The study of soil biological and chemical properties on palm oil plant rhizosphere with and without palm oil mill effluent applications

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Abstract. Palm oil mill effluent (POME) is a by-product of palm oil mills. POME application to the field must comply with the regulations issued by the Minister of Environment. The research objective was to determine the soil biological and chemical properties in the rhizosphere of palm oil plant on the land with and without POME application. The research used factorial randomized block design (RBD) with 2 treatments, the first factor was with and without POME application. The second factor was the sample distance from palm oil trees, namely 0 m, 100 cm, 200 cm, 300 cm and 400 cm. Data were analyzed with the analysis of variance at a 5% level and continued with the DMRT at significantly different treatments. The results showed that the POME application had a significant effect on total microbes, soil respiration and cation exchange capacity. The total microbes, C-organic, soil respiration, cation exchange capacity and alkaline saturation on the POME application land were $3.47 \times 10^{-6}$ CFU ml$^{-1}$, 2.16%, 1.4 mg C (CO$_2$), 11.1 cmol kg$^{-1}$ and 40.75%, while on land without POME applications were $1.63 \times 10^{-6}$ CFU ml$^{-1}$, 2.32%, 0.52 mg CO$_2$, 7.59 cmol kg$^{-1}$, and 70.63%. Soil sampling at a distance of 0, 100 cm, 200 cm, 300 cm and 400 cm from the palm oil tree towards the POME application trench had a significant effect on total microbes and soil respiration. The highest of total microbes and soil respiration at 0 cm from oil palm trees were $3.47 \times 10^{-6}$ CFU ml$^{-1}$ and 1.14 mg CO$_2$. The interaction between soil sampling from the application land and without the application land with the sampling distance treatment from palm oil trees had a significant effect on the soil total microbes parameters. The conclusions of this research were; the application of POME with BOD $180$ mgL$^{-1}$ and COD $593$ mgL$^{-1}$ on palm oil plantations can increase the total soil microbes, soil respiration and cation exchange capacity but did not increase C-organic and alkaline saturation. The closer the application to the palm oil plant rhizosphere, the higher the distribution and microbial activity.

1. Introduction
The palm oil industry continues to grow rapidly in line with the development of downstream industrial products and support from the government for the use of palm oil products for biodiesel. Palm oil fruit bunches often referred to as FFB, are processed in palm oil mills to become CPO. The processing of fresh fruit bunches (FFB) produces CPO [1]. Its byproduct is solids and liquids [2]. This by-product has the potential to become a source of organic matter, a source of nutrients and a source of water for palm oil plants. The percentage of solids produced in the Teluk Siak Factory (TSF) with a processing capacity of 45 tons/hour is; the composition of empty fruit bunches around 18.85% of processed FFB; fibre
around 13% from processed FFB; shells around 5% from processed FFB; and POME around 60.09% of processed FFB [3]. The by-product in the form of POME should have BOD criteria not exceeding 5000 mg/litre, pH 6.0 - 8.0, applied to land other than peat [4]. The palm oil mill effluent was brownish in colour, consisting of dissolved and suspended solids in the form of colloids and oil residue with high COD and BOD content of 68,000 ppm and 27,000 ppm, and is acidic (pH 3.5-4) [5]. Those waste characteristics are not allowed to be flown directly into river bodies or land. The total maximum daily load (TMDL) can be reduced by 110 kg ton⁻¹ CPO and the actual pollution load (APL) can be reduced by 106.48 kg ton⁻¹ CPO. Palm oil mill effluent has the potential to be used as a liquid fertilizer in palm oil plantations (land application) [6]. Based on the analysis of POME, it has the opportunity to increase nutrient and water content in palm oil planted areas. This research aimed to determine the effect of palm oil mill effluent application on total microbes, C-organic content, cation exchange capacity, base saturation and soil respiration at a distance of 0 cm, 100 cm, 200 cm, 300 cm and 400 cm from the palm oil tree towards the application trench.

2. Materials and Methods
2.1. Research design
This research used a factorial randomized block design consisting of 2 factors. Factor I was the POME application (A) consisting of 2 levels, namely A0 (area without POME application) and A1 (area with POME application). Factor II was the sampling distance from palm oil trees (J), consisting of 5 levels, namely 0 cm (J0), 100 cm (J1), 200 cm (J2), 300 cm (J3) and 400 cm (J4) from the tree. Thus, there were 10 treatment combinations with 3 replications. The research was carried out at Adolina Garden of PT. Perkebunan Nusantara IV, Deli Serdang District, Sumatera Utara, Indonesia, in 2018.

Undisturbed soil samples were taken to analyse soil respiration and total microbes. Composite soil was taken to analyse C-organic, cation exchange capacity and base saturation. The data were analysed by the analysis of variance with a confidence interval of 5%. If the analysis results are significantly different, then continue with the Duncan Multiple Range Test (DMRT) with a 5% confidence interval. The observed parameters were total soil microbes, using the Dilution Plating Method (CFU ml⁻¹) [7], soil respiration [8], base saturation, cation exchange capacity and C-organic [9].

3. Results and Discussion
3.1. The Characteristics of Palm Oil Mill Effluent in Adolina Garden
Palm oil mill effluent produced by Adolina Garden is as follows: 1 ton of fresh fruit bunches (FFB) = 0.6 - 0.7 m³ of POME. The application of POME starts from the waste pond to the nearest block area by making a storage ditch. Waste pond volume: 21,560 m³, waste pond depth: 3.5 m, effective waste volume: 80% x 21,560 m³ = 17,248 m³. The dosage of ha⁻¹ POME is 750 m³ ha⁻¹ year⁻¹ with 4 times application rotation a year.

The liquid waste was first processed at the Wastewater Treatment Plant (WWTP) before being flowed into the application trench. The application trench is located between the rows of palm oil plants, every two rows of plants there is one application trench. The characteristics of POME that have been processed and flowed in the application trench can be seen in Table 1.
Table 1. The Characteristics of POME flowed into the application trench at the Adolina Garden of PT. Perkebunan Nusantara IV

| Parameter                     | Unit     | Result   |
|-------------------------------|----------|----------|
| pH at the Laboratory          | -        | 7.71     |
| Total Suspense solid          | mg L⁻¹   | 45       |
| Ammonia as NH₃-N               | mg L⁻¹   | 160      |
| Cadmium                       | mg L⁻¹   | <0.003   |
| Lead                          | mg L⁻¹   | 0.23     |
| Copper                        | mg L⁻¹   | 0.02     |
| Zinc                          | mg L⁻¹   | 0.22     |
| Oil and fat                   | mg L⁻¹   | 51       |
| COD as O₃                     | mg L⁻¹   | 593      |
| BOD as O₃                     | mg L⁻¹   | 180      |

Source: Adolina Garden of PT. Perkebunan Nusantara IV

POME that was channeled into palm oil plantations through the application ditch was POME that has met the quality standards of waste that can be channeled into rivers or land. This can be seen from the pH, that was 7.71, oil and fat was 51 mgL⁻¹, BOD was 180 mgL⁻¹ and COD was 593 mgL⁻¹.

3.2. Total microbes, C-organic, soil respiration, cation exchange capacity and base saturation

The analysis results of total microbes, C-organic, soil respiration, cation exchange capacity and base saturation can be seen in Table 2:

Table 2. Total microbes, C-organic, soil respiration, cation exchange capacity and base saturation

| Treatment | Total Microbes (x10⁶ CFU ml⁻¹) | C-organic (%) | Soil Respiration (mg CO₂) | Cation exchange capacity (cmol.kg⁻¹) | Base Saturation (%) |
|-----------|---------------------------------|---------------|---------------------------|--------------------------------------|---------------------|
|           |                                 |               |                           |                                      |                     |
| A0 (without Application) POME | 1.63b               | 2.32          | 0.52b                     | 7.59b                                | 70.63a              |
| A1 (with Application) POME   | 34.70a               | 2.16          | 1.42a                     | 11.10a                               | 40.75b              |

Soil sampling area (A)

Soil sample distance from palm oil trees (J)

| J0 (0 cm from the tree)  | 34.07a               | 2.39          | 1.40a                     | 6.99                                 | 68.33               |
| J1 (100 cm from the tree)| 17.85b               | 2.20          | 1.05b                     | 10.61                                | 60.34               |
| J2 (200 cm from the tree)| 13.91c               | 2.65          | 1.04b                     | 9.76                                 | 54.70               |
| J3 (300 cm from the tree)| 15.37b               | 1.43          | 0.81c                     | 8.85                                 | 51.90               |
| J4 (400 cm from the tree)| 9.64d                | 2.54          | 0.54d                     | 10.52                                | 43.19               |

A x K

A0J0  | 1.94e               | 2.46          | 0.74                      | 6.48                                 | 70.03               |
A0J1  | 1.83e               | 2.18          | 0.61                      | 7.53                                 | 79.99               |
A0J2  | 1.45e               | 2.85          | 0.66                      | 7.11                                 | 70.00               |
A0J3  | 1.43e               | 1.21          | 0.34                      | 6.71                                 | 73.93               |
A0J4  | 1.51e               | 2.92          | 0.26                      | 10.12                                | 59.20               |
A1J0  | 66.20a              | 2.32          | 2.06                      | 7.49                                 | 66.64               |
A1J1  | 33.87b              | 2.23          | 1.49                      | 13.69                                | 40.68               |
A1J2  | 26.37c              | 2.44          | 1.43                      | 12.42                                | 39.40               |
A1J3  | 29.30c              | 1.65          | 1.29                      | 11.00                                | 29.87               |
A1J4  | 17.77d              | 2.17          | 0.83                      | 10.92                                | 27.17               |
A     | *                   | tn            | *                         | *                                    | *                   |
J     | *                   | tn            | *                         | tn                                   | tn                  |
A x J | *                   | tn            | tn                        | tn                                   | tn                  |
3.3. Total Microbes
The results of statistical analysis showed that the POME application had a significant effect on the total soil microbes. The highest number of microbes was found in the area where POME was applied, namely $3.4.70 \times 10^6$ which was significantly different from the total microbe in the area that was not applied with POME. This was due to the nutrient and water content contained in POME which supporting the soil microbes activity. This was in line with the research of Amelia et. al. which stated that the area applied by POME was dominated by UQ-10 and 10 types of MK which were dominated by MK-8. UQ-10 contains bacteria (Acidiphilium agrobacterium, Ochobactrum, and Spingomonas) and several types of fungi (Aspergillus, Neosartorya, Paecilomyces, and Penicillium/Talaromyces) [10]. The arthropod population of fungi in the area where POME was applied was higher than the area without POME application. There are 6 classes namely Insecta, Arachnida, Malacostraca, Entognatha, Centipede and Diplopoda [11].

The distance of the soil sampling from the palm oil trees indicated that the area closest to the palm oil trees had high microbes population. The total microbes population respectively were 34 x 10^6, 17.85 x 10^6, 13.91 x 10^6, 15.36 x 10^6 and 9.64 x 10^6. The highest number of microbes was identified in the closest area to the rhizosphere [12]. A rhizosphere is a place where microbes can grow and develop properly because the roots produce exudate from plant metabolism. Total soil microbes were higher in A1J0, A1J1, A1J2, A1J3, A1J4 compared to A0J0, A0J1, A0J2, A0J3 and A0J4. The highest total microbes were found in 0 cm sampling distance from palm oil trees in the POME application area. The total microbes were successively reduced when the distance was further away from the root area. The number of microbes was lower in areas without POME application, starting from the root area to approaching the POME application trench. The highest soil moisture was found in the land with POME application, which was 30.75% increase and the lowest was found in the land without POME application, which was 17.24% increase [13]. The number and types of microorganisms in the soil are an indication that the soil is fertile and an indicator of the availability of organic matter in the soil, suitable temperature, adequate water availability and supportive soil ecological conditions [14].

3.4 C-organic
Soil C-organic content in the POME application area was not significantly different from the C-organic content in the area without POME application. The C-organic at a distance of 0 cm, 100 cm, 200 cm, 300 cm and 400 cm from the palm oil trees was not significantly different, as well as the average C-organic in the interactions between treatments. This was due to the POME flowing into the application trenches had been processed in WWTP to meet a BOD of 180 mgL-1 and COD of 593 mgL-1. The POME processing process aims to ensure that it can be used safely in accordance with the Decree of the State Minister for the Environment No. 28 of 2003 concerning Technical Guidelines for the Utilization of Industrial Waste Water for Palm Oil Mill [4]. Organic matter undergoes an overhaul followed by a decrease in BOD, COD, TSS and C/N ratio. The C-organic content of POME in the acidification pond was 10.44%, organic matter overhaul continued until the C-organic content in the secondary anaerobic pond I decreased to 5.52% and C-organic in the aerobic pond to 1.85% [5].

3.5 Soil Respiration
Soil respiration can be used as an indicator for microbial activity, the higher soil respiration indicates high microbial activity. Soil respiration in the area applied by POME was 1.42 mg C-CO2, higher than the respiration in the area without POME application, namely 0.42 mg C-CO2. The highest soil respiration was at a distance closer to the roots (1.40 mg C-CO2) and gradually decreased, namely 1.05 mg C-CO2, 1.04 mg C-CO2, 0.81 mg C-CO2 and 0.54 mg C-CO2 at a distance of 100 cm, 200 cm, 300 cm and 400 cm from the palm oil trees. In the observation of both the interaction treatments, the highest soil respiration was found in the area where POME was applied and close to the palm oil trees. The farther from the roots, the soil respiration decreases. The results of observations and data analysis on soil respiration were in line with the results of the analysis of total microbes data. Soil respiration is a process that occurs due to the activity of microorganisms in the soil. Determination of soil respiration
based on the amount of CO2 produced by microorganisms and the amount of O2 used by soil microorganisms [15].

3.6. Cation exchange capacity
The cation exchange capacity is the number of cations that can be adsorbed by the soil within the weight of the soil. The cations in question are Ca$^{2+}$, K$^+$, Na$^+$, Mg$^{2+}$, NH$_4^+$, H$^+$, Al$^{3+}$ [16]. Based on statistical tests, the cation exchange capacity was significantly different between the POME application and without the POME application. CEC on land with POME application was higher (11.10 cmol.Kg$^{-1}$) than on land without POME application (7.59 cmol.Kg$^{-1}$). CEC is influenced by pH, organic matter and clay mineral types. Soils with high CEC are able to absorb and provide nutrients better than soils with low CEC [16].

The cation exchange capacity was not significantly different at distances of 0 cm, 100 cm, 200 cm, 300 cm and 400 cm from palm oil trees, as well as the interactions between treatments. It was assumed that the distribution of soil cations was evenly distributed over an area of 0-400 cm.

3.7. Base saturation
Base saturation in the application area was significantly different from the land without the POME application. The base saturation in the land without POME application was higher than in the POME application land. The base saturation in the area that was not applied with POME was 70.63% while the area that was applied with POME was 40.75%. The sampling distance from palm oil trees did not significantly affect the base saturation, as well as the interaction between treatments and the distance of soil samples from palm oil trees. Base saturation describes the percentage of the total CEC that is occupied by base cations, namely Ca, Mg, Na and K. The base saturation value is very important for consideration of fertilization and predicting available nutrients for plants [17].

4. Conclusion
The application of POME with BOD of 180 mgL$^{-1}$ and COD of 593 mgL$^{-1}$ on palm oil plantations can increase the soil total microbes, soil respiration and cation exchange capacity but did not increase C-organic and base saturation. The closer the application to the palm oil plant rhizosphere, the higher the distribution and microbial activity.

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