Effect of current strength on electrocoagulation using Al-Fe electrodes in COD and TSS removal of domestic wastewater

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Effect of current strength on electrocoagulation using Al-Fe electrodes in COD and TSS removal of domestic wastewater

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Abstract. Domestic wastewater is wastewater from household activities such as kitchens, baths, laundry, and water closets. Domestic wastewater contains parameters that can cause environmental pollution, so it needs to be treated. One of the domestic waste treatment technologies is electrocoagulation. Electrocoagulation is a continuous coagulation process using direct electric current through electrochemical events. The purpose of this study was to determine the effect of current on electrocoagulation using Al-Fe electrodes in reducing contaminant levels of domestic wastewater (COD and TSS). The electrode configuration used in this study was Al-Fe, with a variation of the current strength used was 1 A, 2 A, 3 A. The electrocoagulation process was carried out continuously with a contact time of 12 minutes. The sampling process was replicated at 12 minutes, 17 minutes, 22 minutes, 27 minutes, 32 minutes, 37 minutes and 42 minutes. The instrument used in this study was an electrocoagulation reactor with dimensions of 6 cm x 10 cm x 18 cm with Al and Fe electrode configurations. Treatment of domestic waste using electrocoagulation and filtration technology can remove COD parameters in the Al-Fe electrode configuration with a current of 2 A and sampling at 27 minutes with an efficiency of 95%. The most optimum removal of TSS parameters of 94% was obtained in the Al-Fe electrode configuration with a current of 2 A and taking samples at 37 minutes.

1. Introduction

Water is an essential element for human life because almost all human life necessary and activities use water. Used water for human activities is called wastewater. Wastewater can be produced from household or industrial activities. Domestic wastewater is wastewater produced from households like cooking, bathing, washing, and water closet [1]. The characteristic wastewater, like grey water and black water, are containing Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), smelly, colored, protein, fat, and detergent [2].

Electrocoagulation is an electrochemical method for water treatment, where an anode occurs in the release of active coagulant in the form of metal ions (aluminum or iron) into a solution. Meanwhile, in the cathode, an electrolysis reaction occurs in the form of hydrogen gas release [3]. Research by Ni'am et al. (2017) shows that the study uses Al and Fe electrodes using different voltage, current strength, and time-proven to reduce COD concentrations by 65% -76% and TSS concentrations reduced by 85% [4].

2. Methodology

2.1. Tools and materials

The tools used in this study consisted of a magnetic stirrer, pump, reactor, electrode, and power supply. Domestic wastewater is placed on a magnetic stirrer so that the laundry waste is homogeneous. Then the waste is pumped to the reactor, which already has two electrode plates. The electrode plate is connected to the power supply according to the anode and cathode used. The electrocoagulation reactor has dimensions of 6 cm x 10 cm x 18 cm with an overflow beside it with a width of 5 cm and a height of 5 cm. The reactor inlet is below, and the outlet is in overflow while the reactor utilizes the upflow. Electrodes are fitted with nuts and bolts measuring 16. Bolts mounted amount to 2 for one pair of electrodes. The nuts and bolts also function as a place for electric current flow from the power supply. The electrodes used are aluminum metal plates and iron metal plates, with a length of 15 cm and a width of 9 cm. The wastewater used as the research object was obtained from the domestic wastewater treatment plant (IPAL) in Sendangguwo Village, Tembalang District, Semarang City.

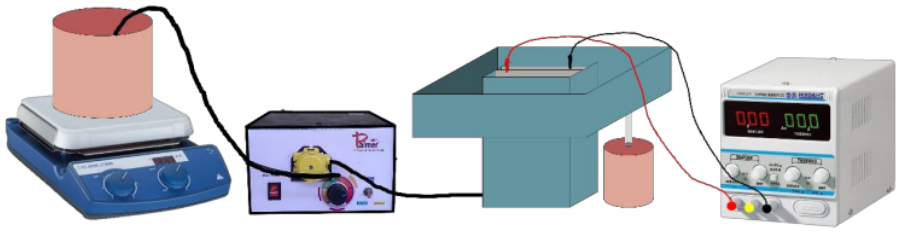

Figure 1. The reactor of electrocoagulation with continuous flow.

2.2. Research variables

The research variables consist of independent variables, dependent variables, and control variables. The independent variables used are current strength, and the dependent variable includes the concentration of COD and TSS. Meanwhile, the control variables in this study are domestic wastewater discharge and reactor size. In this research, variations in current strengths of 1 A, 2 A, and 3 A are performed and, in the Al-Fe electrodes configuration.

2.3. Implementation stage

The electrocoagulation process was carried out continuously with a contact time of 12 minutes. The sampling process was replicated at 12 minutes, 17 minutes, 22 minutes, 27 minutes, 32 minutes, 37 minutes and 42 minutes. To have an optimal result, take a COD test to determine the oxygen content that has been contained. In this COD test, the wastewater will get oxidized by potassium dichromate ($K_2Cr_2O_7$). To get the result, we use the C x f formula, while the unit for the result is by milligram per liter(mg/L), and f is for the dilution factor. After that, continue the TSS measurement, which has compiled on mud and fine sand and microorganisms caused by soil erosion. TSS is a solid substance consisting of dissolved substances and suspended solids.

2.4. Data analysis method

The data analysis method in this research uses the electrocoagulation method to determine the effect of currents strength on the removal of COD and TSS parameters. Then statistical analysis by using SigmaPlot, which consists of a normality test to researching data distribution normality. The ANOVA test or F test (F test) will test the presence or absence of the effect strength current variations and electrode configuration on removal COD and TSS.

3. Results and discussion

3.1. Characteristics of domestic waste

The domestic wastewater that will be researched has the physical characteristics that appear to be particles of suspended and brownish color. Further testing is conducted to determine pH, COD, BOD, TSS, oil and fat levels, and ammonia. The results are in the following table.

Table 1. Characteristics and comparison test results with applicable quality standards.

Parameters	Unit	Test Result	Quality Standard*	Description
pH	-	6,7	6-9	Meet
COD	mg/L	472	100	Not meet
BOD	mg/L	215	30	Not meet
TSS	mg/L	1148	30	Not meet
Oil and Fats	mg/L	18	5	Not meet
Ammonia	mg/L	11	10	Not meet
Total Coliform	Total/100 ml	12900	3000	Not meet

**) Based on Regulation of the Minister of Environment and Forestry Number P.68 of 2016 concerning Domestic Wastewater Quality Standards (MLHK-RI, 2016)*

Based on the results of the characteristic test is known that COD concentration is 472 mg/L. The amount exceeds the standard quality of COD concentration allowed at 100 mg/L. TSS value of 1148 mg/L does not meet the quality standards of 30 mg/L TSS. COD concentration and large TSS value indicated the number of pollutants and suspended solids. Based on such data, a domestic wastewater treatment unit is required to reduce COD's concentration and TSS value to maintain the water body that receives the waste. Because if the COD and TSS content exceeds the quality standard, pollution will occur in the environment, both groundwater and surface water [5].

The research method used is electrocoagulation, and the metal used as Anoda-cathode is aluminum and iron. Electrocoagulation is a water treatment technology using an electrochemical process where an anode will release the active coagulant in the form of Al or Fe ion into the solution. These coagulants can then bind to colloids and created floc.

3.2. Effect of current strength on COD removal

Wastewater that has been processed through electrocoagulation is then tested against the parameters of COD. The test aims to obtain the concentration of COD after the coagulation process so that it can be compared with the concentration of COD before the process of electrocoagulation.

Table 2. COD removal result with Al-Fe electrodes.

Current Strength (A)	Sampling Time (minute)	COD Concentration (mg/L)	Efficiency (%)
1	12	472	-
	17	46	90
	22	76	83
	27	92	80
	32	39	91
	37	92	80
	42	42	90
2	12	472	-
	17	62	86
	22	36	92
	27	22	95

Current Strength (A)	Sampling Time (minute)	COD Concentration (mg/L)	Efficiency (%)
	32	46	90
	37	76	83
	42	82	82
	12	472	-
	17	39	91
	22	66	86
3	27	49	89
	32	42	90
	37	39	91
	42	89	81

COD's test results were obtained from the electrocoagulation process using the electrode plate (Anode-cathode) Al-Fe. The electrocoagulation process is performed for 42 minutes with sampling every 5 minutes, which is at 17 minutes, 22 minutes, 27 minutes, 32 minutes, 37 minutes, and 42 minutes. The current strength used for the electrocoagulation process has a variation of the participating 1A, 2A, and 3A. The initial condition of waste has a COD concentration of 472 mg/l.

According to table 2, the pair of Al-Fe electrodes with a current of 1 A obtained the largest reduction in efficiency at the contact time of 32 minutes with the resulting COD concentration of 39 mg/L. It resulted in an efficiency of 91%. In the Al-Fe electrodes pair with a current strength of 2 A, the largest reduction in efficiency was obtained at 27 minutes of contact time with the resulting COD concentration of 22 mg/L. It resulted in an efficiency of 95%. Meanwhile, on the Al-Fe electrode pair with a current strength of 3 A, the greatest efficiency was decreased at 17 minutes of contact time with the resulting COD concentration of 39 mg/L. It resulted in an efficiency of 91%.

The result shows that the most optimum domestic wastewater treatment results use the Al-Fe electrode configuration, which is electrified with a current strength of 2 A with a decrease in COD concentration of 22 mg/L and obtain a COD removal efficiency of 95% at 27 minutes of contact time. It is because the Al electrode is the anode and Fe the cathode, which in the voltaic series, Al is to the left of Fe, so Al is faster to oxidize, and Fe is faster to reduce so that Al will quickly form Al^{3+} ions. Fe will form OH^- faster; therefore, the coagulant Al $(OH)_3$ will form more quickly.

The decreasing COD concentration is due to the oxidation and reduction processes in the electrocoagulation reactor. At the electrodes, oxygen and hydrogen gas are formed, which will affect the reduction of COD. Based on the double layer theory, the decrease in COD is due to the floc formed by the organic compound ion binds to the coagulant ion, which is positive. The domestic waste molecules are formed into floc, colloid particles in waste are binding particles or other compounds in the waste. The working principle that occurs in electrocoagulation is the same as the double layer theory. The formation of flocculation particle is adsorbed, positively charged coagulants would absorb waste' negative ions such as nitrite, phosphate, and other organic compounds and form flocks which help the COD reduction process [6]. Therefore, it can remove COD by 95%

In the electrocoagulation process, the oxidation of Al metal into Al^{3+} is caused by the potential difference. There will be a flow in an electric circuit when electrons experience a transfer from a place of low potential to a place of high potential. The electric current occurs due to the transfer of electrons, but the direction of motion of the electrons is opposite to the electric current's direction. Therefore, it is obtained in the direction of electric current, namely from places with high potential to places with low potential. The potential difference or voltage or voltage has the letter V's symbol. The potential difference is the difference between the two points between the potentials in a conductor [7]. A potential difference can arise due to a difference in ion concentration near the electrode.

3.3. Effect of current strength on TSS removal

After the electrocoagulation process runs, an *overflow* occurs in the Electrocoagulation reactor, which will be used as a test sample of the TSS parameter.

Table 3. TSS removal result with Al-Fe electrodes.

Current Strength (A)	Sampling Time (minute)	TSS Concentration (mg/L)	Efficiency (%)
	12	1148	-
	17	112	90
	22	508	55
1	27	304	73
	32	256	77
	37	184	83
	42	148	87
	12	1148	-
	17	168	85
	22	108	90
2	27	376	67
	32	204	82
	37	64	94
	42	96	91
	12	1148	-
	17	680	40
	22	476	58
3	27	404	64
	32	676	41
	37	932	18
	42	952	17

Based on the data above, the optimum results of domestic waste processing were obtained using an Al-Fe electrode plate which was energized with a current strength of 2 A with a decrease in TSS concentration of 64 mg/l and obtained a TSS removal efficiency of 94% at the time of contact 37 minutes. It is because the Al electrode is the anode and Fe the cathode, which in the voltaic series, Al is to the left of Fe, so Al is faster to oxidize, and Fe is faster to reduce so that Al will quickly form Al^{3+} ions. Fe will form OH^- faster. Therefore, the coagulant $Al(OH)_3$ will form more quickly.

This electrocoagulation process produces gas in the form of gas bubbles, so the impurities formed in the water will be lifted to the surface of the water. The floccules formed turned out to have relatively small sizes, so the floc caps formed earlier would increase in size over time. After the water undergoes electrocoagulation, a deposition process is carried out to precipitate the particles or floc formed. TSS removal occurs at the highest current strength, which is 2 A. The Al^{3+} ion is oxidized in large quantities and binds to OH- to form a large number of coagulants so that the particles are destabilized in the form of floc quickly and in large numbers [8]. Therefore, it can remove 94% TSS. Domestic waste electrocoagulation process with maximum results can decreased disposal of domestic wastewater [9].

4. Conclusion

Domestic waste electrocoagulation process with maximum results obtained by the configuration of the Al-Fe electrodes in the current strength 2 A and contact time 37 minutes and processing time 42 minutes with the optimum removal of 94% with the final concentration of 64 mg/L and COD's

optimum removal combined with the filtration of 95% with the final concentration of 22 mg/L. The process of domestic waste electrocoagulation with a current strength' variation does not affect COD and TSS removal. It is due to the difference in the current strength variation of the flow of 1 A, 2 A, and 3 A.

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