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ORIGINAL ARTICLE

Car service station wastewater treatment using electrocoagulation technology

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Abstract
Efforts to prevent environmental pollution due to wastewater produced by car service station can be carried out using electrocoagulation technology. The purpose of this study was to analyze the effectiveness of electrocoagulation technology for treating car service station wastewater. This research is an experimental study conducted in a car workshop at PT Jaya Indah Motor Jambi City. The electrocoagulation machine used an Automatic PLC System WWTP 350 L with total dimensions of 1200 x 1200 x1700 mm, power 380Volt/20A (Stanby Steady State). Researchers compared the research data with the wastewater quality standards contained in the Ministry of Environment and Forestry Regulation No. P.68.MENLHK/Setjen/KUM/.I/8/2016. The results showed that the final value of the parameters of the treatment results using electrocoagulation had met the wastewater quality standards (TSS 19.75 mg/L; pH 6.92; BOD 8.46 mg/L; COD 25.07 mg/L; oil and fat 2.75 mg/L; and ammonia 7.12 mg/L).

Keywords: wastewater, car service station, electrocoagulation

Introduction

Sewage is a major problem due to high urbanization, industrialization, population growth, migration, and economic development.[1] Wastewater is a business and/or other activity that negatively impacts the environment. Wastewater can come from households (households) or industries. Wastewater is generated during all industrial production activities. Industrial wastewater is the residual process or residue of industrial activities in liquid form, and its existence in a certain place is undesirable from an environmental point of view because it has no economic value and tends to be thrown away.[2–4] Wastewater produced by motor vehicle washing businesses that are not treated before being discharged into the environment has a negative impact on the environment. Every business can dispose of waste into the environment, but it must be treated first until it meets the established wastewater quality standards. Motor vehicle washing liquid waste has a cloudy color and contains detergents (surfactants) and COD (Chemical Oxygen Demand) in it. The content of surfactants and the high oil content in water can reduce water quality because detergents and oils are difficult to decompose.[5–9]

There are several processes for processing motor vehicle washing liquid waste, including phytoremediation, filtration, coagulation, flocculation, and electrocoagulation several other methods.[6,10–12] Coagulation is the process of adding coagulants or chemicals at a certain dose to the solution, and is a process that depends on chemicals continuously.[13,14] One type of liquid waste treatment that does not use chemicals and is more environmentally friendly is electrocoagulation. The electrocoagulation method can reduce pollutants due to the release of natural coagulants from the electrodes owing to the electrolysis process. This is the principle of adding coagulants using chemicals. One type of coagulation is the

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electrocoagulation method, which has many advantages including this method involves simple equipment, short reaction times, and relatively low maintenance costs.[15–18]

PT Jaya Indah Motor is licensed to serve the business activities of sales, after-sales service/car service station, and supply of Suzuki brand car parts located on Jl. Hos, Cokroaminoto No. 01 Rt. 07, Selamat Village, Danau Sipin District, Jambi City, Jambi Province. In the operational activities of the workshop, PT Jaya Indah Motor produced wastewater from the activities of the Workshop Service of car vehicles. The waste generated includes domestic wastewater, wastewater from machine and workshop maintenance activities such as washing water from mechanical handwork in the sink, washing vehicles after service, and others that cannot be directly discharged into water bodies (drainage) without further treatment. Based on these conditions, the company's wastewater treatment activities need to be carried out to avoid damaging the environment.

Wastewater treatment at PT Jaya Indah Motor still uses an anaerobic aerobic installation system, which has shortcomings in terms of high wastewater parameters. A preliminary study conducted by the researchers found that in December 2022, the results of wastewater treatment at PT Jaya Indah Motor were the value of the TSS parameter in December 89.77 mg/L. The pH was below average in December 3.56. The BOD parameter was still below the quality standard of 7.57 mg/L (December). COD parameter 30.65 mg/L (December). Oil and grease parameter 6.97 mg/L (December). Ammoniac parameter 10.56 mg/L (December). Total coliform parameter 4200/100 L (May). These results are still in the category of exceeding the quality standard of 3000/100 L. This study aims to analyze the effectiveness and efficiency of a wastewater management system and determine the characteristics of wastewater produced or treated through electrocoagulation techniques to reduce wastewater pollutant levels from car service station activities, starting from the process of generating wastewater until the wastewater is treated. Therefore, it is expected that the final results of wastewater treatment are in accordance with the quality standards and applicable laws and regulations, and do not pollute the surrounding environment.

Method

This was an experimental study of car service station wastewater. The treatment of car service station wastewater was carried out using the electrocoagulation method. This processing technique serves to set aside the pollution parameters of workshop wastewater. The results for the processed water were expected to meet the wastewater quality standards of the Ministry of Environment and Forestry Regulation with number: P.68.MENLHK/Setjen/KUM/.I/8/2016.

The experimental method used was to test wastewater parameters including TSS, pH, BOD, COD, oil and fat, ammonia, and total coliforms generated from car repair shop activities. The electro-coagulation machine used an Automatic PLC System WWTP 350 L with total dimensions of 1200 x 1200 x1700 mm, power 380Volt/20A (Stanby Steady State) (Figure 1). Greastrap with a capacity of 0.48 m^3 serves as a filter / filter fat, oil, oil, residual waste carried by sewerage. Storage basin 1 (2 m^3) serves as a neutralization basin and water storage basin from waste that has been filtered from the greastrap, whereas storage basin 2 (2 m^3) serves as a storage basin/overflow of wastewater from storage basin 1. Wastewater Treatment Plant (WWTP) Planning Unit with a capacity of 2.25 m^3 (0.75x1m^3 / day) serves as a waste treatment tool to obtain discharge water that complies with quality standards. The result storage tub 1 to result storage tub 3 serves to accommodate the wastewater resulting from the treatment of the WWTP unit. The workflow of the 350 L WWTP consists of several work processes.

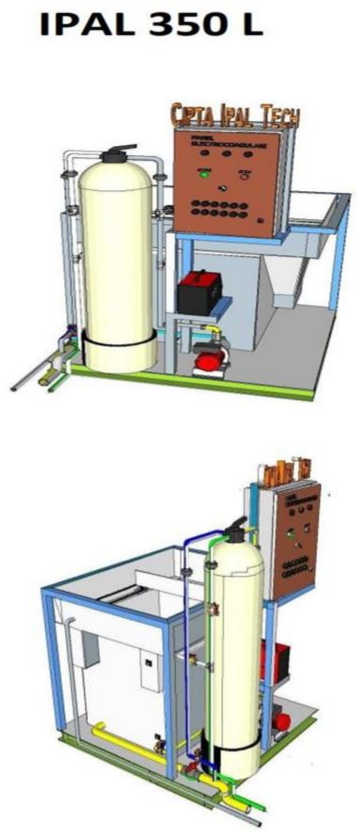

Figure 1. Automatic PLC System 350 L

Wastewater from the kitchen is collected in Tub 1 (Initial Tub) for further processing in the aeration system to minimize the presence of pollutants contained in the water in Tube 1 and dissolve oxygen levels directly in the water. The capacity of Tub 1 was 2 m^3, which functions as a collection of process wastewater from the kitchen area. Furthermore, when a capacity of 2 m^3 was fulfilled, it was channeled through a chopstick pump to the WWTP Unit according to the existing capacity, which was 1 m^3 × 3 processes/day. The water in the WWTP basin is then processed with an electrocoagulation waste treatment system to break down or remove metal ions and particles in the water to achieve final discharge results in accordance with quality standards. The electrocoagulation process lasted 45 min. The water particles will be in a lower position, and the sludge particles will be in the upper position of the water surface. Sludge particles are disposed of with a mechanical system (scrap) to the sludge storage basin, collected in a plastic container, and disposed of in a landfill. After the sludge scraping process, the wastewater was channeled to filter tub. Wastewater from the electrocoagulation process goes through a filtering process in filter tubes 1 and 2 and is then channeled to the final product storage basin. Filter tubes 1 and 2 contained gravel, a sand filter, and carbon. The water produced in the final reservoir was in accordance with the quality standards. Water was collected from four reservoirs with a capacity of 3 m^3 each. Water can also be used for purposes such as watering plants and washing cars. The efficiency of the WWTP was calculated by subtracting the inlet and outlet TSS and then dividing by the inlet TSS and multiplying by 100%.

Results

From the records of the average water flow at the inlet and outlet basins, generated from several wastewater generation sources, it was found that the average wastewater discharge in May was 3.5 m^3/day (inlet) and 3.3 m^3/day (outlet). In June, the average wastewater discharge at the inlet and outlet were both 3.5 m^3/day. The average trend of wastewater flow entering through the inlet into the WWTP machine is still in accordance with the design capacity of the WWTP hydraulic load of 3.5 m^3/day. Estimates of water usage and wastewater discharge refer to SNI 03 7065 2005.

Table 1. Details of water usage at PT Jaya Indah Motor Jambi City
(assuming the number of employees and visitors/consumers is 320 people/day)

Water source	Water usage	Capacity of water use	Estimated wastewater discharge*	
		(m^3/day)	%	(m^3/days)
PDAM	Employee and visitor toilets	0,20	80	0,16
	Workshop (car wash, sink and mechanical toilet)	3,17	80	2,536
	Pantry, canteen	0,13	80	0,104
Total		3.5		2.8

Table 2. Test results before and after electrocoagulation

Parameter	March		April		May		Effluent Quality Standard*
	Before	After	Before	After	Before	After	
TSS (mg/L)	42,40	19,43	60,67	10,75	87,75	19,75	30
pH	4,39	7,61	7,14	6,08	4,61	6,92	6-9
BOD (mg/L)	60,23	2,88	29,31	10,89	8,46	8,46	30
COD (mg/L)	216,85	9,42	147,50	18,09	25,07	25,07	100
Oil and grease (mg/L)	2,79	4,91	2,46	3,24	2,75	2,75	5
Ammoniac (mg/L)	8,42	2,80	0,7446	2,96	7,12	7,12	10
Total coliform (number/100 mL)	2800	2200	3500	2800	3100	2700	3000
WWTP efficiency (%)	54.17		82.28		65.24		

Source: Report of Environmental Laboratory Testing Results of PT Jambi Lestari International.
*Minister of Environment and Forestry Regulation No. P.68: P.68.MENLHK/Setjen/KUM/.I/8/2016

Table 2 shows the test results before and after the wastewater treatment. The parameters measured included TSS, pH, BOD, COD, oil and grease, ammonia, and total coliforms. The tests were conducted in March, April, and May. After treatment, there was a decrease in the parameter values of TSS, BOD, COD, oil and grease, and ammonia. However, the pH of the solution increased. Total coliform values changed to normal values. All parameter values measured in May met the effluent quality standards set at 30 mg/L for TSS, 6-9 for pH, 30 mg/L for BOD, 100 mg/L for COD, 5 mg/L for oil and grease, and 10 mg/L for ammonia.

The wastewater treatment results showed a WWTP efficiency of 54.17% in March, 82.28% in April, and 65.24% in May. It can be seen that the operational and maintenance program implemented by the electrocoagulation technique was successful. The WWTP operators always carry out maintenance of facilities and infrastructure at the WWTP, such as periodic flow measurements to monitor incoming and outgoing discharges, draining sludge in the equalization basin periodically every 6 months, draining sludge in the WWTP tank, cleaning the pump in the control basin, making aerobic bacteria suspensions periodically, and draining the bioindicator pond.

Discussion

After using electrocoagulation technology, in three consecutive months, the values of TSS, pH, BOD, COD, oil and grease, ammonia, and total coliform experienced changes that were close to standard/standard values. However, some parameters such as BOD, COD, and oil and fat values are still far from reaching the normal/standard threshold. The total coliform count decreased from the standard value. These results are considered safe because they are below specified wastewater quality standards.

TSS is the amount of solids that are not dissolved in the water (suspended solids).[19] TSS can give rise to sludge sediment and anaerobic conditions in water when sewage is discharged directly into water bodies. In addition, TSS also indicates the amount of organic matter (BOD. COD, TOC, etc.) or inorganic matter. TSS content was strongly related to the brightness of the water. The presence of suspended solids can inhibit the penetration of light into the water.[20] TSS (Total Suspended Solid) is the amount of suspended solids in a solution. TSS is the solid density of the liquid waste. The TSS content in motor vehicle wash wastewater is caused by dust, heavy metal particles, oil, grease, and chemicals contained in detergents. The decrease in the TSS value in wastewater was due to the particles contained in the negatively charged wastewater.[11] The ions produced by the electrode stabilized the particles contained in the wastewater. The anode will produce Al3+ ions, which will bind OH and form the Al(OH)3 compound, and will bind contaminants, while the cathode will produce hydrogen gas, which will lift the floc to the surface, and the floc that has been formed for a long time will increase and settle to the bottom of the electrocoagulation tub.[21] The principle of the work process of reducing the TSS value in the electrocoagulation process is the growth of the floc mass so that the specific gravity of the floc becomes large and causes the flocs to settle.[22] The effect of the electrocoagulation method on the TSS parameter is because the particles contained in wastewater are generally negatively charged. The positive and negative ions produced by the electrode destabilize the particles contained in the waste.

The increase in pH in the electrocoagulation method is due to the reduction reaction occurring at the cathode of the aluminum electrode, where the reduction reaction creates H+ ions and OH- ions that will form water. Voltage really affects the way the pH increases in electrocoagulation, where if the voltage is increased until an increasing number of H + and OH-ions are created at the cathode electrode, then if it continues to be a lot of water is created until the initial pH is acidic, it is also the opposite if the initial pH is basic, then the reduction reaction takes place at the cathode that produces water until the pH is neutral.[23–25] The results obtained are the same as those of previous research by Fadhila et al.[26], which states that pH can be neutralized by the electrocoagulation method, where the initial pH of 0.56 can be neutralised to 4.1 at a voltage of 12 Volts. The increase in pH in the electrocoagulation method is due to the reduction reaction occurring at the cathode of the aluminum electrode, where the reduction reaction creates H + ions and OH- ions that form water.

Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen required by microorganisms to oxidize carbonaceous material (organic matter). If there is sufficient oxygen, biological decay of organic matter in a serobic way can occur until all organic matter is degraded. BOD is used as a marker of contamination in water bodies.[27] A large BOD value (beyond the quality basis) indicates that the water has been contaminated. The decrease in BOD value is caused by positive charges that will absorb negative ions, and negative and positive charges will meet so that there will be a force of attraction between the two ions, resulting in a strong bond and the formation of a coagulant that will form a floc that can reduce organic compounds in wastewater.[28,29] The results of research conducted by Amri et al.[30] state that the electrocoagulation method is effective in reducing BOD parameters with an initial BOD of 513 mg / l obtaining 71.53% BOD removal at a voltage of 12 Volts. It is explained if the voltage affects the metal ionization method at the anode electrode as a determinant of the reaction rate as well as in the electrocoagulation method to reduce BOD parameters, where at the anode electrode the oxidation of aluminum metal takes place as a result, creating Al3 + ions that act as coagulants. The greater the voltage added to the electrocoagulation method, the greater the pollutants that will be bound into flocs that will settle. As a result, the wastewater becomes clearer than before, so that the organic compounds left in the wastewater become more easily degraded by microorganisms.

The COD value was measured to determine the organic matter content of the wastewater. The COD requirement is the total oxygen required to chemically oxidize organic matter. The reduction in organic matter as a result of COD oxidation indirectly indicates the amount of organic matter contained in the water body. High COD levels indicate the amount of pollutants in the waste. COD indicates the amount of oxygen required to oxidize organic matter by chemical means, whether it is biodegradable or non-biodegradable.[31,32] The COD number is always greater than the BOD because COD represents the total amount of organic matter in the water. The ideal BOD or COD ratio for untreated domestic wastewater is 0.3 to 0.8. If the ratio is below 0.3, it means that the wastewater has a toxic part or microorganism acclimatization is needed to stabilize the sewage water before treatment.[33] The results of experiments by Ni'am et al.[34] obtained the results of research on the electrocoagulation method can reduce the COD and TSS content of Textile Liquid Waste obtained the percentage of COD removal of 76% occurred with a voltage of 12 Volts. The decrease in COD was due to the floc created by the bonding of organic compound ions with positive coagulant ions. Molecules in wastewater are created into flocs, and colloidal particles in the waste are binding particles or other compounds contained in the waste; for example, colloidal Al (OH) 3 is positively charged because its surface binds H + ions. Positively charged coagulants absorb negative ions in impurities, such as organic compound compounds, and create flocs that help reduce COD. The decrease in COD value in wastewater is due to the destabilization of organic materials caused by the coagulant and the electric field in the solution during the electrocoagulation process.[35] Furthermore, the bonds between organic material molecules are broken, causing the molecules to be adsorbed by the coagulant floc and settle at the bottom of the electrocoagulation basin.

Based on their physical properties, oils and fats are compounds that are insoluble in water but can dissolve in solvents with weak polarity or in nonpolar solvents. Oil has a smaller weight than water; as a result, it creates a thin layer on the surface of the water. This situation can reduce the oxygen concentration in water because the fixation of acidic substances is freely retained. Oil and grease must be separated from wastewater before they reach the treatment section because they can disrupt the biological treatment method and block the pipes or filters used.[36] It can be observed that the oil and grease contents continue to decrease when the voltage in the method used is greater. Similarly, the aroma of water (odor) decreases from very pungent to less pungent levels. In this case, odor detection was attempted by smelling the changes in odor without using a measuring instrument. The decrease in aroma (odor) in water occurs as an effect of the decreasing oil and grease content in water.[37]

Ammonia is a nitrogen compound that converts into NH4 + ions at low pH. Ammonia originates from domestic wastewater and fish feeds. Ammonia also originates from denitrification during wastewater decomposition by microbes under anaerobic conditions.[38,39] Nitrogen is an important component in protein synthesis, and nitrogen concentration data are needed to evaluate the possibility of wastewater treatment by biological processes. If nitrogen is insufficient, nitrogen addition is required to treat wastewater. However, to control algal growth in water bodies, nitrogen removal from the treatment effluent is required before discharge.[40,41] Water quality with microbiological parameters can be used to determine the presence of bacteria, viruses, and parasites. The bacteria used as indicators were coliform bacteria. Coliform bacteria are non-sporic organisms that are motile or non-motile, rod-shaped, and able to ferment lactose to produce acid and gas at a temperature of 37 °C in a 48-hour incubation time.[42,43] The management and maintenance of WWTP greatly affect their ability to reduce total coliform content. The high total coliform in the effluent can be caused by the deposition of fecal sludge in the outlet basin that is never drained.[44,45]

Conclusion

The results showed that the values of TSS, pH, BOD, COD, oil and fat, ammonia, and total coliforms experienced changes that were close to standard values after treatment using electrocoagulation techniques. However, some items such as BOD, COD, and oil and fat values are still far from reaching the normal/standard threshold. However, the total coliform count decreased from the standard value. These results are considered safe because they are below the specified wastewater quality standards. Full support from management is needed for the provision of special funds/budget for wastewater management, support for the needs of waste management personnel, such as periodic health checks for waste management officers, support for the repair and procurement of infrastructure, and regular monitoring.

References

1. Turok I, McGranahan G. Urbanization and economic growth: the arguments and evidence for Africa and Asia. Environ Urban. 2013 Oct 28;25(2):465–82.
2. Pratap B, Kumar S, Nand S, Azad I, Bharagava RN, Romanholo Ferreira LF, et al. Wastewater generation and treatment by various eco-friendly technologies: Possible health hazards and further reuse for environmental safety. Chemosphere. 2023 Feb;313:137547.
3. Arumugam N, Chelliapan S, Kamyab H, Thirugnana S, Othman N, Nasri N. Treatment of Wastewater Using Seaweed: A Review. Int J Environ Res Public Health. 2018 Dec 13;15(12):2851.
4. Obaideen K, Shehata N, Sayed ET, Abdelkareem MA, Mahmoud MS, Olabi AG. The role of wastewater treatment in achieving sustainable development goals (SDGs) and sustainability guideline. Energy Nexus. 2022 Sep;7:100112.
5. Bhatti ZA, Mahmood Q, Raja IA, Malik AH, Khan MS, Wu D. Chemical oxidation of carwash industry wastewater as an effort to decrease water pollution. Phys Chem Earth, Parts A/B/C. 2011 Jan;36(9–11):465–9.
6. Espinoza-Montero PJ, Martínez-Huitle CA, Loor-Urgilés LD. Technologies employed for carwash wastewater recovery. J Clean Prod. 2023 May;401:136722.
7. Hu CY, Kuan WH, Ke LW, Wu JM. A Study of Car Wash Wastewater Treatment by Cyclo-Flow Filtration. Water. 2022 May 5;14(9):1476.
8. Kuan WH, Hu CY, Ke LW, Wu JM. A Review of On-Site Carwash Wastewater Treatment. Sustainability. 2022 May 10;14(10):5764.
9. Monney I, Donkor EA, Buamah R. Clean vehicles, polluted waters: empirical estimates of water consumption and pollution loads of the carwash industry. Heliyon. 2020 May;6(5):e03952.
10. Ahmad J, Umar M, Karim SS, Amaduddin M, Akhtar K, Shah F, et al. Design of a car wash waste water treatment process for local car wash stations. J Pakistan Inst Chem Eng. 2017 Jan 1;45(2):83–95.
11. Hashim NH, Zayadi N. Pollutants Characterization of Car Wash Wastewater. Abd Rahman N, Mohd Jaini Z, Yunus R, Rahmat SN, editors. MATEC Web Conf. 2016 Apr 1;47:05008.
12. Salini PJ, Madhu G, Pawels R. Treatment of vehicle wash wastewater by Fenton process and its recycling. Mater Today Proc. 2022;57:2444–51.
13. Lippi M, Ley MBRG, Mendez GP, Junior RAFC. State of art of landfill leachate treatment: literature review and critical evaluation. Ciência e Nat. 2018;e78–e78.
14. El-taweel RM, Mohamed N, Alrefaey KA, Husien S, Abdel-Aziz AB, Salim AI, et al. A review of coagulation explaining its definition, mechanism, coagulant types, and optimization models; RSM, and ANN. Curr Res Green Sustain Chem. 2023;6:100358.
15. Khaldi S, Lounici H, Drouiche M, Drouiche N. Treatment of ointment pharmaceutical wastewater by electrocoagulation process. Desalin Water Treat. 2017;71:152–8.
16. Can OT. COD removal from fruit-juice production wastewater by electrooxidation electrocoagulation and electro-Fenton processes. Desalin Water Treat. 2014 Jan 2;52(1–3):65–73.
17. Gzar HA, Jasim NA, Kseer KM. Electrocoagulation and Chemical Coagulation for Treatment of Al-Kut Textile Wastewater: A Comparative Study. Period Eng Nat Sci. 2020;8(3):1580–90.
18. Włodarczyk-Makuła M, Myszograj S, Włodarczyk M. Removal of Organic Micro-Pollutants from Wastewater in Electrochemical Processes—Review. Energies. 2023 Jul 25;16(15):5591.
19. Ismail AF, Khulbe KC, Matsuura T. RO Membrane Fouling. In: Reverse Osmosis. Elsevier; 2019. p. 189–220.
20. Gazali I, Widiatmono BR, Wirosoedarmo R. Evaluasi Dampak Pembuangan Limbah Cair Pabrik Kertas Terhadap Kualitas Air Sungai Klinter Kabupaten Nganjuk. J Keteknikan Perair Trop dan Biosist. 2013;1(2):1–8.
21. Wulandari M, Setyorini IDW, Handayani AM, Ariani IK, Zulfikar A. Performance of Electrocoagulation Process for Microplastic Fibre Removal from Laundry Wastewater. J Presipitasi Media Komun dan Pengemb Tek Lingkung. 2022;19(1):34–43.
22. Liu Y, Zhang X, Jiang W, Wu M, Li Z. Comprehensive review of floc growth and structure using electrocoagulation: Characterization, measurement, and influencing factors. Chem Eng J. 2021 Aug;417:129310.
23. Syaichurrozi I, Sarto S, Sediawan WB, Hidayat M. Effect of Current and Initial pH on Electrocoagulation in Treating the Distillery Spent Wash with Very High Pollutant Content. Water. 2020 Dec 23;13(1):11.
24. Weiss SF, Christensen ML, Jørgensen MK. Mechanisms behind pH changes during electrocoagulation. AIChE J. 2021 Nov

5;67(11).
25. Erkan HS, Turan NB, Engin GÖ. Membrane Bioreactors for Wastewater Treatment. In 2018. p. 151–200.
26. Fadhila RY, Ihsan I, Sahara S. Pengolahan Limbah Laboratorium Kimia Dengan Kombinasi Metode Elektrokoagulasi, Filtrasi dan Pengikatan Logam Dengan Asam Jawa. J Fis dan Ter. 2018 Jun 30;5(1 SE-Artikel):72–81.
27. American Public Health Association, American Water Works Association, Water Pollution Control Federation. Standard Methods for the Examination of Water and Wastewater. 20th ed. 1999.
28. Water Science School. Biochemical Oxygen Demand (BOD) and Water [Internet]. 2018. Available from: https://www.usgs.gov/special-topics/water-science-school/science/biochemical-oxygen-demand-bod-and-water
29. Shakya BM, Nakamura T, Shrestha S, Pathak S, Nishida K, Malla R. Tap Water Quality Degradation in an Intermittent Water Supply Area. Water, Air, Soil Pollut. 2022 Mar 25;233(3):81.
30. Amri I, Destinefa P, Zultiniar Z. Pengolahan limbah cair tahu menjadi air bersih dengan metode elektrokoagulasi secara kontinyu. Chempublish J. 2020 May 31;5(1):57–67.
31. Aguilar-Torrejón JA, Balderas-Hernández P, Roa-Morales G, Barrera-Díaz CE, Rodríguez-Torres I, Torres-Blancas T. Relationship, importance, and development of analytical techniques: COD, BOD, and, TOC in water—An overview through time. SN Appl Sci. 2023 Apr 27;5(4):118.
32. Hu Z, Grasso D. Water Analysis: Chemical Oxygen Demand. In: Encyclopedia of Analytical Science. Elsevier; 2005. p. 325–30.
33. Srinivas T. Environmental Biotechnology. New Age International; 2008.
34. Ni'am AC, Caroline J, Afandi M. H. Variasi Jumlah Elektroda Dan Besar Tegangan Dalam Menurunkan Kandungan Cod Dan Tss Limbah Cair Tekstil Dengan Metode Elektrokoagulasi. Al-Ard J Tek Lingkung. 2018;3(1):21–6.
35. Naje AS, Abbas SA. Electrocoagulation Technology in Wastewater Treatment: A Review of Methods and Applications. Civ Environ Res. 2013;3(11):29–42.
36. Kulkarni SJ. An Insight into Oil and Grease Removal from Wastewater from Petroleum and Refinery Industries. Int J Pet Petrochemical Eng. 2016;2(1):12–5.
37. Cheremisinoff NP. Handbook of Water and Wastewater Treatment Technologies. Elsevier Inc; 2002.
38. Wei C, Zhang W. Nitrogen Contribution Rate of Anammox in Different Systems and Its Relationship with Environmental Factors. Water. 2023 Jun 1;15(11):2101.
39. Martens DA. Denitrification. In: Encyclopedia of Soils in the Environment. Elsevier; 2005. p. 378–82.
40. Zhou Y, Zhu Y, Zhu J, Li C, Chen G. A Comprehensive Review on Wastewater Nitrogen Removal and Its Recovery Processes. Int J Environ Res Public Health. 2023 Feb 15;20(4):3429.
41. Rahimi S, Modin O, Mijakovic I. Technologies for biological removal and recovery of nitrogen from wastewater. Biotechnol Adv. 2020 Nov;43:107570.
42. Sulistiyawati I. Kuantitas Total Bakteri Coliform pada Instalasi Pengolahan Limbah Cair Medis Laboratorium Klinik. J Ilm Univ Batanghari Jambi. 2019 Oct 15;19(3):675.
43. Some S, Mondal R, Mitra D, Jain D, Verma D, Das S. Microbial pollution of water with special reference to coliform bacteria and their nexus with environment. Energy Nexus. 2021 Nov;1:100008.
44. Hanum K. Evaluation of WWTP with Activated Sludge Technology Combined with Microorganism Biofilters in IMERI Building. Appl Res Civ Eng Environ. 2021;3(01):29–43.
45. Afifudin, Widyastuti M. Analysis of sanitation system and coliform number in groundwater in Wonosari District, Gunungkidul Regency, Indonesia. IOP Conf Ser Earth Environ Sci. 2023 Aug 1;1233(1):012053.