The combination of electroflotation-biocoagulation process using *Aloe vera* for river water treatment

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**Abstract.** An evaluation of the combination of electroflotation-biocoagulation performance using *Aloe vera* as biocoagulant in the treatment of river water has been conducted. Titanium electrodes were used as anode and stainless as cathode in the electroflotation reactor, with a 20 V DC of constant voltage for 30 minutes. The parameter dose of *Aloe vera* was 1.0, 1.5, and 2 g/200 mL water. The effectiveness of the electroflotation-biocoagulation process was reflected by the measurement of turbidity, total dissolved solids (TDS), pH. The results showed that the electroflotation-biocoagulation process decreased the turbidity as much as 97%, TDS as much as 82.64%, and changes in the pH value to 6.6 from the initial concentration of water.

1. **Introduction**

Water is a universal need. Most living things need water to support their lives. Water itself has an important role for humans, ranging from the needs of bathing, washing and toileting, household to industrial needs. The need for clean water increases with population growth. Clean water conditions are strongly influenced by human activities, both on a household and industrial scale. Water sources commonly used by the water treatment plant to process raw water into clean water are springs, river water, shallow wells, and deep wells \[1\]. The water quality status might be considered for water resources management \[2\].

The conventional physicochemical methods commonly used for water treatment in water treatment plants are coagulation/flocculation, and sedimentation. Coagulation is a treatment process by adding and mixing a coagulant. The most common coagulants are aluminum salts such as poly aluminum chloride (PAC), iron salts, and including inorganic polymers with large molecular weight \[3\]. Several studies report that aluminum compounds can trigger Alzheimer’s disease \[4\]. However, the use of natural ingredients as a coagulant is currently being developed because it has several advantages, including being biodegradable, safe for human health, and free of toxins \[5\].

The available natural coagulants include extracts of microorganisms, animals, and plants that are safe for human health \[6\]. *Aloe vera* has the potential to be a natural coagulant because it contains complex carbohydrates and sugars that can bind to particles in water to reduce water turbidity. *Aloe vera* was used as a coagulant to clear well water \[7\]. The results showed that the turbidity of water decreased from 18 NTU to 5 NTU while hardness decreased from 314.28 mg /L to 114.77 mg /L, which was obtained...
at an optimum ratio of 0.3 mL in 500 mL of sample water. The color decreased from 187 TCU to 58.67 TCU, which was obtained at an optimum ratio of 0.5 mL in 500 mL of sample water. However, the coagulation process is not very efficient if the effluent contains a low suspended density [8].

Electroflotation is the process of separating pollutants in liquids by floating the substances or particles of pollutants dispersed in the water to the surface using the lifting force of bubbles of oxygen and hydrogen gas that is formed from the electrolysis reaction [9]. Electroflotation can be an alternative as it is efficient and can be used for small, medium, or even large-scale processing of suspended solids [10]. A study in the combination of electroflotation and coagulation has conducted by optimization of coagulant concentration, pH, processing time, and flow strength [8]. The experiment showed that at the coagulant concentration of 639 mg/L, the optimal condition with the results of COD reduction from 684 to 204 mgO2/L and BOD5 reduction from 100 to 85 mgO2/L.

In this study, river water was prepared to produce clean water by the combination process of electroflotation and coagulation using Aloe vera as biocoagulant. The obtained result from electroflotation and biocoagulation were compared with the result of the combination process of electroflotation-biocoagulation.

2. Materials and methods

2.1. Preparing river water samples
The water sample used in this study was collected from Selokan Mataram river, Yogyakarta, Indonesia. Water samples were collected using a plastic bottle dipped in water until fully loaded. The water sample was then measured by the turbidity level using a turbidimeter (TN-100 Eutech, Netherland), TDS/pH using a pH/TDS meter (H19813-5, Romania).

2.2. Designed electroflotation reactors and voltage optimization
In the electroflotation process, a glass plate reactor was used with the dimensions of 10 (L) x 10 (W) x 15 (H). The electrodes were stainless steel wires (5 cm (L) x 7 cm (W) for the cathode and titanium (Ø 4.5 cm, 0.3 cm thick) for the anode. Voltage optimization (i.e. 10, 20, 30 V) in the electroflotation process was carried out by using a 0.001 NaCl electrolyte solution for 30 mins. The bubbles distribution was divided into three categories namely < 5, 5, and 5> mm. The number of bubbles was counted manually using a millimeter scale that was assembled with an 8x magnifying glass and an image of the bubble on the surface of the electrode was photographed by a digital camera (Nikon, Coolpix 3200, Japan) as shown in Figure 1. The bubble distribution was also verified by ImageJ software. The optimum voltage obtained which produced high bubble density was then used in the combination of electroflotation-biocoagulation process.

![Figure 1. Image processing on the bubble counting.](image-url)
2.3. Treatment of river water using Aloe vera as biocoagulant
The biocoagulant used in this study was Aloe vera which had been cleaned and the gel part was separated from remaining external skins. The dosage of Aloe vera used in the experiment as much as 1, 1.5, and 2 g in a 200 mL of river water. The coagulation was obtained by rapid stirring for 30 secs. and slow stirring for 30 mins. using a magnetic stirrer [11]. Directly after the coagulation ended then the solution was allowed to stand until the sediment formed before the clarified solution was tested for turbidity, TDS, and pH. The optimum dose was then further used in the combination of electroflotation-biocoagulation process.

2.4. Performance evaluation of electroflotation-biocoagulation
A river water of 500 mL was treated by the combination of electroflotation-biocoagulation at constant voltage of 20 V for 60 mins. The performance was evaluated by measuring the turbidity, TDS, and pH. The turbidity and TDS reduction were calculated according to Eq-1 and Eq-2.

\[
\text{Turbidity reduction} = \left(\frac{T_i - T_f}{T_i}\right) \times 100
\]

\[
\text{Total dissolved solids reduction} = \left(\frac{TDS_i - TDS_f}{TDS_i}\right) \times 100
\]

Where:
- \(T_i\) = initial turbidity (NTU) of the water sample
- \(T_f\) = turbidity (NTU) after the process
- \(TDS_i\) = initial of total dissolved solids (mg/L) of the water sample
- \(TDS_f\) = dissolved solids (mg/L) after the process.

3. Result and discussion
3.1. River water characteristic
At the initial evaluation, it was found that the turbidity, TDS, and pH of river water sample from the Selokan Mataram was as much as 866 NTU, 125 mg/L, and 6.7 respectively. Turbidity is derived from suspended materials such as mud, sand, organic and inorganic materials, plankton and other microscopic organisms [12]. High turbidity level in river water affects the aquatic life [13]. The initial parameter analysis aimed to evaluate the effectiveness of the combination of electroflotation-biocoagulation using Aloe vera as biocoagulant in the river water treatment.

3.2. Voltage optimization
Table 1 shows the number of bubbles formed in the voltage optimization process. In general, the number of bubbles produced on the surface of the cathode was higher than the anode. Assuming equal temperature and pressure for both gases, the produced hydrogen gas has, therefore, twice the volume of the produced oxygen gas because the mole ratio of hydrogen to oxygen is 2/1 (two atoms of H per 1 atom of O) in the water molecule. As the volume of gases depends on the number of moles of its components, the volume of hydrogen is twice as that of oxygen according to Eq-3 and Eq-4.

\[
\text{Anode: } 2\text{H}_2\text{O} (\text{aq}) \rightarrow \text{O}_2 (\text{g}) + 4\text{H}^+ (\text{aq}) + 4\text{e}^-
\]

\[
\text{Cathode: } 2\text{H}_2\text{O} (\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2 (\text{g}) + 2\text{OH}^- (\text{aq})
\]

The number of bubbles produced at a voltage of 20 V was higher and more uniform than at voltage of 10 V and 30 V. Therefore, the constant voltage of 20 V was applied in the combination of electroflotation-biocoagulation process.
**3.3. Effect of Aloe vera on biocoagulation**

Table 2 shows the effect of Aloe vera doses on the biocoagulation. The pH was adjusted under an alkaline pH (i.e. ~8 to 10) before the evaluation, so that the initial physico-chemical of river water had been changed then the natural one. The addition of 1g of Aloe vera in river water decreased the turbidity level as much as 91.4%, and TDS as much as 61.9% from initial concentration. At the optimum dosage of biocoagulant, the colloids have been neutralized and precipitated, but excessive biocoagulant dosage will cause the water to become turbid again because since it cannot interact with another colloidal particles of different charge [14]. Aloe vera has the potential to decrease the turbidity in water since the material contains complex carbohydrates and sugar which can bind with pollutant particles in water [9].
Table 2. Effect of Aloe vera doses on biocoagulation.

| Dosage (g/500 mL) | Parameter       | Turbidity (NTU) | TDS (mg/L) | pH  |
|------------------|-----------------|-----------------|------------|-----|
| Initial (after adjusted pH) |                | 912             | 205        | 8.5 |
| Aloe vera 1      |                 | 78.1 (91.4%)    | 78.2 (61.9%)| 7.1 |
| Aloe vera 1.5    |                 | 186 (79.6%)     | 185 (9.8%) | 7.5 |
| Aloe vera 2      |                 | 191 (79.1%)     | 190 (7.3%) | 7.7 |

Percentage in the bracket was the turbidity and TDS reduction.

3.4. Combination of electroflotation-biocoagulation

Table 3 shows the effectiveness of the combination of electroflotation-biocoagulation process with Aloe vera. In this regard, the pH of the river water was not adjusted because under these conditions the hydrogen and oxygen bubbles were formed optimally [10]. The results showed that, in general, the combination of electroflotation-biocoagulation process was effective in treating water samples into clean water. The combination of electroflotation-biocoagulation process can reduce turbidity as much as 97% and TDS as much as 82.6%. The sludge characteristic was given by sludge mass (%) which was measured according to Eq-5.

\[
\text{Sludge mass} \% = \frac{(\text{WS}_{\text{wet}} - \text{WS}_{\text{dried}})}{\text{WS}_{\text{wet}}} \times 100
\]

(5)

Where WS<sub>wet</sub> is the weight of sludge in wet (g) and WS<sub>dried</sub> is the weight of sludge in dried (g).

The formation of sludge was evaluated in each treatment process by calculating the sludge mass to determine the effectiveness of the combination of electroflotation-biocoagulation process. In the biocoagulation, the sludge formation was the lowest (38.32%) than EB (45.76%), and electroflotation. Lower the sludge mass, better the sludge settling [15]. However, the turbidity and TDS level in electroflotation and biocoagulation was higher than EB so that the process has competitiveness on the water treatment.

The results showed that the biocoagulant has high in the combination of electroflotation-biocoagulation process. This was due to the assistant of electroflotation on flocculation by electron transfer from water electrolysis. While the biocoagulation process was binding with colloidal particles only rely on the stirring process.

Table 3. Evaluation of electroflotation-biocoagulation process.

| Treatments                                    | Parameter       | Turbidity (NTU) | TDS (mg/L) | pH  | Sludge mass (%) |
|-----------------------------------------------|-----------------|-----------------|------------|-----|-----------------|
| Initial (without adjusted pH)                 |                 | 866             | 125        | 6.7 | 54.34           |
| Electroflotation                              |                 | 250 (71.1%)     | 108 (13.6%)| 6.6 | 38.32           |
| Biocoagulant (Aloe vera 1g/500 mL)            |                 | 78.1 (94.6%)    | 78.2 (57.0%)| 7.1 | 45.76           |
| Electroflotation-biocoagulation (EB)          |                 | 21.7 (97.0%)    | 6.6 (82.6%)| 6.6 | 38.32           |

4. Conclusion

From this study, it can be concluded that the addition of biocoagulant (Aloe vera) can enhance the performance of electroflotation in the treatment of the water river (i.e. the combination of electroflotation-biocoagulation). This was indicated by the reduction of turbidity and TDS level in the combination of electroflotation-biocoagulation process respectively as much as 97% and 82.6% compared to the electroflotation and biocoagulation process alone.
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