The simultaneous of electroflotation and biocoagulation on the treatment of peat water using mung bean (Vigna radiata) as natural coagulant

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Abstract. The simultaneous of electroflotation and biocoagulation performance using mung bean flour (Vigna radiata) with 250 mesh as a natural coagulant on the treatment of peat water has been carried out. The electroflotation was carried out using graphite as anode and stainless steel as a cathode electrode with a DC constant voltage of 20 V for 30 mins operation. The mung bean in the doses of 1.0, 1.5, and 2.0 g/500 mL was used to treat the peat water. The effectiveness of the simultaneous of electroflotation and biocoagulation was in term of turbidity, total dissolved solids (TDS), and pH. Initially, the peat water sample had the parameters as much as 224.3 NTU, 1076 mg/L, and 2.7 respectively for turbidity, total dissolved solids (TDS), and pH. The results showed that the simultaneous of electroflotation and biocoagulation (EB) process had decreased those parameters as much as 84.5%, 70.2%, and changes the pH to be 6.8.

1. Introduction
The peat water is mostly obtained in lowland peatland areas. The characteristics found in peat water are a high degree of acidity (pH), a concentrated color intensity, and a high concentration of suspended particles [1]. One of the main compounds contained in peat water is humic acid which is known to damage endothelial cells when accumulated in the human body [2]. Humic acid in peat water can form a complex compound with metals through the adsorption of complex bonds and chelates [3]. Heavy metals such as iron (Fe) have also potential to toxicant causes for organisms, so it will be very dangerous if it accumulates in the human body and causes pollution in the water system [4]. The conventional methods commonly used in water remediation such as coagulation and flocculation [5]. However, the process of both methods still has difficulties caused by the complexity of the process and its high-cost rate [6]. Electrofotation is a method of purification by forming hydrogen gas and oxygen through electrolysis of water which causes particles dispersed in water to rise to the surface [7]. Coagulation is a chemical additive process commonly used in water treatment [8]. The coagulants that are often used in the coagulation process are aluminum, ferric chloride, and poly aluminum chloride (PAC) [9]. However, chemical coagulants based on aluminum compound can cause damage to the nervous system if it accumulates in the human body as in senile dementia (Alzheimer's) [10].
The use of plant-based coagulants (biocoagulant) is an alternative to be applied in clean water processing because the biocoagulant is non-toxic and had a high biodegradable level [8]. In this study, the coagulation process using a protein-based biocoagulants interaction with peat water samples is evaluated. Mung bean flour (Vigna radiata) is evaluated as biocoagulant as it contains a protein that can used to decrease the turbidity [11]. The enhancement of electroflotation using mung beans flour in the peat water treatment is also evaluated.

2. Materials and methods

2.1. Designed electroflotation reactors and voltage optimization

The electroflotation reactor was made from a glass plate with the dimensions of 10 cm (l) x 10 cm (w) x 15 cm (h) and can accommodate a 500 mL of peat water samples. The electrodes were used graphite with dimensions of 5 cm (l) x 7 cm (w) as an anode and stainless-steel net wire with dimensions of 5 cm (l) x 7 cm (w) as a cathode. Voltage optimization in the electroflotation process was carried out using 0.001 M NaCl as electrolyte solutions in the DC constant voltage of 10, 20, and 30 V for 30 mins. The bubbles were generated at the electrode surface and the image was captured by digital camera (Nikon Coolpix 3200, Japan)-assisted with 8× magnification of magnifying glass (Figure 1). Direct counting of bubbles from photo image was classified based on size categories namely <0.5, 0.5, and 0.5> mm. The bubble distribution was also verified by ImageJ software.

![Figure 1. Bubble distribution was counting using a camera and image processor.](image)

2.2. Electroflotation and biocoagulation (EB) process

Peat water sample was prepared by dissolving 0.05 g of humic acid into 1 L dionized water to be 50 mg/L of peat concentration according to elswhere publication [12] (Sudoh, 2015) The biocoagulant used in this study was mung bean flour (Vigna radiata). Dried mung bean seeds were mashed and sieved to obtain 250 mesh particle size. The biocoagulant dose used in the study was 1.0, 1.5, and 2.0 g in 200 mL of peat water. Biocoagulation of peat water was carried out using a magnetic stirrer with 30 secs. of rapid stirring and 30 mins. of slow stirring. The peat water was then allowed to stand for 30 mins. until mass precipitate was formed. The clarified solution was then measured the turbidity (Turbidimeter, TN100 Eutech, Netherland), total dissolved solids (TDS), and pH (pH/TDS meter, H19813-5, Romania). Furthermore, the optimum dose of biocoagulant obtained in this step further was used in the electroflotation of peat water treatment. The simultaneous of electroflotation and biocoagulation (EB) process of peat water treatment was carried out in 500 mL at constant voltage of 20 V for 30 min. The performance of EB process was evaluated based on the percentage removal of turbidity, and total dissolved solids (TDS) as shown in Eq-1 and pH solution.

Removal (%) = [(Initila score – Final score) / Initial score] × 100  (1)
3. Results and discussion
3.1. Voltage optimization in electroflotation
Voltage optimization was conducted using an electrolyte solution to determine the optimum voltage applied in peat water treatment based on the size of the generated bubbles as described above. The results of bubble distribution were shown in Table 1. Bubble gases (i.e. O\textsubscript{2} and H\textsubscript{2}) were formed in the electrolysis of water as shown in Eq-2 and Eq-3.

\begin{align}
\text{Anode: } &2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4 \text{H}^+ + 4e^- \\
\text{Cathode: } &2\text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2 + 2 \text{OH}^- 
\end{align}

Table 1. Influence of constant voltage on the bubble distribution

| Anode | Cathode | Bubble distribution |
|-------|---------|---------------------|
| 10 V  | 10 V    | ![image1](image1.png) |
| 20 V  | 20 V    | ![image2](image2.png) |
| 30 V  | 30 V    | ![image3](image3.png) |

The small number of bubbles were generated from the anode and cathode by the size of 0.5 mm and > 0.5 mm at a constant voltage of 10 V. While contrary results showed that small number of bubbles at the anode formed when 30 V of constant voltage was applied in the electroflotation. Finally, the constant voltage of 20 V was used on the treatment of peat water since it gave a uniformity in the bubbles size and continue bubble production at the anode and cathode which provide optimum flotation ability [13]. Figure 2 shows the comparison results of peat water treatment before and after the electroflotation.
3.2. Optimization of biocoagulant dose
The biocoagulation of peat water was prepared using mung bean as biocoagulants. This fact could be based on the hydrophilic interaction between the protein contained in mung bean and peat water, so that facilitate the formation of the flock, which reduce the level of turbidity in the peat water [14]. Biocoagulant dosage were intended to determine the optimum dose to be used in peat water treatment using a simultaneous electrofotation and biocoagulation. Table 2 shows the optimum dosage of biocoagulant. A dose with 1.5 g of biocoagulant was the optimum concentration on the biocoagulation process, which used further on the simultaneous EB process.

| Dosage (g/500 mL) | Parameter       |
|-------------------|-----------------|
|                   | Turbidity (NTU)| TDS (mg/L) | pH    | Sludge mass (%) | Light intensity (Lux) |
| Initial peat water| 224.3           | 1076       | 2.7   |                | 152.3                 |
| Mung bean 1       | 111.6 (50.2%)   | 481 (55.2%)| 6.1   | 61.7            | 311                   |
| Mung bean 1.5     | 77.7 (65.3%)    | 266 (75.2%)| 6.8   | 72.2            | 323                   |
| Mung bean 2       | 208.6 (6.9%)    | 566 (47.3%)| 6.2   | 78              | 316                   |

The percentage in parentheses was calculated using Eq-1 and pH was adjusted by the addition of 1.0 M NaOH.

3.3. Electroflotation-biocoagulation performance
The simultaneous electrofotation and biocoagulation (EB) process was carried out using 1.5 g of mung bean as biocoagulant in 200 mL peat water at a constant voltage of 20 V for 30 mins. Table 3 shows the results obtained from the simultaneous EB process. Biocoagulant was able to form micro-sized flocks in turbid water by van der Waals tensile forces, as well as neutralize the electric charge. The addition of biocoagulant formed the micro flock formed and then converted into macro flock, which uplifting to the surface by the bubble in the EB process [15]. This process had decreased the turbidity as much as 84.5% and TDS as much as 70.2%. Also, pH of peat water changed from 2.7 to 6.8. Figure 3 shows the light intensity in the peat water, indicating the clearness of solution before and after treatment.
Figure 3. Initial peat water, 152.3 Lux (a), biocoagulation 1.5 g, 323 Lux (b), electroflotation 20 V, 361.6 Lux (c), and the simultaneous electroflotation-biocoagulation 1.5 g, 355 Lux (d).

Table 3. The results of the electroflotation-biocoagulation method using the optimum dose and voltage.

| Peat water treatment | Parameter | Turbidity (NTU) | TDS (mg/L) | pH | Sludge Mass (%) | Light intensity (Lux) |
|----------------------|-----------|----------------|------------|----|----------------|---------------------|
| Initial              |           | 224.3          | 1076       | 2.7|               | 152.3               |
| Electroflotation     |           | 30.2 (86 %)    | 305 (71.6 %) | 5.0| 57.1           | 361.6               |
| EB 1.5 g             |           | 34.6 (84.5 %)  | 320 (70.2 %) | 6.8| 72.7           | 355                 |

The percentage in parentheses was calculated using Eq-1

4. Conclusions
Based on the results presented in this study, it can be concluded that the mung bean as biocoagulant can improve the performance of electroflotation on peat water treatment on the decreasing of turbidity as much as 84.5% and TDS as much as 70.2%, and changed the pH 2.7 to 6.8 (closer to neutral freshwater).

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