JOURNAL OF CHEMICAL PROCESS ENGINEERING
p-ISSN : 2527-4457
e-ISSN : 2655-2957

Vol. 10 No. 1 (2025)

Research Paper

Evaluation of Electrocoagulation Process Efficiency in Laboratory Wastewater Treatment with Various Current Densities

Muhrinsyah Fatimura[a*], Tuty Emilia Agustina[b] ,Ian Kurniawan[a] , Rully Masriatini[a],Nurlela[a] ,Reno Fitriyanti [a]

[a] *Chemical Engineering Department, Faculty of Engineering, PGRI University Palembang l. Jend. A. Yani Lorong Gotong Royong, 9/10 Ulu, Kec. Seberang Ulu II, Palembang City, South Sumatra 30116, Indonesia*
[b] *Chemical Engineering Study Program, Faculty of Engineering, Sriwijaya University, Jl. Raya Palembang - Prabumulih Km. 32 Indralaya, OI, South Sumatra 30662 Indonesia*

Artikel Histori : Submitted 22 December 2024, **Revised** 6 Januari 2025, **Accepted** 21 February 2025, **Online** 31 May 2025.
https://doi.org/10.33096/jcpe.v10i1.1533

ABSTRACT: *Laboratory wastewater contains harmful compounds such as COD, TSS, heavy metals, and toxic compounds that require treatment before being discharged into the environment. Laboratory wastewater contains various hazardous pollutants that can pollute the environment if not managed properly. This study aims to evaluate the efficiency of the electrocoagulation process in the treatment of laboratory wastewater of the Chemical Engineering Study Program of PGRI University Palembang with variations in current density and reaction time. The experimental method was used by designing an electrocoagulation reactor using aluminum electrodes. The independent variables tested include current density (76.92 A/m², 87.17 A/m², and 102.56 A/m²) and reaction time of 15, 30, 60 minutes. Parameters analyzed included COD, TSS, TDS, pH, electrode consumption, and energy consumption. The results showed that the electrocoagulation process effectively reduced pollutant parameters; at a current density of 102.56 A/m² for 60 minutes, COD decreased to 63.5 mg/L, TSS to 23.52 mg/L, pH increased to 8, and turbidity reduced to 20.48 NTU. The specific energy consumption reached 18.2 kWh/m³ with an operational cost of Rp27,300/m³. Based on the analysis, the optimal current density for laboratory wastewater treatment is 102.56 A/m² with a reaction time of 60 minutes. Electrocoagulation technology is recommended as an efficient, effective, and environmentally friendly treatment method for laboratory wastewater in higher education institutions.*

Keywords: *Electrocoagulation, laboratory wastewater, current density, COD, TSS*

1. INTRODUCTION

Laboratories are one of the sources of pollutants in water where these activities are integrated from various scientific activities, research, and analysis carried out in various institutions such as universities, research institutes, hospitals, and industries. Where laboratories produce residual wastewater can come from a variety of sources, including chemicals, biological materials, toxic materials, and other solid wastes. Improper treatment of laboratory waste can have serious negative impacts on the environment and human health. Therefore, it is important to understand and address the broad system of issues associated with laboratory waste treatment in order to narrow down effective and sustainable solutions. Laboratory waste management is very important to maintain the cleanliness, health, and safety of the environment and laboratory workers. Laboratory waste can contain hazardous chemicals and toxic compounds which, if disposed of inappropriately, can pollute the soil, water and air. If the content of this hazardous material can be processed properly, it can minimize the content of hazardous substances that will be disposed of in water bodies.

In the chemical industry today waste treatment must be in every production process where the suggestion of a wastewater treatment plant is an obligation in an industry. While for laboratory activities, waste from household activities, agricultural activities are still not handled specifically. [1]. Laboratory waste is the result of activities during practicum, washing water and remaining chemicals. Where it contains various types of metal and non-metal compounds that can be divided into cation and anion ions where there is a

Published by
Department of Chemical Engineering
Faculty of Industrial Technology
Universitas Muslim Indonesia, Makassar
Address
Jalan Urip Sumohardjo km. 05 (Kampus 2 UMI) Makassar- Sulawesi Selatan
e-mail : jcpe@umi.ac.id

Corresponding Author *
m.fatimura@univpgri-palembang.ac.id

dangerous ion content including Cr^{6+} , Cd^{2+} , Zn^{2+} , Hg^{+} , Fe^{2+} , Cu^{2+} , Mn^{2+} , NH^{4+} , NO^{3-} , PO_4^{3-} and SO_4^{2-} . [2]. Testing in the laboratory starting from research preparation, practicum and sample testing using chemical reagents. Chemical reagents that are often used are substances that contain organic, inorganic, heavy metal compounds, are acidic, alkaline, irritative, reactive and toxic. [3].

Wastewater from the laboratory of the Faculty of Engineering, PGRI University Palembang, especially the Chemical Engineering study program, the source comes from several student practicums and student and lecturer research that contains hazardous substances such as: organic and inorganic compounds, substances used in analyzing using strong acids, weak acids and bases where the waste has been only accommodated in the diregen and so far there has been no wastewater treatment process. For this reason, this research will provide input on efficient and effective wastewater treatment alternatives that can be used in the PGRI University Palembang environment, especially wastewater treatment for the Chemical Engineering Study Program laboratory. The need for wastewater treatment before being released into the environment requires special treatment in accordance with the characteristics of the waste. Wastewater treatment product targets usually refer to wastewater quality standards or are suitable for disposal into the environment according to local Government Regulations and or PERMEN Lingkungan Hidup Number 05 of 2014. [4].

Several wastewater treatment methods are often used such as precipitation, ion exchange, adsorption, coagulation and membrane filtration. [5]. The chemical precipitation process has been widely used to treat wastewater because the process is relatively cheap and easy to control but leaves a large amount of sludge that can form during the precipitation process. [6]. The ion exchange method can remove COD content in wastewater quickly and efficiently, but is strongly influenced by the pH of the wastewater [7]. Adsorption processes using adsorbents such as: activated carbon, kaolinite, and agricultural waste are considered an economical method to reduce COD content in wastewater, but the adsorption capacity among adsorbents varies, so adsorbents must be regenerated after use [8]. Membrane processes can also remove COD efficiently, but membrane impurities leave problems, as well as the presence of complex compounds that can inhibit COD removal in wastewater [9].

Electrocoagulation is a promising method for treating wastewater, utilizing direct electric current to facilitate the removal of pollutants through electrochemical processes. Electrodes, usually made of aluminum and iron, play an important role in treatment efficiency [10]. The electric current forms a number of chemical reactions depending on the type and nature of the electrodes as well as the solution medium [11]. Electrocoagulation has demonstrated high removal efficiencies for a variety of pollutants, including heavy metals, organic compounds, and pathogens. For example, achieving up to 95% removal of kinetic hydrate inhibitors in wastewater using aluminum electrodes [12]. Unlike traditional chemical coagulation, electrocoagulation minimizes the need for chemical additives, reducing the risk of secondary pollution. Controlled dissolution of coagulants through electric current regulation is a key advantage.[12]. The method also reduces environmental impact by preventing the release of harmful substances into natural water bodies [13]. While electrocoagulation offers many benefits, it is important to consider factors such as electrode material, current density, and pH, which significantly affect its efficiency [14]. Several methods are used wastewater treatment, electrocoagulation method has gained attention due to its effectiveness in removing various pollutants. From the above background, this research aims to evaluate the Efficiency of the Electrocoagulation Process in Laboratory Wastewater Treatment with Various Current Densities on wastewater such as COD, TSS, TDS, pH parameters derived from laboratory wastewater from the chemical engineering study program at PGRI University Palembang.

2. MATERIALS AND METHOD

2.1 Tools and Materials

The tools used in this study are as follows: Electrocoagulation Reactor, DC Power Supply, Aluminum Electrode, pH Meter, Measuring Glass, Beaker glass. The materials used in this study are as follows: Laboratory Wastewater of Chemical Engineering Study Program

The research method used in this research is through tool design and experiments.

2.2 Research Procedures

a. Electrocoagulation Reactor Design

Before carrying out the experiment, the design of the electrocoagulation reactor tool was carried out first as shown in Figure 2.1. the design of this tool consists of: Waste water tank equipment, pumps, electrocoagulation reactors, power supply and settling tanks.

b. Implementation of research:

Collecting laboratory wastewater and analyzing the initial characteristics of wastewater consisting of COD, TSS, TDS, pH parameters. Prepare an electrocoagulation reactor using Aluminum electrodes measuring 15cmx 13cmx2mm, where the electrode distance between the anode and cathode is 1.5 cm, the electrode arrangement uses Monopolar parallel (MP-P). Variation of Current Density by Setting the current density at a value of 76.92A/m², 87.17A/m² , 102.56 A/m².

Putting Wastewater into the electrocoagulation reactor as much as 2 liters. Installing Aluminum Electrodes as many as 6 pieces by adjusting the distance between electrodes 1.5 cm where the electrode size is 15 cmx 13cmx 2 mm. Running the electrocoagulation reactor by adjusting the electric current by turning on the DC power supply through the reactor and running the electrocoagulation process with a current density of 76.92A / m² with a reaction time of 15, 30, 60 minutes. Analyzing COD, TSS, TDS, pH at each reaction time of 15, 30, 60 minutes. Weighing the mass of Aluminum (Al) electrodes at each time 15,30,60 minutes after the electrocoagulation process. Analogous to the above procedure was carried out with a current density of 87.17A/m² , 102.56 A/m².

Calculating the efficiency of the electrocoagulation process.

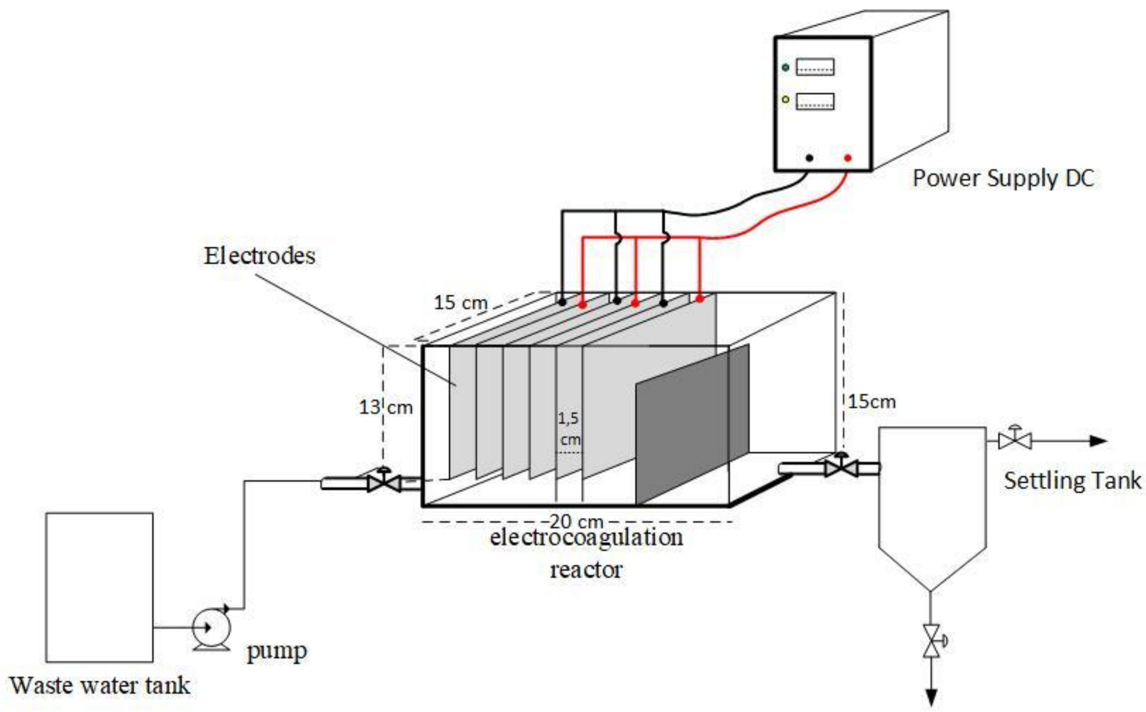

Figure 2.1. Flow chart of wastewater treatment using Electrocoagulation Reactor.

3. RESULTS AND DISCUSSION

Table 3.1. Initial characteristics of laboratory wastewater before electrocoagulation process

Parameters	Results
COD (mg/l)	1270
TSS (mg/l)	112
pH	5,96
Turbidity (NTU)	256

In Figure 3.1 COD decreased significantly as the current and reaction time increased. At a current of 1.5 A (76.92 A/m²), COD decreased from 762 mg/L to 127 mg/L after 60 minutes. At a current of 2 A (102.56 A/m²), the decrease was sharper, from 444.5 mg/L to 63.5 mg/L. This indicates that higher currents increase the oxidation efficiency of organic pollutants through faster and more effective floc formation. Current density controls anode dissolution speed as well as hydrogen production speed [15]. It is important to note that the higher the current density, the smaller the bubble size [16][17]. Therefore, there is an increase in the contact area between the gas (H_2) and the pollutants and the contaminant removal speed is favored, and the flotation efficiency is increased. [18][17].

Figure 3.2 Turbidity (NTU) Turbidity reduction is one indicator of the success of the electrocoagulation process. At a current density of 102.56 A/m², turbidity decreased dramatically from 112.64 NTU to 20.48 NTU in 60 minutes, reflecting optimal floc stability and particle settling. It is important to note that pH has a significant influence on the performance of the Electrocoagulation process. However, poor removal occurs at low pH (<2.0) or high pH (>10). This condition is caused by the amphoteric character of $Al(OH)_3$ which will not precipitate at pH less than 2.0. However, a high pH will increase the solubility of $Al(OH)_3$ and cause the formation of $Al(OH)^-$ solution which is not good for water treatment. [19].

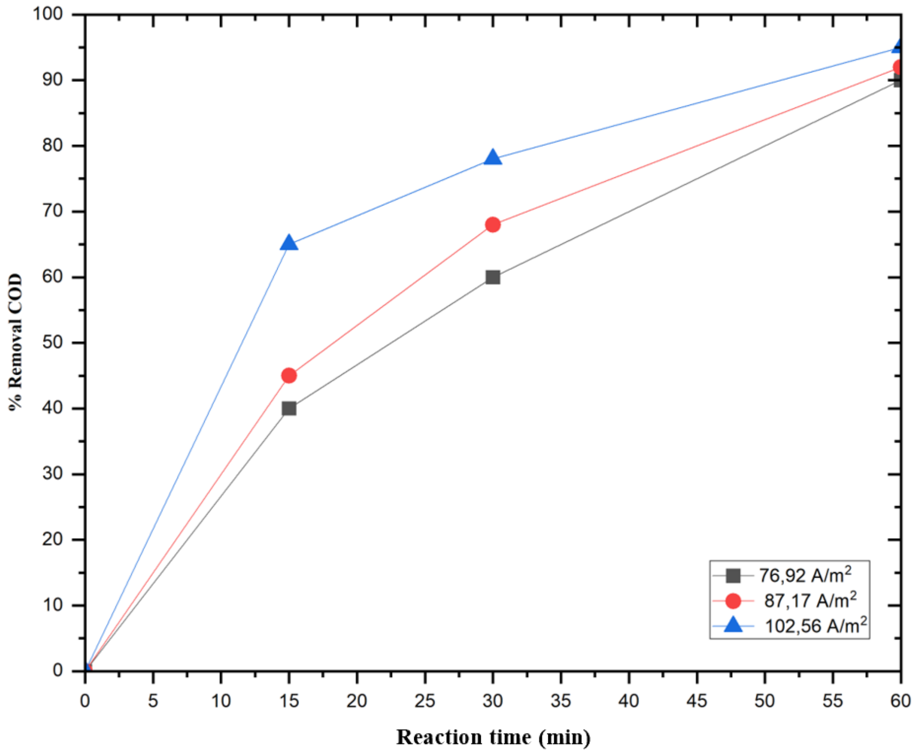

Figure 3.1 Effect of current density on COD removal efficiency

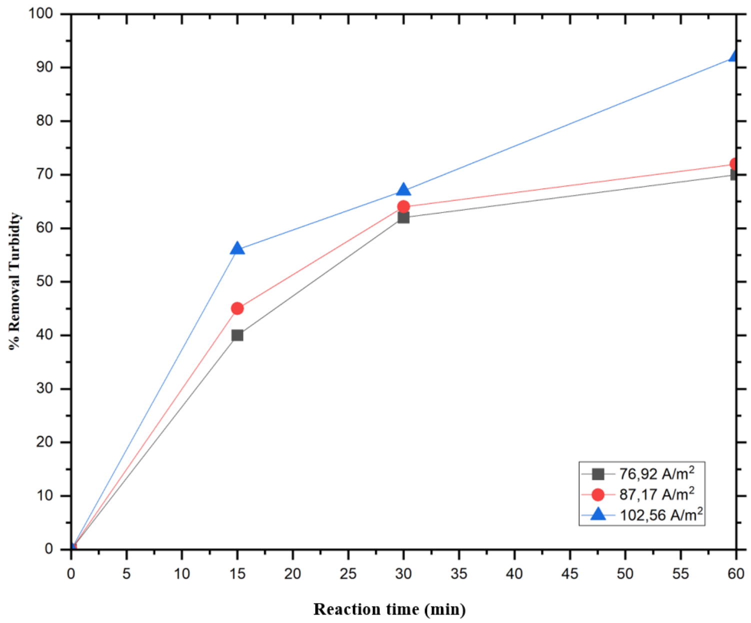

Figure 3.2 Effect of current density on turbidity removal efficiency

Figure 3.3 The TSS concentration also decreased significantly. At the highest current density (102.56 A/m²), TSS was reduced from 50.4 mg/L to 23.52 mg/L in 60 minutes. This indicates a better settling efficiency of suspended particles due to increased electrostatic forces. It is known that the electric potential not only determines the coagulant dosage rate but also the rate and size of bubble production, and floc growth which can affect the treatment efficiency of the electrocoagulation process [20].

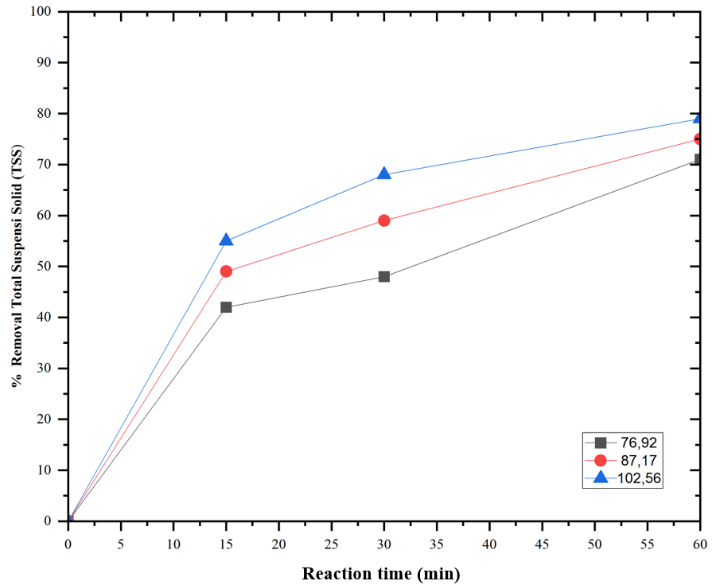

Figure 3.3 Effect of current density on total suspended solids (TSS) removal efficiency

Figure 3.4. The increase in pH from initial conditions to the end of the process indicates that the electrochemical reaction produces alkaline metal hydroxides, which aid flocculation and settling. At a current of 2 A, the pH increased from 6.7 to 8 in 60 minutes, approaching neutral to slightly alkaline values, which is in line with wastewater treatment standards. Another study showed that the pH stabilized below 9 starting

with a value close to 8.5 with an Al anode. [20]. Current density significantly affects pH [21]. Higher current densities increase the rate of coagulant formation, which can lead to a rise in pH due to the production of hydroxyl ions (OH^-) during electrolysis. [22].

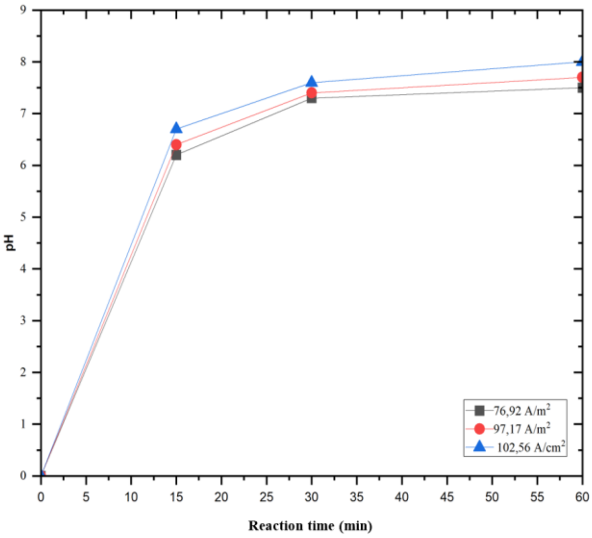

Figure 3.4 Effect of current density on pH

Table 3.2 Energy consumption used during the electrocoagulation process

Current (A)	Current Density (A/m)^2	Reaction Time (minutes)	Voltage (V)	Consumption Energy (KWH)	Consumption Energy process (kWh/m3)	Cost Operation (Rp/m3)
		15	6,70	0,00168	0,838	1.256,25
1,5	76,92	30	7,30	0,00548	2,738	4.106,25
		60	7,60	0,01140	5,700	8.550,00
		15	10,20	0,00289	1,445	2.167,50
1,7	87,17	30	14,70	0,01250	6,248	9.371,25
		60	15,10	0,02567	12,835	19.252,50
		15	11,13	0,00371	1,855	2.782,50
2	102,56	30	17,70	0,01770	8,850	13.275,00
		60	18,20	0,03640	18,200	27.300,00

Figure 3.5 Relationship between current density, reaction time, and Energy Consumption Increasing the current density from 76.92 A/m^2 to 102.56 A/m^2 resulted in a significant increase in electrical energy consumption at each duration of reaction time, at a reaction time of 60 minutes, the energy consumption increased from 0.01140 kWh (76.92 A/m^2) to 0.03640 kWh (102.56 A/m^2). The electrocoagulation process shows that higher currents exponentially increase energy consumption. [23]. The relationship between Energy Consumption per Volume of Water (kWh/m^3) Processed and reaction time increased with reaction time at each current. For example, at a current density of 87.17 A/m^2 , the CEv rose from 1.445 kWh/m^3 (15 min) to 12.835 kWh/m^3 (60 min). This increase indicates that longer process duration requires more specific energy to achieve the same treatment level. Material selection and electrode configuration affect energy usage [24].

In Table 3.2, the operating cost (Rp/m^3) increases significantly with increasing reaction time. At a current density of 102.56 A/m^2 , the operating cost increases from Rp 2,782.50 (15 min) to Rp 27,300.00 (60 min). This indicates that cost efficiency needs to be considered at longer reaction times. Effect of current frequency on operating cost At the same reaction time in Figure 3.6, an increase in current increases OC. For example, for 60 minutes, the OC increased from IDR 8,550 (76.92 A/m^2) to IDR 27,300 (102.56 A/m^2). This is because increasing the current increases the energy demand proportionally.

Energy Use Efficiency

The use of high current density (102.56A/m^2) results in shorter reaction time efficiency for certain results, but energy consumption and operating costs become very high. For real applications, a compromise between energy consumption and operating costs should be made based on wastewater quality targets. The increase in operating costs in laboratory wastewater treatment needs to be considered. A larger electrode surface area can reduce the applied voltage and operating costs, suggesting that current density should be optimized along with electrode size for efficient energy use. [25].

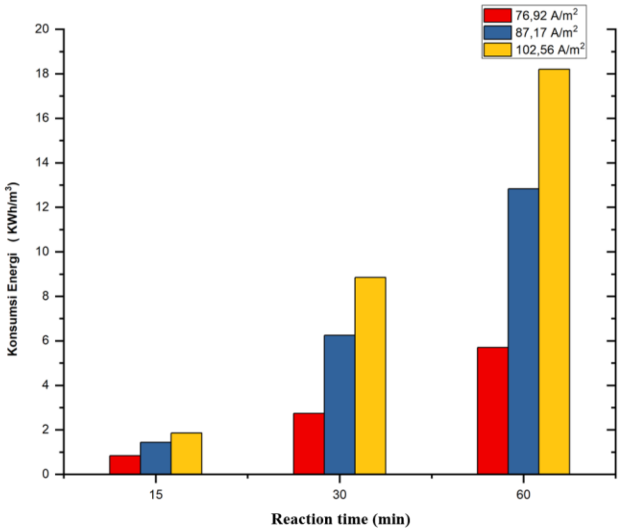

Figure 3.5 Effect of Current Density on Electrical Energy Consumption (Kwh/m)^3

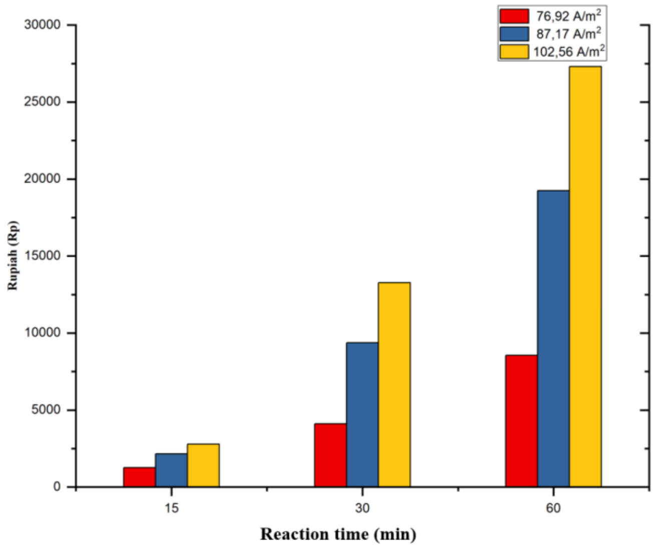

Figure 3.6 Effect of current density on electrocoagulation treatment cost

4. CONCLUSIONS

The electrocoagulation process proved effective in reducing pollutant parameters, especially COD, TSS, pH, and Turbidity, with efficiency increasing as current density and reaction time increased. At the highest current density (102.56 A/m²) for 60 minutes, COD could be reduced to 63.5 mg/L (95%), TSS to 23.52 mg/L (79%), pH increased to 8, and Turbidity reduced to 20.48 NTU (92%). These results show that electrocoagulation is able to achieve wastewater quality standards in accordance with the Minister of Environment Regulation Number 05 of 2014. Energy consumption increased as current density and reaction time increased. The highest specific energy consumption was recorded at 18.2 kWh/m³ with an operational cost of Rp27,300/m³ at a current density of 102.56 A/m² and a reaction time of 60 minutes.

REFERENCES

[1] N. Anggraini, T. E. Agustina, and F. Hadiah, "Effect of pH in Laboratory Wastewater Treatment by Adsorption Method for Reduction of Heavy Metal Levels of Pb, Cu, and Cd," *J. Ilmu Lingkung.*, vol. 20, no. 2, pp. 345–355, 2022, doi: 10.14710/jil.20.2.345-355.

[2] Y. Sukmawardani and V. Amalia, "Chemistry Laboratorium Liquid Waste Treatment Using Electrocoagulation Method," *J. Kartika Kim.*, vol. 2, no. 2, pp. 100–106, 2019, doi: 10.26874/jkk.v2i2.29.

[3] I. Nurhayati and S. Vigiani, "Reduction of Iron (Fe), Chromium (Cr), COD AND BOD Levels of Laboratory Liquid Waste by Dilution," vol. 14, no. 1, pp. 74–87, 2020.

[4] M. Joning, L. Melawaty, R. Sira Sarungallo, and P. Studi Teknik Kimia, "Electrocoagulation Method For The Treatment Of Laboratory Wastewater Containing Heavy Metals," *Chem. Eng. J.*, vol. 1, no. 1, pp. 1–14, 2022.

[5] F. Fu and Q. Wang, "Removal of heavy metal ions from wastewaters: A review," *J. Environ. Manage.*, vol. 92, no. 3, pp. 407–418, 2011, doi: https://doi.org/10.1016/j.jenvman.2010.11.011.

[6] S. K. Gunatilake, "Methods of removing heavy metals from industrial wastewater. Multidiscip Eng Sci Stud 1: 12--18," 2015.

[7] M. J. K. Ahmed and M. Ahmaruzzaman, "A review on potential usage of industrial waste materials for binding heavy metal ions from aqueous solutions," *J. Water Process Eng.*, vol. 10, pp. 39–47, 2016, doi: https://doi.org/10.1016/j.jwpe.2016.01.014.

[8] S. De Gisi, G. Lofrano, M. Grassi, and M. Notarnicola, "Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review," *Sustain. Mater. Technol.*, vol. 9, pp. 10–40, 2016, doi: https://doi.org/10.1016/j.susmat.2016.06.002.

[9] S. S. Hosseini, E. Bringas, N. R. Tan, I. Ortiz, M. Ghahramani, and M. A. Alaei Shahmirzadi, "Recent progress in development of high performance polymeric membranes and materials for metal plating wastewater treatment: A review," *J. Water Process Eng.*, vol. 9, pp. 78–110, 2016, doi: https://doi.org/10.1016/j.jwpe.2015.11.005.

[10] M. Guerreiro Crizel, T. M. Barreto, M. A. Fiori, G. L. Colpani, and J. M. Muneron de Mello, "Electrocoagulation Process as a Consolidated Technology in the Treatment of Industrial Effluents and as a Promising Process in the Treatment of Effluents Generated by Car Washes: A Brief Review," *ACS ES&T Water*, vol. 4, no. 5, pp. 1978–2004, May 2024, doi: 10.1021/acsestwater.3c00413.

[11] D. A. N. T. Dan, "Electrochemistry: Electrochemical Cell, Thermodynamic and Kinetic Aspects," *J. Mar. Sci. Res. Oceanogr.*, vol. 5, no. 2, 2022, doi: 10.33140/jmsro.05.02.01.

[12] J. S. Al-Marri, A. B. Abouedwan, M. I. Ahmad, and N. Bensalah, "Electrocoagulation using aluminum electrodes as a sustainable and economic method for the removal of kinetic hydrate inhibitor (polyvinyl pyrrolidone) from produced wastewaters," *Front. Water*, vol. 5, 2023, doi: 10.3389/frwa.2023.1305347.

[13] R. K.S, R. Anil, R. Varghese, S. Siby, E. A. Jose, and T. Thomas, "Solar-Powered Unit with Novel Reversible Inversion for Sustainable Electrocoagulation," in *2024 7th International Conference on*

Circuit Power and Computing Technologies (ICCPCT), 2024, pp. 1199–1204. doi: 10.1109/ICCPCT61902.2024.10673224.

[14] M. Bharti, P. P. Das, and M. K. Purkait, "A review on the treatment of water and wastewater by electrocoagulation process: Advances and emerging applications," *J. Environ. Chem. Eng.*, vol. 11, no. 6, p. 111558, 2023, doi: https://doi.org/10.1016/j.jece.2023.111558.

[15] K. Wei *et al.*, "Morphological engineering coupled with electronic engineering accelerates H2 production at the high current density," *Sep. Purif. Technol.*, vol. 326, p. 124814, 2023, doi: https://doi.org/10.1016/j.seppur.2023.124814.

[16] X. Lv *et al.*, "Characterization of Bubble Behavior in Aluminum Reduction Cells BT - Light Metals 2016," E. Williams, Ed., Cham: Springer International Publishing, 2016, pp. 347–352. doi: 10.1007/978-3-319-48251-4_57.

[17] N. Hajlaoui, I. Ksentini, M. Kotti, and L. Ben Mansour, "Experimental Study of Current Density and Liquid Phase Electric Conductivity Effects on Bubble Size Distribution in an Electroflotation Column," *Russ. J. Electrochem.*, vol. 55, no. 5, pp. 358–363, 2019, doi: 10.1134/S1023193519040025.

[18] R. S. Putra, M. Sarkawi, F. Faikha, and L. Fitmoko, "Analysis of Bubbles Size Produced in Electroflotation Using Graphite and Stainless Steel Electrode With DinoCapture 2.0," in *2021 IEEE International Conference on Health, Instrumentation & Measurement, and Natural Sciences (InHeNce)*, 2021, pp. 1–5. doi: 10.1109/InHeNce52833.2021.9537230.

[19] Ş. İrdemez, Z. Bingül, S. Kul, F. Ekmekyapar Torun, and N. Demircioğlu, "The effect of pH on removal of phosphate from water using aluminum electrodes by electrocoagulation method," *El-Cezeri J. Sci. Eng.*, vol. 8, no. 3, pp. 1472–1479, 2021, doi: 10.31202/ecjse.948309.

[20] Y. Kwon, "A Study on pH Stability by Constant Current Control in Multi-stage Alkaline Water Ionizer TT - A Study on pH Stability by Constant Current Control in Multi-stage Alkaline Water Ionizer," *J. Inst. Electron. Inf. Eng.*, vol. 59, no. 10, pp. 121–128, 2022, doi: 10.5573/ieie.2022.59.10.121.

[21] F. Augusto Costa Mafra Passos, J. da Cruz Trajano de Souza, I. Daniel dos Santos, R. Neumann, P. Paulo Medeiros Ribeiro, and A. Junqueira Bourdot Dutra, "Effect of pH and current density on the physical properties of cobalt obtained by electrowinning from sulfate solutions," *Miner. Eng.*, vol. 211, p. 108697, 2024, doi: https://doi.org/10.1016/j.mineng.2024.108697.

[22] N. Galvão, J. B. de Souza, and C. M. de S. Vidal, "Landfill leachate treatment by electrocoagulation: Effects of current density and electrolysis time," *J. Environ. Chem. Eng.*, vol. 8, no. 5, p. 104368, 2020, doi: https://doi.org/10.1016/j.jece.2020.104368.

[23] S. U. Khan, M. Asif, F. Alam, N. A. Khan, and I. H. Farooqi, "Optimizing Fluoride Removal and Energy Consumption in a Batch Reactor Using Electrocoagulation: A Smart Treatment Technology BT - Smart Cities—Opportunities and Challenges," S. Ahmed, S. M. Abbas, and H. Zia, Eds., Singapore: Springer Singapore, 2020, pp. 767–778.

[24] M. Ebba, P. Asaithambi, and E. Alemayehu, "Investigation on operating parameters and cost using an electrocoagulation process for wastewater treatment," *Appl. Water Sci.*, vol. 11, no. 11, p. 175, 2021, doi: 10.1007/s13201-021-01517-y.

[25] B. Nareerob and P. Jitto, "Effect of Current and Electrodes Area to Color Removal Efficiency and Energy Consumption by Electrocoagulation Process BT - Sustainable Development of Water and Environment," H.-Y. Jeon, Ed., Cham: Springer International Publishing, 2021, pp. 169–179.