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Reduction of tofu industry liquid waste pollutants using the electrocoagulation method, with the influence of the distance between electrodes and contact time

[Reduksi polutan limbah cair industri tahu menggunakan metode elektrokoagulasi, dengan pengaruh jarak antar elektroda dan waktu kontak]

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ABSTRACT

Tofu production produces solid waste and liquid waste which can pollute the environment. Industrial wastewater treatment has been carried out using various methods, one of which is the electrocoagulation method. The purpose of this study was to analyze the effect of distance between electrodes and contact time on reducing TSS, TDS, turbidity, and pH levels of tofu industrial wastewater and to obtain the best treatment in reducing pH, TSS, TDS, turbidity, and COD levels. The research was conducted using a Factorial Randomized Block Design with 3 replications. The electrocoagulation process was carried out using variations of distance between electrode of 1.0, 1.5, and 2.0 cm and contact times of 30, 45, and 60 minutes. The experimental data were analyzed using Analysis of Variance (ANOVA) and Honestly Significant Difference (HSD) test at a significance level of 5%. Based on the results of the study, it was concluded that the distance between electrodes and contact time affected the reduction of wastewater pollutants. The results showed that a distance between electrodes of 1.0 cm with a contact time of 60 minutes was the best treatment, which resulted in the largest reduction in TSS, TDS, and turbidity values of up to 69.05 percent, 59.34 percent, and 98.15 percent, respectively, the largest increase in pH of up to 28.45 percent, and reduction of COD of up 48.90 percent.

Keywords: electrocoagulation; electrode distance; contact time

ABSTRAK

Produksi tahu menghasilkan limbah padat dan limbah cair yang dapat mencemari lingkungan. Pengolahan limbah cair industri telah dilakukan dengan berbagai metode, salah satunya adalah metode elektrokagulasi. Tujuan penelitian ini adalah untuk menganalisis pengaruh jarak antar elektroda dan waktu kontak terhadap penurunan kadar TSS, TDS, kekeruhan, dan pH pada limbah cair industri tahu serta untuk memperoleh perlakuan terbaik dalam menurunkan kadar pH, TSS, TDS, kekeruhan, dan COD. Penelitian dilakukan menggunakan Rancangan Acak Kelompok (RAK) faktorial dengan 3 ulangan. Proses elektrokagulasi dilakukan dengan variasi jarak antar elektroda 1,0; 1,5; dan 2,0 cm serta waktu kontak 30, 45, dan 60 menit. Data hasil percobaan dianalisis menggunakan Analisis Ragam (ANOVA) dan uji Beda Nyata Jujur (BNJ) pada taraf signifikansi 5%. Berdasarkan hasil penelitian, disimpulkan bahwa jarak antar elektroda dan waktu kontak berpengaruh terhadap penurunan polutan limb ah cair tahu. Hasil penelitian menunjukkan bahwa jarak antar elektroda 1,0 cm dengan waktu kontak 60 menit merupakan perlakuan terbaik yang menghasilkan penurunan TSS, TDS, dan kekeruhan masing -masing sebesar 69,05%, 59,34%, dan 98,15%, peningkatan pH sebe sar 28,45%, serta penurunan COD hingga 48,90%.

Kata kunci: elektrokoagulasi; jarak elektroda; waktu kontak

Introduction

Average tofu consumption in Indonesia increased from 0.148 kg/capita per week in 2022 to 0.152 kg/capita per week in 2023 (BPS, 2024). The increasing tofu production will impact the environment because the tofu production process produces waste that has the potential to pollute waters (Putri & Purnama, 2022).

The washing, pressing, and filtering processes had the potential to become sources of liquid waste in the tofu industry (Kaswinarni, 2007). The tofu industry's liquid waste that was not properly handled will produce an unpleasant odor. This odor was caused by the presence of protein that was broken down by

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microorganisms, forming H_2S and ammonia gas (Ratnani et al., 2010). According to (Idral Amri et al., 2020), tofu industry wastewater contained TSS, TDS, and pH of 560 mg/L, 4250 mg/L, and 5.7, respectively. The high TSS, TDS, and pH values were due to the high protein, carbohydrate, and fat content of tofu industry wastewater (Rahayu et al., 2021).

Wastewater from the tofu industry had the potential to pollute water bodies if not properly treated and discharged directly into waterways (Kurniawan et al., 2024). Several technologies had been used to treat tofu industry wastewater, one of which was electrocoagulation. The electrocoagulation method had the advantages of requiring no additional chemicals, simple equipment, and a relatively fast colloid reduction process (Hanif et al., 2025). The principle of the electrocoagulation method was to combine electrochemical and coagulation processes, utilizing reduction and oxidation reactions (Hanif et al., 2025). The oxidation process occurred at the anode, producing coagulants and hydroxyl ions. The reduction process occurred at the cathode and produced hydrogen gas (Windiastuti et al., 2024). The electrocoagulation process was able to reduce contaminated and suspended parts of liquid waste (Hanif et al., 2025). This study applied the treatment of tofu liquid waste using the electrocoagulation method. The application of the electrocoagulation method was expected to produce a simple processing method and did not require additional chemicals, so it could be faster in reducing colloids. The purpose of this study was to analyze the effect of the distance between electrodes and contact time on reducing TSS, TDS, turbidity, and pH levels of tofu industrial liquid waste and to obtain the best treatment in reducing COD, TSS, TDS, turbidity, and increasing pH levels.

Methodology

Research location and methods

The research was conducted at the Environmental Engineering Laboratory of the Sumatra Institute of Technology. Tofu wastewater samples were obtained from the Gunung Sulah tofu industrial area in Bandar Lampung. Electrocoagulation was carried out at a voltage of 25 volts using a batch system. The electrocoagulation process was carried out using variations in the distance between electrodes of 1.0, 1.5, and 2.0 cm with contact times of 30, 45, and 60 minutes. The study was conducted using a randomized block design, with the first factor being the distance between electrodes and the second factor being the contact time of the electrocoagulation process. The experiment was carried out with three repetitions. The experimental data were analyzed using Analysis of Variance (ANOVA), followed by the Honestly Significant Difference (HSD) test at a significance level of 5%.

Procedure

Tofu industry wastewater was initially characterized using TSS, TDS, turbidity, and pH parameters. The electrocoagulation process was carried out using a 1000 mL glass beaker. Two pairs of 15 x 4 cm aluminum electrodes were inserted into the beaker, at a distance of 1.0, 1.5, and 2.0 cm apart. A voltage of 25 volts was applied to the electrodes, and air was circulated through an aerator hose. The electrocoagulation process was carried out for 30, 45, and 60 minutes. After electrocoagulation, the samples were allowed to settle for 24 hours and then characterized.

Sample characterization was carried out to determine the TSS, TDS, turbidity, and pH values. TSS analysis was performed using the SNI 06-6989.3-2004 gravimetric method. TDS analysis was conducted using the SNI 6989.27:2019 method, turbidity value analysis using the SNI 06-6989.25.2005 method with a nephelometer, and pH analysis was conducted using the SNI 06-6989.11-2004 method. The results of the characterization of tofu industrial wastewater that had been treated by electrocoagulation were then compared with the results of the initial characterization of tofu industrial liquid waste.

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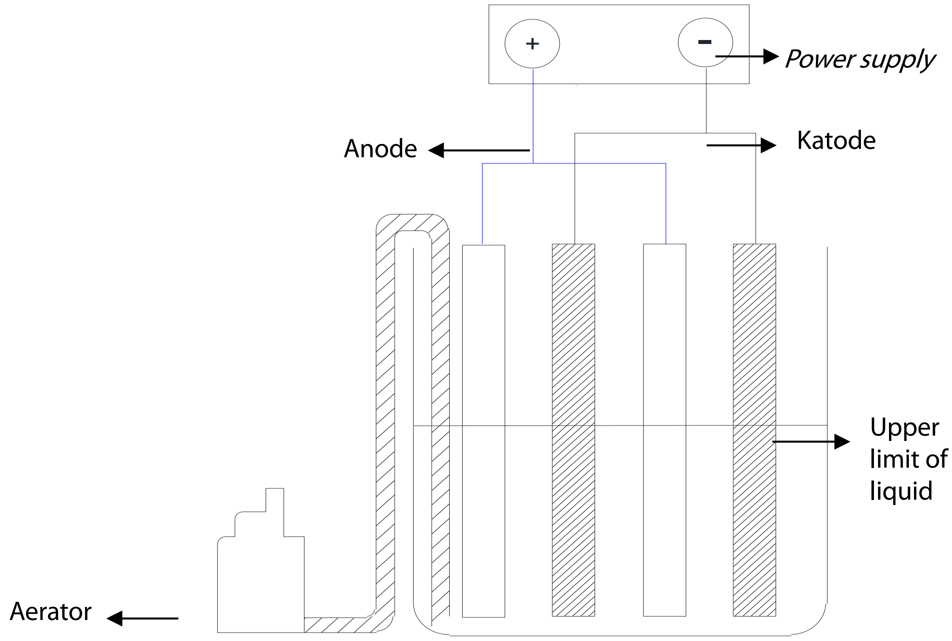

Figure 1. Schematic of the electrocoagulation equipment for tofu industry wastewater

Result and discussion

Electrocoagulation

The effect of varying the distance between electrodes and the contact time was identified and evaluated under specific conditions at a constant temperature.

Total suspended solids

Total Suspended Solids (TSS) are solids containing insoluble organic and inorganic materials, typically retained in a filter with a maximum particle size of 2 µm. The decrease in TSS values during electrocoagulation was caused by changes in the period of bonded flocs (Windiastuti et al., 2024). This process resulted in a significant increase in specific gravity, leading to the formation of precipitation and colloids. Formation of colloids was due to pollutants bound by $Al(OH)_3$ ions being pushed to the surface by H_2 gas.

The TSS value indicated the presence of suspended solids in water; therefore, water turbidity was influenced by TSS content (Armus et al., 2022). Figure 2 shows that the TSS value decreases with increasing distance between electrodes and increasing contact time. Based on ANOVA and HSD tests, all treatments produced TSS values that were not significantly different (p-value ≥ 0.05). On the other hand, research data revealed that an electrode distance of 1.0 cm and a contact time of 60 minutes resulted in the largest TSS reduction, that was 566 mg/L.

(Khaled et al., 2019) found that the smaller the distance between the electrodes, the lower the electrical resistance and the faster the oxidation reaction, thus accelerating the floc formation process. Increasing the contact time between the electrode and the sample resulted in a decrease in TSS due to increased floc formation (Khandegar & Saroha, 2013).

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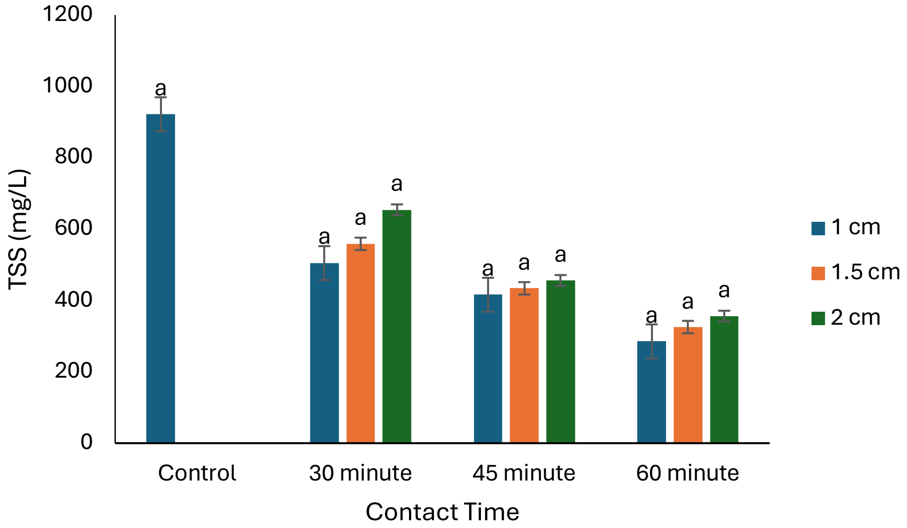

Figure 2. Graph of TSS reduction caused by differences in electrode distance and contact time

Total dissolved solids

The total dissolved solids (TDS) value indicated the presence of dissolved solids in water, consisting of organic and inorganic compounds (Weber-Scannell & Duffy, 2007). Based on the ANOVA results, the distance between electrodes and contact time significantly influenced the TDS value (p-value 0.000 < 0.05). The interaction factor of the distance between electrodes and contact time also significantly influenced the TDS value (p-value 0.002 < 0.05). Further analysis using the HSD test showed that the electrode distance of 1.0 cm and the contact time of 60 minutes caused a decrease of 59.34% with a TDS value of 4025.67 mg/L. The decrease distance between electrodes reduced the TDS value.

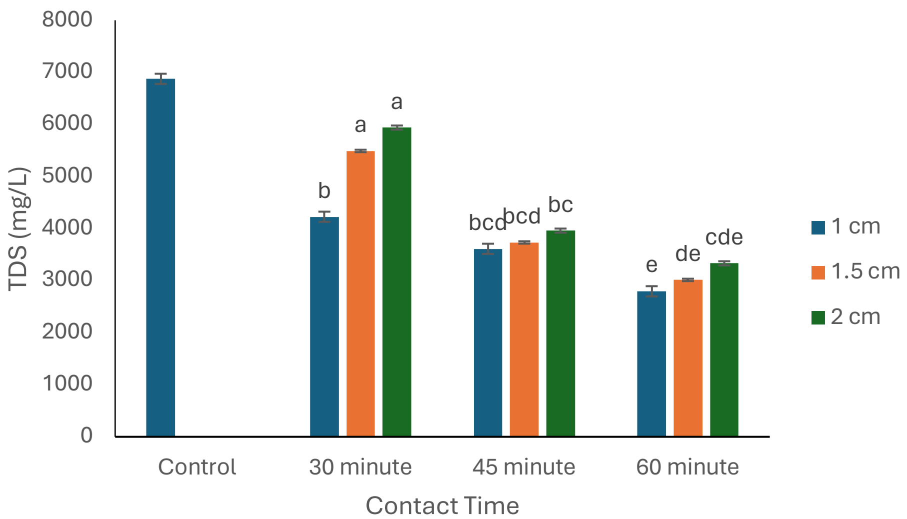

Figure 3. Graph of TDS reduction caused by differences in electrode distance and contact time

Figure 3 shows that a decrease in TDS value was related to the decrease in the distance between electrodes and the longer contact time. A comparison of all nine treatments showed the largest TSS reduction was at an electrode distance of 1.0 cm and a time of 60 minutes, and the smallest TSS reduction occurred at an electrode distance of 2.0 cm and a time of 30 minutes. The decrease in TDS occurred due to the oxidation process at the anode, which produces OH^- ions and Al^{3+} ions, which react to produce $Al(OH)_3$ (Sahu et al., 2014).

The formation of $Al(OH)_3$ occurred because the small distance between the electrodes accelerated floc formation, and the adsorption properties were able to bind pollutants into flocs (Kabdaşlı et al., 2012),

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resulting in colloids bound to each other and forming flocs at the bottom of the reactor (Masrullita et al., 2021). Longer contact times increased floc formation (Aljaberi, 2018).

Turbidity

Turbidity is a measure of water clarity caused by the presence of suspended organic and inorganic particles. It is measured using light effects as a basis for determining raw water conditions, nd it's shown using the Nephelometric Turbidity Unit (NTU) scale. Turbidity is generally caused by the presence of mixed or colloidal matter in the water, which significantly impacts both aesthetics and water quality (Windiastuti et al., 2024).

Turbidity makes it harder for sunlight to pass through the water, thus affecting its aesthetic value. Turbidity was caused by high TSS content due to the mixture of solids and liquids in the water body (Armus et al., 2022). ANOVA results showed that the distance between electrodes and contact time significantly influenced turbidity reduction (p-value 0.000 < 0.05). The interaction between the distance between electrodes and contact time also significantly affected turbidity reduction (p-value 0.000 < 0.05). Further analysis using the HSD test showed that the 1.0 cm distance between electrodes and 60 minutes of contact time resulted in the largest turbidity reduction, with a value of 1206.7 NTU. Figure 4 shows the turbidity reduction resulting from the electrocoagulation process.

Turbidity was influenced by the TSS content of the material; therefore, the higher the suspended solids content, the higher the turbidity value (Asmadi & Suharno, 2012). Turbidity decreases with decreasing distance between electrodes.

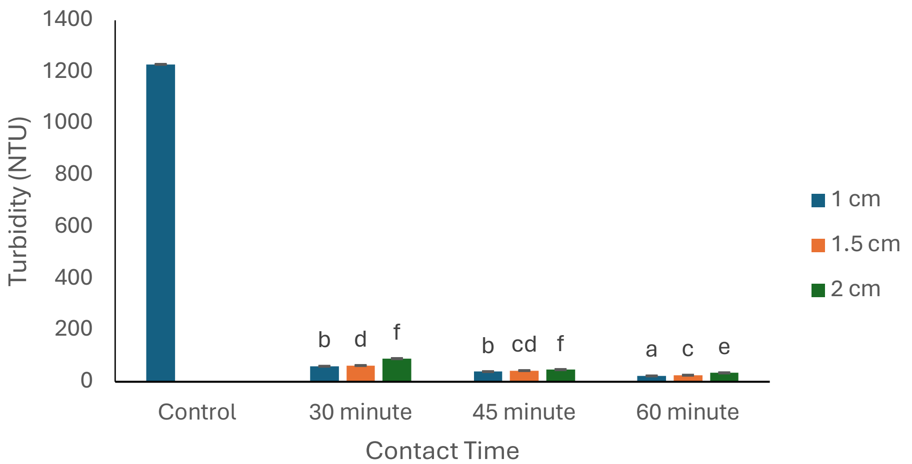

Figure 4. Graph of turbidity reduction caused by differences in electrode distance and contact time

pH

During the electrocoagulation process, an increase in pH occured due to the formation of hydrogen gas, which bound Al^{3+} ions and formed Al(OH)3 in a basic state (Hermida et al., 2020; Lestari & Tuhu, 2018; Windiastuti et al., 2024). Based on the results of the ANOVA test, the distance between electrodes significantly affected the pH (p-value 0.040 <0.05), and the contact time factor also significantly affected the pH (p-value 0.000 <0.05). However, the interaction of the two factors, the distance between electrodes and contact time, did not have a significant effect on the pH (p-value 0.190 > 0.05). Based on further tests with HSD, an electrode distance of 1,0 cm with a contact time of 30 minutes increased the pH from 5.74 to 7.00; likewise, the longest contact time (60 minutes) could increase the pH from 5.74 to 7.34. Figure 5 shows the increase in pH value that occurred during the electrocoagulation process. Figure 5 Shows that the pH value obtained from all treatments has met the quality standards set by the Minister of Environment Regulation No. 5 of 2014, in which pH should be in the range of 6-9. The acidity value decreased due to the redox reaction at the cathode, which produced basic OH^- ions (Wardani & Arifiyana, 2020).

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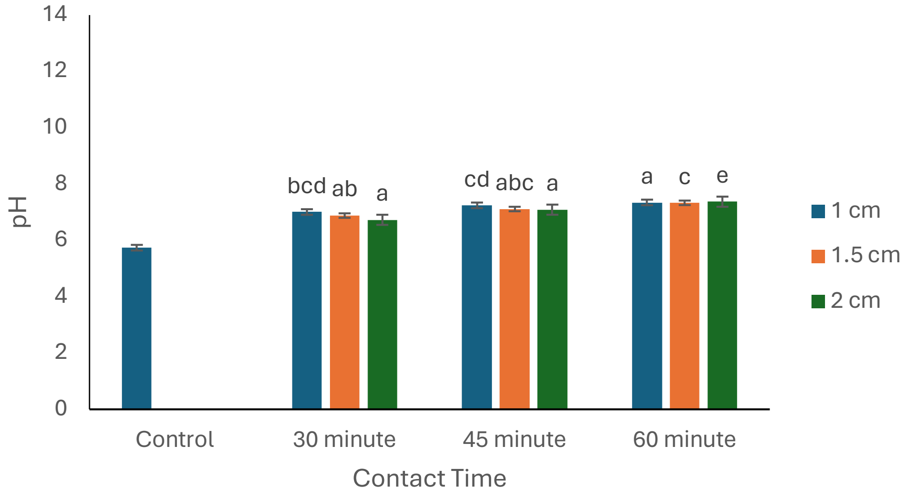

Figure 5. Graph of pH increase caused by differences in electrode distance and contact time

Chemical oxygen demand **(COD)**

A decrease in COD concentration indicated a decrease in organic compounds in wastewater. The COD measurements were conducted to determine the amount of oxygen required to oxidize organic compounds in water (Farida Hanum et al., 2015). High levels of pollutants in wastewater were indicated by high COD values (Naillah et al., 2021).

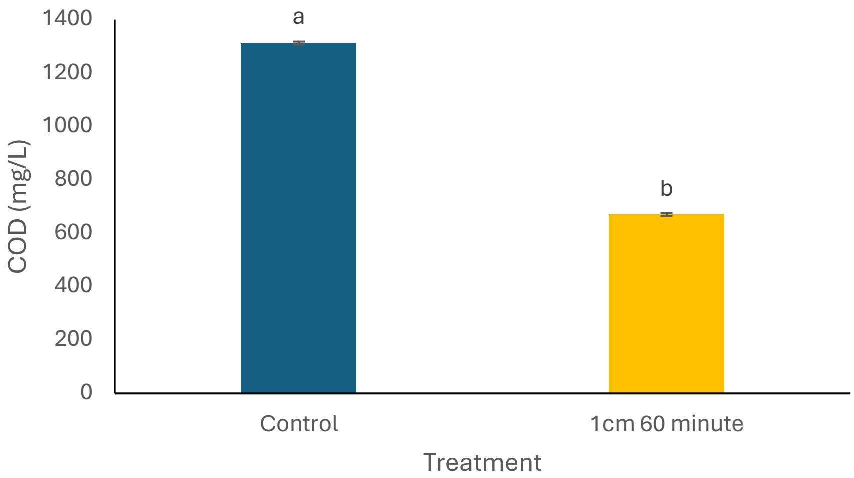

Figure 6. Comparison graph of COD control values with treatment results at an electrode distance of 1 cm and a contact time of 60 minutes

COD testing was performed only on the best treatment based on the greatest reduction in TSS, TDS, and turbidity value. The best treatment was obtained from treatment with a distance between electrodes of 1.0 cm and a contact time of 60 minutes. The initial COD value was 1312 mg/L, after electrocoagulation treatment, the COD value decreased to 670 mg/L, representing a 48.90 percent 3 pt the research that has been done, it can be concluded that the distance between electrodes and contact time affects the reduction of TSS, TDS, turbidity levels and increase the pH. The largest reduction in TSS, TDS, and turbidity values resulted from the electrocoagulation process with a distance between electrodes of 1.0 cm and a contact time of 60 minutes. Such treatment can reduce TSS, TDS, and turbidity values by up to 69.05 percent, 59.34 percent, and 98.15 percent, respectively, and successfully increase pH in accordance with the quality standards set by the Minister of Environment No. 5 of 2014. The electrocoagulation treatment with a distance between electrodes of 1.0 cm and a contact time of 60 minutes also reduced COD of wastewater by up to 48.90 percent.

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References

Aljaberi, F. Y. (2018). Investigation of electrocoagulation reactor design effect on the value of total dissolved solids via the treatment of simulated wastewater. *Desalination and Water Treatment*, 120, 141–149.

Armus, R., Mukrim, M. I., Sitorus, E., Pasanda, O., Tangio, J., Marzuki, I., Mohammad, E., Syahrir, M., & Mastutie, F. (2022). Basics of waste management process (in Indonesian). In *Yayasan Kita Menulis* (Vol. 5, Issue 3).

Asmadi, & Suharno. (2012). Basics of wastewater treatment technology (In Indonesian). G*osyen Publishing.*

Farida Hanum, Rondang Tambun, M. Yusuf Ritonga, & William Wardhana Kasim. (2015). Application of electrocoagulation in palm oil mill wastewater treatment (in Indonesian). *Jurnal Teknik Kimia USU*, 4(4), 13–17. https://doi.org/10.32734/jtk.v4i4.1508

Hanif, H., Hamdan, A.M., Rahman, A., Yunasar, Y. (2025). Reduction of organic pollutant levels in slaughterhouse wastewater using the electrocoagulation method. *Indonesian Journal of Chemical Analysis, 8(01), 40-49.*

Hermida, L., Kustiani, I., & Suharno. (2020). Performance evaluation of batch recycle electrocoagulation system with monopolar electrode arrangement in processing tapioca liquid waste (in Indonesian). *Jurnal Profesi Insinyur Universitas Lampung*, 1(1), 20–28. https://doi.org/10.23960/jpi.v1n1.13

Idral Amri, Pratiwi Destinefa, & Zultiniar. (2020). The effect of voltage and flow rate on the processing of tofu liquid waste into clean water using the continuous electrocoagulation method (in Indonesian). *Journal of Bioprocess, Chemical and Environmental Engineering Science*, 1(1), 1–5. https://doi.org/10.31258/jbchees.1.1.1-5

Kabdaşlı, I., Arslan-Alaton, I., Ölmez-Hancı, T., & Tünay, O. (2012). Electrocoagulation applications for industrial wastewaters: a critical review. *Environmental Technology Reviews*, 1(1), 2–45.

Kaswinarni, F. (2007). Technical study of solid and liquid waste processing in the tofu industry (in Indonesian). In *Universitas Diponegoro*.

Khaled, B., Wided, B., Béchir, H., Elimame, E., Mouna, L., & Zied, T. (2019). Investigation of electrocoagulation reactor design parameters effect on the removal of cadmium from synthetic and phosphate industrial wastewater. *Arabian Journal of Chemistry*, 12(8), 1848–1859. https://doi.org/10.1016/j.arabjc.2014.12.012

Khandegar, V., & Saroha, A. K. (2013). Electrocoagulation for the treatment of textile industry effluent A review. *Journal of Environmental Management*, 128, 949–963.

Kurniawan, L., Maryudi, M., Astuti, E. (2024). Utilization of tofu liquid waste as liquid organic fertilizer using the fermentation method with activator effective microorganisms 4 (EM-4); A Review. *Equilibrium Journal of Chemical Engineering, 8(1), 100-112.*

Lestari, N. D., & Tuhu, A. (2018). Penurunan TSS dan warna limbah industri batik secara elektro koagulasi. *Jurnal Ilmiah Teknik Lingkungan*, 6(1), 37–44.

Mallesh, B. (2018). A review of electrocoagulation process for wastewater treatment. *International Journal of ChemTech Research*, *May*. https://doi.org/10.20902/ijctr.2018.110333.11(3), 289-302

Masrullita, M., Hakim, L., Nurlaila, R., & Azila, N. (2021). The effect of time and current strength on the processing of brackish water into clean water using the electrocoagulation process (in Indonesian). *Jurnal Teknologi Kimia Unimal*, 10(1), 111–122.

Naillah, A., Budiarti, L. Y., & Heriyani, F. (2021). Literature review: river water quality analysis with a review of ph, temperature, BOD, COD, DO parameters against coliform (in Indonesian). *Homeostasis*, 4(2), 487–494.

Putri, R. A., & Purnama, H. (2022). The effect of voltage and time on leachate treatment using the electrocoagulation-zeolite adsorption method (in Indonesian). *Jurnal Reka Lingkungan*, 10(2), 135–144. https://doi.org/10.26760/rekalingkungan.v10i2.135-144

Rahayu, E. S., Rahayu, S., Sidar, A., Purwadi, T., & Rochdyanto, S. (2021). Teknologi Proses Produksi Tahu (I. Flora Maharani (ed.)). *PT Kanisius.*

ISSN (electronic): 2302-4399 http://jurnal.fp.unila.ac.id/index.php/jthp/index
Ratnani, R. D., Hartati, I., & Kurniasari, L. (2010). Utilization of water hyacinth (eichornia crassipes) to reduce COD (chemical oxygen depletion), pH, odor, and color in liquid tofu waste (in Indonesian). In *Jurnal Lingkungan* (Vol. 2).

Sahu, O., Mazumdar, B., & Chaudhari, P. K. (2014). Treatment of wastewater by electrocoagulation: A review. *Environmental Science and Pollution Research*, 21(4), 2397–2413. https://doi.org/10.1007/s11356-013-2208-6

Wardani, R. K., & Arifiyana, D. (2020). *S*uhu, waktu dan kelarutan kalsium oksalatpada umbi porang (1st ed.). *Penerbit Graniti*, 58.

Weber-Scannell, P. K., & Duffy, L. K. (2007). Effects of Total dissolved solids on aquatic organisms: a review of literature and recommendation for salmonid species. *American Journal of Environmental Sciences*, 3(1), 1–6.

Windiastuti, E., Indrasti, N. S., Hasanudin, U., Bindar, Y., & Suprihatin. (2024). Effect of electrocoagulation on improving the quality of palm oil liquid waste. *EnvironmentAsia*, 17(3), 174–184. https://doi.org/10.14456/ea.2024.45