Total nitrogen (711 mg/L), ammonia nitrogen (36 mg/L), oil and fat (8020 mg/L), pH 3.5 and temperature 84^{o}C [2].

POME is the wastewater generated from palm oil mills. The composition and characteristics of POME depend on the raw material quality, season, time of operation, and treatment [3]. POME effluent has a foul odor, can reduce water quality, will affect the active organisms in the vicinity, and can cause serious environmental pollution if not handled properly [4]. POME discharged into water bodies causes the waters to turn brown, smelly, and slimy and causes deoxygenation [5]. Discharging untreated POME into the soil will alter its physical and chemical properties and nutritional status, causing an undesirable decrease in pH and an increase in salinity [6]. Exposure to POME effluent is responsible for significantly decreasing plankton diversity and physiological and reproductive disturbances in fish [7]. The use of large amounts of water in the palm oil processing process will also impact the scarcity of clean water [8]. Hence, the treatment of palm oil mill effluent is mandatory to overcome the pollution caused by the presence of such waste. In Indonesia, the acceptable levels of palm oil industry effluent are determined by Government Regulation No. 5/2014 on palm oil industry effluent (Table 1). Generally, palm oil processing plants in Indonesia use anaerobic and aerobic processes to treat the wastewater.

Table 1. Parameter limits for POME before discharged into waterways.

Parameters (unit)	Indonesian Standard Limit
pH	6-9
BOD5 (mg/L)	100
COD (mg/L)	350
TSS (mg/L)	250
Oil and fat (mg/L)	25
Total Nitrogen (mg/L)	50

Source: Indonesian standard for POME (2014)

The reduction of POME organic and pollutant levels through processing at the first (primary) stage is good, but still does not meet the quality standards of palm oil industry waste, so an advanced stage is often called Palm Oil Mill Secondary Effluent (POMSE). Although POMSE has been treated, the characteristics of POMSE do not meet the discharge criteria of palm oil industry waste. Palm oil mill secondary effluent (POMSE) treatment involves long retention times, slow start-up, and requires large land areas [9]. The land area required will increase with increasing production [10], so no additional ponds would result in less effective management. The ineffectiveness of processing is indicated by community reports through news reports in local and national news media about alleged water pollution due to palm oil mill waste. The research site survey showed turbid river waters, oil residue, brown-black color, dead fish, and foul odor. Hence, research is needed to determine the waste characteristics in the sewage treatment pond.

2 Experimental Details

2.1 POMSE Sampling

POMSE samples were collected from various composite locations, including at the outlet of the biological primary pond (upstream), at the last pond location before land application (outlet aerobic pond), and at the midpoint of the biological secondary pond (facultative pond). Sample collection followed the Indonesian National Standard (SNI) 6989.59:2008. Samples

collected were placed in the polypropylene container and were directed to be transported from the mill to the laboratory without any delay. The analyses were done on the same day it was collected.

Pond A (Fig. 1) is the last anaerobic pond for primary treatment. The pond's dimensions are 57×50 meters with a thickness of 5.5 meters. Sample was taken from pond inlet A or the outlet of the primary pond. while pond B is a facultative treatment pond. There are 3 aerobic facultative ponds in the POME effluent treatment at this palm oil mill (namely facultative 1, 2, & 3). The sample in this study was taken from facultative pond 3 which flows into the final pond. and pond C is the final or last treatment pond. The sample taken is the effluent outlet that will lead to the discharge. This pond has a volume of 25,000 m^3.

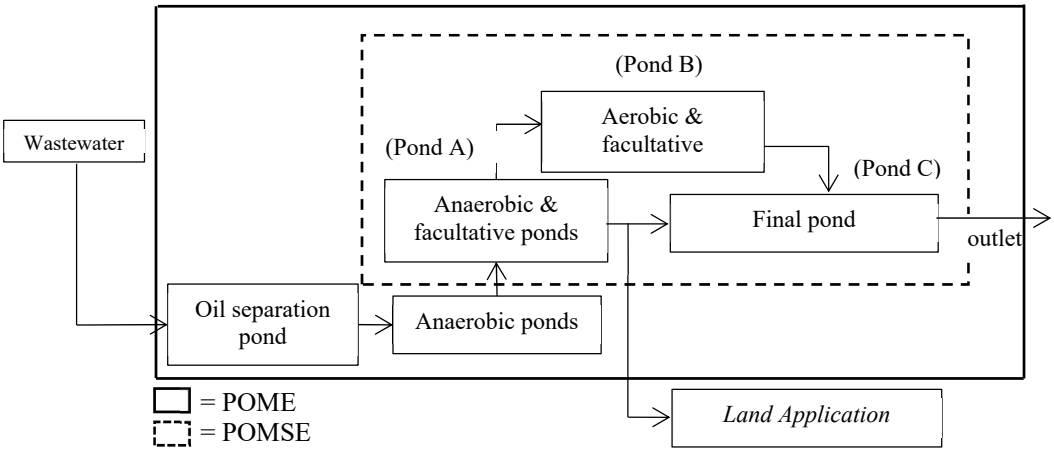

Fig. 1. Effluent treatment flow of POME

2.2 Material

HCl, H_2SO_4, organic solvents, N-Hexane, Methyl tert-butyl ether, Na_2SO_4, KH_2PO_4, NH_4Cl, $Na_2C_2O_4$, $KMnO_4$, Ag_2SO_4, glass-fiber filter, Whatman Grade 934 AH, Gelman type A/E, E-D Scientific Specialties grade 161, K_2SO_4, $CuSO_4$, H_2SO_4, NaOH, $Na_2S_2O_3$, $5H_2O$, $Na_2B_4O_7$, H_3BO_3, Methyl orange, Na_2CO_3.

2.3 Physicochemical parameters test

Biological Oxygen Demand (BOD) by Titrimetric method (SNI 6989.72-2009); Chemical Oxygen Demand (COD) by Titrimetric method (SNI 6989.73-2019); Total Suspended Solid (TSS) by Titrimetric method (SNI 6989.3-2019); Oil/Lipid (SNI 6989.10-2011) by Gravimetric method; Total Nitrogen assay was carried out by the Kjeldahl method as described by [11]; pH by pH meter.

2.4 Color and odor wastewater test

The color of wastewater samples was determined using Hach DR5000U Spectrometry based on the 10048-ADMI Weighted Ordinate Method. Unpleasant odor was directly observed in locations.

3 Results and Discussion

3.1 Color and odor

The POMSE observed from the three secondary treatment ponds had different colors (Fig. 2). POMSE is described as a waste product that is liquid and brown. POMSE at the inlet was still very turbid and had a bad odor, while the effluent color in the last pond was slightly more transparent and had less odor than in the previous ponds. While POMSE is not poisonous, it emits an unpleasant odor, which can be a nuisance to people living near palm oil mills [12]. The POMSE color of each sample is different. The POMSE color is dominantly brown, dark brown, and then yellow. POME has water-soluble components such as palm fruits, various lipids and carbohydrates, and compounds consisting of nitrogen and organic compounds with a brown color [13].

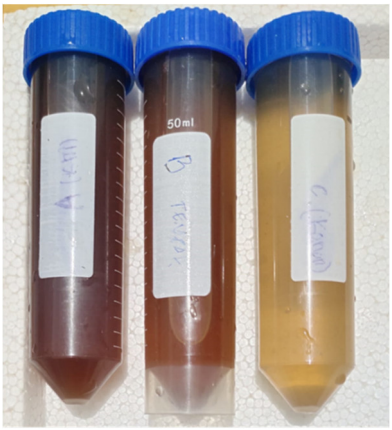

Fig. 2. POMSE Color: A. Pond A (Inlet POMSE); B. Pond B (Midpoint POMSE); C. Pond C (Last POMSE Pond).

3.2 Phsycochemical characteristics of POMSE

3.2.1 pH value.

The physical-chemical parameters of POMSE tested in the three treatment ponds sampled showed fluctuations (Fig. 3-6). The pH value in Pond A was more acidic and increased to highly alkaline in Pond B but decreased in Pond C. However, the pH value in all ponds remains within the acceptable pH value. pH values are 6-9. Microorganisms in water are able to grow and develop at a certain pH condition. The optimum conditions for the growth of bacteria and fungi were found to be at pH 6. The pH value in the POMSE pond is higher than in the POME primary treatment pond; the pH value ranges from 3 [14, 15]. The pH value after POME treatment through electrocoagulation is relatively neutral due to the continuous release of hydroxide ions (OH-) by the cathode into the POME solution during the electrocoagulation process [16]. Therefore, in the POMSE treatment process, which generally uses microorganisms, the pH value is a very important indicator. The optimal growth pH of bacteria is, respectively, 5.0–9.0 [17], 8-9 [18], and 7.0 [19]. The pH value is a critical factor that influences its biodegradation process [20].

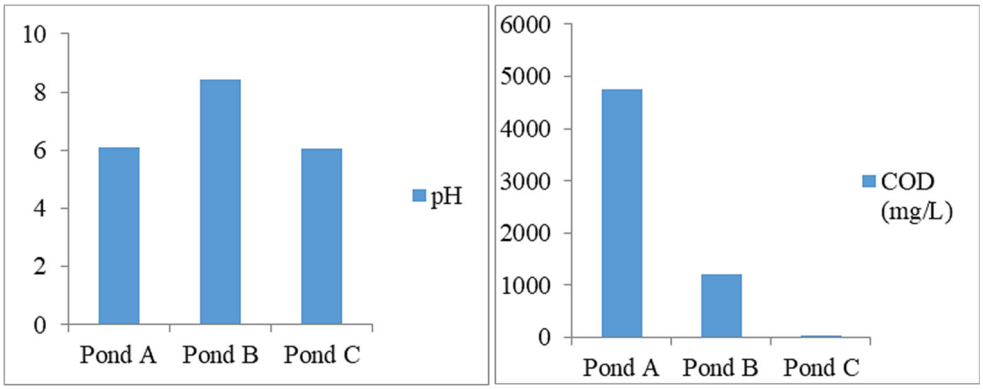

Fig. 3. The pH and COD values of POMSE in Pond A, Pond B & Pond C

3.2.2 COD values

Our research showed that the COD value in Pond C was 26.33 mg/L. This number of pollutants has decreased greatly compared to the COD value in ponds A and B. The observed COD values are still very high in the anaerobic and aerobic secondary ponds but have decreased significantly so that the value has met the established quality standards in the last pond. Some studies show values similar to the data obtained (Table 2). COD values in final discharge are 48−75 mg/L [19].

3.2.3 BOD values

The BOD value has decreased significantly from the previous ponds. The Indonesian standard limit of the palm industry for BOD is 100 mg/L. The lower BOD value is due to maximum biodegradation by microorganisms, especially bacteria. BOD values POMSE between 249−273 mg/L [21]. The BOD values from Pond A to Pond B and from Pond B to Pond C decreased significantly by 77% and 92%, respectively (Table 3). High COD values are responsible for the impairment of aquatic life [22]. The COD and BOD are important parameters used as indicators of wastewater's composition and environmental impact. The decreased BOD and COD values are usually followed by a decrease in TSS.

3.2.4 TSS values

Thus, also with the data obtained, based on our research, the TSS value has decreased significantly and remains only 30 mg/L in the last pond of treatment. Although some studies show different values for the TSS parameter, the TSS value in our research is lower than the POMSE value in some studies. TSS values 1635−1875 mg/L [20]; 56−233 mg/L [19]. The high TSS value will cause pollution to the environment, especially water. TSS can clog fish gills, killing them or reducing their growth.

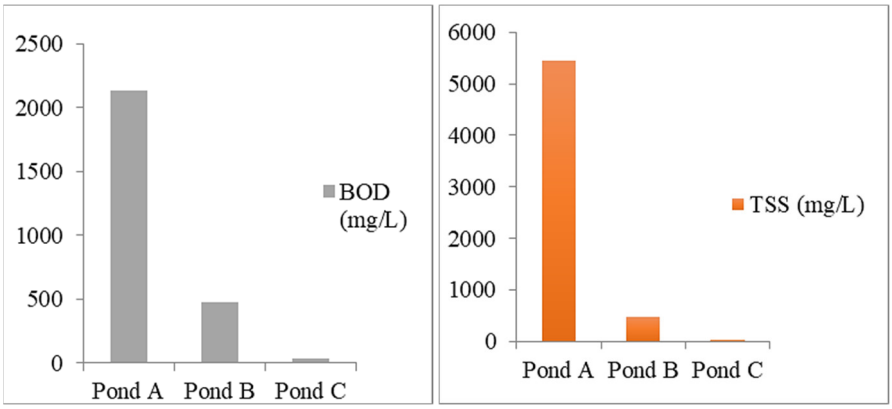

Fig 4. BOD and TSS values of POMSE in Pond A, Pond B & Pond C.

These solids could reduce light penetration, thus reducing the ability of algae to produce food and oxygen [24]. POMSE contains a high concentration of organic matter, COD concentration in the range of 1854 mg/L, BOD of 160 mg/L, TSS of 1138 mg/L, and pH 8,1 [22].

3.2.5 Oil and fat values

In addition, compared to BOD, COD, TSS, and total N, the oil and fat values from this study met the quality standards (Fig. 5). There was a significant decrease in values from the POMSE inlet pond to the last pond (Table 3). The treatment of POME through an aerobic biodegradation process with a consortium of microorganisms will facilitate the effective conversion of oil and fat present in POME into environmentally safe biomass [24]

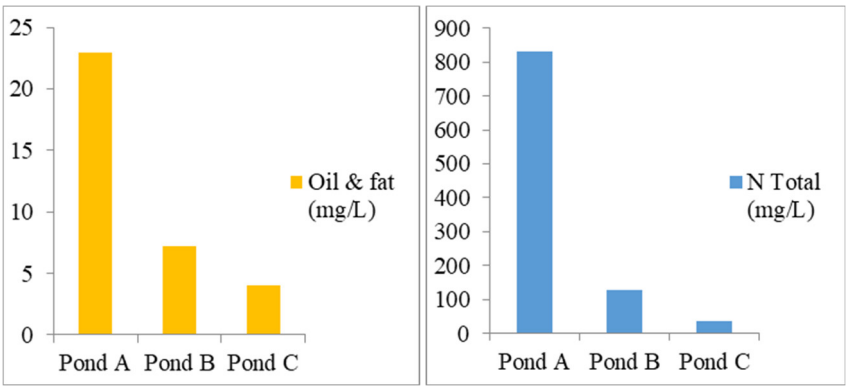

Fig. 5. Value of oil & fat and N total POMSE in Pond A, Pond B & Pond C.

3.2.6 N total value

Total N value is one of the organic pollutants in palm oil mill effluent. In this research, the total N value in POMSE fluctuated very high in Pond A but decreased significantly in Pond B and Pond C (Table 3) total N removal efficiency influenced by degradation by microorganisms. Total N removal by microalgae is efficient up to 63% [25]. Although the total N values that we obtained were lower than some other studies on POMSE (Table 2), the total N values in Pond A and Pond B did not meet the quality standard for the palm oil industry in Indonesia, which is 50 mg/L (Table 1).

Table 2. Measured physicochemical parameter of POMSE by other studies

Parameter	[24]	[19]	[25]
pH	9.0	7.86−8.3	8.31−8.34
COD mg/L	1,600	3,234−4,044	2,630−3,504
BOD mg/L	160	249−270	1,150−1,170.
TSS mg/L	14,787	1,635−1,875	2,090−2,560
N total mg/L	N/A	N/A	170−510

N/A: Not Available.

Table 3. Efficiency removal (%) of wastewater parameters

Parameter	Pond A-B	Pond B-C
COD	75	98
BOD	77	92
TSS	91	93
N total	84	71
Oil and fat	68	44

4 Summary

This research aims to describe the physicochemical properties of palm oil mill secondary effluent (POMSE), which can be used to evaluate the effluent treatment carried out by palm oil mills, especially in Riau province. The research was carried out using direct observation and laboratory analysis. The results of this research were the physicochemical parameter values of several POMSE ponds. From the generated data in this study, the physicochemical properties of POMSE have met Indonesian standards for the palm industry.

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