Relative Coagulation Effectiveness of Baobab (*Adansonia digitata L*.) Seeds and Aluminium Sulphate in the Purification of Domestic Sewage

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Abstract

This study investigates the relative effectiveness of Adansonia digitata (Baobab) seeds and Aluminium sulphate for the purification of domestic sewage. De-fatted, powdered Baobab seed extract (bio-coagulant) and Aluminium sulphates (chemical coagulant) were used in the purification process. Physicochemical and bacteriological properties of domestic sewage were investigated before and after the treatment on weekly basis for a period of 7weeks. Treatments imposed include: control culture (no coagulant), 100 mg/l of Alum, 100 mg/l, 150 mg/l and 200 mg/l of Adansonia digitata seeds. The experimental design was Completely Randomized Design (CRD) replicated thrice and One-way Analysis of Variance (ANOVA) was used to determine significant difference among means of the various parameters measured. Total hardness of the waste water was reduced from 8.5mg/l at the point of collection to 7.25mg/l after 7weeks of treatment, in both 100mg/l and 200mg/l of baobab treatments. For the microbial studies, the sewage treated showed a great reduction in Total Coliform Count over the period of study. 100mg/l baobab seeds treatment worked best in reduction of TCC, while 100mg/l of Alum performed least. The study revealed that Adansonia digitata seeds perform well as a bio-coagulant and disinfectant, and can be used as an alternative coagulant to alum in the treatment of domestic sewage.

Keywords: *Waste water, organic coagulant, Domestic sewage*

1.0 Introduction

Environmental preservation and sustainability are the main stay of the contemporary environmental scientist and researcher concerned with expeditious use of the fast depleting resources of the earth[1]. Hence, water forms considered spent or unwanted are now systemically repurposed for proper disposal or ultimate reuse. In the same light, chemical coagulant erstwhile the most prevalent agent for local waste treatment are recently been revaluated because of their perceived effects on the natural ecosystem[2].Although, chemical coagulants especially alum, are relatively inexpensive when local production is possible, the threat to ecosystem is deem too expensive to discard[3], [4]

Traditionally waste water treatment entails water clarification and disinfection comprising of five major unit process. This include coagulation, flocculation, sedimentation, filtration, and disinfection.[5], [6]. The systematic combination of this processes get rids of impurities and improves water quality and are designed for varying degrees of waste water contamination. In the same light, pre-existing quality of the waste water, the quality of the treated water and cost of water treatment also play vital roles in the selection of the type of treatment process [7]. In view of the benefits of organic treatments in tandem with sustainable use of natural resource, non-chemical water treatment is adjured cheap, readily available, environment friendly and a veritable tool to providing water to every household in Africa [8], [9].

Reports indicates that many developing countries such as India, Brazil have successfully employed natural coagulants in treatment of waste water [10]–[12].Plant materials such as moringa seeds have been reported to contain coagulant proteins, which is responsible for their bio-coagulation, disinfectant, and biosorptive properties that enhances the treatment of water[3]. However, the use of natural coagulant in the treatment of water has not been fully explored and documented, hence, the findings of this work would add to the chronology of evidence on its performance and ultimately contribute towards accessibility of quality water in rural parts of Africa [4], [13].

2.0 Materials and Methods

2.1 Sewage Sample Collection

Sewage samples used for the test were collected from a kitchenette waste water outlet in a dormitory in University of Ilorin, Kwara State, Nigeria.

Sampling bottles were used for the collection of the sewage on a weekly basis. The procedures used in the collection of the sewage include:

i. The bottles were labelled to distinguish them from one another;

ii. The bottles containing each sample were noted at collection point.

iii. The bottles were properly stored in a cool dry place.

iv. Analysis of the sewage commenced after two hours of collection.

The samples collected were immediately transported to the laboratory for analysis. Seeds of *Adansonia digitata* (Baobab) tree which had been removed from the fruit that was used in this research were collected from Federal College of Forestry, Jos, Plateau State, Nigeria as shown in (Plates 3.1 and 3.2).

(a)

(b)

Plate 3.1 (a) Dried fruits of *Adansonia digitata* (b) Dried seeds of *Adansonia digitata*

2.2 Methods

2.2.1 Sample Preparation

Seeds of *Adansonia digitata* (Baobab) tree were properly washed with water, dried in the sun for 3 – 4 days, pounded into powder using mortar and pestle, and sieved through a pore size of about 1mm.

The powdered seed sample (*Adansonia digitata* seed) was de-fatted using ethanol in electro-thermal Soxhlet extractor. 100g of powdered seeds was weighed and put into the thimble of the Soxhlet extractor, the apparatus was mounted and allowed to run for 1 hour, after which the powder is removed and dried over a hot plate at low heat to evaporate the solvent used (ethanol). The *Adansonia digitata* cake residue, after oil extraction, was used in the preparation of the extract. Three different concentrations (100mg/l, 150mg/l and 200mg/l) of the coagulant reagent were prepared by suspending the required weighed amount of de-fatted powdered seed in 1L of distilled water, which was then stirred continuously for 15 minutes to extract active components. The suspension was then filtered through a filter paper.

2.2.2 Procedure for Laboratory Test

The experiment was conducted under a controlled natural environment where parameters like human activities, rainfall, solar intensity, and other effects that may affect the end result of the experiment were avoided.

Laboratory tests were carried out to investigate the relative coagulation potential of Aluminium Sulphate (Alum) and *Adansonia digitata* (Baobab) grounded seeds on the purification of domestic sewage. The parameters investigated are physiochemical properties (i.e. electrical conductivity, pH, hardness, total solids, suspended solid, dissolved solids, biochemical oxygen demand -BOD, chemical oxygen demand -COD, and bacteriological properties (i.e. bacterial count).

2.2.3 Physiochemical Properties

The electrical conductivity, pH value, temperature, and turbidity were measured using Hanna-edge digital meter, pH meter, thermometer, and digital turbidity meter respectively. The sewage colour was determined through eye observation.

The total solid measured by the material residue left in a container after evaporation of a sample and its subsequent drying in an oven at a defined temperature. Total solids include total suspended solids (i.e. the portion of total solids retained by a filter when the sewage is passthrough a filter) and total dissolved solids (i.e. the portion of total solids that dissolved and passes through the filter with the sewage but were recovered through evaporation of the liquid in the sewage).

The Biochemical Oxygen Demand (BOD), which is the quantity of dissolved oxygen required for microbial metabolism of organic compounds in water, was measured using the following procedure;

i. The dissolved oxygen in water sample is first found out and noted.
ii. 20ml of the sewage sample is pipetted into the BOD bottle using a pipette
iii. Then addition of 5ml of 10% MnSO4 solution and 5ml of alkaline iodide solution.
iv. The BOD bottle is stopped and inverted several times for thorough mixing until a dirty brown mixture is formed.
v. Addition of 10ml of 25% of HCl solution mixed thoroughly will give a reddish-yellow solution.
vi. The whole content is then emptied into a 25ml conical flask and 3 drops of starch indicator is added.
vii. Titration of the precipitate with 0.05m Na2S2O3 is done to attain a colourless solution as the end point of the reaction.

$$\text{Dissolved Oxygen (mg/l)} = \frac{TitreValue \times Molarity\ 8000}{Volume(cm)3\ of sample} \quad (1)$$

The BOD is then determined by subtracting dissolved oxygen content after five days (DO_5) from the initial dissolved oxygen content of the first day.

2.2.4 Bacteriological Properties

This is the estimation of the population of the coliform bacteria present in the sewage. Below is the procedure used in the determination of this properties;

1. 10ml of sample is poured into the flask using a funnel containing a filter paper.
2. The sample is then placed in a sterile Petri dish (containing agar- the growth medium), which is pressed down gently while removing the filter paper.
3. After tapping the Petri dish shut, the dish is then placed in the incubator to allow growth of bacteria.
4. Growth of Coliform is encouraged and those of other organisms that are used for bioremediation, while those of other organisms are suppressed during the period of incubation.

5. The cells which later develop into individual colonies are counted directly for the calculation of Coliform Microbial Density (CMD) and the Bacteria growth and Fungi growth are also counted.

2.2.5. Experimental design

The experiment was design based on Completely Randomized Design (CRD) with three replicated. Waste water was collected into fifteen 15-litres capacity plastic containers, three of the plastic containers contained control cultures with no coagulant, another three containers contained 100mg/L of alum, another three containers contained 100mg/L of *Adansonia digitata* seeds, another three containers contained 150mg/L of *Adansonia digitata* seeds, and the last three containers contained 200mg/L of *Adansonia digitata* seeds, each under a controlled environment.

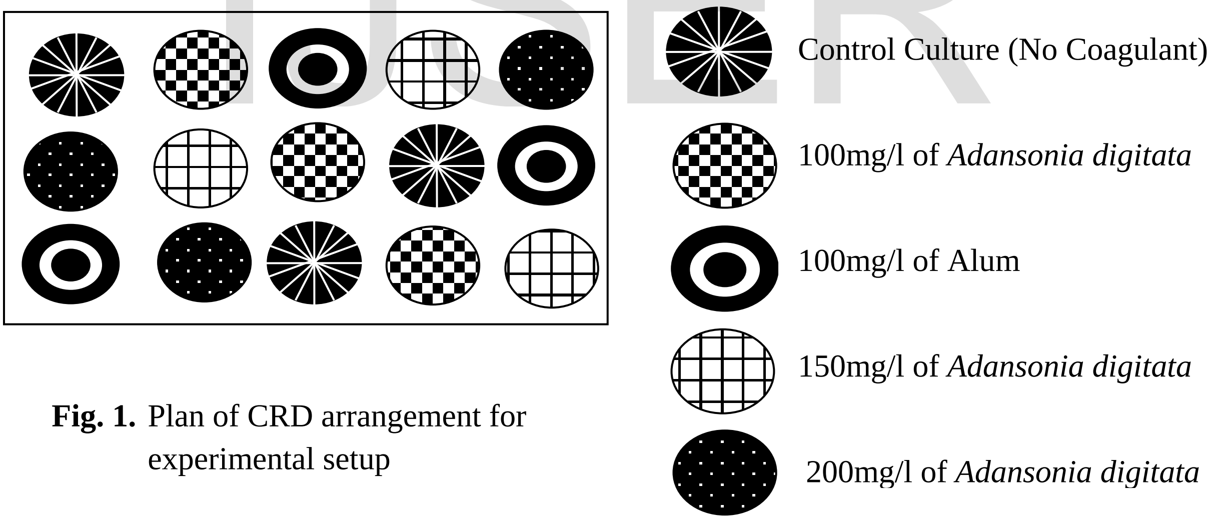

Fig. 1. Plan of CRD arrangement for experimental setup

3.0 Results and Discussion

3.1 Physicochemical Properties

3.1.1. Total Hardness

The result of the total hardness of the sewage is shown in Figure 2. It was observed that the total hardness of the domestic sewage at the point of collection was 8.5mg/l. At the end of the test, the total hardness for the control culture, 100mg/l of alum, 100mg/l of baobab, 150mg/l of baobab, and 200mg/l of baobab was 9.75mg/l, 9.6mg/l, 7.25mg/l, 7.55mg/l, and 7.25mg/l respectively.

In comparison with Nigeria Industrial Standard (NIS) for portable water, the permissible amount is 150mg/l. Hence, the values obtained at the point of collection, control culture and the treatment imposed are all safe and minimal[15].The results of the analysis of variance (ANOVA) displayed on Table 1 shows that F(df 4, 6 = 1.68, p <0.00), indicated a statistically significant relationship between the variables, with 100mg/l of alum and 150mg/l of baobab recording the best results.

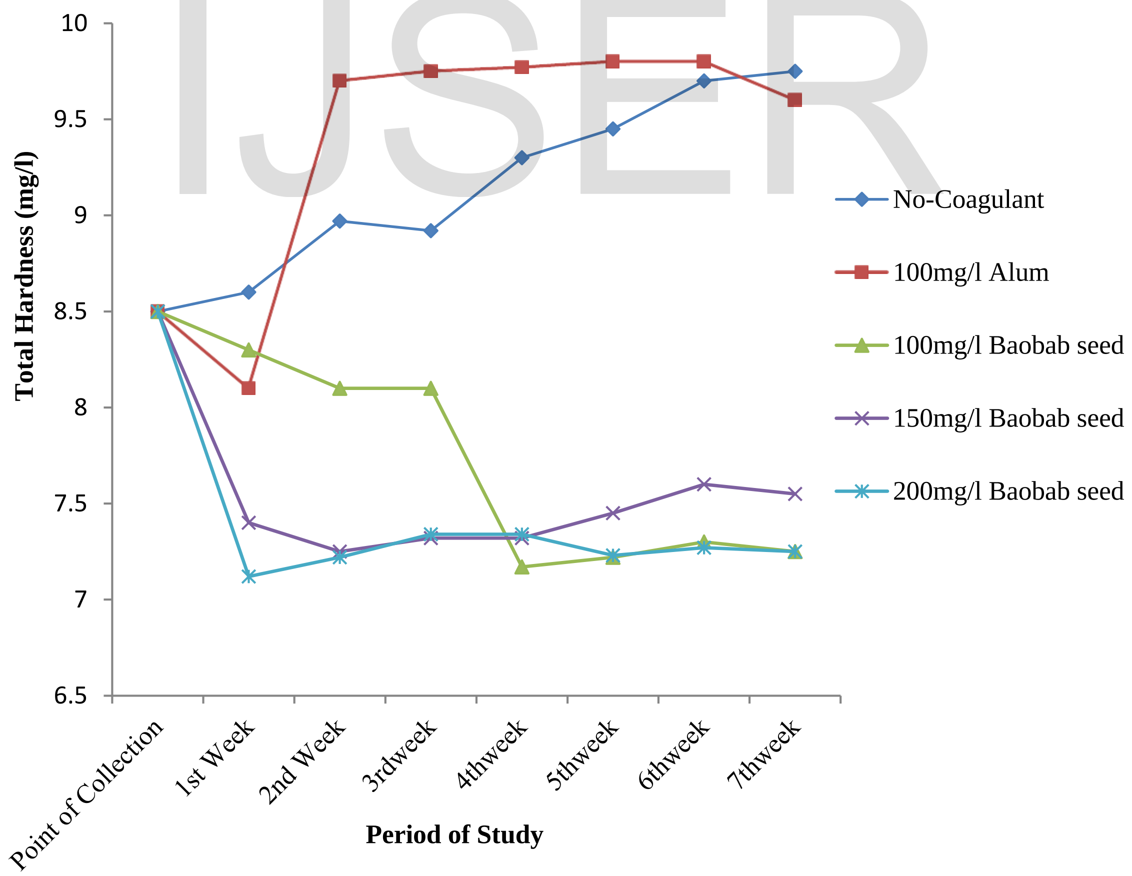

Fig 2. Effects of coagulation on Total Hardness

Table 1. Statistical Analysis of Total Hardness using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.680	4	.420	1.680	.00[b]
	Residual	.500	2	.250		
	Total	2.180	6			

a. Dependent Variable: no coagulant
b. Predictors: (Constant), 200mg/l Baobab seeds, 150mg/l Baobab seeds, 100mg/l Baobab seeds, 100mg/l Alum.

3.1.2. Sewage pH

The pH of the domestic sewage at the point of collection was 6.7 and at the end of the test; pH for the control culture, 100mg/l of alum, 100mg/l of baobab,150mg/l of baobab, and 200mg/l of baobab was 6.65, 6.6, 6.9, 7.3 and 7.15 respectively. In comparison with NIS, the safe limit of pH falls within 6.5-8.5, therefore the values obtained at the point of collection, the control culture and those for sewage treated with alum and baobab seeds fall within the lower limit and upper limit, and are acceptable. Figure 3 and Table 2 show the effect of coagulation on pH and the results of the statistical analysis respectively.

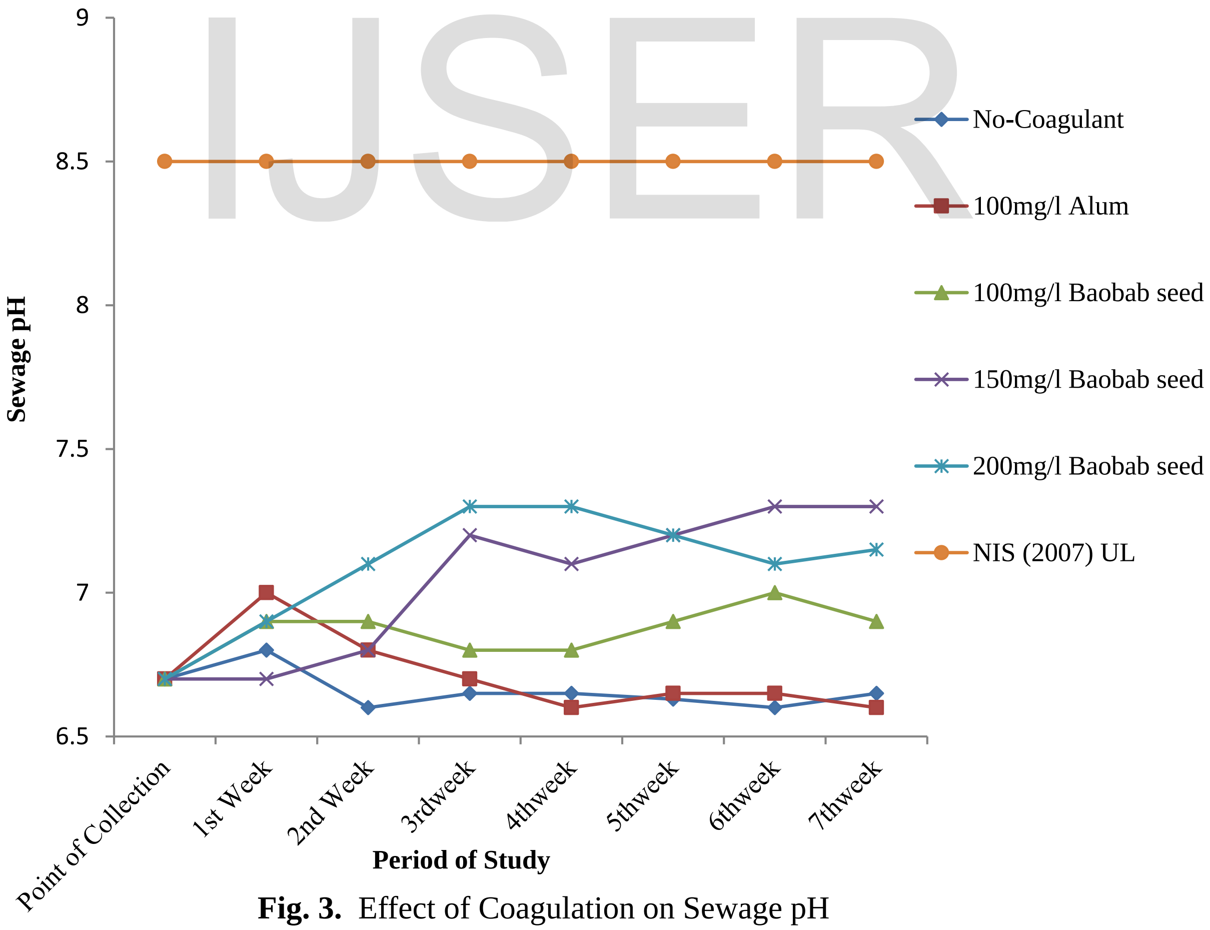

Fig. 3. Effect of Coagulation on Sewage pH

Table 2. Statistical Analysis of pH using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
	Regression	5548.754	4	1387.188	75.648	.013[b]
1	Residual	36.675	2	18.337		
	Total	5585.429	6			

Table 3. Standardized Coefficients Table for Effect of Coagulation on pH

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	-55.837	9.314		-5.995	.027
100mg/l Alum	2.832	.523	1.415	5.419	.032
100mg/l Baobab seed	1.869	.465	1.373	-4.021	.057
150mg/l Baobab seed	.113	.232	.061	.487	.674
200mg/l Baobab seed	1.518	.399	.912	3.810	.063

3.1.3. Total Solids

The results on the analysis of variance (ANOVA) for the model are as shown in Table 4. Total Solids at the point of collection was 53.7 mg/l. After the seventh week of experiment, the value for the Control culture was 53.8mg/l, 53.67mg/l for the 100mg/l of alum, 53.52 mg/l for the 100mg/l of baobab seed, 53.58mg/l for the 150mg/l of baobab seed and 53.66mg/l for the 200mg/l of baobab seed (Fig. 4). From this result, it can be deduced that there are no major changes observed in the values at point of collection and those after treatment, although the biocoagulant samples show improvement in the level of total solids.

Table 4 Statistical Analysis of Total Solids using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
	Regression	.064	4	.016	.896	.588[b]
1	Residual	.036	2	.018		
	Total	.100	6			

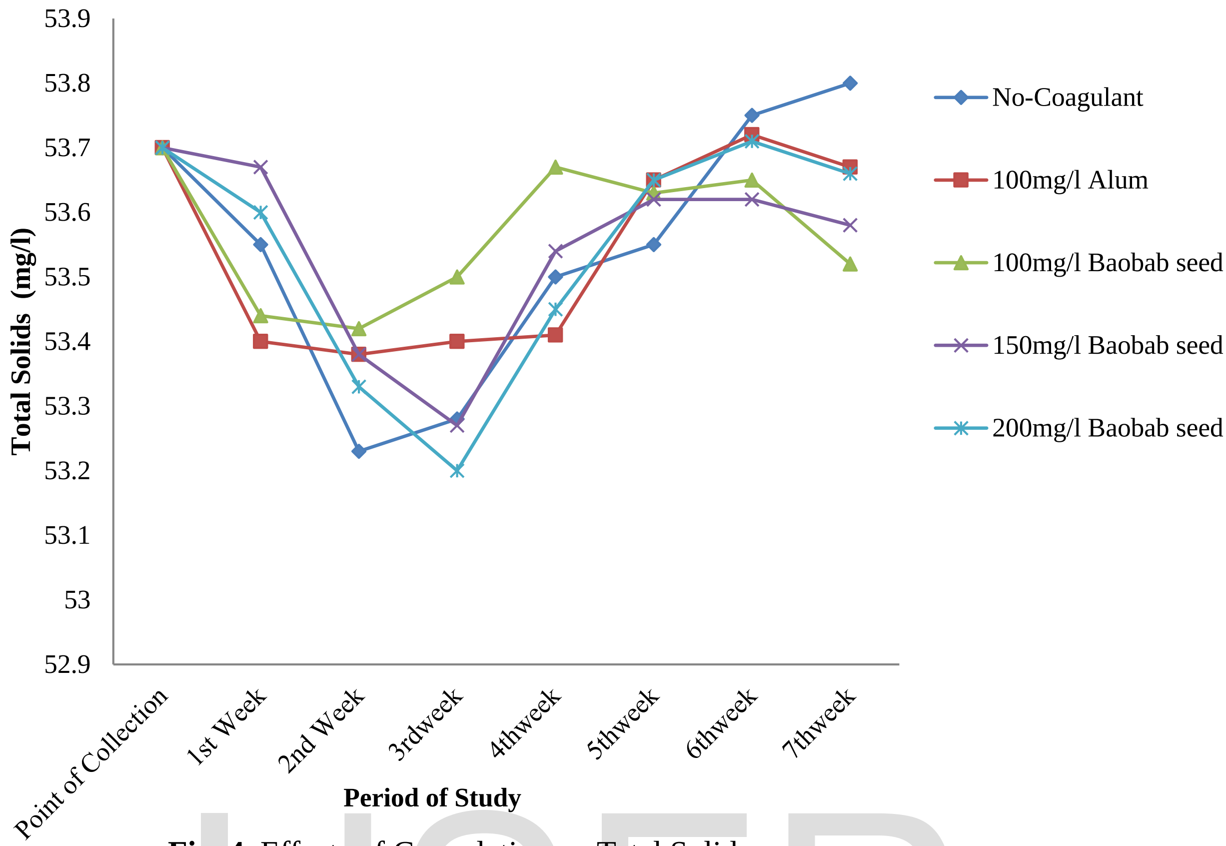

Fig. 4 Effects of Coagulation on Total Solids

3.1.4 Total Dissolved Solids

Figure 5 shows the variation in the values of Total dissolved solids (TDS) of the sample. It reveals that the TDS at the point of collection was 32.5mg/l and this shows that pollution level was still minimal, there was a significant reduction in its level at the end of the experiment to31.8mg/l for the control culture, 28.9mg/l for the 100mg/l of Alum, 27.23mg/l for the 100mg/l of Baobab seed, 27.4mg/l for the 150mg/l of Baobab seed, and 29.2mg/l for the 200mg/l of Baobab seed respectively. From the experiment, it was observed that the 100mg/l of Baobab seed was more effective in the reduction of TDS. The constructed multiple regression model of the independent variables is shown in Table 5 (100mg/1 alum, 100mg/1 baobab seed, 150mg/1 baobab seed, 200mg/1 baobab seeds) account for .50% variance in the dependent variable (dissolved solid with no-coagulant). The independent variable, 200mg/1 baobab seed has the weakest effect on dependent variable (no coagulant) because the significant value was greater than 0.05 alpha value.

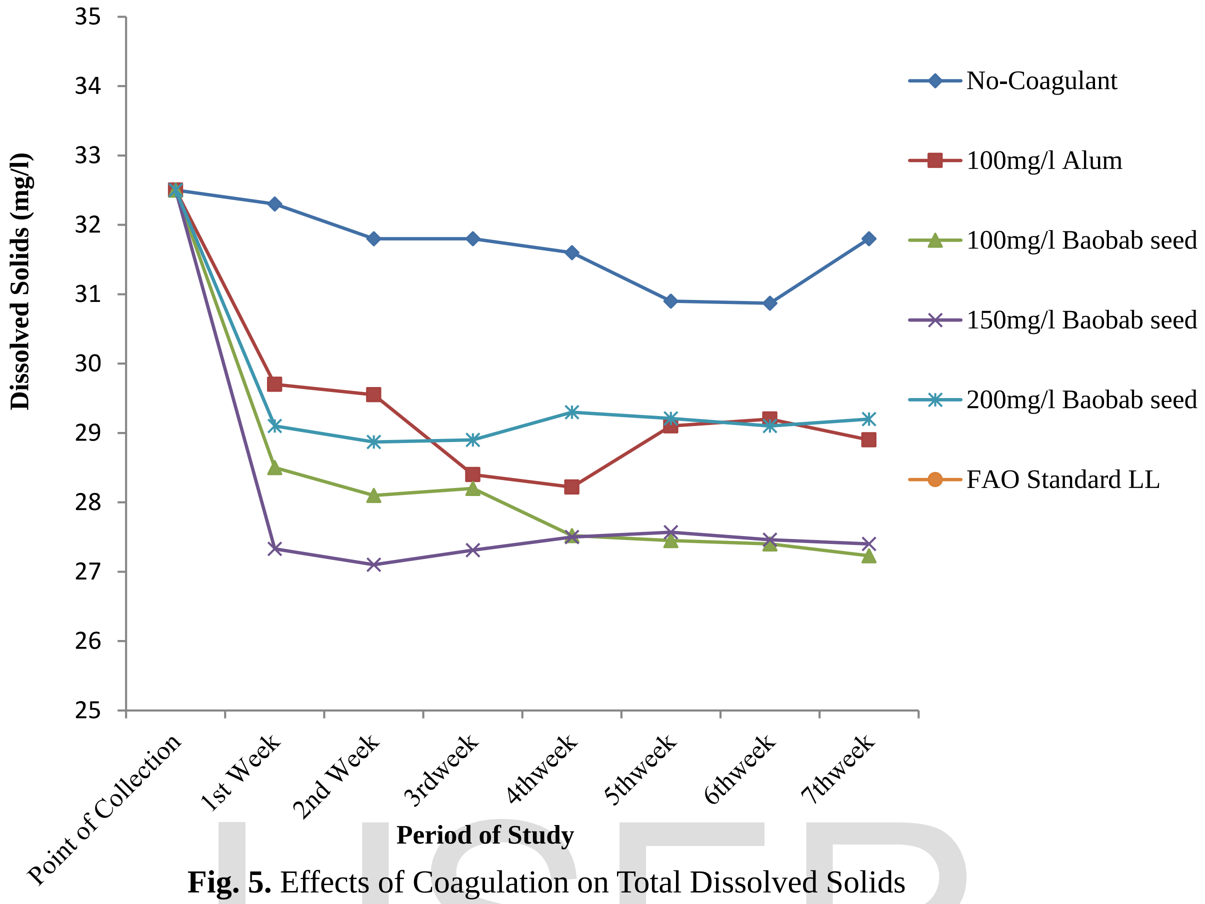

Fig. 5. Effects of Coagulation on Total Dissolved Solids

Table 5. Statistical Analysis of TDS using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
	Regression	1.680	4	.420	1.680	.406[b]
1	Residual	.500	2	.250		
	Total	2.180	6			

a. Dependent Variable: no coagulant
b. Predictors: (Constant), 200mg/l baobab seeds, 150mg/l baobab seeds, 100mg/l alum, 100mg/l baobab seeds

3.1.5 Total Suspended Solids

Figure 6 shows the variations in the values of total suspended solid. At the point of collection, the domestic sewage was 21.2 mg/l, at the end of the seven weeks' period of study, values for control culture, 100 mg/l of alum, 100 mg/l of baobab seed, 150mg/l of baobab seed and lastly 200mg/l of baobab seed were 22 mg/l, 24.77 mg/l, 26.29 mg/l, 26.18 mg/l and 24.46 mg/l respectively. Statistical analysis of total suspended solids using ANOVA is shown in Table 6.

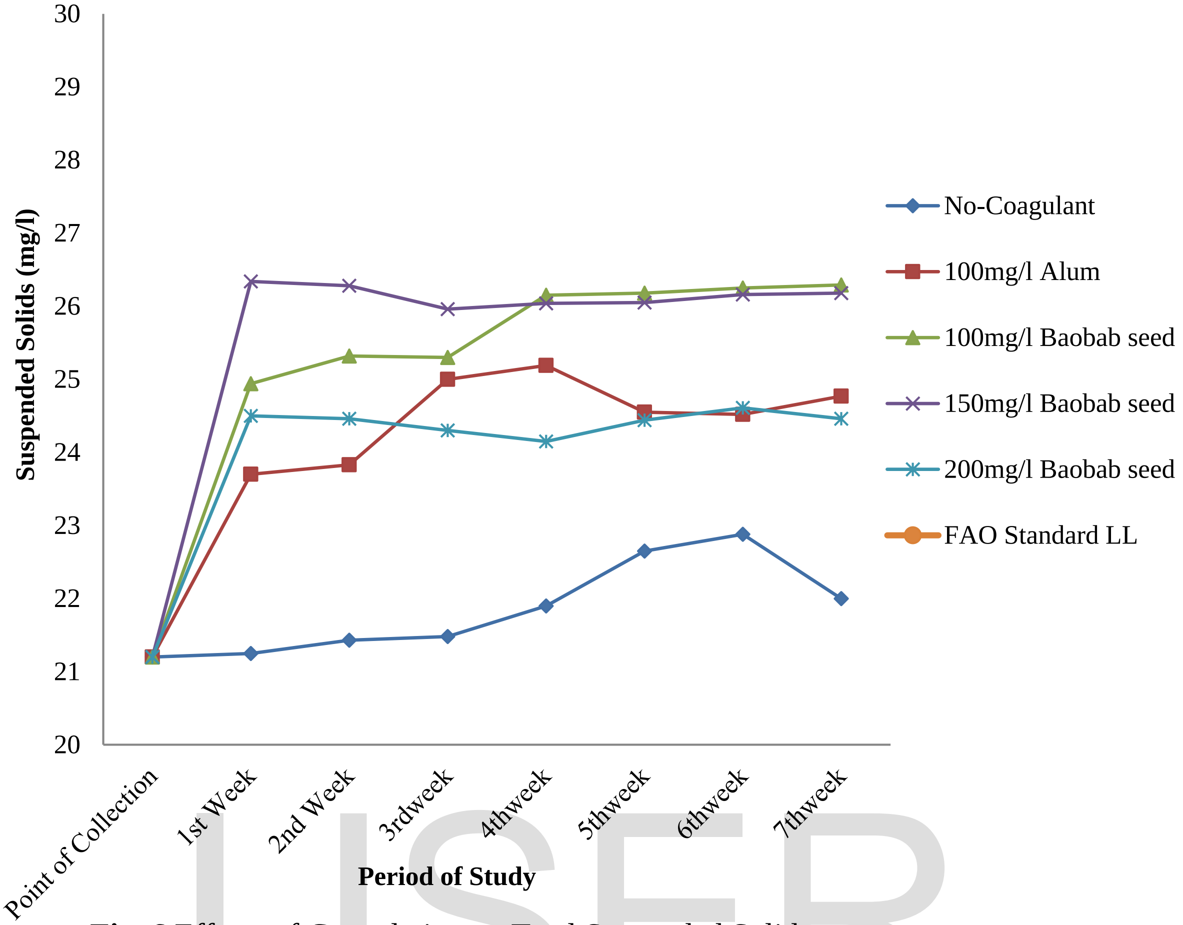

Fig. 6 Effects of Coagulation on Total Suspended Solids

3.1.6. Conductivity

Statistical analysis of Conductivity using ANOVA is shown in Table 7. From the result, it was observed that there is no significant relationship at F(df 4, 6 = .814, p >0.00). The conductivity at the point of collection was 457 µS/cm (microsiemens per centimeter). Figure 7 shows the effect of coagulation on Conductivity. It was observed that there is an average increment after seven weeks of test for control culture,100 mg/l of Alum, 100 mg/l of Baobab seed, 150mg/l of Baobab seed and 200mg/l of Baobab seedwere380µS/cm, 753 µS/cm ,522 µS/cm ,507 µS/cm, and596µS/cm respectively.

Table 7. Statistical Analysis of Conductivity using ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.533	4	.133	.814	.616[b]
	Residual	.327	2	.164		
	Total	.860	6			

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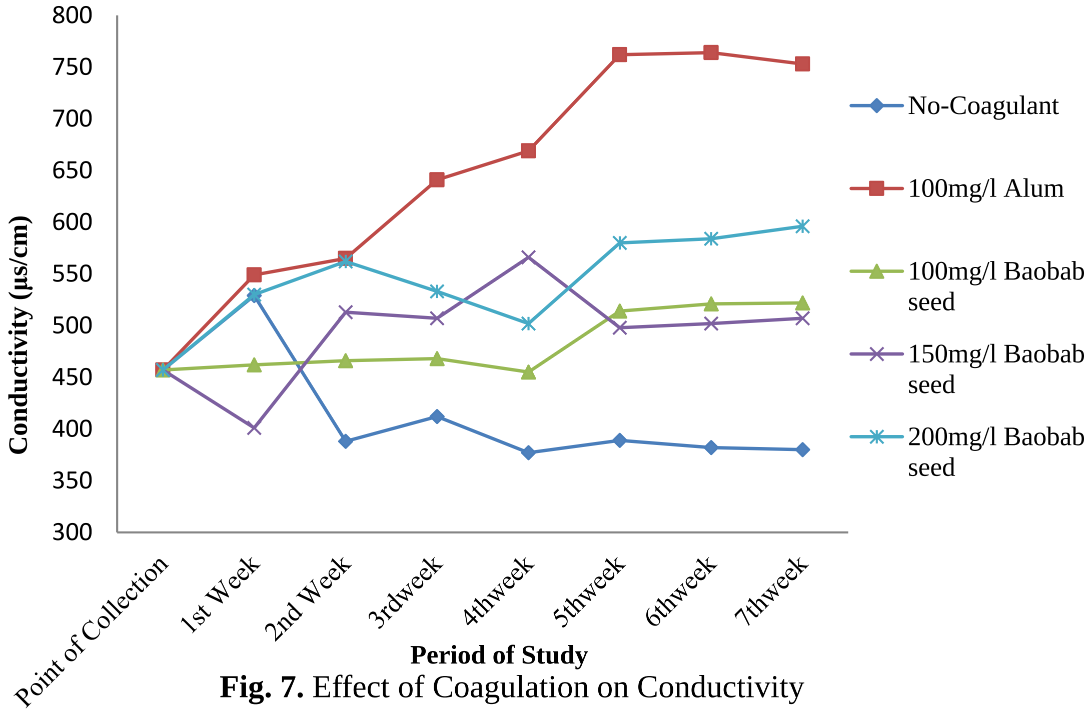

Fig. 7. Effect of Coagulation on Conductivity

3.1.7. Biochemical oxygen demand (BOD)

Figure 8 shows the variations in the values of BOD. BOD was 66.7 mg/l at the point of collection, after the period of study, for control culture,100 mg/l of alum, 100 mg/l of baobab seed, 150mg/l of baobab seed and 200mg/l of baobab seed, the values were 66.9 mg/l, 65.5 mg/l, 66.3 mg/l, 65.9 mg/l, and 65mg/l respectively. The results of the analysis of variance (Table 8) which revealed that F(df 4, 6 = 5.184, p >0.00), indicated that there is no significant relationship between the independent and dependent variables.

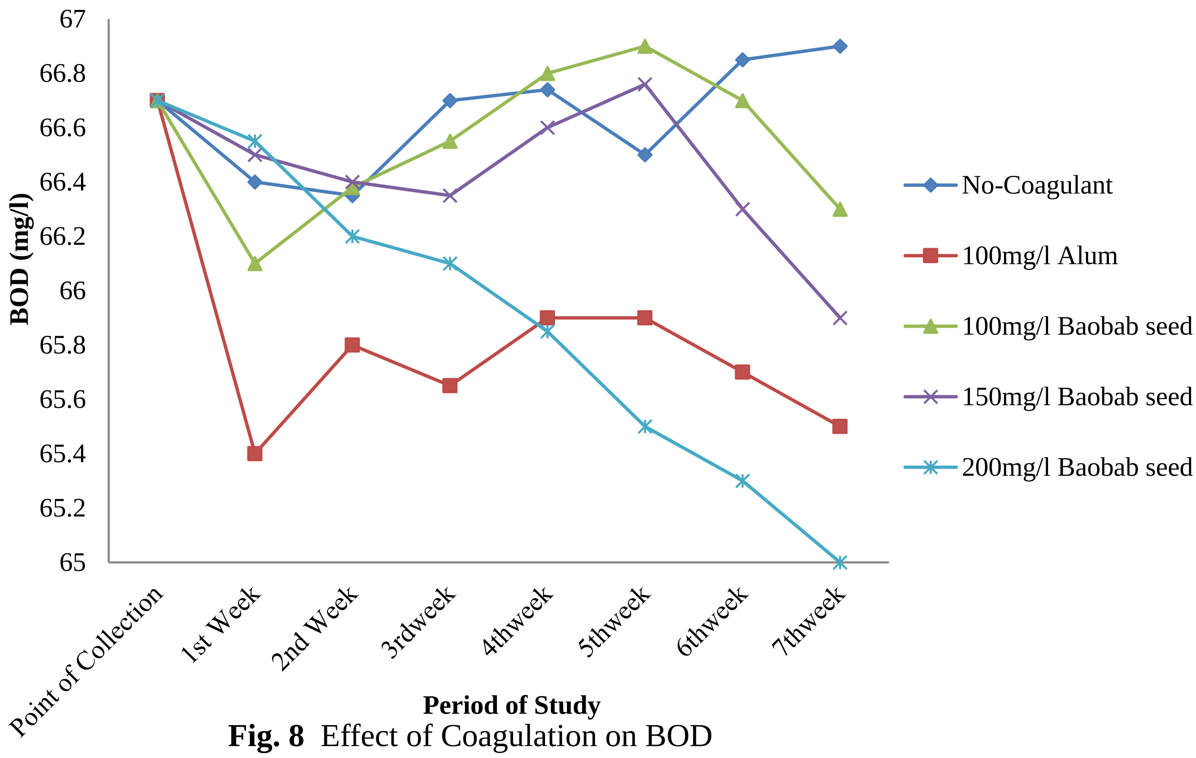

Fig. 8 Effect of Coagulation on BOD

Table 8 Statistical Analysis of Biochemical Oxygen Demand using ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	.003	4	.001	5.184	.317[b]
1	Residual	.000	1	.000		
	Total	.003	5			

3.1.7. Chemical oxygen demand (COD)

Figure 9 shows the variations in the values of COD. COD was 32.75 mg/l at the point of collection, but after the period of study, for control culture,100 mg/l of alum, 100 mg/l of baobab seed, 150mg/l of baobab seed and 200mg/l of baobab seed, the values were 32.45 mg/l, 32.38 mg/l, 32.3 mg/l, 32.42 mg/l, and 32.4mg/l respectively. The Adjusted R square (.62) has good fit. This revealed that the constructed multiple regression model of the independent variables (100mg/1 alum, 100mg/1 baobab seed, 150mg/1 baobab seed, 200mg/1 baobab seeds) account for .62% variance in the dependent variable (no coagulant). The results on the analysis of variance revealed that F(df 4, 6 = 14.371, p >0.00), indicating that there is significant relationship between the variables (Table 9). Based on this significant relationship, the coefficient for the Beta weight for the amount of standard deviation unit of change in the dependent variable was calculated. For reduction of COD, 100mg/l alum and 100mg/l baobab seed treatments have the strongest positive result.

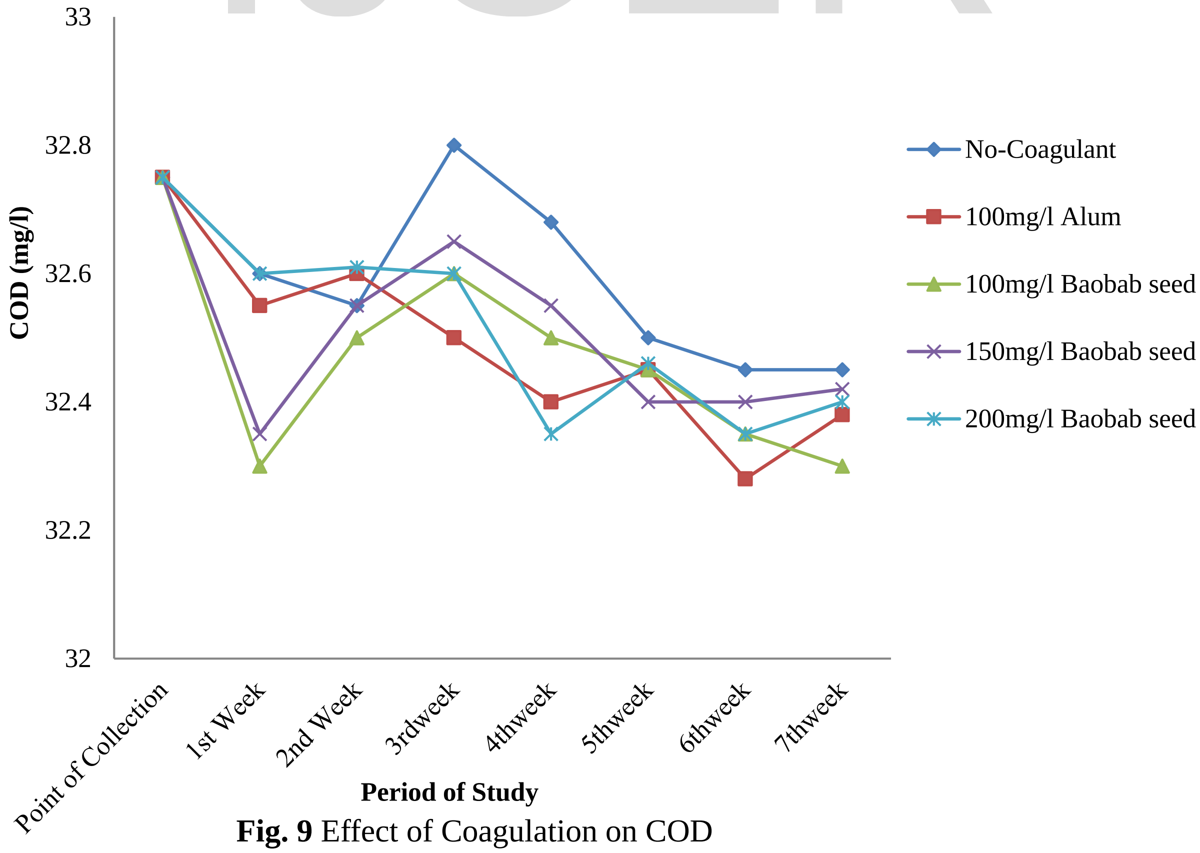

Fig. 9 Effect of Coagulation on COD

Table 9. Statistical Analysis of Chemical Oxygen Demand using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
	Regression	21.763	4	5.441	14.371	.066[b]
1	Residual	.757	2	.379		
	Total	22.520	6			

3.2. Bacteriological Properties

3.2.1 Total Coliform Count

The TCC at the point of collection was 115 CFU/ml. At the end of the seven weeks' study, it has greatly reduced to 26 CFU/ml in the control culture, 24 CFU/ml in the 100mg/l of alum treatment, and 12 CFU/ml, 18 CFU/ml, and 20 CFU/ml in the 100 mg/l of baobab seed, 150mg/l of baobab seed and 200mg/l of baobab seed treatments respectively (Fig. 10). From these results, it is observed that the 100mg/l of baobab seed worked best among the ranges of treatment. Although, the Nigerian Industrial Standard gives the permissible limit for total coliform count to be 10 CFU/ml, and the results do not fall on or below this, it can be said that all the treatments were effective in disinfecting the domestic wastewater. Table 10 shows the result of the statistical analysis of Total Coliform Count using ANOVA**.**

From the result in Table 4.10, the Adjusted R square (.50) has good fit. This revealed that the constructed multiple regression model of the independent variables (100mg/l alum, 100mg/l baobab seed, 150mg/l baobab seed, 200mg/l baobab seed) account for.50% variance in the dependent variable (no-coagulant). The results show that baobab seed possess disinfectant properties.

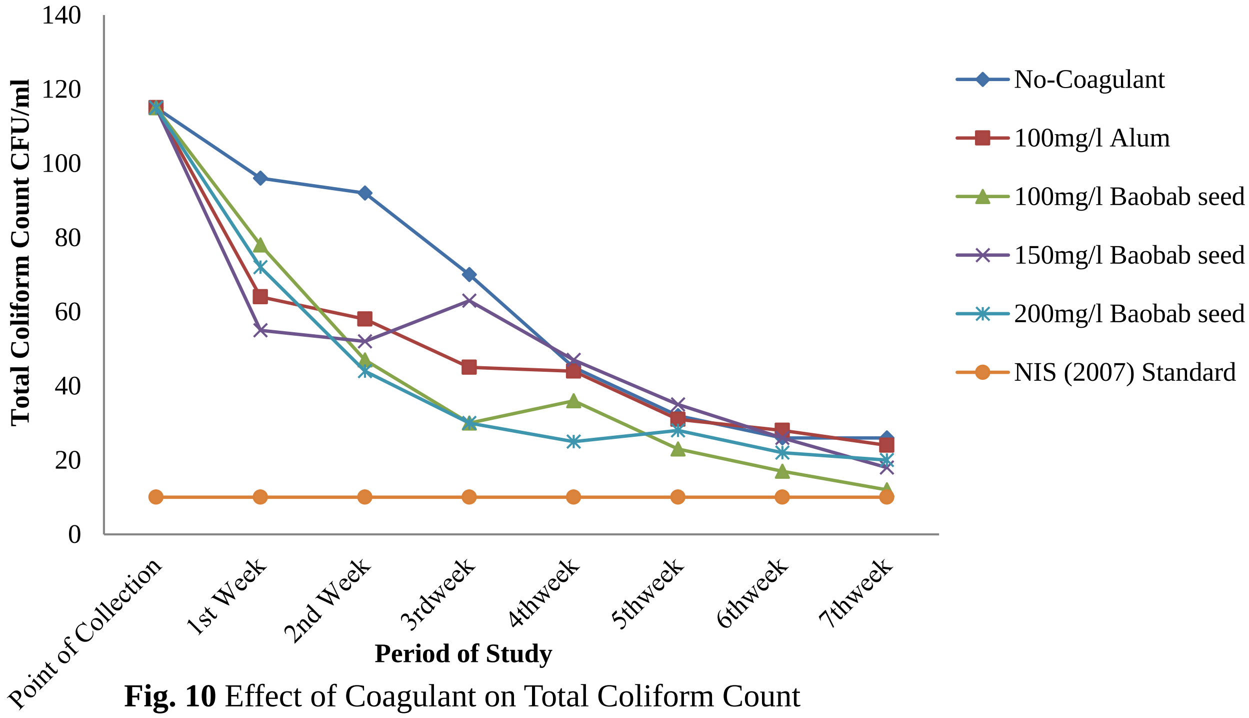

Fig. 10 Effect of Coagulant on Total Coliform Count

Table 10 Statistical Analysis of Total Coliform Count using ANOVA

	Model	Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.523	4	.113	.514	.051[b]
	Residual	.307	2	.174		
	Total	.960	6			

a. Dependent Variable: no coagulant
b. Predictors: (Constant), 200mg/l baobab seed, 150mg/l baobab seed, 100mg/l baobab seed, 100mg/l alum.

Table 11 Model Summary of Effects of coagulation on Total Coliform Count

Model	R	R square	Adjusted R square	Std. Error of the Estimate
.987[a]	.610	-.112	.50445	.520

4.0 Conclusion

The study displays that the seeds of *Adansonia digitata* contain materials that can act as an effective natural coagulant. Baobab plant is readily available in many parts of Africa, environmentally friendly and a verified source of natural coagulant suitable for water clarification and disinfection. The Boabab seeds possess to be a veritable tool for waste purification for proper disposal and reuse. It can also be noted that the seeds possess promising bio-sorbent properties. Furthermore, the dosage of the bio-coagulant displays significant effects on the coagulation effectiveness. The use of *Adansonia digitata* seeds in treating domestic waste water should be encouraged as it helps in reducing cost of water treatment and aids to improve water quality.

The study shows that an optimal dose of 100mg/l of Baobab seed treatment worked best, followed by 150mg/l of Baobab, which has the next best positive results on the sewage. It was found, however, that the treatments did not produce total coliform-free water, but that there is a significant disinfectant property in the bio-coagulant. The efficacy of *Adansonia digitate* seeds as a bio-sorbent may be improved by the chemical or physical modification of the nature of the bio-sorbent (e.g. by treating to form activated carbon).

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