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Comparative Study of the Effect of Natural and Synthetic Coagulants on the Treatment of Industrial Effluents

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Abstract

Ground seeds of *Jatropha curcas* were tested for their coagulatory activities on industrial effluents from a vegetable oil producing company Port Harcourt, Nigeria. These were treated within six hours of collection using synthetic coagulants (Aluminum sulphate and ferric chloride) and *Jatropha curcas*, as the natural coagulant. Concentrations of coagulants ranged from 0.5mg/ml to 3.5mg/ml; the set up was in duplicate sets. Physicochemical parameters and microbial load were measured using standard techniques. Ground dried seeds of *J. curcas* showed good coagulatory properties. For instance, they resulted in the reduction of the turbidity, microbial load and biological oxygen demand (BOD) of the industrial effluent. The chemical oxygen demand (COD) of the industrial effluent was enhanced by more than four folds. The results obtained from testing the industrial effluent with *Jatropha curcas* were comparable to those obtained using synthetic coagulants such as aluminum sulphate and ferric chloride. The turbidity of the industrial effluent was reduced by as much as 72.7% while the microbial load was reduced by 99.9%. The effect of the ground seed of *Jatropha curcas* on the temperature and pH of the effluent were mostly moderating, but the effluent became slightly alkaline after treatment. Slightly alkaline condition enhances overall hydrocarbon biodegradation in industrial effluents. Apart from the above characteristics of the effluent affected by the treatment with *Jatropha curcas*, the effluent produced after treatment was colorless and odorless. The apparent removal of color and odor from the effluent were important for these are some of the most objectionable properties of industrial and domestic effluents.

Keywords: Natural coagulants, *Jatropha curcas*, aluminium sulphate, ferric chloride.

INTRODUCTION

Anthropogenic activities have greatly modified the earth and led to habitat alteration and pollution which has adversely affected the existence of other living organisms. Though water is of great importance to the existence of life, man has introduced vast amounts of hazardous chemical substances into waterbodies all over the world (WHO, 2011; Nand *et al*., 2012; Ravikumar and Sheeja, 2013). As a result, there is a scarcity of portable water in different parts of the globe (Hashim *et al*., 2019; Mohammed *et al*., 2020).

Thus, many scientific researches have been carried out on the treatment of polluted water using various strategies such as chemical precipitation, lime coagulation, ion and exchange, reverse osmosis and solvent extraction (Azizul-Rahman *et al*., 2014). Although the chemical method is the most effective and commonly used technique, a transition from chemical to natural coagulants has been observed due to various limitations posed by chemical-based coagulants (Choudhary *et al*., 2019; Abdulla *et al*., 2020). The natural coagulants deployed in water treatment are of plant, animal or microbial origin (Prabhakaran *et al*., 2022).

These include starch, cellulose derivatives, gelatin, galactomannans, chitosan, alginate, glues and microbial polysaccharides which are all non-toxic. Molecular bridging, adsorption and charge neutralization constitute the stages of the treatment process using natural coagulants.

Water treatment using chemical-based coagulants (such as, ferric chloride $FeCl_3$, alum $AlCl_3$, synthetic polymers [Polyacrylamide] and Poly aluminum) is the conventional method (Alwi *et al*., 2013; Choy *et al*., 2014). It however leads to the production of a large volume of non-biodegradable sludge (Carvalho *et al.*, 2016). Natural coagulants on the other hand serve as an alternative sustainable strategy as they are cheap, safe and biodegradable with a great capacity to maintain the pH of water being treated. Water treatment using natural coagulants especially in rural areas may facilitate health and hygiene and improve the living standard of all individuals.

Coagulants that were used in this study are both natural and synthetic. The natural coagulant is scientifically called *Jatropha curcas* which is commonly known as 'Achicha' among the Igbo speaking clans of Nigeria. It is also called Barbados Nut or Physic Nut. *Jatropha curcas* is a member of Euphorbaceae- spurge family; they are monoecious or occasionally diecious herbs, shrubs or trees, often with milky juice, sometimes fleshy and cactus-like. The Euphorbaceae are of considerable economic importance since products of the family include rubber (*Hevea)*, tung oil (*Aleurities faradic*), castor oil (*Ricimus*), cassava and tapioca (*Manihot*) (Mogbo *et al*., 2020). The use of coagulants derived from natural sources such as indigenous plants have been reported as an efficient alternative which offers significant technical, economic and environmental advantage (Shetty *et al*., 2022).

The synthetic coagulants used in this study are aluminum sulphate (Alum) and ferric chloride. Aluminum sulphate is also known as alum, filter alum, and alumina sulphate. Alum is the most widely used coagulant. Alum is available in dry form as powder or in lump form. It can also be purchased and fed as a liquid. Alum has no exact formula due to the varying water molecules of hydration, which may be attached to the aluminum sulphate molecules. Once in water, alum can react with hydroxides, carbonates, bicarbonates and other anions to form large positively charged molecules. Carbon dioxide and sulphate are generally by-products of these reactions (Bratby, 2006).

Ferric chloride is equally becoming more extensively used as a coagulant due partially to the fact that the material can be purchased as a liquid. Ferric chloride may also be purchased as an anhydrous solid. Liquid ferric chloride is highly corrosive and must be isolated from all corrodible metals. Like ferric sulphate; ferric chloride exhibits a wide pH range for coagulation and the ferric ion does not easily become soluble. As a result, many plants are replacing alum with ferric chloride to eliminate the penetration of aluminum ions through the plant filters. Ferric chloride also reacts as an acid in water to reduce alkalinity (Madhari *et al*., 2021). Other inorganic coagulants are available, such as potash alum, ammonia alum, ferrous sulphate (coppers) and chlorinated coppers, but none of these materials are widely used.

Therefore, the aim of this work is to compare the effect of natural and synthetic coagulants on the treatment of industrial effluents.

MATERIALS AND METHODS

Industrial effluent samples used in this study were collected from a vegetable oil company in Port Harcourt, Nigeria. The industrial effluents were usually channeled into the settling tanks where they stayed for between two weeks and one month before being discharged into the river. The industrial effluent samples were collected in bottles from the settling tanks. The composition of the effluent samples included water, oil, , spent products such as soaps, detergents, vegetable oil, traces of micro-organisms, some in organic substances and organic matter such as carbohydrates, traces of proteins etc.

Sample collection: The effluent samples collected were tested and treated within six hours of collection. The synthetic coagulants (Aluminum sulphate and ferric chloride) used were obtained from the Department of Animal and Environmental Biology, Rivers State University Port Harcourt, while the natural coagulant (*Jatropha curcas*) was obtained from various locations in Mbaise in Imo State, Nigeria. The seed samples of *Jatropha curcas* were sun-dried for several weeks and then opened to remove the inner endocarps which were further sun-dried in Gallenkamp hot box oven at a temperature of 40°C for a period of 3 hours per day for five days (Mohammed *et al*., 2020). A kitchen blender was used to grind the seeds to fine powder, and the required powdered forms were obtained using sieves of 425µm and 300µm sizes.

Treatment of effluents with the coagulants: Various weights for the doses of the coagulants were determined using a weighing balance, (Triple Beam Balance). The concentration 0.5mg/ml, 1.0mg/m, 1.5mg/ml, 2.0mg/ml, 2.5mg/ml and 3.5mg/ml were also prepared using 10ml pipette. The solution was prepared by adding each concentration into 200ml of the effluent. Duplicate sets of concentration of these solutions were prepared.

Measurement of Parameters: The pH of the effluent samples was determined before and after treatment using Toledo mettler (Model MP 220) pH meter.

The chemical oxygen demand (COD) of the effluent samples was determined by the titrimetric method using ferrous ammonium sulphate $(NH_4)_2$, SO_4, Feso4, $6H_2O$. One gram of Mercuric sulphate was introduced into 50ml of effluent samples in a flat bottom flask and 5ml of sulfuric acid containing silver sulphate was added to dissolve the mercuric sulphate. Twenty-five milliliter of potassium chromate was then added. The flat bottom flask was connected to a condenser and placed on the electric heating mantle. The remaining 70ml of sulfuric acid containing silver sulfate was added into the flask. After 2 hours of heating, the solution was allowed to cool and then flushed down with 150ml of distilled water through the condenser. Volumetric analysis was carried out on the solution by adding 8 drops of ferrion indicator and titrated with 0.1N ferrous ammonium sulfate. The COD was computed as follows:

$$COD = \text{Blank Reading} - \frac{\text{Sample Reading} \times N \times 8000 \times 5}{50}$$

Where

N = Normality of Ferrous ammonium Sulfate

5 = Dilution factor for Sample quantity

50 = Volume taken

8000 = Molecular Weight of oxygen in mg.

Turbidity: Various doses of *Jatropha curcas*, aluminum sulphate and ferric chloride were used in the treatment of the various effluent samples. The concentrations of 0.5mg/ml, 1.0mg/ml,1.5mg/ml,2.0mg/ml, 2.5mg/ml,3.0mg/ml and 3.5mg/ml were introduced into 250ml of effluent samples respectively. The mixture of effluent and coagulant was shaken vigorously and allowed to stand for 4 – 6 hours after which the turbidity was measured using a Haze meter. Colour/absorbance of the effluent was determined by membrane filtration method using Sintered glass (Schleicher and Schuell Model 589) Schwarz band) membrane filtration kit. The method consists of determining the initial weight of the membrane filter, size 1.2mm, then filtering a measured volume of the effluent through the membrane filter. The particles that could not pass through the pore size were trapped and the membrane filter was dried in the oven at 45°c for 3 hours and reweighed to determine the difference in weight, which was due to suspended solids. The turbidity was computed as follows:

$$\frac{\text{(Mass of filter + Suspended solid – (initial mass of filter)} \times 1000\text{ml}}{\text{Sample Volume (ml)}}$$

The suspended solid was determined before and after treatment with different coagulants.

Microbial Load: The microbial load was determined before and after treatment of industrial effluent samples with the various coagulants. Pour plate was used in the process. Nutrient agar and plate count agar were used for the culturing. The samples were incubated at 37°C for 24 hours. The number of colonies were counted using DBK colony counter (DBK Instrument Bombay- India) and expressed as cfu/ml (colony forming units per ml). Bacteria were identified using standard methodology (FDA, 1979). Bacteria were further identified based on their gram reaction, observed microscopically and identified by means of morphologic, physiologic, genetic and serological methods (Talaro, 1996).

Biological oxygen Demand: A Wheaton BOD bottle was filled completely with industrial effluent to exclude air; different coagulants were added above the sample level and the samples were incubated at 20°C for five days. The BOD of industrial effluent before and after treatment with the various coagulants were determined as BOD_5

Data Analysis: Analysis of variance was applied to determine the result obtained after treatment of industrial effluent with the respective coagulants.

Turbidity: The effect of various concentrations of the coagulants used, *Jatropha curcas*, aluminum sulphate and ferric chloride, on the turbidity of industrial effluent are shown in Tables 1- 3. The results showed a reduction in turbidity in the range of 62.82- 73.45% for *Jatropha curcas*, 87.24 -96.71% for aluminum sulphate (alum) and 71.78 – 98.32% for ferric chloride.

RESULTS

The reduction in turbidity increased in concentration of the coagulants up to a maximum, after which there was reduction with subsequent increase in concentration. The maximum concentration of the coagulant varied, 1.5mg/ml for *Jatropha curcas*, 1.5mg/ml for aluminum sulphate and 0.5mg/ml for ferric chloride.

Table 1: Effect of *Jatropha curcas* on the turbidity of industrial effluent

Concentration (mg/ml)	Initial Turbidity (EBC Unit)	Final Turbidity (EBC Unit)	Reduction Percentage (%)
0.5	15.54	4.56	70.62
1.0	15.54	4.38	71.78
1.5	15.54	4.12	73.45
2.0	15.54	5.41	65.14
2.5	15.54	5.48	64.69
3.0	15.54	5.75	62.95
3.5	15.54	5.52	62.82

Table 2: Effect of Aluminium sulphate on the turbidity of industrial effluent

(mg/ml)	(EBC Unit)	(EBC Unit)	Reduction Percentage (%)
0.5	15.54	1.98	87.24
1.0	15.54	40.52	96.65
1.5	15.54	0.51	96.71
2.0	15.54	0.53	96.58
2.5	15.54	0.55	96.46
3.0	15.54	0.55	96.46
3.5	15.54	0.57	96.33

Table 3: Effect of ferric chloride on the turbidity of industrial effluent

Concentration (mg/ml)	Initial Turbidity (EBC Unit)	Final Turbidity (EBC Unit)	Reduction Percentage (%)
0.5	15.54	0.28	98.32
1.0	15.54	2.68	82.73
1.5	15.54	3.24	79.12
2.0	15.54	3.68	76.29
2.5	15.54	3.68	76.29
3.0	15.54	4.34	72.04
3.5	15.54	4.38	71.78

Chemical Oxygen Demand (COD): The effect of various coagulants on the chemical oxygen demand is shown in Tables 4-7.

Treatment with coagulants enhanced the chemical oxygen demand of the industrial effluent.

The chemical oxygen demand was increased by as much as 39.20% by ferric chloride, 85.96% by aluminum sulphate and 297.53% by *Jatropha curcas*. There was also relationship between increase in chemical oxygen demand (COD) and the concentration of the various coagulants used in the treatment of industrial effluent.

Table 4: Effect of ferric chloride on the chemical oxygen demand of industrial effluent

Concentration (mg/ml)	Raw industrial effluent with initial reading (mg/l)	Treatment with final reading (mg/l)	Percentage Enhancement (%)
0.5	456	616	35.09
1.0	488	631	29.30
1.5	976	1,261	29.20
2.0	368	469	27.45
2.5	488	630	29.10
3.0	648	902	39.20
3.5	368	476	29.35

Table 5: Effect of aluminium sulphate on the chemical oxygen demand of industrial effluent

Concentration (mg/ml)	Raw industrial effluent with initial reading (mg/l)	Treatment with final reading (mg/l)	Percentage Enhancement (%)
0.5	456	848	85.96
1.0	488	808	65.57
1.5	976	1,611	65.06
2.0	368	512	39.13
2.5	488	806	65.16
3.0	648	1,098	69.44
3.5	368	607	64.94

Table 6: Effect of *Jatropha curcas* on the chemical oxygen demand of industrial effluent

Concentration (mg/ml)	Raw industrial effluent with initial reading (mg/l)	Treatment with final reading (mg/l)	Percentage Enhancement (%)
0.5	456	1,632	257.85
1.0	488	1,856	280.32
1.5	976	3,718	280.94
2.0	368	1,384	276.09
2.5	488	1,859	280.94
3.0	648	2,576	297.53
3.5	368	1,402	280.98

Table 7: comparative study of the effect of coagulants on chemical oxygen demand of industrial effluent

Coagulant sample	Conc. (mg/ml)	Initial COD reading (mg/ml)	Final COD reading (mg/ml)	Percentage enhancement (%)
$Al_2(SO_4)_3.4H_20$	0.5	456	848	85.96
$FeCl_3.6H_20$	0.5	456	616	35.09
Jatropha curcas	0.5	456	1,632	257.85
$Al_2(SO_4)_3.4H_20$	1.0	488	808	65.57
$FeCl_3.6H_20$	1.0	488	631	29.30
Jatropha curcas	1.0	488	1,856	280.32
$Al_2(SO_4)_3.4H_20$	1.5	976	1,611	65.00
$FeCl_3.6H_20$	1.5	976	1,261	29.20
Jatropha curcas	1.5	976	3,718	280.94
$Al_2(SO_4)_3.4H_20$	2.0	368	512	39.13
$FeCl_3.6H_20$	2.0	368	469	27.45
Jatropha curcas	2.0	368	1,384	276.09
$Al_2(SO_4)_3.4H_20$	2.5	488	806	65.16
$FeCl_3.6H_20$	2.5	488	630	29.10
Jatropha curcas	2.5	488	1,859	280.94
$Al_2(SO_4)_3.4H_20$	3.0	648	1,098	69.44
$FeCl_3.6H_20$	3.0	648	902	39.20
Jatropha curcas	3.0	648	2,576	297.53
$Al_2(SO_4)_3.4H_20$	3.5	368	607	64.95
$FeCl_3.6H_20$	3.5	368	476	29.35
Jatropha curcas	3.5	368	1,402	280.98

Temperature: The addition of the various coagulants did not affect the temperature of industrial effluent as shown in Table 8.

pH: Ferric chloride and aluminum sulphate reduced the pH of the effluent, making it more acidic, (table 4.8). Ferric chloride reduced the pH from 8.88-3.88 while aluminum sulphate reduced the pH from 8.88 - 4.33. Ground seeds of *Jatropha curcas* reduced it slightly from 8.88 to 6.00.

Suspended solids: The result of the effect of the coagulants on suspended solids in industrial effluent is shown in Table 9.

The general tendency is that with treatment the amount of suspended solids increased. Aluminum sulphate increased in the amount of suspended solids better than either ferric chloride or *Jatropha curcas.* Aluminum sulphate increased the suspended solids by 25.80%, ferric chloride by 24.27% and *Jatropha curcas* by 17.27%.

Table 8: Effect of coagulants on the temperature and pH of industrial effluents

Coagulant sample	Concentration (mg/ml)	Temperature (^oC)		Change in Temperature	pH		Reduction in pH
		Initial	Final		Initial	Final	
$Al_2(SO_4)_3.4H_20$	0.5	28.1	28.2	0.1	5.88	4.23	1.65
	1.0	26.4	26.3	0.1	4.34	3.96	0.65
	1.5	26.4	26.3	0.1	5.46	3.67	1.79
	2.0	24.4	23.5	0.9	5.88	3.75	2.13
	2.5	25.4	25.2	0.2	4.42	3.72	1.10
	3.0	25.4	25.6	-0.2	5.46	3.65	1.85
	3.5	24.4	24.5	-0.1	5.48	3.67	1.81
$FeCl_3.6H_20$	0.5	28.1	28.2	-0.1	5.88	2.86	3.02
	1.0	26.4	26.2	0.2	4.34	2.64	1.70
	1.5	26.4	26.4	0.0	5.46	2.36	3.10
	2.0	24.4	23.5	0.9	5.88	2.13	3.75
	2.5	25.4	25.2	0.2	4.42	2.74	1.98
	3.0	25.4	25.6	0.2	5.46	2.26	3.20
	3.5	24.4	24.5	-0.1	5.48	2.36	3.12
Jatropha curcas	0.5	28.1	28.1	0.0	5.88	5.98	0.10
	1.0	26.4	26.5	-0.1	4.34	4.44	-0.10
	1.5	26.4	26.4	0.0	5.46	5.51	-0.5
	2.0	26.4	23.5	0.9	5.88	6.25	-0.37
	2.5	25.4	25.2	-0.2	4.42	4.62	-0.20
	3.0	25.4	25.4	0.0	5.46	5.51	0.5
	3.5	24.4	24.5	-0.1	5.48	5.56	-0.8

Biological oxygen demand: The effect of the coagulants on the biological oxygen demand (BOD) of the effluent is shown in Table 10. *Jatropha curcas* reduced the biological oxygen demand (BOD) in the range of 38.23 -52.92% while ferric chloride reduced the same BOD in the range of 58.33 -82.50% and aluminum sulphate reduced it in the range of 30.21-50.40%. Generally, the BOD was reduced by more than 50%, to 30.0mg/l and 12.66mg/l by *Jatropha curcas*, aluminum sulphate and ferric chloride respectively.

Table 9: Effect of coagulants on the total suspended solids of industrial effluent

Coagulant sample	Concentration (mg/ml)	Suspension solid		Change in suspension solid	% increase in weight
		Initial	Final		
$Al_2(SO_4)_3.4H_20$	0.5	11.64	13.21	1.57	13.49
	1.0	11.52	13.72	2.20	19.09
	2.0	12.40	14.60	2.20	25.80
	2.5	10.36	12.68	2.32	22.39
	3.0	10.40	12.00	1.60	15.38
$FeCl_3.6H_20$	0.5	11.64	11.83	0.19	11.63
	1.0	11.52	13.45	1.93	16.75
	2.0	12.40	15.41	3.00	24.27
	2.5	10.36	12.59	2.23	21.52
	3.0	10.40	11.37	0.07	9.33
Jatropha curcas	0.5	11.64	12.97	1.33	11.43
	1.0	11.52	14.60	3.08	12.80
	2.0	12.40	15.07	2.67	17.27
	2.5	10.36	11.59	1.23	12.26
	3.0	10.40	11.01	0.61	5.85

Table 10: Effect of coagulants on biological oxygen demand

Coagulant sample	Initial BOD	Final BOD	% Increase
Aluminium sulphate	456	318	48.33
	456	411	50.40
	456	430	30.21
	456	480	42.30
Ferric chloride	456	490	58.33
	456	521	65.33
	456	509	74.44
	456	611	82.50
Jatropha curcas	456	616	35.08
	456	631	38.23
	456	630	38.15
	456	607	52.92

Antimicrobial Effects: The results shown in Tables 11 and 12 indicate a reduction in the microbial load of the effluent after treatment with the coagulants. *Jatropha curcas* ground seeds exhibited a higher antimicrobial activity than ferric chloride or aluminum sulphate. Ground seeds of *Jatropha curcas* reduced the microbial load by 99.76%. Cell viability tests showed a general decrease in cell number upon the treatment of industrial effluent with the coagulants. Microorganisms found in this study are *Pseudomonas, Aeromonas, Achromobacter, Mycobacterium,* *Corynebacterium* and many other microorganisms associated with the production and spoilage of vegetables oil. Apart from turbidity and microbial load reduction treatment of industrial effluent with *Jatropha curcas* ground seeds produced an effluent that was almost colorless and odorless. All the results were analyzed statistically using ANOVA.

DISCUSSION

In conventional industrial effluent treatment, the techniques commonly used are coagulation and flocculation using lime, aluminum sulphate (alum) or ferric /ferrous salts respectively (Prabhakaran *et al*., 2022). However, some plant products show considerable coagulatory properties. The effective use of plant products, such as ground seed of *Moringa oleifera* in clarifying muddy water has earlier been demonstrated (Shetty *et al*., 2022). This had stimulated interest in alternative ways of achieving effective and low-cost technology for industrial effluent treatment. *Jatropha curcas* used in this study has demonstrated a high degree of turbidity reduction comparable to those achieved in turbidity reduction by adding ground seeds of *Jatropha curcas* for instance the range of reduction achieved in this study, ground seeds of *Jatropha curcas* was 62.85-73.44%while that of ferric chloride was in the range of 71.78-98.32% and that of aluminum sulphate was 87.24-96.71%. These three coagulants compared favorably in turbidity reduction and showed no significant difference in their ability to reduce turbidity in wastewater ($p>0.5$). The analysis also indicated that this reduction in turbidity of industrial effluent after treatment with the three coagulants were significant. A higher range of turbidity reduction 75.26-84.94% was reported earlier by Aririatu and Gwadia (1999), for the same materials working on domestic effluent. This reduction is also consistent with findings of this study

Table 11: Effects of coagulants on the microbial load of industrial effluent on nutrient agar medium

Coagulant sample	Concentration (mg/ml)	Initial microbial count before treatment (cfu/ml)	Final microbial count after treatment (cfu/ml)	Percentage reduction (%)
$Al_2(SO_4)_3.4H_20$	0.5	4.78×10^7	1.67×10^4	99.96
	1.0	3.65×10^6	2.05×10^3	99.94
	1.5	2.72×10^5	1.61×10^3	99.40
	2.0	1.81×10^5	0.78×10^2	99.33
	2.5	3.04×10^5	1.06×10^2	99.96
	3.0	3.04×10^5	0.98×10^2	99.98
	3.5	2.69×10^5	0.64×10^2	99.99
$FeCl_3.6H_20$	0.5	4.78×10^5	2.54×10^2	99.46
	1.0	3.65×10^7	2.62×10^4	99.28
	1.5	2.72×10^6	1.89×10^4	99.97
	2.0	1.81×10^5	1.21×10^3	99.97
	2.5	3.04×10^5	1.58×10^3	99.97
	3.0	3.04×10^5	1.40×10^3	99.98
	3.5	2.69×10^5	1.18×10^3	99.56
Jatropha curcas	0.5	4.78×10^7	1.02×10^3	99.99
	1.0	3.65×10^6	1.97×10^2	99.99
	1.5	2.72×10^5	0.78×10^2	99.95
	2.0	1.81×10^5	0.48×10^2	99.96
	2.5	3.04×10^5	0.68×10^2	99.97
	3.0	3.04×10^5	0.46×10^2	99.98
	3.5	2.69×10^5	0.19×10^2	99.99

Table 12: Effect of coagulants on microbial load of industrial effluent

Coagulant sample	Concentration (mg/ml)	Initial microbial count before treatment (cfu/ml)	Final microbial count after treatment (cfu/ml)	Percentage reduction (%)
$Al_2(SO_4)_3.4H_20$	0.5	1.02×10^4	Nil	100
	1.0	1.20×10^4	Nil	100
	1.5	3.60×10^4	Nil	100
	2.0	6.80×10^4	Nil	100
	2.5	1.02×10^4	3.09×10^2	96.17
	3.0	2.30×10^4	1.28×10^3	96.43
	3.5	4.80×10^4	4.40×10^2	99.08
$FeCl_3.6H_20$	0.5	1.02×10^4	9.80×10^2	90.39
	1.0	1.20×10^4	Nil	99.95
	1.5	3.60×10^4	Nil	100
	2.0	6.80×10^4	Nil	100
	2.5	1.02×10^4	3.50×10^2	96.56
	3.0	2.30×10^4	9.80×10^2	95.73
	3.5	4.80×10^4	2.40×10^2	99.00
Jatropha curcas	0.5	1.02×10^4	Nil	100
	1.0	1.20×10^4	0.06×10^2	100
	1.5	3.60×10^4	0.11×10^2	96.96
	2.0	6.80×10^4	Nil	100
	2.5	1.02×10^4	1.20×10^2	98.82
	3.0	2.30×10^4	Nil	100
	3.5	4.80×10^4	0.07×10^2	99.98

The ground seed of *Jatropha curcas* reduced the BOD of industrial effluent by as much as 55.56% while enhancing the chemical oxygen demand (COD) by as much as four folds. The enhancement of COD is important since COD determine the amount of oxygen consumed per litre of waste during the oxidation of organic matter. The implication is that with the addition of ground seeds of *Jatropha curcas* almost all the organic compounds in the effluent water were oxidized. The entire dose of coagulants used showed significant difference on the activities of each coagulant on the chemical oxygen demand of the industrial effluent treated ($p < 0.5$). The problem of domestic and industrial effluent management centers on their objectionable odor and high BOD.

The ability of ground seeds of *J. curcas* to reduce turbidity and BOD of the industrial effluents sampled is an important property to be considered in small and large- scale industrial effluent management.

The effect of ground seeds of *Jatropha curcas* on the temperature and pH of industrial effluent are mostly moderating, since the effluent became slightly alkaline and the temperature slightly changed. Slightly alkaline pH favors higher number of micro-organism involved in biodegradation. This finding is in line with those of Vablooke *et al.* (1975) which showed that there is evidence that overall hydrocarbon biodegradation is higher under slightly alkaline than acidic conditions.

In general, slightly alkaline condition of pH 6 to 8 is regarded as a favorable chemical factor enhancing bioremediation (Madhari *et al*., 2021). Statistics analysis of the data on the effect of data on the pH on the treatment of industrial effluent with both ferric chloride and *Jatropha curcas* showed significant difference on the effect of ($p<0.05$).

The antimicrobial effect of the coagulants on the industrial effluent studied indicated a reduction microbial load of the effluent by much as 99%. Viability studies indicated that the reduction in microbial load was broad based.

The activities of each of the coagulants on industrial effluents were compared to the untreated effluent using analysis of variance for turbidity, p H, and suspended solids respectively. The comparative analysis carried out gave a value of 3.14 at 1% significance, at 6 degrees of freedom. A comparative analysis of the activities of the various coagulants on industrial effluent was also determined using analysis of variance.

Jatropha curcas ground seeds and ferric chloride reduced the biological oxygen demand (BOD) of industrial effluent from 68mg/l to 32.0mg/l and from 72.0mg/l to 12.66mg/l respectively. This is encouraging since the allowable discharge level for industrial is in the range of 15.80- 39.0mg/l (WHO, 2011). The problem of industrial effluent management centres on its objectionable odour and high BOD.

Jatropha curcas reduced the BOD and reduced the objectionable odour. Therefore, the ability of ground seeds of *J. curcas* to reduce the turbidity, microbial load and improve the COD of industrial effluent management. That ground seeds of *J. curcas* compared favorably with synthetic coagulants like aluminum sulphate and ferric chloride indicates that the use of such natural substance (natural coagulants) is not only of great economic importance but could be the best cost-effective alternative to prevent pollution from such wastewaters.

CONCLUSION

Environmental sustainability criteria involving the utilization of biodegradable and plant- based coagulants that are eco-friendly and capable of generating biodegradable sludge is gaining acceptance in environmental pollution control. It has been observed from the result of this investigation that *J. curcas* ground seeds compared favorably with both ferric chloride and aluminum sulphate in the reduction of turbidity, biological oxygen demand (BOD) and the removal of other objectionable qualities of industrial effluent. Improving the performance of using natural coagulants (*Jatropha curcas*) on the effluent treatment will reduce operating cost and improve company image. The usefulness of this natural coagulant can be applied in effluent management in industries, alternative pollution prevention and an approach to sustainable industrial development.

RECOMMENDATION

The tree of *Jatropha curcas* has a high growth yield rate and is indigenous to many countries in the developing world. The seed of *J. curcas* has also shown coagulatory property. *J. curcas* could be applied like alum in the treatment of industrial effluent and other sources of cloudy or muddy water used for domestic purposes like; washing of household items and irrigation. Since this natural coagulant is easily available and cheap, it could be managed by the rural Communities for domestic use. It has also been recommended for use in effluent treatment in importance but could be the best cost-effective alternative to prevent pollution from such wastewaters.

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