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EFFECTIVENESS OF ELECTRO-COAGULATION TREATMENT METHOD ON THE PHYSIO-CHEMICAL PARAMETERS AND HEAVY METALS IN RUBBER LATEX WASTEWATER

Fakorede, E. O.[1*] and Adewumi, J. R.[2]

[1]*Department of Civil and Environmental Engineering, Elizade University P.M.B. 002, Ilara-Mokin, Ondo State,*
[2]*Department of Civil Engineering, Federal University of Technology, P.M.B. 704, Akure, Nigeria*
**Corresponding author: Fakoredeben40@gmail.com*
Tel: +2347033120744

ABSTRACT

Electrocoagulation has been employed as a treatment technique for treating various wastewaters. This study focuses on the performance of the electrocoagulation process for the treatment of rubber latex wastewater (RW) using Aluminum-Aluminum (AL-AL) and Aluminum-Carbon (AL-C) electrodes. Rubber latex wastewater (RW) was obtained locally from the plastic industry in Araromi-Obu, Ondo State of Nigeria with an initial concentration of 7.30, 28°C, 65.53mg/L and 785.23mg/L for pH, Temperature, BOD, and COD respectively and subjected to electrocoagulation using (AL-AL) and (AL-C) electrodes. Effects of electrocoagulation time and electrode types were studied and achieved under the following initial conditions of 30V, current density of 15mA, inter-distance electrodes of 1.5cm. The results revealed that this process could reduce the concentration of BOD, COD and Lead in RW. The highest removal efficiencies of 98.74% and 98.47% (COD); 82.02% and 79.12 (BOD); 90% and 83.33% (Lead), were obtained for AL-AL and AL-C electrodes respectively. From this study, it can be concluded that electrocoagulation is effective in the treatment of RW. It is recommended that Rubber producing industries could adopt this treatment method to treat their wastewater rather than disposal into the environment without treatment.

Key words: Aluminum, Carbon, Electrocoagulation, Rubber Latex Wastewater,

INTRODUCTION

Increasing environmental pollution has been an issue of concern in the world (Xiaoyan *et al.,* 2010). This is ascribed to its impact and consequently deterioration in water quality as well as other parts of the environment which results in the alteration of the natural standard due to pollution (Hariraj and Brijesh, 2016). Increase in human daily activities, for example, industrialization has increased the amount of pollution to the present level of great concern. Hazardous conditions like Ozone depletion, green-house effect, and global warming have resulted from the release of toxic vaporous substances into the atmosphere (Ghanim and Ajjam, 2013). Likewise, the improper release of wastewaters into the environment has antagonistically influenced the soil quality, water bodies, and the whole ecosystem (Shakir and Husein, 2009).

Vidal *et al.* (2016) reported that, with fast growth industrialization in the world today, high paces of water utilization in the most recent decade have put inordinate pressure on existing water resources expanding the expense of raw water for industrialization applications. As such, wastewater is a major pollutant source into the environment.

According to Ghanim and Ajjam (2013), industrial wastewater pollutants vary from industry to industry. Rubber industry consume high volumes of water, utilizes chemical compounds and different utilities to produce enormous amounts of wastes and effluent. Release of untreated rubber effluent to waterways brought about water contamination that influenced the human wellbeing. However, they essentially comprise of high chemical oxygen demand (COD), suspended and dissolved solids, biological oxygen demand, oil, color, metals, organic chemicals, e.t.c. (El-Sawy *et al.,* 2013). In view of the negative effect of these pollutants in the environment, the treatment of rubber wastewater pollution turns out to be a vital source of environmental pollution. This is because of the considerable harm caused on the environment by these contaminants (El-Shazly, and Daous, 2013). As such, there is need to treat the wastewater preceding its release to the environment.

Wastewaters can be treated by various techniques. Some of these methods include but not limited to precipitation, coagulation, flocculation, adsorption, filtration, buoyancy, particle trade, turn around assimilation, chlorination, ozonation, and so forth. Chemical substances are mostly utilized for industrial wastewater treatment for the removal of the targeted contaminants.

With a new global trend towards a sustainable development, the industry needs to concentrate on the most effective wastewater cleaner production techniques, and reusing of wastewater. Electrocoagulation is a productive treatment technique for wastewaters treatment. This is on the grounds that it effectively turbidity and diminishes the degree of suspended solids (El-Shazly, and Daous, 2013). Electrocoagulation otherwise called radio recurrence diathermy or short-wave electrolysis is a procedure utilized for wash water treatment, wastewater treatment, industrial processed water, and therapeutic treatment (Elham *et al.,* 2016). The significant favorable circumstances of electrocoagulation over other conventional methods, for example, chemical coagulation and adsorption, are "in situ" reactive agents, and does not produce secondary pollution (Muhammad *et al.* 2011). According to Adejumobi *et al*. (2012) electricity-based electrocoagulation method expels contaminants that are difficult to be evacuated by filtration or other synthetic treatment methods. Some of such contaminants include physio-chemical parameters, and heavy metals. This research is aimed at evaluating the efficacy of electrocoagulation treatment technique on the removal of physio-chemical parameters from rubber latex wastewaters by varying treatment time and electrode types.

MATERIALS AND METHODS

Effluent Collection and Characteristics

This study was carried out at the environmental and toxicology laboratory, Elizade University Ilara-Mokin Ondo State of Nigeria. Rubber wastewater was obtained from plastic industry at Araromi-Obu Ondo state. Rubber latex wastewater was obtained from the discharge tank where all wastewaters are collected before being discharged to receiving stream. A clean and sterilized 25liter container was used to collect the wastewater. The container was corked, sealed, and refrigerated until the starting time of the analysis. The effluent was characterized to determine their pH, temperature, Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solid (TS), Total Suspended Solid (TSS), Total Dissolve Solid (TDS), Electrical Conductivity (EC) and heavy metal, prior to its treatment in accordance with Adejumobi *et al*. (2012). Samples pH and Temperature were measured using a pH meter (HI-98107). Chemical Oxygen Demand (COD) of the wastewater sample was obtained through open reflux method. Biological oxygen demand (BOD) was determined using azide modification method (5210A). Total suspended solid (TSS), Total dissolved solid (TDS), Total Solid (TS) were determined using Gravimetric method and Heavy metals concentrations were calculated using flame absorption spectrophotometer (Buck Scientific AAS 235ATS model). All parameters were measured in mg/L with the exception of EC measured in µS/cm while pH was unitless. Analysis of variance (ANOVA) was the statistical tool used together with computer SPSS 16.0 windows and excel application.

Experimental Setup

A laboratory scale galvanostatic electro-chemical setup made up of cells, electrodes, and other accessories were arranged. Two set of electrocoagulation systems were made, Aluminum-Aluminum (AL-AL) and Aluminum-Carbon (AL-C) electrodes. Carbon rod electrode of 15cm in height, 2cm in diameter and Aluminum rod electrode of 8cm in height and 1cm in diameter were used and acts as the anode and cathode (the difference in dimension of Aluminum and Carbon is due to commercial size of production). The electro-coagulator used was a 1-litre plastic vessel with a working volume of 800 ml, equipped with a magnetic stirrer as shown in Figure 1.

Figure 1: *Electro-coagulation Reactor*

The separation between the anode and the cathode was kept at 1.5 cm. The wastewater in the reactor was stirred with a magnetic stirrer at rotating velocity of 120 rpm. Constant direct current was supplied by a DC power supply. The current readings were measured with an ammeter while the temperature measurement was taken using pH meter (HI-98107).

Experimental Procedure

After characterization of the wastewaters using standard methods of measurements (APHA, 2012), several electrocoagulation (EC) batch experiment runs were performed. Initially, the wastewaters were rigorously stirred for some minutes using the stirrer. This was to ensure proper homogenization of the samples. During the EC experiment, the effect of treatment time and electrode types were studied. The pH, temperature, Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solid (TS), Total Suspended Solid (TSS), Total Dissolve Solid (TDS), Electrical Conductivity (EC) of untreated and treated RW sample were done in triplicate. Before each run, electrodes were washed thoroughly to remove any surface grease or solid residues.

In the treatment of RW, two distinctive electrocoagulation set-ups were made to run for 1, 2, and 3 hours with a DC Power Supply of consistent voltage and current of 30v and 15mA. The initial segment utilizes Aluminum terminals as anode and cathode, while the others used Aluminum-Carbon Electrodes as anode and cathode. As the set-up is put ON it starts to run and with 3-hours of interim some particles of the molecule were formed on the anodes. In each test run, after proper homogeneous mixing was accomplished, 150 ml of supernatant sample was obtained at each 1hour for the following 3-hours to perform physical and chemical investigation according to Adejumobi *et al.* (2012) In each experimental run, after proper homogeneous stirring is achieved, 150 ml of supernatant sample was collected for laboratory analysis.

The removal efficiency by EC process for the removal of physio-chemical parameters such as Bio-chemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solid (TS), Total Suspended Solid (TSS), Total Dissolve Solid (TDS), Electrical Conductivity (EC) and heavy metals like cadmium, chromium and lead were determined using:

Percentage Removal = $\frac{C_0 - C_1}{C_0}\ x\ 100$ ………………………………….. 1

Where: C_o= initial concentration of the sample

C_1= final concentration of the sample

RESULTS AND DISCUSSION

Characterization of Rubber Latex Wastewater before and after Electrocoagulation

Table 1, shows the mean characterization results of RW for 1st, 2nd and 3rd hour of treatment using AL-AL and AL-C electrodes. From the results shown in Table 1, Electrocoagulation treatment accomplishes a significant reduction in the solids (both suspended and dissolved solids) in RW. This is in agreement with the report of (Phalakornkule *et al.,* 2010), and (Akyol, 2012). The pH of the raw wastewater and treated effluent ranges between 7.3-8.9 and 7.3-7.9 for AL-AL and AL-C electrodes, respectively. The pH values of

RW before and after are within NESREA, 2009 permissible limit (6 -9). This implies that both the raw and treated RW are basically alkaline as reported in Lakshmanan *et al.* (2010) and the alkaline nature of the wastewater was instrumental to the effective removal of COD and BOD. This observation is supported by the research conducted by (Adeogun and Balakrishnan, 2017) for the removal of COD, BOD, and turbidity from textile mill wastewater.

Effect of Operating Parameters

Effect of treatment time on electrocoagulation treatment of (RW)

The results of electro-coagulation treatment of RW for 1-hour; 2-hour and 3-hour are shown in Figures 2 – 4 respectively. Pollutant removal efficiency of the two experimental set up shows that 76.35% of BOD_5 and 98.29% of COD were removed after first hour of treatment thereby reducing the initial concentration of BOD from 65.53 to 15.50 mg/L and COD from 785.23 to 13.44 mg/L when treated with AL-AL, whereas 74.48% of BOD_5 and 98.29% of COD were removed after first hour of treatment, thus reducing the initial concentration of BOD from 65.53 to 16.53 mg/L and COD from 785.23 to 13.40 mg/L when treated with AL-C electrodes. This result has made the effluents to fall within the permissible limit set by (NESREA, 2009)

The mean values of TS, TSS and TDS of the raw RW were 1627.00 mg/L, 98.00 mg/L and 1529.00 mg/L respectively. These values were reduced to 973.00 mg/L, 31.00 mg/L, 942.00 mg/L in AL-AL experimental set up and 1097 mg/L, 25.70 mg/L, 1071.30 mg/L in AL-C experimental set up respectively. This shows that the removal efficiency of TS, TSS and TDS were 40.20%, 73.77% and 38.84% respectively for AL-AL and 32.58%, 73.38% and 29.93% for AL-C experimental set up. The values obtained for these impurities are well below the permissible limit of 1500 mg/L, and 30 mg/L for TS, TSS respectively and expect for TDS that is above 500 mg/L as recommended by (NESREA, 2009) in the first hour of the experimental run. The results of these physical impurities obtained in this research are in support of the findings of (Hariraj and Brijesh, 2016) conducted for industrial wastewater.

The electrical conductivity (EC) removal efficiency of 38.87% and 36.84% was obtained for AL-AL and AL-C experimental set up respectively. It is worth nothing that AL-AL electrodes experimental set up performed far better that AL-C experiment. Although, the NESREA (2009) standard did not specify the limit of EC in wastewater effluents but the 38.87% removal efficiency obtained shows a promising result from the experimental set up. Joseph *et al.* (2018) also obtained 43.35% removal when he conducted electro-coagulation treatment of palm oil and paint wastewaters.

Table 1: Characterization of RW Before and After Electrocoagulation

Parameter	Units	NESREA Permissible Limit	RW before treatment	Mean values after treatment AL-AL Electrodes			Mean values After treatment AL-C Electrodes		
				1st hr	2nd hrs	3rd hrs	1st hr	2nd hrs	3rd hrs
pH	-	6-9	7.3	8.90	8.60	8.80	7.90	7.81	7.90
T^0C	^0C	40	28^0C	28^0C	28^0C	28^0C	28^0C	28^0C	28^0C
BOD	mg/L	30	65.53	15.50	14.11	11.78	16.53	15.18	13.68
COD	mg/L	90	785.23	13.44	9.77	9.89	13.4	12.34	12.01
(TS)	mg/L	1500	1627.00	973.0	204.0	89.0	1097	464.0	146.9
(TSS)	mg/L	30	98.00	31.0	28.90	27.99	25.70	24.77	25.10
(TDS)	mg/L	500	1529.00	942.0	175.10	61.01	1071.30	439.23	121.80
(EC)	µ/cm	-	247.00	156.0	141.00	175.00	151.00	138.00	98.00
Colour		Colourless	White	-	Clear	Clear	-	Clear	Clear
Odour	-	Smell	Odourless		Odourless	Odourless		Odourless	Odourless

Figure 2: *Treatment of RW for 1-Hour*

The results of further treatment of RW for 2-hour and 3-hour are shown in graphical presentation in Figure 3 and 4. The results indicate slow improvement in percentage removal of all pollutants as compared with 1-hour treatment.

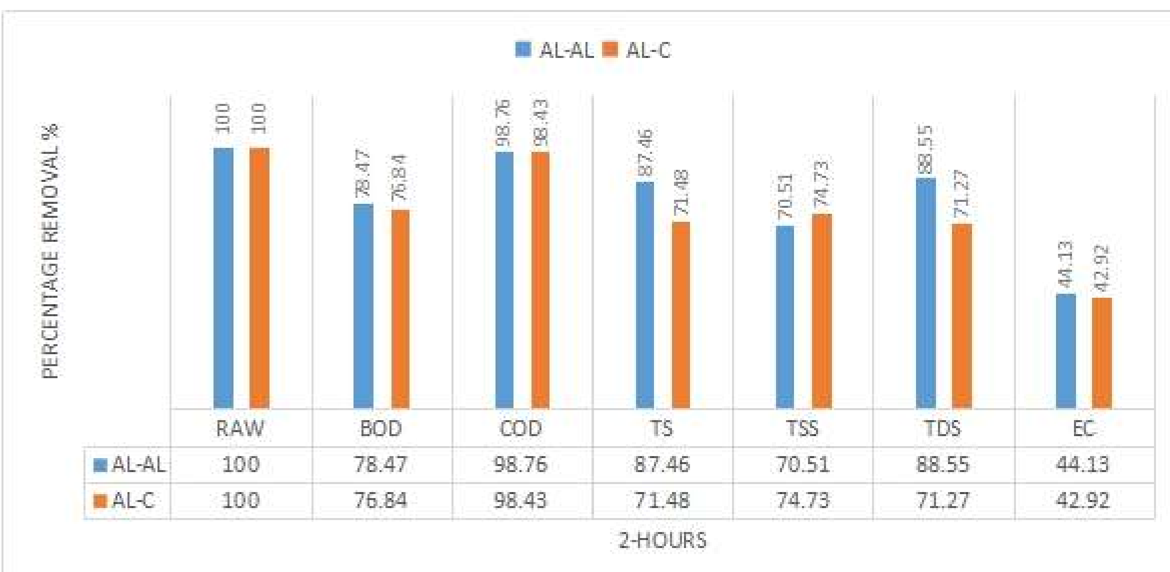

Figure 3: *Treatment of RW for 2-Hours*

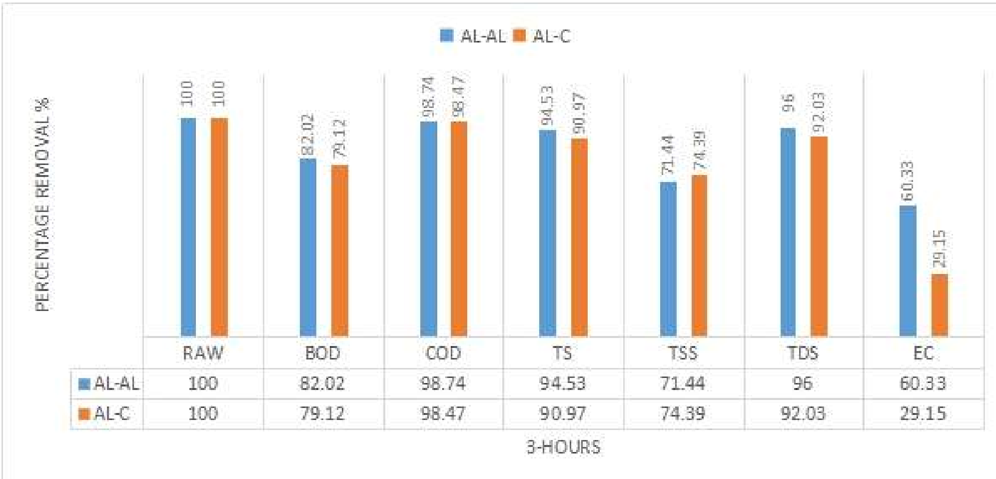

Figure 4: *Treatment of RW for 3-Hours.*

Analysis of heavy metals of RW

Effect of treatment time on heavy metals in RW

The results of analysis of heavy metals of (RW) for 1-hour; 2-hour and 3-hour respectively using AL-AL and AL-C electrodes are shown in Table 2. The concentration of cadmium and lead was reduced from 0.22mg/L and 0.8 mg/L to 0.11 mg/L and 0.02 mg/L respectively in AL-AL electrode set up while it was reduced to 0.10 mg/L and 0.24 mg/L in AL-C electrode set up. This gives a removal efficiency of 33.32% for cadmium and 66.67% for lead. However, chromium was not detected in both raw and treated RW in this research which was also reported in Pulkka *et al*. (2016).

Table 2: Result of The Analysis of Heavy Metals of RW using AL-AL and AL-C electrodes

Parameter	Units	AL-AL Electrodes			AL-C Electrodes		
		Mean	**Standard Deviation**	**% Removal**	**Mean**	**Standard deviation**	**% Removal**
				1-Hour of Treatment			
Cadmium	(mg/l)	0.11	0.01	33.32	0.10	0.01	26.67
Chromium	(mg/l)	ND	ND	ND	ND	ND	ND
Lead	(mg/l)	0.20	0.01	66.67	0.24	0.01	60.00
				2-Hours of Treatment			
Cadmium	(mg/l)	0.06	0.01	60.00	0.07	0.01	53.33
Chromium	(mg/l)	ND	ND	ND	ND	ND	ND
Lead	(mg/l)	0.11	0.02	81.67	0.13	0.01	78.33
				3-Hours of Treatment			
Cadmium	(mg/l)	0.04	0.01	73.33	0.04	0.00	70.33
Chromium	(mg/l)	ND	ND	ND	ND	ND	ND
Lead	(mg/l)	0.06	0.01	90.00	0.10	0.01	83.33

CONCLUSION

Electrocoagulation studies were performed to evaluate the influence of Aluminum and Carbon electrodes (i.e. AL-AL and AL-C) on the removal of pollutants from rubber latex wastewater. The results of the study indicated that electrocoagulation can effectively treat rubber latex wastewater and prevent environmental pollution. The treatment rate was shown to increase at constant applied voltage and reaction time interval of 1-hour. After 3-hours treatment, the BOD, COD and Lead reduced to 98.74%, 82.02%, and 90.00% respectively for Al-Al electrodes while it reduced to 98.47%, 76.64%, and 83.33% respectively for AL-C. The levels of removal of COD, BOD, and other pollutants using AL-AL electrodes has great impact than AL-C electrode. This method is therefore recommended as a sustainable method of treating rubber latex wastewater to avoid environmental pollution.

REFERENCES

Adejumobi, I.A., Olanipekun, A.J., Adebis, O.I., and Adetomi, A.A. (2012). Development of multi AC/DC power supply system for Domestic and laboratory use. 12(1): 1-16.

Adeogun, A.I., and Balakrishnan, R.B. (2017) “Kinetics, isothermal and thermodynamics studies of electrocoagulation removal of basic dye rhodamine B from aqueous solution using steel electrodes,” Applied Water Science. (7)4: 1711–1723.

Akyol A. (2012). ’Treatment of paint manufacturing wastewater by electrocoagulation,” Desalination.285: 91–99.

APHA, Standard methods for the examination of water and wastewater, 22nd edition edited by E. W. Rice, R. B. Baird, A. D. Eaton and L. S. (2012) Clesceri. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF), Washington, D.C., USA.

Elham, R.S., Akram, G., Saeid, A., Maryam, D., and Nasrin, N. (2016) “Removal of Reactive Red 141 Dye from Synthetic Wastewater by Electrocoagulation Process: Investigation of Operational Parameters,” Iranian Journal of Health, Safety and Environment. (3)1: 123-131

El-Sawy, N.M., Sokker, H.H., Hassan, M.A., and El-Anadouli, B.E. (2013) “Treatment of paint wastewater by radiation combined with coagulation and adsorption,” International Journal of Environment and Waste Management. (11) 1: 87–99.

El-Shazly, A.H., and Daous, M.A. (2013) “Kinetics and performance of phosphate removal from hot industrial effluents using a continuous flow electrocoagulation reactor,” International Journal of Electrochemical Science. (8)1: 184–194,

Ghanim, A.N., and Ajjam, S.K. (2013) “Modeling of textiles wastewater electrocoagulation via adsorption isotherm kinetics,” Mechanical and Material Engineering. (13)1: 49-57

Hariraj, S., and Brijesh, K.M. (2016) “Assessment of kinetics behavior of electrocoagulation process for the removal of suspended solids and metals from synthetic water,” Environmental Engineering Research. 3(1): 1-9

Joseph, T.N., Ozioma, O.O., and Chinedu, M.A. (2018) “Removal of Solids from Palm Oil Mill Effluent and Paint Wastewater Using Electrocoagulation Technique. International Journal of Electro-chemistry, (34)2: 109-115

Lakshmanan, D., Clifford, D.A., Samanta, G. (2010). Comparative study of arsenic removal by using iron electrocoagulation and chemical coagulation. Water Resource. 44: 5641-5652.

Muhammad, S., Alaadin, A.B., and Muhammad, N.A. (2011) “Electrocoagulation for the treatment of wastewater for reuse in irrigation and plantation,” Journal of Basic and Applied Sciences. (7)1: 11–20.

NESREA Act and Regulations 2009: A New Dawn in Environmental Compliance and Enforcement in Nigeria; 2009.

Phalakornkule, C., Mangmeemak, J., Intrachod, K., and Nuntakumjorn, B. (2010) “Pretreatment of palm oil mill effluent by electrocoagulation and coagulation,” Science Asia. (36)2: 142–149.

Pulkka, S., Martikainen, M., Bhatnagar, A., Sillanpaa, M.(2016) “Electrochemical methods for the removal of anionic contaminants from water – A review. Separation and Purification Technology. 132: 252–271 ·

Shakir, I.K. and Husein, B.I. (2009) “Lead removal from industrial wastewater by electrocoagulation process," Iraqi Journal of Chemical and Petroleum Engineering. (10)2: 35–42.

Vidal, J., Villegas, L., Peralta-Hernández, M.J., and Salazar Gonzále, R. (2016) "Removal of Acid Black 194 dye from water by electrocoagulation with aluminum anode," *Journal of Environmental Science and Health, Part A:* Toxic/Hazardous Substances and Environmental Engineering. (51)4: 289–296.

Xiaoyan, W., Qing, F., Yafan, Z., Shuhuai, D., Vladimir, N. (2010). Public Perceptions and Support of Environmental Management in the Source Area of Drinking Water for Beijing, China, Environmental Engineering research. (15)1: 49-56.