COMMUNICATIONS IN SCIENCE AND TECHNOLOGY
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Peat water electrocoagulator design with aluminium electrodes in household scale for cleaning water supply

Ferry Hadary[a,*], Sri Rezeki[b], Hansen[b], Sri Utari Shinta Dewi[b], Darul Giring Alana[b], Adith Anindito[b], Supi Yulianto[b], Desisius Gumilar[a], Lisa Astridni Putri[c]

[a]*Department of Electrical Engineering, Faculty of Engineering, Universitas Tanjungpura, Pontianak 78124, Indonesia*
[b]*Department of Chemical Engineering, Faculty of Engineering, Universitas Tanjungpura, Pontianak 78124, Indonesia*
[c]*Department of Environmental Engineering, Faculty of Engineering, Universitas Tanjungpura, Pontianak 78124, Indonesia*

Article history:
Received: 27 March 2025 / Received in revised form: 8 June 2025 / Accepted: 13 June 2025

Abstract

The peat water studied contained colour, turbidity, organic substances, and iron that were sufficient to be analysed for the use of electrocoagulation. The aluminium electrodes were contacted with peat water by varying electrode plates, sedimentation time, electrolyte concentration, stirring speed, and contact time to produce clean water. The results showed that the electrocoagulator with the 3 pairs of electrode plates, 60-minute sedimentation time, 75 g NaCl electrolyte concentration, stirring speed at 75 rpm, and 60-minute electrocoagulation time was the most optimal variation. The results showed that the electrocoagulation method was able to reduce the pollutant levels in peat water. The results of this treatment also met the standards of the Ministry of Health and based on the calculation of cost incurred by the electrocoagulation method, i.e. $ 0.154/day, $ 4.641/month and $ 55.693/year.

Keywords: Electrocoagulation; clean water; peat water; water quality; aluminium electrodes

1. Introduction

Indonesia is one of the countries with the largest peatland area in the world [1] with the estimation of 20.6 million hectares, or approximately 10.8% of Indonesia's land area [2]. In several regions, such as Riau, Jambi, and Kalimantan, peat water is one of the surface water sources for the communities [3]. Characteristically, peat water is brownish-red, contains high organic substances and iron, and has a sour taste and odour, pH around 3 – 5, and low hardness. The natural condition of peat water in terms of its quality, which is not suitable as a source of clean water for consumption due to the high concentrations of organic compounds has become the main concern [4]. Untreated peat water is unsafe to drink and can pose a wide range of health problems, including toxicity [5]. In addition, the consumption of untreated peat water can lead to various waterborne diseases such as diarrhoea, typhoid, and dysentery [6]. There are three primary categories of water treatment plants, which generally are the chemical, biological, and physical processes. Typically, conventional water treatment facilities integrate these diverse treatment methodologies. Several studies have been conducted on peat water treatment using a bio coagulant hybrid with ceramic membrane [7], ultrafiltration membranes [8] and the potential of palm frond-based magnetic biochar [9]. All of these technologies can effectively reduce contaminants, but require chemical coagulants and high operating costs [10]. Other studies on peat water treatment include neutralizations, aeration, flocculation, coagulation, sedimentation, and filtration processes [11].

Peat water requires a special treatment enabling it to be used as a water source for household purposes [12]. One alternative to convert peat water into clean water is through the electrocoagulation method that has some advantages including simple equipment, being operatable, large and stable flocs, few water bonds in sedimentation, rapid sedimentation, little sludge and no addition of chemical coagulants and equipment [13]. Through electrocoagulation (EC) methods, it is possible to process peat water into clean water for household usage to improve the water quality [6]. EC is a method of wastewater treatment utilizing electrochemistry to remove any impurities, particulate matter, and ions from wastewater. This process involves the application of an electric current [14]. The EC process utilizes the principles of coagulation, flotation, and electrochemistry. Compared to conventional methods, the utilization of EC technology offers more benefits including the capacity for effective and expeditious matter separation, the

* Corresponding author. Tel.: +6281352211595
Email: ferry.hadary@ee.untan.ac.id
https://doi.org/10.21924/cst.10.1.2025.1694

elimination of the necessity for pH adjustment, the generation of coagulants directly through electrochemistry, and the maintenance of low operational costs.

Peat water treatment mainly using the coagulation process includes chemical and EC [15]. Electrocoagulation using coagulation method successfully removed DOM, colour, Fe, and TSS from peat water with 92.02%, 100%, 87.50%, and 78.97% removal efficiency, respectively [16-17]. Based on related studies, this method was found to be capable of removing the colour, turbidity, total suspended solids (TSS), total organic carbon (TOC), chemical oxygen demand (COD), and biological oxygen demand (BOD) from natural peat water [13,18,19] . Several commercial electrodes such as iron [17] copper [13] and aluminium [18] have been used in peat water treatment with electrocoagulation. Here, aluminium electrodes had the best removal of organic substances from peat water [19]. EC has a similar principle as chemical coagulation-flotation [20]. It also has met the water treatment plant in industrial processes in recent technology for reducing energy consumption [21].

In West Kalimantan Province the peatlands encompass an area of 1.73 million ha [22]. However, they are associated with fires and smoke that recur annually, levels of carbon dioxide and the presence of toxins in the environment [23]. As a consequence, the communities in West Kalimantan exclusively rely on rainwater, river water, or mountain water for their potable water needs. Pontianak, the capital of West Kalimantan, relies on natural sources such as rainwater, river water, mountain water, and processed water supplied by the local Drinking Water Company for its potable water requirements, [22]. In [18], the electrocoagulation was performed in batch with electrodes distance at 1 cm. The aluminium electrodes were contacted with peat water by varying the current density and processing time. In [22] an experimental study was conducted on batch and continuous electrocoagulation systems to study the effectiveness of solar power systems in supplying electricity to the electrocoagulation system; the parameters used in this study consisted of variations in number of electrodes and treatment time. Later projects used the electrocoagulation process in reducing turbidity [23] with various mixing, current densities, and detention times. The higher the current density given and the longer the detention time used, the higher the processing efficiency and the formed flock volume deposited.

Based on the background explained above, this study aims to develop a household-scale peat water treatment electrocoagulation system to produce clean water that meets the requirements of clean water quality based on the Regulation of the Minister of Health Number 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene and Sanitation Needs for Solus Per Aqua Swimming Pools and Public Baths. The parameters used in this study consisted of variations in the number of aluminium electrode plates, sedimentation times, electrolyte concentrations, stirring speeds, and contact times. This study is expected to find out the most optimal variation to reduce the level of contaminants in peat water.

Table 1 shows the comparison of the existing models with the one proposed in this study. Ultimately, the findings of this study are expected to contribute to the literature on innovative electrocoagulation, offering insights that are able to facilitate sustainable water resource management in peatland areas. Through this work, we aim to highlight the feasibility of electrocoagulation as an effective strategy to address peat water treatment and improve water quality in different situations.

Table 1. Comparison of similar research

Reference	Electrode number	Sedimentation time	Electrolyte concentration	Stirring speed	Contact time
[18]	✓	X	X	X	✓
[23]	X	X	X	✓	✓
[24]	✓	X	X	X	✓
[25]	✓	X	✓	X	✓
[26]	✓	X	✓	✓	✓
[27]	✓	X	✓	X	✓
[28]	✓	X	X	✓	✓
[29]	X	✓	✓	X	✓
[30]	✓	X	X	X	✓
[17]	✓	X	X	X	✓
Our work	✓	✓	✓	✓	✓

2. Materials and Methods

2.1. Sample analysis

Peat water sampling was carried out by considering the location or sampling point. Reformasi street, Pontianak City, West Kalimantan was chosen as the research location in consideration to its good accessibility and is included in the peatland area. Fig. 1 depicts the reddish brownish peat water in West Kalimantan. The peat water samples were transferred into large containers for processing and into 1500 mL bottles for the analysis of their characteristics at the Ministry of Industry, Centre for Standardization and Industrial Services, Pontianak, West Kalimantan. Several parameter analyses for treated peat water included colour, turbidity, organic substances as $KMnO_4$, iron (Fe) and pH. Table 2 presents the summary of the test method used to analyse the parameters.

Fig. 1. Peat water before any treatment

Peat water samples before any treatment were analysed to examine check their physical and chemical properties. As shown in Table 2, the results were then compared with the clean water quality as required based on the Regulation of the Minister of Health Number 32 of 2017 on Environmental Health Quality Standards and Water Health Requirements for

Hygiene and Sanitation Needs of Solus Per Aqua Swimming Pools and Public Baths.

Table 2. Parameter used in peat water analysis

Parameter	Test Method
Colour	SNI 6989.80:2011
Turbidity	SNI 06-6989.25-2005
Organic Substances as $KMnO_4$	SNI 06-6989.22-2004
Iron (Fe)	SNI-6989.4:2009
pH	SNI 06-6989.11.2004

Table 3. Characteristic of peat water sample

Parameter	Unit	Sample	Max value allowed	Description
Colour	Unit Pt-Co	1118	50	Not fulfilled
Turbidity	NTU	38.9	25	Not fulfilled
Organic Substances	mg/L	412	10	Not fulfilled
Iron	mg/L	1.03	1.0	Not fulfilled
pH	-	5.39	6.5-8.5	Fulfilled

Based on the characteristics of the peat water sample above, some parameters i.e. colour, turbidity, organic substances ($KMnO_4$), iron (Fe) and pH did not meet the quality standards of clean water and they were then improved in this research through the EC method. During EC treatment with aluminium electrodes, oxidation and reduction reactions occurred in parallel. The longer the contact time, the higher the amount of dissolved Al^{3+} produced. Thus, the release of Al^{3+} ions attracted to OH^- forming $Al(OH)_3$. The $Al(OH)_3$ molecules subsequently were bound to pollutants, resulting in the formation of larger substances through a precipitation mechanism, leading to the effective removal of pollutants from water [31]. The reaction is presented in the equations below:

$$\text{Cathode} : 6H2O(l) + 6e(aq) \rightarrow 3H2(g) + 6OH\text{-}(aq) \quad (1)$$

$$\text{Anode} : 2Al(s) \rightarrow 2Al3+(aq) + 6e\text{-}(aq) \quad (2)$$

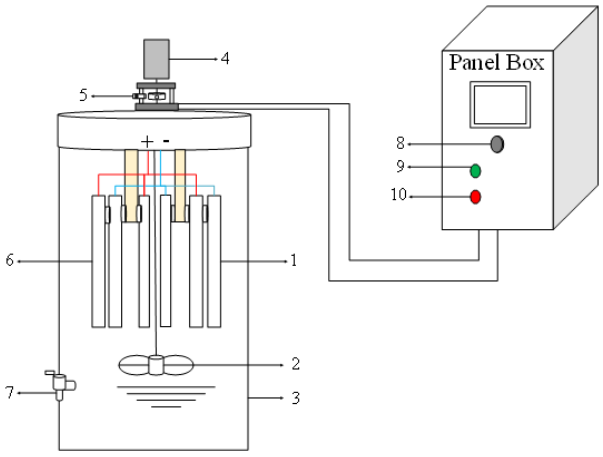
$$2Al(s) + 6H2O(l) \rightarrow 2Al3+(aq) + 3H2(g) + 6OH\text{-}(aq) \quad (3)$$

$$2Al(s) + 6H2O(l) \rightarrow 2Al(OH)_3(s) + 3H2(g) \quad (4)$$

Some parameters affected EC's performance in terms of removal efficiency, colour, turbidity, organic substances, and iron. Subsequently, the effects of the number of electrodes, sedimentation time, electrolyte concentration, stirring speed, and contact time were investigated.

2.2. Instrument design and production

This study used a batch reactor utilizing a 200 litres water drum as a place for the electrocoagulation process. The electrocoagulation tank was made of HDPE plastic with a diameter of 51 cm and a height of 100 cm. The use of a capacity of 200 litres was because each household in West Kalimantan on average requires about 200 litres of water per day for daily needs, such as bathing, cooking, washing, and others. The household scale of the EC system was composed of two components: (i) a peat water storage chamber, and (ii) an EC power supply. Fig. 2 illustrates the fabricated EC model composing of a number of components. The aluminium electrodes utilized in the EC process were energized by a direct current (DC) power supply and aluminium (Al) electrode plates as the active surface area were formed rectangular with a size of 20 cm x 35 cm x 0.3 cm. The electrocoagulator was assembled to obtain the operating conditions with the input voltage AC of 200-240V, input frequency of 50/60 Hz, input current of 3.5 A, output voltage DC of 12 V, output current of 30 A, power of 360 W, efficiency of 70%, dimensions of 16 x 10.8 x 5.2 cm, and rainproof IP62. The 2D image of the household scale EC system is illustrated in Fig. 2.



Description:
1) Cathode; 2) Agitator; 3) Electrocoagulator; 4) Agitation motor; 5) Speed detector; 6) Anode; 7) Outlet; 8) Knob speed; 9) Run; 10) Stop

Fig. 2. Scheme of peat water electrocoagulator design

2.3. Experimental studies

A series of experimental studies were conducted using aluminium electrodes to ascertain the optimal design for the system. The EC performance was examined by analysing the final colour, turbidity, organic substances as $KMnO_4$, iron (Fe) and pH following the peat water treatment. Fig. 3 shows 2 pairs, 3 pairs and 4 pairs of aluminium electrodes used, and Table 4 tabulates a total of five sets of experiments conducted. The EC reactor, a specialized apparatus designed for this study, was utilized in the experimental setup.

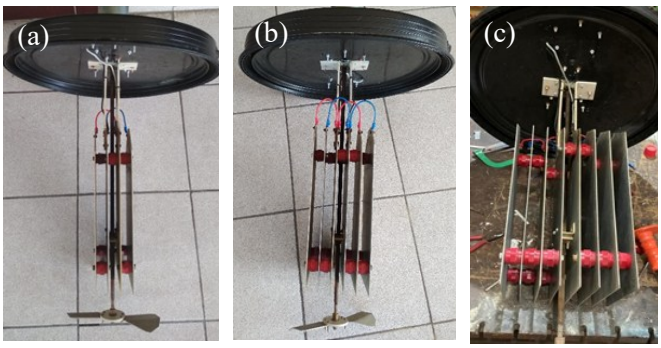


Fig. 3. Pairs of electrodes; (a) 2 pairs; (b) 3 pairs; (c) 4 pairs

Table 4. Changed and constant parameters

Experiment	Changed variables	Constant variables
Set 1	Number of electrode plates • 2 – 4 pair electrode plates (4, 6, 8 electrodes) • Electrode plates with active surface area of 1 pair of electrodes used at 700 cm^2 • Input voltage of 12 volt • Distance between plates at 2.5 cm	• Added 75 grams of NaCl as electrolyte • Stirring speeds at 150 rpm in 1 hour • Flocculation process in 3 minutes with a stirring speed at 50 rpm • Electricity switched off to proceed to sedimentation • Sedimentation time in 12 hours
Set 2	Sedimentation time • Variation of sedimentation times in 30, 40, 50, 60 and 70 minutes.	• 3 pairs the number of electrode plates used as the optimum results • Added 75 grams of NaCl as electrolyte • Stirring speed at 150 rpm in 1 hour • Flocculation process in 3 minutes with the stirring speed at 50 rpm
Set 3	Electrolyte Concentration • Variation of electrolyte concentrations in 15, 30, 45, 60, and 75 grams used NaCl	• 3 pairs the number of electrode plates used as the optimum results • Sedimentation time in 60 minutes as the optimum results • Stirring speed at 150 rpm in 1 hour • Flocculation process in 3 minutes with the stirring speed at 50 rpm
Set 4	Stirring speeds • Variation of stirring speeds at 50, 75, 100, 125 and 150 rpm	• 3 pairs the number of electrode plates used as the optimum results • Sedimentation time in 60 minutes as the optimum results • Electrolyte concentration in 75 grams as the optimum results • 1 hour reaction time
Set 5	Contact time • Variation of electrocoagulation times in 15, 30, 45 and 60 minutes.	• 3 pairs the number of electrode plates used as the optimum results • Sedimentation time in 60 minutes as the optimum results • Electrolyte concentration in 75 grams as the optimum results • Stirring speed at 75 rpm as the optimum results

2.4. Data analysis

The removal efficiency in percentage for each parameter studied was calculated using equation (1) [21]. The results of this experiment were then interpreted in a graphic form. The variables in this equation are defined as follows: R as the removal efficiency in percentage (%), C_0 as the concentration of pollutants before treatment and C_1 as the concentration of pollutants after treatment.

$$R = (C_0 - C_1/C_0)\ x\ 100\% \quad (5)$$

Electrical energy and electrode material affected the operating cost of EC. The electrical energy consumption could be calculated using equation (6) [32]. Then, correlation analysis was used to investigate the associative relationship between independent and dependent variables. Pearson's mathematical formulation was used to quantify the degree of relationship (R) between variables in which X and Y was calculated using equation (7) [33].

$$C_{energy} = U\ x\ I\ x\ t\ /\ 60\ x\ V \quad (6)$$

where:

C_{energy} = energy consumption per cubic meter of water (kWh/m^3)
U = applied voltage in volt (V)
I = applied current in ampere (A)
t = treatment time in minutes
V = volume of treated water (dm^3)

$$R = n\,(\sum XY) - (\sum X).(\sum Y) / \sqrt{n(\sum X\hat{}2) - (\sum X)\hat{}2}\ \sqrt{n(\sum Y\hat{}2) - (\sum Y)\hat{}2} \quad (7)$$

where:

n = number of observations
x = measures of variable 1
y = measures of variable 2
$\sum xy$ = sum of the product of respective variable measures
$\sum x$ = sum of the measures of variable 1
$\sum y$ = sum of the measures of variable 2
$\sum x^2$ = sum of squared values of the measures of variable 1
$\sum y^2$ = sum of squared values of the measures of variable 2

3. Results and Discussion

3.1. Effect of electrode number

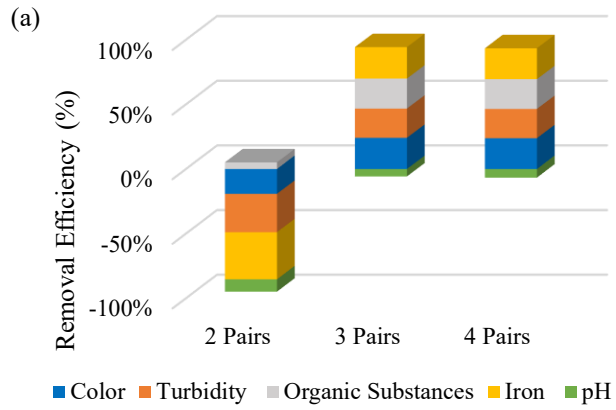
The subsequent results presented the removal efficiency of various parameters in comparison with the number of electrodes. 3 pairs of electrode plates were considered as the optimum number to improve all parameters studied. The more the electrode plates used, the greater the surface area of the electrodes to improve the electrocoagulation system's performance due to the reduction of resistance value. An increase in the spacing of the electrodes will decrease the treatment cost but it might decrease the behaviour efficiency [30]. After treatment, 3 pairs of electrodes were able to remove 99.10% of colour, 92.90% of turbidity, 95.46% of organic substances, and 100% of iron (Fe). Fig. 4 displays that the use of 3 pairs of aluminium electrodes with an active surface area of 700 cm^2, the distance between the plates at 2.5 cm and the distance between the electrodes at 2.5 cm, supplied with an electric voltage of 12 volts provided the most optimal results. The design of this electrocoagulator was based on the results of direct research in the field for 3 consecutive years.

Lin et al. [34] stated that the removal of pollutants will be much higher using aluminium electrode plates. The more Al^{3+} released from the oxidation reaction on the aluminium electrode, functioning as an anode, the more the pollutants can be bound and floated or precipitated. The additional release of Al^{3+} (from the oxidation process in the anode) is followed by the increasing formation of $Al(OH)_3$, which functions as the coagulant, thereby accelerating the pollutant removal in peat water [35]. The results of research by Sutanto et al. [36] showed that under the same conditions, using 3 pairs of electrodes was found more efficient than that of 2 pairs. Thus, it can be concluded that 3 pairs were able to give the best efficiency and optimize the performance of the system.

A study conducted by Xu et al. [37] showed that an excess of electric current has the potential to induce electrode passivation in electrocoagulation processes. The development of inhibitory oxide layers on the anode surface, which hinders the dissociation of metal ions from the electrode, is a potential consequence of an excessive supply of electric current in electrocoagulation [38]. Electrode passivation might occur due to the loss of electroactivity from the presence of a passive layer in electrocoagulation treatment [39]. The contaminants reduction by using an electrode plate distance of 2.5 cm can

cause rapid electron transfer from the anode to the cathode so that a reduction reaction can occur at the cathode. This reduction reaction will produce hydroxyl ions, which will bind to Al^{3+} from oxidation at the anode and produce aluminium hydroxide coagulant that will absorb colour [40]. The colour absorption process is not optimal due to the very close distance of the aluminium electrode plate; as a result, the coagulant formed is only around the electrode and not evenly distributed [41]. In addition, the very close distance of the electrode plate can cause a short circuit between the electrodes due to the large amount of coagulant formed around it [42].

This decrease is caused by an increase in the travel time of electrons from the anode to the cathode, causing intermolecular interactions to weaken and a decrease in the coagulation power of the colour [30,32]. When aluminium is used as the anode, it undergoes electrolysis according to Eq. 3 to form trivalent aluminium ions, which is followed by spontaneous hydrolysis according to Eq. 4 [21]. Therefore, EC using aluminium anode is considered as pH neutralizer [12,28,29]. Fig. 4 shows the effectiveness of electrode number to reduce the studied parameters.



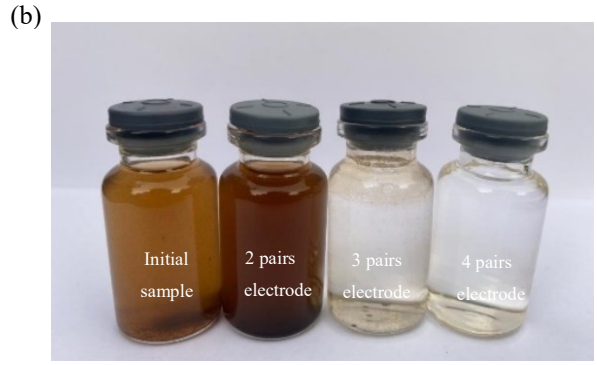
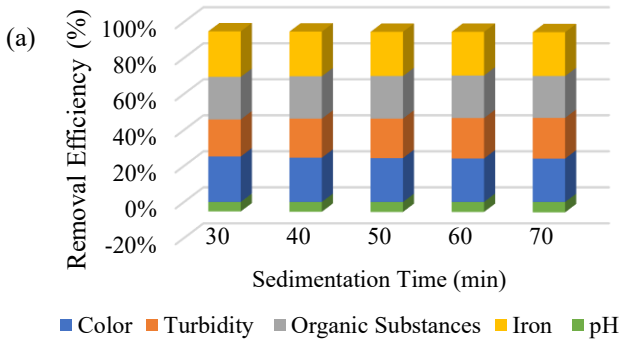


Fig. 4. (a) Effectiveness of electrode number to reduce the studied parameters and (b) the samples before and after treatment

3.2. Effect of sedimentation times

The soluble and colloid contaminants are absorbed by the coagulant. These contaminants can be removed through the sedimentation process [44]. The optimum parameters from previous experiments were set as the constant of this experiment. The constant was the 3 pairs of electrodes with a 2.5-cm electrode distance. The sedimentation times manipulated included 30, 40, 50, 60, and 70 minutes. The findings revealed the effectiveness of the removal of parameters based on reaction time in relation to sedimentation time. The most optimum result for sedimentation time was w60 minutes where it successfully removed 99.59% for colour, 92.54% for turbidity, 97.33% for organic substances such as $KMnO_4$, and 100% for iron (Fe).

The sedimentation rate of each treatment might have different results; this is determined by the factors of specific gravity, shape, particle size, viscosity, and flow in the settling basin [45]. pH is one of the key factors determining the performance of the electrocoagulation mechanism because it regulates the hydrolysis of metals produced in reactive media and affects the electrocoagulation mechanism [46]. Fig. 5 shows the effectiveness of sedimentation time to reduce the studied parameters.



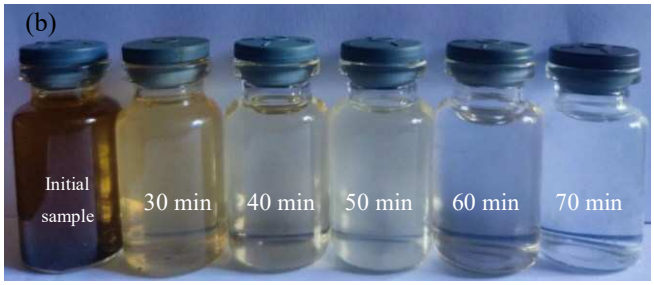


Fig. 5. (a) Effectiveness of sedimentation time to reduce studied parameters (b) the samples before and after treatment

Electrocoagulation can cause the removal of colour and organic substances in peat water due to the release of $Al(OH)_3$ compounds in the form of coagulants, which then bind to pollutants and settle as sludge. While, the released H_2 compound then also binds to pollutants to produce flocs that form on the water surface as foam. The greater the current density and the longer the contact time, the better the clarity of the peat water [47].

3.3. Effect of electrolyte concentration

In the context of electrochemical processes, the presence of a supporting electrolyte is imperative. This is due to the fact that the absence of an electrolyte can lead to undesirable effects, such as migration, which can compromise the stability and efficiency of the process. The addition of an electrolyte serves to enhance solution conductivity, thereby reducing ohmic drop and energy consumption [48]. Alternatively, the electrolyte has some appreciable effects on the electrode solution kinetics of the sacrificial anodes, and it can influence the double-layer shielding by the coagulants to form the flocs [20]. Each electrolyte variation ranged from 15, 30, 45, 60, to

75 grams of NaCl. The highest electrolyte concentration, 75 grams NaCl, showed the highest performance, successfully removing 99.11% for colour, 92.90% for turbidity, 95.46% for organic substances such as $KMnO_4$, and 100% for iron (Fe). [49]. Fig. 6 shows effectiveness of electrolyte concentration to reduce the parameters studied.

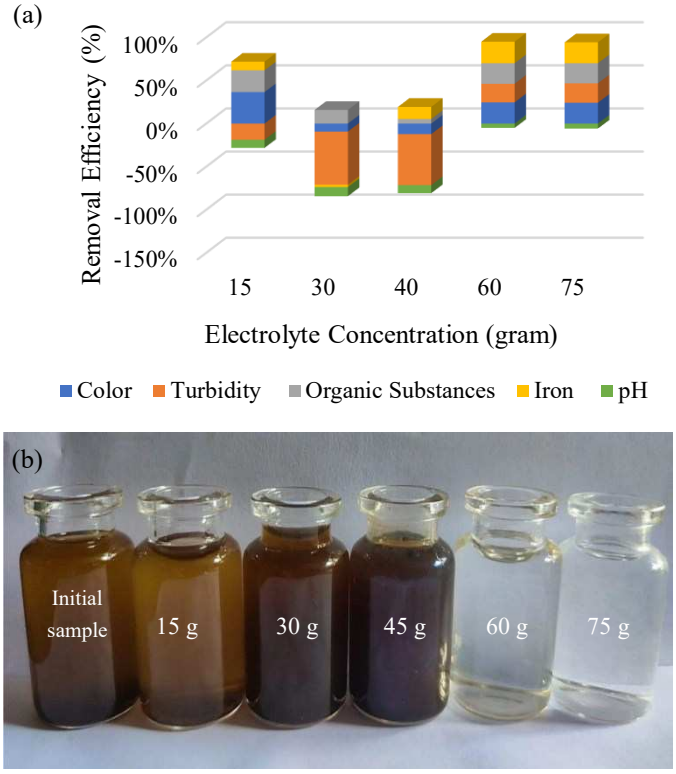


Fig. 6. (a) Effectiveness of electrolyte concentration to reducing studied parameters (b) the samples before and after treated

The addition of electrolytes in electrocoagulation aims to increase conductivity. The greater concentration of NaCl added results in increased electrical conductivity so that the formation of Al^{3+} ions will increase and react with OH^- ions to form coagulant $Al(OH)_3$. Also, the higher quantity of Al $(OH)_3$ formation will accelerate the process of adsorption of pollutants. The electrocoagulation process with the addition of supporting electrolytes is able to remove pollutants greater than the electrocoagulation process without the addition of supporting electrolytes [22]. Chloride anions have been shown to mitigate the adverse effects of other anions, thereby preventing calcium carbonate precipitation in hard water. This process can result in the formation of an insulating layer on the electrode surface [12]. For very high current densities, chloride anions can also be oxidized into the active forms of chlorine, such as hypochlorite anions that can oxidize organic compounds [31] and iron ions [32]. In the context of disinfection, the recommendation for ensuring normal operation in wastewater treatment processes is that 20% of the anions present should be Cl^- [50]. In general, the current intensity in the electrocoagulation system increases with the NaCl concentration [51]. The presence of NaCl in the solution has been shown to reduce electrical resistance, thereby transitioning the solution from a weak electrolyte state to a strong one [52]. Consequently, the incorporation of NaCl into the solution has been shown to enhance its electrical conductivity [53].

3.4. Effect of stirring speed

The stirring speed at 75 rpm was able to remove 99.93% for colour, 97.73% for turbidity, 97.16 for organic substances such as $KMnO_4$, and 99% for iron (Fe). The primary function of the stirring speed is to facilitate the efficient transfer of the coagulant matter, produced by the solution of electrodes to the reactor. In the event that the coagulant matter does not disperse efficiently within the reactor, the content of the reactor cannot be homogenous, and regional differences may be observed. Conversely, an increase in stirring speed can lead to the homogenization of system variables, such as temperature and pH. However, it is imperative to note that elevated stirring speeds have the potential to disrupt flocks formed within the reactor, resulting in the formation of smaller flocks that are more challenging to dislodge from the water [54]. Fig. 7 shows the effectiveness of stirring speed to reduce the studied parameters.

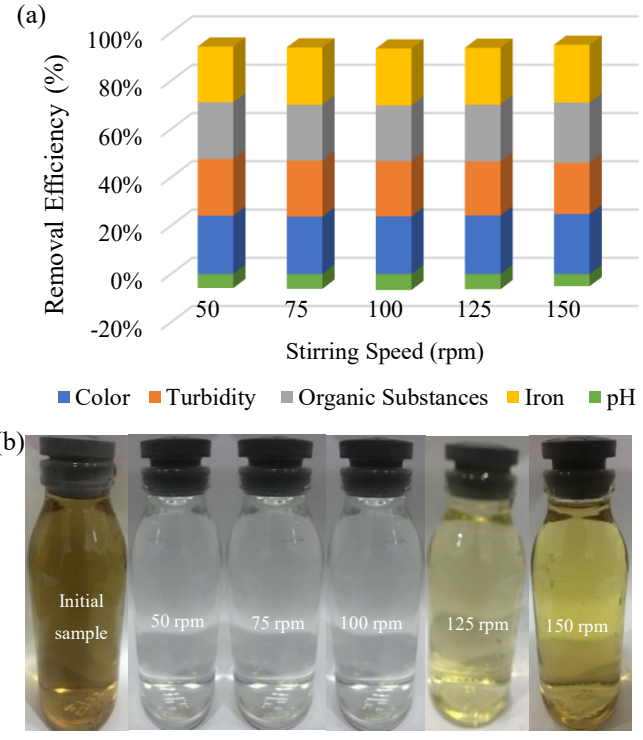


Fig. 7. (a) Effectiveness of stirring speed to reduce the studied parameters (b) the samples before and after treatment

Stirring is an important unit in water treatment that significantly affects the reaction and control of the sedimentation process [31]. The stirring speed will increase the frequency of collisions between the coagulant and the surrounding particles to facilitate floc formation. The higher stirring speed causes the coagulant movement to bind pollutants through collisions between particles to be greater so that more flocs are formed and cause the removal of organic components and metals in water. In their study, Khaled et al. examined the impact of moderate agitation speed on the rate of pollutant elimination. They found that this method resulted in significantly faster removal rates. However, a slight decline in removal efficiency was observed when the agitation rate was increased. This phenomenon can be attributed to the disruption of flocs caused by excessive agitation, thereby compromising

the efficiency of pollutant removal. Moreover, the higher the agitation, the more energy the agitator consumed, thus requiring the higher cost [55].

3.5. Effect of contact time

The optimum time was obtained in the electrocoagulation treatment for 60 minutes so as to obtain water quality results with 99.74% for colour, 96% for turbidity, 97% for organic substances, and 99% for iron (Fe). Fig. 8 describes the variation of contact times used i.e. 15, 30, 45, and 60 minutes. These parameters met the clean water quality standards, except for the organic substance parameter. The longer contact time in electrocoagulation caused the release of more electrons and Al^{3+} into the water, which then reacted with OH- ions and negatively charged colloids to form $Al(OH)_3$. The $Al(OH)_3$ coagulant would bind the colloidal particles to form flocs. Due to the large number of flocs formed, organic compounds and metal ions were removed in water, which would affect water quality. Contact time was required for the stirring process between the adsorbent and the adsorbate. The contact time affected the removal efficiency in which the longer the contact between the adsorbent and the adsorbate, the more adsorbate to diffuse into the adsorbent [56].

The higher the voltage and the longer the contact time given, the water produced from the use of the electrocoagulation method is cleaner and suitable for use [33]. The processing time has been demonstrated to exert a substantial influence on the Fe content found in peat water. It has been observed that an increase in processing time resulted in a decrease in Fe content in the filtrate obtained. This phenomenon occurred for every variation of current density [18].

A study conducted by Tak and Vellanki [57] reported that an extended treatment time could enhance the anode oxidation rate, which eventually increased metal hydroxide coagulants production. A prolonged treatment duration also leads to a substantial reduction in contaminants, primarily through the mechanisms of sweep coagulants and co-precipitation [13,17,6].

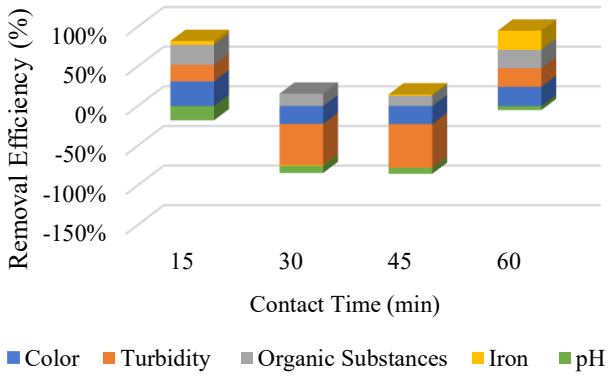


Fig. 8. Effectiveness of contact time to reducing studied parameters

The findings concerning the contact time of the electrode plates indicated that each variation in plate area exhibited an increase at contact times of 15, 30, and 45 minutes, followed by a decrease at a contact time of 60 minutes. The initial surge in turbidity could be attributed to the capacity of the electrodes to generate reactions capable of disrupting flocs, a phenomenon facilitated by the substantial production of hydroxide ions (H_2). This heightened turbidity is a consequence of the elevated levels of hydroxide ions, which are known to be a primary cause of turbidity in peat water [58].

3.6. Correlation analysis

The results of the research showed that the number of electrodes, sedimentation time, electrolyte concentration, stirring speed and contact time had an effect on reducing the concentration of colour, turbidity, organic substances, iron and pH. Correlation value between the number of electrodes and the removal of colour, turbidity, organic substances, and iron was found at 0.869, 0.871, 0.870, and 0.866, respectively. This means that the relationship between the number of electrodes and the percentage of removal of each pollutant parameter was highly strong as it approached 1. The relationship between the two variables was in the same direction, as indicated by a positive correlation coefficient value, indicating that the longer the operating time, the greater the increase in the percentage of elimination of each parameter. The test results of each independent variable, except for the stirring speed on the removal of pH, had a negative correlation, which showed an inverse relationship. A negative correlation value indicated the negative relationship between two variables. This means that if one variable decreases, other variable will increase.

The results of the correlation test showed that sedimentation time had a negative correlation value with colour of -0.595, while turbidity had a positive correlation value of 0.946, organic substances of 0.670 and iron of 0.953. Furthermore, the results of the correlation test showed that the value of electrolyte concentration had a positive correlation value with the removal of pollutant parameters of 0.037 for colour, 0.731 for turbidity, 0.792 for organic substances and 0.901 for iron. The results of the correlation test showed that the value of the stirring speed had a negative correlation value with the removal of pollutant parameters of -0.866 for colour, -0.883 for turbidity, -0.872 for organic substances and -0.734 for iron.

The results of the correlation test showed that the value of contact time had a positive correlation value with the removal of pollutant parameters of 0.492 for colour, 0.318 for turbidity, 0.865 for organic substances and 0.779 for iron. The effect of contact time occurred in the electrocoagulation process will affect the number of dissolved anodes. This will result in the formation of $Al(OH)_3$, which will increase and cause the binding of contaminants so that the efficiency of reducing pollutant concentration increases [59].

3.7. Cost operational analysis

Economic analysis was conducted to compare the electrocoagulation method with the conventional purchase of clean water to figure out which one between the two methods was more economical from the economic aspects. The electrical energy consumption is directly proportional to the electric current values [17]. Electricity costs used for the peat water electrocoagulation process with a capacity of 200 litres amounted to $ 0.313 and the cost of electrolyte needs in one

treatment was $ 0.460. Based on the economic feasibility analysis to compare the electrocoagulation method with the purchase of clean water, to meet the water needs of 2000 litres the electrocoagulation method is more economical with a processing cost of $ 0.773. The total cost required to purchase water if the average price for purchasing 2000 litres of water is $ 8.970. Then, the costs incurred per day are $ 1.226, $ 36.803 per month and $ 441.637 per year.

The operational cost for electrocoagulation system includes the price of materials, electrical cost, maintenance and other fixed costs dependent on electricity consumption. The total operating cost that can be saved in peat water treatment using the electrocoagulation method is $ 38.584/year, so the electrocoagulation method is more economical in terms of energy consumption costs and electrolyte use with processing costs incurred of $ 0.154/day, $ 4.641/month and $ 55.693/year. The cost of processing using the electrocoagulation method is considered much more economical compared to purchasing clean water. The total operating costs increase when the current density increases.

4. Conclusion

The electrocoagulation treatment system was proven to be a feasible process for the treatment of the peat water. For the most optimum variations of the household scale electrocoagulator to remove polluting parameters are three pairs of electrode plates, sedimentation time of 60 minutes, electrolyte concentration of 75 grams, stirring speed at 75 rpm, and 60-minute contact time with an increase in the parameter value of acidity degree (pH) of 6.88. The total operational costs to treat peat water was found IDR2.522,112/day, IDR75.663,36/month and IDR907.960,32/year. A detailed technical and economic analysis of the whole process is necessary for a more precise comparison of the electrode material. Furthermore, the alternative use of in expensive and renewable energies in EC should also be investigated to make much more attractive eco-sustainable processes in practice. Overall, this study has demonstrated that electrocoagulation treatment system could be employed in peatlands area of West Kalimantan to produce clean water from peat water sources. However, practical problems related to continuous treatment of peat water in natural conditions remain and need to be studied further.

Acknowledgements

This research was funded by the Faculty of Engineering, Universitas Tanjungpura through DIPA Universitas Tanjungpura Fiscal Year 2021, Number: SP DIPA-023.17.2.677517/2021, November 23rd, 2020.

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