EFFECT OF TIME AND VOLTAGE ON POLLUTANT REMOVER IN GOLD TREATMENT WASTEWATER WITH ELECTROCOAGULATION BATCH REACTOR

Rr Dina Asrifah[*], Titi Tiara Anasstasia[*], Mia Fitri Aurilia[*]

[*]*Department of Environmental Engineering, University of Pembangunan Nasional "Veteran" Yogyakarta, Indonesia, dina_asrifah@upnyk.ac.id, tiara.anasstasia@upnyk.ac.id, miaaftr@gmail.com*

Email Correspondence : dina_asrifah@upnyk.ac.id

Received : November 11, 2020 Accepted : March 29, 2021 Published : June 30, 2021

Abstract: Wastewater from gold treatment by amalgamation has a high TSS value and heavy metal content in the form of Cu and Hg. This content can endanger the surrounding environment. Therefore, wastewater must be treated until it shows results below the permitted quality standards. Wastewater treatment is carried out using the batch reactor electrocoagulation method. The purpose of this study was to determine the efficiency value and optimal conditions by reducing the TSS, Cu, and Hg content in wastewater based on the effect of time (10 minutes) and voltage (4.5 volts, 6 volts, and 7.5 volts). This calculation of the efficiency and analysis showed that the optimal conditions occurred at a voltage of 6 volts from the three parameters, there are TSS = 97.49%, Cu = 95.71%, and Hg = 98.95%. Based on the test results after treatment, the wastewater still needs to be treated until it is below the safe quality standard according to Government Regulation of Indonesia Republic No. 82 of 2001 class 4.
Keywords: electrocoagulation, gold treatment, batch, wastewater.

Abstrak: Air limbah pencucian emas dengan metode amalgamasi memiliki nilai TSS yang tinggi dan kandungan logam berat berupa Cu dan Hg. Kandungan tersebut dapat membahayakan lingkungan sekitar. Oleh karena itu, air limbah harus diolah hingga menunjukkan hasil di bawah baku mutu yang diizinkan. Pengolahan air limbah dilakukan dengan metode elektrokoagulasi reaktor batch. Tujuan penelitian ini adalah untuk mengetahui nilai efisiensi dan kondisi optimal dengan mereduksi kandungan TSS, Cu, dan Hg pada limbah cair berdasarkan pengaruh waktu (10 menit) dan tegangan (4,5 volt, 6 volt, dan 7,5 volt). Hasil perhitungan efisiensi dan analisis ini menunjukkan bahwa kondisi optimal terjadi pada tegangan 6 volt dari ketiga parameter yaitu TSS = 97,49%, Cu = 95,71%, dan Hg = 98,95%. Berdasarkan hasil pengujian setelah diolah, air limbah masih perlu diolah hingga berada di bawah baku mutu aman sesuai dengan PP RI No. 82 Tahun 2001 pada kelas 4.
Kata kunci: air limbah, elektrokoagulasi, batch, pengolahan emas

Recommended APA Citation :

Asrifah, R. D., Anasstasia, T. T., & Aurilia. M. F. (2021). Effect of Time and Voltage on Pollutant Remover in Gold Treatment Wastewater With Electrocoagulation Batch Reactor. *Elkawnie*, *7*(1), 172-181. https://doi.org/10.22373/ekw.v7i1.8226

Introduction

Kulon Progo Regency has the potential buried gold. Due to the economic limitations of the local people, traditional gold mining is their source of income. Mining is carried out using simple tools such as hoes, crowbars, and hammers by following the quartz veins in the andesite. Mining activities include extracting gold ore, grinding gold ore using logs, and gold treatment amalgamation using mercury as a gold binder. The working of the amalgamation process itself is heated until the mercury is evaporated then the gold could be extracted (Esdaile and Chalker, 2018). Mercury is a heavy metal that is liquid, volatile, and dangerous if it accumulates in the body of living things. This gold extraction process is carried out because it is the easiest method, low cost, and does not require complicated equipment. According to Bazrafshan et al. (2015), mercury is one of the toxic heavy metals components that is a neurotoxin for the body system and causes central nervous system damages.

Waste resulting from the amalgamation of gold processing consists of wastewater and tailings containing mercury and other hazardous contaminants. Mining wastewater has a highly dependent composition on the type of ore being mined and chemicals in mineral extraction (Malmekina, 2020). The waste is immediately disposed of in a reservoir with a layer of soil without any treatment. Meanwhile, gold treatment continues as well as the resulting waste will continue to increase. Gold treatment was carried out on the riverbank near the resident's houses. If the intensity of rain is high and the wastewater exceeds its volume capacity, the wastewater in the reservoir will overflow. This can harm the environment and the living things around it. Therefore, wastewater must be treated first before being discharged and flowed into water bodies until it is below the permitted quality standards. Wastewater treatment in this study used the electrocoagulation method with a batch reactor.

Heavy metals in wastewater can be reduced using chemical treatment with the coagulation process, absorption, and ion exchange; physically chemically by electrocoagulation and solidification processes; and biologically by phytoremediation and bioremediation processes (Asrifah et al., 2020; Mamelkina et al., 2017). Many researchers have used different methods to remove heavy metals from other wastewaters, one of which is electrochemical treatments that contain electrocoagulation, elector-floatation, and electrodeposition process (Azimi et al., 2016). Electrocoagulation is one of the electrochemical water treatment methods in which the anode releases an active coagulant in the form of metal ions into the solution. While at the cathode, there is an electrolytic reaction in releasing hydrogen gas (Mamelkina et al., 2019; Touahria et al., 2016). The function of electrocoagulation in the process of destabilizing suspensions, emulsions, and solutions containing contaminants by passing an electric current through the water to form clumps that loosen easily and result in neutralization of negative surface charges (Shim et al., 2014). According to the research from

Ingelsson et al. (2020), one of the purposes of electrocoagulation treatment technology is for a sustainable alternative in economics and the environment. Another advantage of electrocoagulation treatment is its formation of a stable floc which can be separated by filtration. The flotation process which produces gas bubbles can remove pollutants using flotation. Electrocoagulation devices have fewer units and thus have lower maintenance costs (Ribeiro et al., 2019).

In the electrocoagulation unit, there are metal sheets arranged in pairs or called electrodes. One side is called the anode, and the other is the cathode. Based on the research from Gilhotra et al. (2018), stainless steel can also be used as electrodes in the electrocoagulation process and, in that case, are used for arsenic removal. Electrocoagulation uses the principle of electrochemistry, where the cathode will lose electrons or be oxidized, while water will gain electrons, thus making wastewater better after being treated (Hakizimana et al., 2017). Electrodes are usually made of aluminium, iron, or a little bit of stainless because these metals are cheap, easy to obtain, effectively proven, and non-toxic (Hernaningsih, 2016). The electrode is a device for delivering electric current into wastewater. The electrodes in this electrocoagulation process use aluminium. Besides that, electrocoagulation treatment can effectively remove a wide range of contaminants and convenient in operation because of the cost-effectiveness, less sludge generation, environmental compatibility, and safe in the process (Babu et al., 2020). Although wastewater treatment is a stable engineering science, combining, simplifying, and centralizing the process is a new experience and opportunity in developing countries. The purpose of this study was to determine the efficiency value and optimal conditions by reducing the content of suspended solids (TSS), copper (Cu), and mercury (Hg) in gold wastewater treatment based on the influence of time and voltage in the electrocoagulation process.

Methods

This research was conducted on a laboratory scale using original gold wastewater treatment from traditional gold mining in Kulon Progo Regency. In this study, the introduction treatment stage was carried out, aiming to determine the effective time that can be used to carry out the electrocoagulation process. The time variations used were 10 minutes, 15 minutes, and 20 minutes. The voltage used is 6 volts (Asrifah, 2020). The principal method of electrocoagulation is showed in **Fig. 1.** The test parameters used in the pretreatment were EC and Turbidity. The purpose of this measurement is to determine the initial condition of the wastewater.

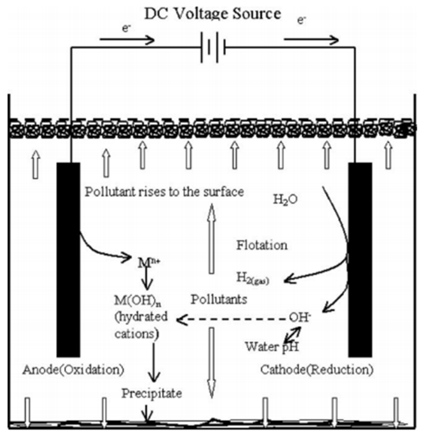

Figure 1. Schematic diagram of Electrocoagulation (Mollah, 2004)

The research flow diagram can be seen in **Fig. 2.** Then the electrocoagulation process was carried out with a batch reactor using a 1000 mL volume measuring cup and electrodes in the form of a pair of plates (anode and cathode) made of aluminium with a size of 40 mm x 30 mm (length x width). The electrodes are placed in the middle of the reactor, with a distance between the electrodes is 40 mm. Then connect the electrodes by flowing DC (Direct Current) electric current. The main thing in this research is the variation of contact time and mains voltage. While the variation of the voltage used is 4.5 volts, 6 volts, and 7.5 volts with the best time selection is 20 minutes based on the introduction treatment.

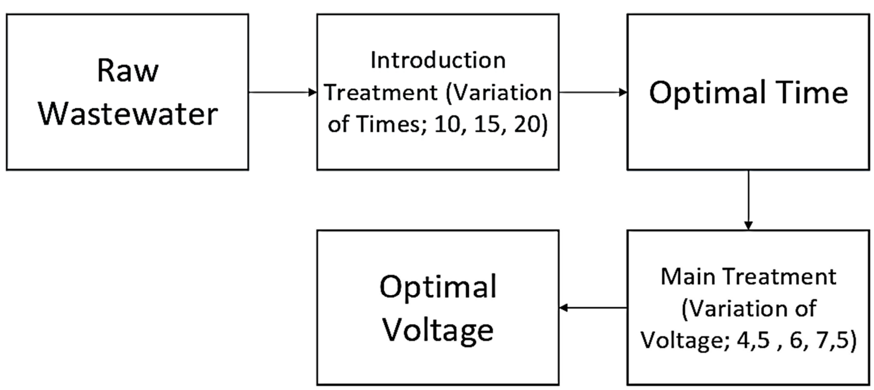

Figure 2. Research Flow Diagram

The test results after electrocoagulation treatment were calculated the removal efficiency of TSS, Cu, and Hg parameters using the following formula:

$$CR(\%) = \frac{C_0 - C}{C_0} \; x \; 100\% \qquad (1)$$

Before electrocoagulation treatment, the initial test results were compared with the Minister of Environment Decree No. 202 of 2004 concerning Wastewater Quality Standards for Gold and or Copper Mining Business and or Activities. After testing in the laboratory, the gold washing wastewater process contaminant has various parameters that reach a higher level above quality standard. It means that the gold washing wastewater needs treatment before being discharged into the environment.

The wastewater treated will be checked at the level of each parameter using Government Regulation of Indonesia Republic No. 82 of 2001 class 4 concerning Management of Water Quality and Water Pollution Control. The results of the efficiency calculations are analyzed and graphed. Class 4 water quality standards are intended to irrigate plants and/or other designation that require the same water quality. The parameters, standard threshold, and test method can be seen in **Table 1.**

Table 1. Water Quality Standard and Test Method

Parameter	Units	Quality Standard	Test Method
Total Suspended Solid (TSS)	mg/L	400	SNI 6989.3-2019
Copper (Cu)	mg/L	0,2	SNI 6989.6-2009
Mercury (Hg)	mg/L	0,005	Mercury Analyzer
Electric Conductivity (EC)	mS/cm	-	Electricity Meter
Turbidity	NTU	-	Turbidity Meter

Result and Discussion

The wastewater of gold mining before electrocoagulation treatment obtained very high TSS and Hg yields. The results of the TSS parameter test were 5863 mg/L, and the Hg parameter was 4.47 mg/L. Compared with the Minister of Environment Decree No. 202 of 2004 concerning Wastewater Quality Standards for Gold and or Copper Mining Business and or Activities, the test results for TSS and Hg parameters are far above the safe threshold. Based on these results, it is necessary to conduct electrocoagulation treatment to reduce levels of pollutant parameters before they are discharged and flowed into the environment. This is to anticipate the bad impacts caused. The result of the Cu parameter test was 0.07 mg/L. These results are below the applicable quality standard threshold. Copper is a dangerous heavy metal and can pollute the environment by accumulating living things around it. Therefore, treatment must still be done to reduce levels of Cu. The results of measurements of gold processing wastewater before electrocoagulation treatment can be seen in **Table 2.**

Table 2. The Initial Test Result Before Treatment

Parameter	Units	Quality Standard	Test Method	Result
TSS	mg/L	400	SNI 6989.3-2019	5863
Cu	mg/L	0.2	SNI 6989.6-2009	0.07
Hg	mg/L	0.005	Mercury Analyzer	4.47
EC	mS/cm	-	Electricity Meter	2.8/2.87
Turbidity	NTU	-	Turbidity Meter	>1000

As shown in the table above, EC and Turbidity parameters are also tested as initial waste, namely at the Introduction Treatment stage. After testing, the effective time of testing was 20 minutes, with the EC value increasing to 2.76/2.89 mS/cm and the turbidity to 96/167 NTU. The EC value increases after introducing the treatment because, during the electrocoagulation process, the ions are broken down to decompose the waste so that the EC value is higher. Meanwhile, the turbidity value will decrease because the decomposed waste will settle, thus reducing the turbidity value. This turbidity value indicates the number of suspended solids and gas bubbles generated during electrocoagulation (Niazmand et al., 2020). After the introduction of the treatment, wastewater will be treated as the primary treatment. The result can be seen in **Table 3.**

Table 3. Result of Introduction Treatment

Time (minutes)	Before		After	
	EC (mS/cm)	Turbidity (NTU)	EC (mS/cm)	Turbidity (NTU)
10	2.8/2.87	>1000	2.76/2.89	178/134
15	2.8/2.87	>1000	2.83/2.92	123/118
20	2.8/2.87	>1000	2.98/2.91	96/167

Electrocoagulation treatment with voltage variations of 4.5 volts, 6 volts, 7.5 volts, and constant variations, which is contact time of 10 minutes on pollutants in gold processing wastewater decreased. The parameters measured after treatment were TSS, Cu, and Hg. Each parameter shows a different result. The biggest decrease occurred in TSS and Hg parameters. Based on the Minister of Environment Decree No. 202 of 2004 concerning Wastewater Quality Standards for Gold and or Copper Mining Businesses and or Activities, TSS parameters before treatment shows a value above the quality standard threshold and after treatment becomes the quality standard threshold according to Government Regulation of Indonesia Republic No. 82 of 2001 class 4 concerning Water Quality Management and Water Pollution Control.

Meanwhile, the results of the Cu parameter after treatment were still below the quality standard threshold. Furthermore, for the Hg parameter, the results after treatment were still above the quality standard threshold. Based on the test results of the three parameters after treatment, the wastewater still has to be processed to a safe threshold for disposal into the environment. The test results after electrocoagulation treatment and inefficiency values can be seen in **Table 4.**

Table 4. Result of Wastewater Treatment using Electrocoagulation

Voltage (Volt)	Time (minutes)	TSS (mg/L)	Cu (mg/L)	Hg (mg/L)	TSS Removal (%)	Cu Removal (%)	Hg Removal (%)
4,5	20	133	0.04	0.0466	97.73	42.85	98.95
6	20	147	0.003	0.0467	97.49	95.71	98.95
7,5	20	387	0.02	0.0637	93.39	71.42	98.57

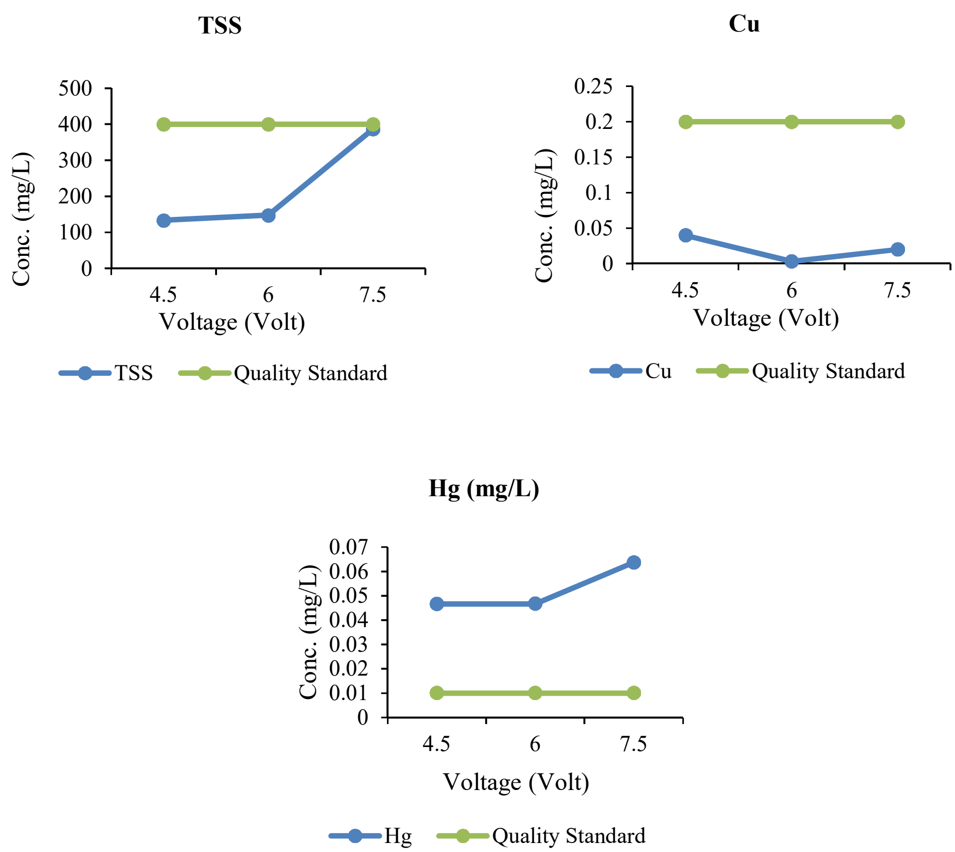

Figure 3. The relationship between treatment results with the amount of voltage and processing time 20 minutes at a plate distance of 4 cm.

Based on the calculation of removal efficiency results, different results are obtained for each voltage value. The efficiency value of the TSS parameter obtained the highest result of 97.73% at 4.5 volts. The efficiency value of the Cu parameter obtained the highest result of 95.71% found at a voltage of 6 volts. The efficiency value of the Hg parameter obtained the highest result of 98.95% found at 4.5 volts and 6 volts. Electrocoagulation treatment in reducing pollutant levels in optimal conditions is found at a voltage of 6 volts from all parameters, including TSS (97.49%), Cu (95.71%), and Hg (98.95%). Even though the Hg efficiency reaches 98%, the Hg content in the wastewater is still above the initial standard, so further processing is required. These results indicate the high efficiency of free heavy metal removal using electrocoagulation with aluminium electrodes. Mercury (Hg) is a heavy metal that is easy to precipitate due to its density. The reduction and oxidation processes in the electrocoagulation process lead to changes in plate weight, namely the initial weight of 1059 mg to 1106 mg and 1051 to 959 mg. Electrode plate affects the electrocoagulation process. This is related to the reactions that occur at each electrode used (Mulyani et al., 2017).

Conclusion

Wastewater treatment from the gold amalgamation process using the batch reactor electrocoagulation method obtained optimal results at a voltage of 6 volts. The values of the three parameters TSS, Cu, and Hg, were obtained at 97.49%, 95.71%, and 98.95%. Wastewater after electrocoagulation treatment still has to be treated to the safe threshold for disposal into the environment because Hg levels are still obtained above the quality standard threshold according to Government Regulation of Indonesia Republic No. 82 of 2001 class 4 concerning Management of Water Quality and Water Pollution Control.

Acknowledgements

Thank you to LPPM UPN "Veteran" Yogyakarta for their support for this research grant with number B/105/UN.62/PT/VII/2020 so that this research can be carried out properly. And also thanks to all those who involved, either directly or indirectly in this research. Hopefully this research can be useful both for the academic community, practitioner, government, or the local community.

References

Asrifah, RR D., (2020). TSS, Cu, and Hg Removal With Electrocoagulation Method for Gold Mine Wastewater, 2th ICEMINE, Yogyakarta, AIP Publishing. https://doi.org/10.1063/5.0010499

Asrifah, R.D., Anasstasia, T.T., Aurilia, M.F., Utama, V.F., Wulandari, D., Widhiananto, P.A., & Wibowo, B.Y. (2020). The Effect of Flow Rate Discharge on TDS, pH, TSS, and Cu in Electrocoagulation with Continuous Reactors. In *Proceeding of LPPM UPN "Veteran" Yogyakarta Conference Series-Engineering and Science Series*, 1(1), 737-746. https://doi.org/10.31098/ess.v1i1.171

Azimi, A., Azari, A., Rezakazemi, M., & Ansarpour, M. (2017). Removal of Heavy Metals from Industrial Wastewaters: A Review. *ChemBioEng Reviews*, 4(1), 37-59. https://doi.org/10.1002/cben.201600010

Babu, D.S., Anantha Singh, T. S., Nidheesh, P. V., & Suresh Kumar, M. (2020). Industrial Wastewater Treatment by Electrocoagulation

Process. *Separation Science and Technology*, *55*(17), 3195-3227. https://doi.org/10.1080/01496395.2019.1671866.

Bazrafshan, E., Mohammadi, L., Ansari-Moghaddam, A., & Mahvi, A.H. (2015). Heavy Metals Removal from Aqueous Environments by Electrocoagulation Process– A Systematic Review. *J Environ Health Sci Engineer*, 13(74). https://doi.org/10.1186/s40201-015-0233-8.

Esdaile, L. J., & Chalker, J. M. (2018). The Mercury Problem in Artisanal and Small-Scale Gold Mining. *Chemistry-A European Journal*, 24(27), 6905-6916. https://doi.org/10.1002/chem.201704840.

Gilhotra, V., Das, L., Sharma, A., Kang T.S., Singh, P., Dhuria, R.S., & Bhatti, M.S. (2018). Electrocoagulation Technology for High Strength Arsenic Wastewater: Process Optimization and Mechanistic Study. *Journal of Cleaner Production*, 198, 693-703. https://doi.org/10.1016/j.jclepro.2018.07.023.

Hakizimana, J. N., Gourich, B., Chafi, M., Stiriba, Y., Vial, C., Drogui, P., & Naja, J. (2017). Electrocoagulation Process in Water Treatment: A Review of Electrocoagulation Modeling Approaches. *Desalination*, 404, 1-21.

Hernaningsih, T. (2016). Tinjauan Teknologi Pengolahan Air Limbah Industri dengan Proses Elektrokoagulasi. Badan Pengkajian dan Penerapan Teknologi. *Jurnal Rekayasa Lingkungan*, 9(1), 31-36. https://doi.org/10.29122/jrl.v9i1.1988

Ingelsson, M., Yasri, N., & Roberts, E.P.L. (2020). Electrode Passivation, Faradaic Efficiency, and Performance Enhancement Strategies in Electrocoagulation—A Review. *Water Research*, 187. https://doi.org/10.1016/j.watres.2020.116433.

Keputusan Menteri Negara Lingkungan Hidup No. 202 Tahun 2004 tentang Baku Mutu Air Limbah bagi Usaha dan atau Kegiatan Pertambangan Bijih Emas dan atau Tembaga

Mamelkina, M. (2020). Treatment of Mining Waters by Electrocoagulation. *Lappeenranta-Lahti University of Technology LUT: LUT University Press*.

Mamelkina, M. A., Cotillas, S., Lacasa, E., Sáez, C., Tuunila, R., Sillanpää, M., & Rodrigo, M. A. (2017). Removal of Sulfate from Mining Waters by Electrocoagulation. *Separation and Purification Technology,* 182, 87-93.

Mamelkina, M. A., Tuunila, R., Sillänpää, M., & Häkkinen, A. (2019). Systematic Study on Sulfate Removal from Mining Waters by Electrocoagulation. *Separation and Purification Technology,* 216, 43-50.

Mollah, M., Morkovsky, P., Gomes, J., Kesmez, M., Parga, J., & Cocke, D. (2004). Fundamentals, present and future perspectives of electrocoagulation. Journal of Hazardous Materials, 114(1-3), 199–210. doi:10.1016/j.jhazmat.2004.08.009

Mulyani, I.M., Prayitno, M.F. and Kusumastuti, E., (2017). Pengaruh Jenis Plat Elektroda pada Proses Elektrokoagulasi untuk Menurunkan Kadar Thorium dalam Limbah Hasil Pengolahan Logam Tanah Jarang. *Jurnal Pusat Sains dan Teknologi Akselerator*.

Niazmand, R., Jahani, M., Sabbagh, F., & Rezania, S. (2020). Optimization of electrocoagulation conditions for the purification of table olive debittering wastewater using response surface methodology. *Water (Switzerland)*, *12*(6). https://doi.org/10.3390/W12061687

Peraturan Pemerintah Republik Indonesia No. 82 Tahun 2001 kelas 4 tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air

Ribeiro, T. d. S., Grossi, C. D., Merma, A. G., dos Santos, B. F., & Torem, M. L. (2019). Removal of Boron from Mining Wastewaters by Electrocoagulation Method: Modelling Experimental Data Using Artificial Neural Networks. *Minerals Engineering*, 131, 8-13.

Touahria, S., Hazourli, S., Touahria, K., Eulmi, A., & Aitbara, A. (2016). Clarification of Industrial Mining Wastewater Using Electrocoagulation. *International Journal of Electrochemical Science,* 11(7), 5710–5723. https://doi.org/10.20964/2016.07.51

Shim, H. Y., Lee, K. S., Lee, D. S., Jeon, D. S., Park, M. S., Shin, J. S., … Chung, D. Y. (2014). Application of Electrocoagulation and Electrolysis on the Precipitation of Heavy Metals and Particulate Solids in Washwater from the Soil Washing. *Journal of Agricultural Chemistry and Environment*, *03*(04), 130–138. https://doi.org/10.4236/jacen.2014.34015