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Original Article

Relative Coagulation Effectiveness of *Jatropha curcas* Press Cake (Physic Nut) and Aluminium Sulphate in Purifying Domestic Sewage

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Abstract

An investigation was conducted on the relative effectiveness of using press cake of dried *Jatropha curcas* (Physic nut) seed and alum (Aluminium sulphate) for the purification of domestic sewage. The experimental design used was Completely Randomized Design (CRD) replicated three times. Physical and chemical properties of domestic sewage were investigated before and after the purification exercise. Treatments imposed included: the control culture (no alum and *Jatropha*), 10 mg/l of Aluminium Sulphate (alum) treatment, 80 mg/l of *J. curcas* treatment, 100 mg/l of *J. curcas* treatment and 120 mg/l of *J. curcas* treatment. The results showed that for the total dissolved solids, cultured tanks treated with 80 mg/l of *J. curcas* reduced the sewage concentration from 30.1 mg/l to 23.20 mg/l, Biological Oxygen Demand (BOD) was reduced from 30.55 mg/l to 30.10 mg/l, increased acidity from 5.33 mg/l to 5.66 mg/l, reduced alkalinity from 6.35 mg/l to 6.0 mg/l, reduced pH from 7.6 to 6.55, and likewise 10 mg/l of alum also reduced pH from 7.6 to 6.55. The cultured tanks treated with 120 mg/l of *J. curcas* performed best in reducing turbidity and Chemical Oxygen Demand (COD) of the sewage. The turbidity was reduced from 5.99 NTU to 5.6 NTU; 120 mg/l of *J. curcas* also reduced total hardness from 9.6 mg/l to 7.15 mg/l, total solids from 55.6 mg/l to 55.17 mg/l. Cultured tanks treated with 10 mg/l of alum reduced total dissolved solids from 30.1 mg/l to 24.30 mg/l, while those treated with 80 mg/l of *J. curcas* reduced it from 30.1 mg/l to 23.20 mg/l, 100 mg/l and 120 mg/l of *J. curcas* reduced it to 25.20 mg/l. Total suspended solids increased from 25.5 mg/l to 30.96 mg/l for 10 mg/l of alum, to 30.22 mg/l for 80 mg/l of *J. curcas*, 30.26 mg/l for 100 mg/l of *J. curcas* and 30.38 mg/l for 120 mg/l of *J. curcas*. Conductivity increased withion the study period from 525 µS/cm to 830 µS/cm for 10 mg/l of alum, to 590 µS/cm for 80 mg/l of *J. curcas*, 634 µS/cm for 100 mg/l of *J. curcas* and finally to 662 µS/cm for 120 mg/l of *J. curcas*. The results show that, within the reduction of BOD, pH, alkalinity and total solids, 80 mg/l of *J. curcas* performed best, while for reduction of COD and turbidity, 120 mg/l of *J. curcas* gave the best results. The study showed that *Jatropha curcas* was effective in purifying domestic sewage with little or no harmful effect on the ecology.

Keywords: chemical and bacteriological properties, coagulation, domestic sewage, physical traits

Introduction

In most parts of sub-Saharan Africa, water demand far outstrips supply. In Nigeria, rural water supply and sanitation projects implemented in several rural districts in the country by the Community Water and Sanitation Agency (CWSA) are currently facing certain drawbacks due to poor management and financial constraints (WaterAid, 2007). The outcome of this is that the few installed water facilities for these communities are unable to suffice the needs of the population. Rural communities most often rely greatly on ground water provided that it is available in sufficient quantities, and also on surface water which may be contaminated in most cases.

Most of the diseases causing death in the country are related to poor water and sanitation, with malaria, diarrhea and cholera being the main causes of mortality. Two major epidemics were recorded in 1991 and in 1999, with fatality ranging from 2.2 to 3.4% (WHO, 2005).

Water collection and storage practices, especially the choice of water collection and storage containers, are fundamental in determining household water quality (Sobsey, 2002). Murcott (2006) identified three broad areas of water quality: physical, chemical and microbiological, that can be improved by household water treatment. Physical removal technologies include ceramic and bio-sand filters, cloth filters, coagulation and flocculation practices. Boiling, solar disinfection (SODIS) and chlorination are examples of technologies that improve microbial quality of water (WHO, 2004).

One of the goals in water treatment is the removal of turbidity and other contaminants including natural organic materials and organisms. Previous studies has shown that the application of alum in water may be

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related with the Alzheimer disease (Kawahara, 2005; Shcherbatykh and Carpenter, 2007; Kawahara and Kato-Negishi, 2011) and that is why the use of coagulants from sources such as plants, animal and microorganisms has attracted interest in finding replacement for alum and also to reduce dependency on alum usage.

Ali *et al*. (2010) reported that *Moringa oleifera* seeds are an efficient and cost effective natural coagulant that can be used as an alternative to aluminium sulphate and other coagulants for water treatment. Yongabi (2004, 2010) reported that the seed powder of physic nut (*Jatropha curcas)* is very useful in wastewater treatment.

The objective of this study was to investigate the relative effectiveness of using *Jatropha curcas* and aluminium sulphate (alum) in the purification of domestic sewage.

Materials and Methods

Experimental design

The sewage sample was cultured in a 16 liter capacity container for a period of seven weeks. Physical and chemical tests were carried out daily at the point of collection, for a period of seven weeks. The experiment was designed based on Completely Randomized Design (CRD); the design was replicated three times.

Treatments imposed included: the control culture (no alum and *J. curcas*), 10 mg/l of Aluminium sulphate (alum) treatment, 80 mg/l of *J. curcas* treatment, 100 mg/l of *J. curcas* treatment and 120 mg/l of *J. curcas* treatment.

Physical and chemical analyses

Physical parameters of sewage samples such as pH, conductivity, total dissolved solids and hardness were determined using EDTA titration, while electrical conductivity was done using conductivity meter. Turbidity was determined using the Jackson's turbidimeter. Total dissolved solids, total solids, total suspended solids, dissolved solids were determined using the gravimetric method.

All the analyses were carried out using standard procedures recommended by the American Public Health Association (APHA, 2006; AWWA, 2012). Chemical properties such as total hardness were determined using the complexometric titration (EDTA), dissolved oxygen by the Winkler method, biochemical oxygen demand and chemical oxygen demand using standard procedure (APHA, 2006; AWWA, 2012); the chloride ion was determined by the Mohr method, nitrate by the colorimetric method and phosphate using the spectrophotometric method of determination (APHA, 2006; AWWA, 2012).

Statistical analysis

Analysis of variance (ANOVA) was performed on the results obtained from water analysis. Mean separation was done where significant difference existed using Duncan multiple range test procedure as described in the SAS 8.3 software. Significant difference was accepted at $P < 0.05$ (SAS, 2002).

Results and Discussion

The results of the physical and chemical analyses performed on the sewage samples collected are as shown in Figs. 1-10, while statistical analyses are as shown in Tables 1-10. Fig. 1 shows the variations in the values of pH. The pH of the domestic sewage at the point of collection was 7.6 and at the end of the test pH was finally reduced to 6.65 for the control culture, 6.55 for the 10 mg/l of Aluminium sulphate (alum), 6.55 for the 80 mg/l of *J. curcas*, 7.0 for the 100 mg/l of *J. curcas* and finally 7.1 for 120 mg/l of *J. curcas*. The results show that samples cultured with 80 mg/l of *Jatropha* was more effective than those treated with 100 mg/l and 120 mg/l of *J. curcas* respectively, in reducing the pH of sewage. The final result for the containers treated with 80 mg/l of *Jatropha* (6.55) was comparable with those treated with 10 mg/l of alum (6.55). Using the Nigeria Industrial Standard for drinking water (NIS 2007) ranges 6.5 – 8.5 show that all the treatments imposed effectively reduced the pH of sewage. Table 1 shows the ANOVA test results for pH for the tested he concentration (F_{cal} = 24.779) and with significant difference (P = 0.000). Fig. 2 shows the variations in the values of hardness. Total hardness of the domestic sewage at the point of collection was 9.6 mg/l whereas at the end of the test total hardness was finally reduced to 9.6 mg/l for the control culture, 9.2 mg/l for the 10 mg/l of Aluminium sulphate (alum), 7.2 mg/l for the 80 mg/l of *J. curcas*, 7.3 mg/l for the 100 mg/l of *J. curcas* and finally 7.15 mg/l for 120 mg/l of *J. curcas*. In comparison with NIS (2007), the permissible amount is 150 mg/l; therefore, the values obtained at the point of collection, control culture and the treatments imposed are all safe and minimal.

The ANOVA test results for total solids are given in Table 2, (the concentration F_{cal} = 22.246 and with significant difference P = 0.000). As evidenced in Fig. 3, the value of total solids at the point of collection was 55.6 mg/l and this indicated a low presence of solid particles in the domestic sewage. The average drop of total solid for the control culture, after the seventh week of the experiment, was 55.30 mg/l, 55.26 mg/l for the 10 mg/l of alum, 55.19 mg/l for the 80 mg/l of *J. curcas*, 55.18 mg/l for the 100 mg/l of *Jatropha* and 55.17 mg/l for the 120 mg/l of *J. curcas*. From these results, it can be deduced that 120 mg/l of *J. curcas* were more effective than the other treatments imposed as compare to the values of point of collection. ANOVA test results are shown in Table 3, the concentration (F_{cal} = 0.850), with significant difference (P = 0.505).

Fig. 4 shows the variations in the values of dissolved oxygen, which at the point of collection was 96.3 mg/l; after the periods of study, it later drop to 93.90 mg/l for control culture, 82.20 mg/l for the 10 mg/l of alum, 81.60 mg/l for the 80 mg/l of *J. curcas*, 60 mg/l for the 100 mg/l of *J. curcas* and finally 89.70 mg/l for the 120 mg/l of *J. curcas*. There was formation of small organism in the water during the course of the experiment. It was observed that the water was favorable to these organisms and also aid in the formation of dissolved oxygen. The suitability of the water to the organisms also proved that the water was conducive for them to live and since the water was not harmful to their sustenance, that show it cannot be harmful to plants or human after treatment. The ANOVA test results are given in Table 4, the concentration F_{cal} = 20.458 and significant difference determined for (P = 0.000).

Fig. 5 shows the variation in the values of total dissolved solids. From Fig. 4 and 5, it can be noted that the total dissolved solid at the point of collection was 30.1 mg/l and this shows that even though pollution level was minimal, there was a significant reduction in its level at the end of the experiment to 29.90 mg/l for the control culture at the end of the seventh week, 24.30 mg/l for the 10 mg/l of alum, 23.20 mg/l for the 80 mg/l of *J. curcas*, 25.20 mg/l for the 100 mg/l of *J. curcas* and 25.20 mg/l for the 120 mg/l of *J. curcas* respectively. For the experiment, it was observed that the 80 mg/l of *J. curcas* was more effective in the treatment of the domestic sewage. The ANOVA test results are summarised in Table 5, the concentration (F_{cal} =1.624) and with significant difference (P = 0.193). These are solid particles (organic and inorganic) suspended within the sewage, but are undissolved.

Fig. 6 shows the variations in the values of total suspended solids (TSS); at the point of collection, the domestic sewage was 25.5 mg/l, whereas along the line of the analysis, average TSS for the period of seven weeks for control culture (no *J. curcas*), 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and lastly 120 mg/l of *J. curcas* were 25.54 mg/l, 30.96 mg/l, 30.22 mg/l, 30.26 mg/l and 30.38 mg/l respectively. The ANOVA test results are given in Table 6, with the concentration (F_{cal} = 0.626) and significant difference (P = 0.647).

Fig. 7 shows that the alkalinity at the collection point was 6.35 mg/l for all treatments. By comparing control culture value and the values of treatments imposed to point of collection, it can be observed that alkalinity decreased to average value of 5.5 mg/l for the control culture, it decreased to 5.1 mg/l for the 10 mg/l of alum, it decreased to 5.2 mg/l for the 80 mg/l of *J. curcas*, it decreased to 5.3 mg/l for the 100 mg/l of *J. curcas* and lastly, it decreased to 5.4 mg/l for the 120 mg/l of *J. curcas*. This implied that 80 mg/l of *J. curcas* was more effective among the ranges of *Jatropha* use. The ANOVA test results are given in Tables 4 and 7, with the concentration F_{cal} = 0.844 and significant difference (P = 0.508)

Fig. 8 shows that the conductivity at the point of collection was 525 μS/cm (microsiemens per centimeter) and increased during the experiment period at room temperature (25 °C). The average increments after seven weeks of test for control culture, 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and 120 mg/l of *J. curcas* were 597 μS/cm, 830 μS/cm, 590 μS/cm, 634 μS/cm and 662 μS/cm respectively. In comparison with NIS (2007), the permissible amount is 1,000 μS/cm, which implies that all treatments imposed were safe and conductivity was minimal. From the ANOVA test, it resulted data summarised in Table 8, with the concentration F_{cal} = 5.036 and with significant difference (P = 0.003).

Fig. 9 shows the variations in the values of Biological Oxygen Demand (BOD); at the point of collection, the BOD level of the domestic sewage was 30.55 mg/l, along the line of the analysis, and the average BOD removed for the period of seven weeks for control culture (no *J. curcas*), 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and lastly 120 mg/l of *J. curcas* were 30.25 mg/l, 20.08 mg/l, 30.10 mg/l, 30.18 mg/l and 30.20 mg/l. respectively. When compared to that of point of collection, 10 mg/l of alum were more effective and 80 mg/l of *J. curcas* also reduced BOD as compared with other ranges of *Jatropha*. Consequently, increasing the ranges of *J. curcas* may lead to wastage of coagulant material without sufficient increase in the removal of BOD. The ANOVA test results are given in Table 9, the concentration F_{cal} = 0.979 and with significant difference (P = 0.433).

The turbidity at the point of collection was 5.99 NTU (Fig. 10). The reduced turbidity level for the control culture, 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and 120 mg/l of *J. curcas* during the process of the experiment were 5.75 NTU, 5.78 NTU, 5.73 NTU, 5.70 NTU and 5.60 NTU. Also, in comparison to NIS (2007) with the permissible amount of 5 NTU, all the values for the treatments imposed were higher. The ANOVA test results are given in Table 10, the concentration F_{cal} = 1.799 and with significant difference (P = 0.154).

Fig. 11 shows the variations in the values of acidity; at the point of collection, the domestic sewage was 5.33 mg/l; along the line of the test, the increase in the level of acidity for the period of seven weeks for control culture (no *J. curcas*), 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and lastly 120 mg/l of *J. curcas* were 6.35 mg/l, 6.88 mg/l, 6.37 mg/l, 5.66 mg/l and 5.65 mg/l respectively. When compared to that of point of

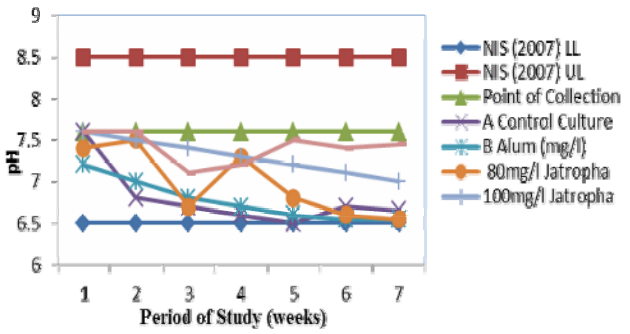

Fig. 1. Effects of *Jatropha curcas* treatment on pH

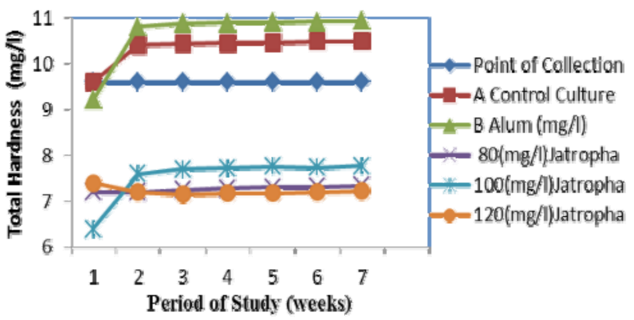

Fig. 2. Effects of *Jatropha curcas* treatment on total hardness

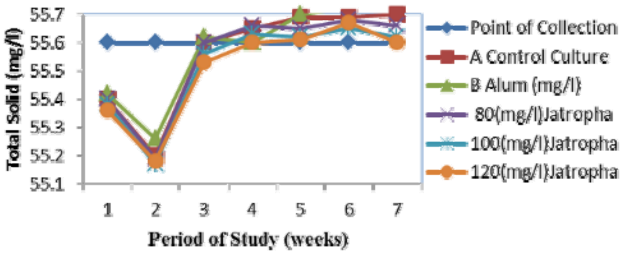

Fig. 3. Effects of *Jatropha curcas* treatment on total solid

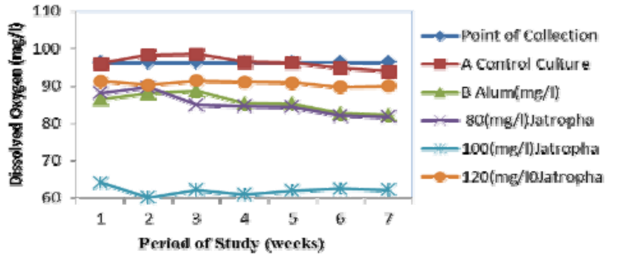

Fig. 4. Effects of *Jatropha curcas* treatment on dissolved oxygen

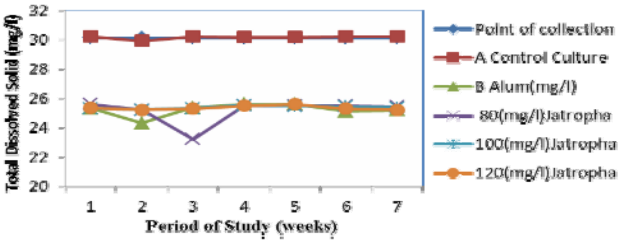

Fig. 5. Effects of *Jatropha curcas* treatment on total dissolved solid

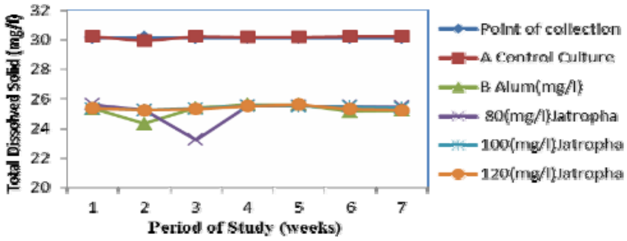

Fig. 6. Effects of *Jatropha curcas* treatment on total suspended solid

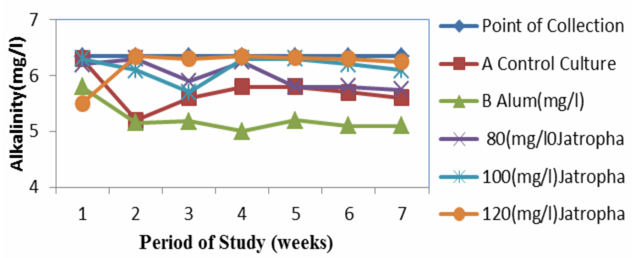

Fig. 7. Effects of *Jatropha curcas* treatment on alkalinity

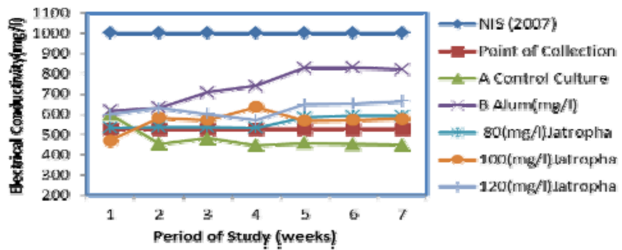

Fig. 8. Effects of *Jatropha curcas* treatment on conductivity

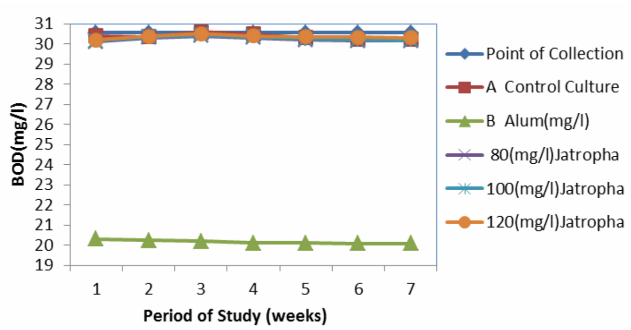

Fig. 9. Effects of *Jatropha curcas* treatment on BOD

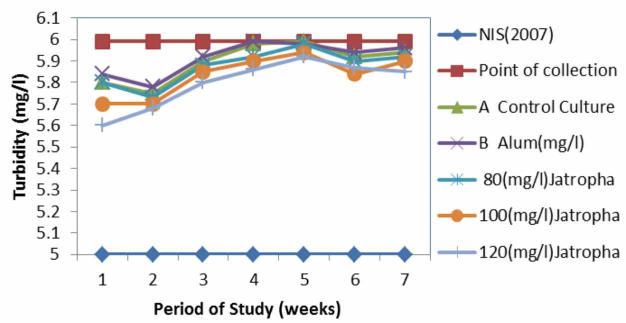

Fig. 10. Effects of *Jatropha curcas* treatment on turbidity

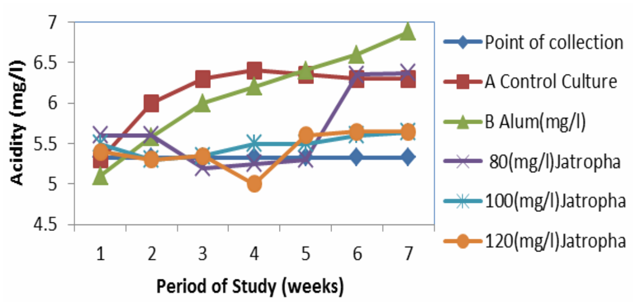

Fig. 11. Effects of *Jatropha curcas* treatment on acidity

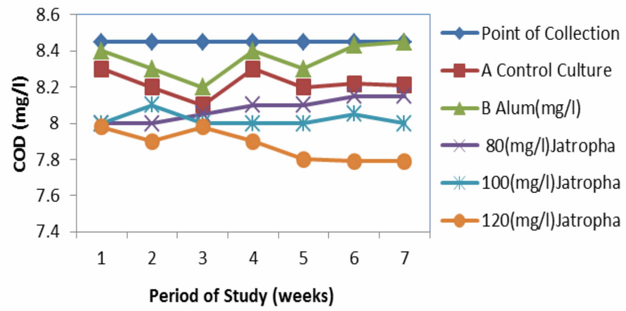

Fig. 12. Effects of *Jatropha curcas* treatment on COD

Table 1. Statistical analysis of pH

	Sum of squares	df	Mean square	F	Sig.
Treatments	27.316	4	6.829	24.779	.000
Errors	8.544	31	.276		
Total	35.860	35			

Table 2. Statistical analysis of total hardness

	Sum of squares	df	Mean square	F	Sig.
Treatments	105.585	4	26.396	22.246	.000
Errors	36.783	31	1.187		
Total	142.368	35			

Table 3. Statistical analysis of total solids

	Sum of squares	df	Mean square	F	Sig.
Treatments	232.487	4	58.122	.850	.505
Errors	2120.178	31	68.393		
Total	2352.665	35			

Table 4. Statistical analysis of dissolved oxygen

	Sum of squares	df	Mean square	F	Sig.
Treatments	4128.289	4	1032.072	20.458	.000
Errors	1563.900	31	50.448		
Total	5692.189	35			

Table 5. Statistical analysis of total dissolved solid

	Sum of squares	df	Mean square	F	Sig.
Treatments	166.235	4	41.559	1.624	.193
Errors	793.220	31	25.588		
Total	959.455	35			

Table 6. Statistical analysis of TSS

	Sum of squares	df	Mean square	F	Sig.
Treatments	3705.216	4	926.304	.626	.647
Errors	45840.686	31	1478.732		
Total	49545.902	35			

Table 7. Statistical analysis of alkalinity

	Sum of squares	df	Mean square	F	Sig.
Treatments	785.958	4	196.490	.844	.508
Errors	7215.202	31	232.748		
Total	8001.161	35			

Table 8. Statistical analysis of conductivity

	Sum of squares	Df	Mean square	F	Sig.
Treatments	391505.893	4	97876.473	5.036	.003
Errors	602471.679	31	19434.570		
Total	993977.572	35			

Table 9. Statistical analysis of BOD

	Sum of squares	df	Mean square	F	Sig.
Treatments	27108.328	4	6777.082	.979	.433
Errors	214692.879	31	6925.577		
Total	241801.207	35			

Table 10. Statistical analysis of turbidity

	Sum of squares	df	Mean square	F	Sig.
Treatments	1.376	4	.344	1.799	.154
Errors	5.928	31	.191		
Total	7.304	35			

Table 11. Statistical analysis of acidity

	Sum of squares	df	Mean square	F	Sig.
Treatments	97.815	4	24.454	1.439	.245
Errors	526.820	31	16.994		
Total	624.635	35			

Table 12. Statistical analysis of COD

	Sum of squares	df	Mean square	F	Sig.
Treatments	2.302	4	.575	10.224	.000
Errors	1.745	31	.056		
Total	4.046	35			

collection, 10 mg/l of alum were more effective; 80 mg/l of *J. curcas* also increased the acidity as compared with other ranges of *Jatropha*. Consequently, increasing the ranges of *J. curcas* may leads to wastage of coagulant material without sufficient results. From the ANOVA test results Table 11, with the concentration $F_{cal} = 1.439$ and with significant difference (P = 0.245).

Fig. 12 shows the variations in the values of Chemical Oxygen Demand (COD); at the point of collection, the domestic sewage was 8.45 mg/l; during the periods of study, COD removed for the period of seven weeks for control culture (no *J. curcas*), 10 mg/l of alum, 80 mg/l of *J. curcas*, 100 mg/l of *J. curcas* and lastly 120 mg/l of *J. curcas* were 8.4 mg/l, 8.2 mg/l, 8.17 mg/l, 8.05 mg/l and 7.8 mg/l respectively. The ANOVA test results are given in Table 12, the concentration $F_{cal} = 10.224$ and with significant difference (P = 0.000).

The obtained data prove that *J. curcasis* can be an effective natural coagulant. Water coagulation with alum are usually very acidic and thus dangerous for human consumption, as it is liable to harming the gastrointestinal tract. *J. curcas* can be cultivated very cheaply at the household level or in small communal nurseries, which is to be encouraged among the rural populations.

Conclusions

The study showed that *Jatropha curcas* was effective in purifying domestic sewage with little or no harmful effect on the ecology. The study showed the reduction in BOD, which brings about aerobic decomposition of organic matter in sewage. *J. curcasis* can be an effective natural coagulant, which can be used in improving the physicochemical characteristics of water in terms of pH, turbidity, total dissolved solids, suspended solids, alkalinity and conductivity etc. In coagulation, *Jatropha* seeds hardly affect pH of water as compared to alum which requires pH adjustment after treatment. This is likely to reduce the high cost of the current water treatment systems. Thus, *J. curcas* seeds present a viable alternative coagulant to alum in treating water for rural dwellers, since alum has side effects like Alzheimer's disease while *J. curcas* is environmentally friendly, cheap to cultivate and without side effects.

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