Degradation of biochemical oxygen demand (BOD) and potential of hydrogen (pH) in POME by DBD plasma

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Abstract. Plasma technology was used in palm oil liquid waste (POME) management research. Plasma discharge generated in a Dielectric Barrier Discharge (DBD) plasma reactor was utilized to decrease BOD content and pH in POME. The DBD plasma reactor, with spiral-rod configuration, used in this study has 50 windings. Charge carrier mobility was calculated based on the electrical characteristics of the reactor to determine its effect on the decrease in BOD and pH levels of the sample. The effect of the gas flow rate on pH and BOD was also determined on the 1 hour and 2 hours treated samples. The results showed that 1 hour irradiation with the gas flow rate of 1.5 L/min resulted in pH of 9 and BOD of 180.30 mg/L, decrease from control sample having BOD of 342.86 mg/L and pH of 11, this is the most effective decrease compared to that obtained from 2 hours irradiation and 1.5 L/min flow rate. The results obtained approached the value permitted by the environmental ministerial regulation of 2005, concerning to Quality Standards of Domestic Wastewater. These results suggest that plasma technology is potential for the management of POME.

1. Introduction
Indonesia is one of the country’s largest exporter of palm oil in the world[1]. In the year 2016 Indonesia has produced 320 million tons and exported 270 million tons to various countries such as India, China, Malaysia, Singapore, and the Netherlands. The amount of increased production in the oil palm industry resulted in the amount of liquid waste oil palm production increases, and if not done the handling and processing of waste, it will negatively impact the environment [2]. Palm oil is the liquid waste containing organic compounds, nutrients, wastewater containing 95–96% water, 0.6–0.7% oil and 4–5% total solids including 2–4% suspended solids [3]. The management of liquid waste oil palm Government set guidelines regarding the quality of liquid waste industrial activity and State Minister of the environment, number: 112 the year 2005 about The Raw Domestic Wastewater Quality is shown in Table 1.

Some research is done to reduce the negative effects of the waste oil palm liquid chemical way namely aerobic system with ultrasonic membrane for the wastewater treatment of palm oil obtained concentrations of COD ranging between 65,600 mg/l up to 86,400 mg/l [4]. The research of Ali Yuzir et al. using the anaerobic method of COD value to decrease by 15% from the initial value of 93% [5]. Another method that is chickpea powder (Cicer arietinum) process produced hydrogen production...
maximum with optimum pH 6.69[6]. Whereas, the method ultrafiltration (UF) for the secondary processing of POME obtained as a result of the pH of 9.05 [7]. Whereas, the method is utilizing renewable technology plasma. Plasma is the fourth phase of matter consisting of the electron, ion, and plasma-neutral, are distinguished into three types namely cold plasma, thermal plasma and warm plasma [8]. Plasma is used for a variety of applications covering the areas of environmental air pollutants, wastewater and drinking water, and solid waste disposal, thermal plasma technology in economically more efficient sewage handling and comparison of technologies other [9].

### Table 1. The raw domestic wastewater quality

| Parameter  | Unit | Maximum Levels |
|------------|------|----------------|
| pH         |      | 6-9            |
| BOD        | mg/l | 100            |
| COD        | mg/l | 100            |
| TSS        | mg/l | 100            |
| Oil and Fat| mg/l | 10             |

Plasma technology has been used for the processing of liquid waste in the production of hydrogen obtained an internal consumption amounted 60-70% [10]. Other research that is handling liquid waste argon-chlorine injection plasma technology brings about result destruction of chloroform is obtained with the efficiency of at least 99% energy efficiency and reach 100 gkWh-1 [11]. With the utilization of Dielectric Barrier Discharge method (DBD) can be used as a method for the management of liquid waste oil palm produces high efficiency rating with 19 kV voltage produces a decrease of 55% BOD, COD of 53% and 40% fat liquid with a time of 4 hours [12], while other research pomes with DBD plasma obtained the most optimal results in 60 seconds with a value of Chemical Oxygen Demand (COD) of 115.62 mg/L or still 18% compared with the initial values and TSS 1018 mg/L [13].

This research was conducted on the processing of liquid waste oil palm using plasma discharge method DBD, i.e. do characteristics between current and voltage in the reactor DBD argon gas flow rate varies with the samples and sample measurements, without value the mobility of the charge carriers plasma sample without or with samples with the argon gas flow rate variations, measured on the pH and BOD the sample with the argon gas flow rate variations as well as the old treatment 1 hour and 2 hours on voltage 5 kV. The results obtained will be adjusted to the values indicated in the decision of the Minister of State for the environment, and number: 112 the year 2005 about the Raw Domestic wastewater Quality.

### 2. Methods

#### 2.1 Material

**2.1.1 The Liquid Waste Oil Palm (POME)**

POME obtained from the PT. Gajah Mada Street, TALENT, and Samarinda, East Kalimantan. Retrieved data is initially, BOD; 342, 86 mg/l, COD; 645.99 mg/l TSS; 1192 mg/l, and pH; 11.

**2.2 Methods**

**2.2.1 Experimental Apparatus**

The reactor is the Dielectric Barrier Discharge (DBD). The main components of the reactor is a glass tube made from pyrex with 0.25 cm thick and 2 cm in diameter and the height of the tube by 30 cm that served as barrier discharge between the two electrodes. The two electrodes in the form of electrodes deep in the Interior are made from stainless steel and with a diameter of 2 cm and a height of 30 cm as well as the outer electrodes in the form of a coil with copper wire totaling 50 coils. The reactor is connected to the AC voltage source (maximum voltage of 20 kV and frequency 25 kHz) with variations of 0.5 kV-5 kV, voltage measurements given in the voltage divider system of generator through high-voltage probe (maximum voltage of 28 kV **EC 1010, EnG 1010, Made in Taiwan**) and
attached voltage can be determined using digital clamp meters (KYORITSU Kew Snap 2010 Model, Made in Japan). Argon gas flow that works using the flowmeter (Model Kofloc RX! 600A Kojima scale of 1 – 10 L/minute, Made in Japan) with a variation of the flow of 0.5 L/min – 3 L/minute. Electric current using a multimeter (Sanwa electronic instrument CD772 made by Tokyo). Experimental is done with two treatments, i.e., without samples and samples with which is affected by time of 1 hour and 2 hours of granting 5 kV voltage. In Figure 1, is an experimental DBD scheme shown.

![Set-up research plasma discharge DBD](image)

**Figure 1.** Set-up research plasma discharge DBD

2.2.2. **Average Mobility Carrier**
The value of average mobility of charge carriers in plasma generated by plasma discharge reactor DBD can be determined Equation 1 as follows:

\[ \mu_{RT} = \frac{C^2 d^3}{2S \varepsilon_t} \]  

(1)

With \( \mu \) is mobility with units \((cm^2/V.s)\), \( C \) is an inner constant \((mA/kV)\), \( d \) is the distance between electrodes \((m)\), \( S \) is the area affected by plasma discharge \((m^2)\), \( \varepsilon_t \) is the total permittivity of the material \((F/m)\) [14].

2.2.3. **Biological oxygen demand (BOD)**
Biological oxygen demand (BOD) or biological oxygen requirement is the amount of oxygen required by the microorganisms in the water environment to degrade or oxidize the organic wastes contained in the water[15].

2.2.4. **Potential Of Hydrogen (PH)**
pH is a measure of hydrogen ion concentration of a solution that shows the solution acidic or alkaline will. Liquid waste has a low pH that is \( \leq 4.3 \) indicating that the waste contains mineral acids or high organic acid [16].

3. **Result and Discussion**

3.1. **The Mobility Of The Charge Carriers Rate On Plasma Discharge Reactor DBD**
The research of voltage that is used to generate a plasma discharge of 0.5 kV to 5 kV with intervals of 0.5 kV.

Figure 2 Note that mobility values increase with increasing argon gas flow rate given on reactor [13,14]. This applies to a reactor or samples without a DBD sample every variation of argon gas flow rate, then the visible difference that the value of the gradient with samples smaller than without the
sample. It is popularly attributed to the presence of the additional permits liquid waste material Palm (\(\varepsilon_3\)) resulting in ionization and waste moves in turbulence in the reactor produces an increase in the plasma discharge. The increase happened will generate larger capacitive currents[14]. The mobility of the charge carriers are the mean in an electric field will move because of the style of electrostatics. On mobility without samples or with sample each of argon gas flow rate of 0.5 L/min up to 3 L/min average mobility of charge carriers is obtained as shown in Figure 2.

![Figure 2](image-url)

**Figure 2.** The mobility of the charge carriers rate on plasma discharge reactor DBD

3.2. Biochemical Oxygen Demand (BOD) In Sample

The results of the analysis of the obtained value of the BOD in units of mg/liter on 13 samples specified. The value of BOD (control of 342.86 mg/l with 100% indicating the percentage of the sample has a very high oxygen consumption so that the organism can be lethal and damaging the environment, the value of the BOD as a comparison to a sample get DBD plasma treatment. The value of the percentage of the BOD of the samples depends on long hours and 2 hours pengobatan1 shown in Figure 3 as follows:

![Figure 3](image-url)

**Figure 3.** percentage of the value of BOD against argon gas flow rate function
BOD on the sample controls and samples with treatment based on old DBD plasma treatment 1 hour and 2 hours retrieved the value of BOD. The value of BOD the most optimal approach of standard quality raw palm oil liquid waste is sampled with the argon gas flow rate of 1.5 L/minute long treatment 1 hour of 180, 30 mg/l with the percentage of the BOD of 52, 58%. Then the DBD plasma treatment can lower the amount of BOD in waste liquid palm oil due to the average charge carriers that are affected by movements of the turbulence between the argon plasma discharge, gas, palm oil, and waste. Then it will happen between recombination-ionization of all three repeatedly (AC) produce energy and electric field [13]. Due to the electric field arising (and have the charge ion) then the oxygen and residue in samples of experience solving Solving $O_2$. Bond yields $O$ -radical experience recombination becomes neutral again, then going on the reduction of oxygen $(O_2)$ in samples as well as the color sample yields becomes more clear from the circumstances first.

3.3. Potential Of Hydrogen (pH) In Sample

Figure 4 PH values of the entire sample have a base due to the pH values obtained are within the range of 8-14. However, the most optimal sample to qualify a given sample is long treatment 2 hours. That is because during testing the pH of samples with long treatment 2 hours have absorption energy of photon radiation (discharge plasma) for longer so that the interaction between the electron ($e$), argon gas ($Ar$), water ($H_2O$), oxygen ($O_2$), and ozone ($O_3$)and $OH^- ions carrier generates more than $H^+$ and generate sample is alkaline [16]. $OH^-$ is generated by the release of the bond on the water and ozone undergo recombination and reaction ionization continuously.

![Figure 4](image_url)

Figure 4. Graph of pH test results on samples of argon gas flow rate

4. Conclusion

Based on the results of the study it can be concluded that the value of mobility ($\mu$) without samples greater than mobility with samples and optimal pH and BOD results approaching the raw quality standard that applies is the old peradiasian 1 hour at argon gas flow rate of 1.5 L/minute, i.e., the BOD of 180.30 mg/liter and pH of 9.

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