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RELATIVE COAGULATION POTENTIALS OF ALUMINUM SULPHATE AND *MANGIFERA INDICA* SEEDS IN PURIFYING DOMESTIC WASTE WATER

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ABSTRACT
The high cost of most chemical coagulants and their non-availability coupled with their negative health impacts necessitates the use of natural or bio-coagulants. This study compares the effectiveness of using powdered extract from matured dried *Mangifera indica (M. indica)* seeds (bio-coagulant) with Aluminum sulphate (alum, chemical coagulant) for the coagulation of domestic waste water. The treatments include: control culture (no coagulant is added), 150 mg/L of alum, 100 mg/L, 150 mg/L and 200 mg/L of *M. indica* seeds. All the treatments were cultured in 15-litres buckets. The experiment was design based on Completely Randomized Design (CRD) replicated 3times. Physical, chemical and bacteriological properties of the domestic sewage were determined before and after the application of the coagulants on weekly basis. Results show that for turbidity, at the point of collection, the value was 013NTU was reduced to a minimum value of 001NTU for both 100 mg/L and 150 mg/L of *M. indica* seeds treatments. The Total Hardness at the point of collection was 2.73 mg/L; the highest value during the period of study was 5.30 mg/L at the fifth week for the alum treatment, followed by 4.37 at the fourth week for 100 mg/L of *M. indica* seeds treatment. The study showed that *M. indica* seeds powder perform very well as a bio-coagulant and be used as a replacement for alum or any other chemical coagulant in the purification of domestic waste water.

Keywords: *Mangifera indica*, Alum, Sewage, Physio-chemical and bacteriological properties

INTRODUCTION
Water treatment chemicals are effective and used worldwide, but scientific evidence shows that exposure to chemicals during coagulation with metal salts may be associated with adverse health effects [1]. Aluminium, which is the major component of aluminium sulphate (alum), polyaluminium chloride (PAC) and polyaluminium silica sulphate (PASS), could induce Alzheimer's disease and other similar related problems that are associated with residual aluminium in treated water [2]. Moreover, monomers of some synthetic organic polymers such as acryl amide have neurotoxicity and strong carcinogenic properties [3].Iron coagulants such as ferric sulphate ($Fe_2(SO_4)_3$), ferrous sulphate ($FeSO_4$) and ferric chloride ($FeCl_2$) are generally cheaper, produce heavier flocs, and perform over a wider pH range than aluminium coagulants [4]. However, iron coagulants are not used as much as aluminium due to staining effect, corrosiveness, and they require more alkalinity than alum. Iron coagulants react with phosphorous and bicarbonate compounds in water causing precipitation of calcium carbonate and magnesium

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hydroxides [5]. Synthetic or natural polyelectrolyte can also be used as both primary coagulants and coagulant aids [3]. Polyelectrolyte primary coagulants are cationic with high charge density and low molecular weight, while synthetic polyelectrolyte coagulant aids have relatively high molecular weights and facilitate flocculation through inter-particle bridging [6]. Polyelectrolytes are more expensive than aluminium and iron salts in terms of material cost, overall operating costs can be lower because of reduced need for pH adjustment, lower sludge volumes, no increase in total dissolved solids in treated water and shorter settling time. However, they are not readily available and also costly for most parts of the developing world. Natural polyelectrolyte such as water-soluble proteins released from crushed seed kernels are potential alternatives to synthetic polyelectrolytes. The merits of natural polyelectrolytes over synthetic include safety to human health, biodegradability and a wide effective range of flocculation for various colloidal suspensions [7]. Natural coagulants are usually presumed safe for human health while the use of aluminum salts may induce Alzheimer's disease. Some studies on natural coagulants have been carried out and various natural coagulants were produced or extracted from microorganisms, animals or plants. However, these natural materials have not been recognized or duly supported due to lack of knowledge on their exact nature and the mechanism by which they function. As a consequence, the natural materials have been unable to compete effectively with the commonly used water chemicals [8].The main objective of this study was to investigate the relative coagulation effectiveness of *M. indica* seeds over alum in purification of domestic waste water.

MATERIALS AND METHOD

Experimental Design

The sewage sample was cultured in a 15-litre capacity container for a period of seven weeks. Physical and chemical tests were carried out at the point of collection and daily for a period of seven weeks. The experiment was designed based on Completely Randomized Design (CRD); the design was replicated three times. The treatments imposed include: control culture (no coagulant), 150 mg/L of alum, 100 mg/L of *M. indica* seeds, 150 mg/L of *M. indica* seeds and 200 mg/L of *M. indica* seeds.

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 and American Public Health Association [9] and [10]. Chemical properties such as total hardness was determined using the complex metric titration (EDTA), dissolved oxygen by the Winkler method, biochemical oxygen demand and chemical oxygen demand using standard procedure [9] and [10].The

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chloride ion was determined the Mohr method, nitrate by the colorimetric method and phosphate using the spectrophotometric method of determination [9] and [10].

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 $p < 0.05$ [11].

RESULTS AND DISCUSSION

Total Hardness

Figureure 1 shows the total hardness at the point of collection was 2.73 mg/L this means corrosion level is minimal. Figure 1 also shows that after fourth week, total hardness was increased to 3.14 mg/L for the control culture treatment, 5.30 mg/L for Alum, 2.32 mg/L for 100 mg/L of, 4.30 mg/L for 150 mg/L and 3.57 mg/L for 150 mg/L of *M. indica* seeds treatment. The results shows that treatment with the 100 mg/L of *M. indica* seeds applied to treat wastewater performed best in reducing the total hardness of water comparing with WHO [12] standard of 10.00 mg/L. The results of the ANOVA analysis (Table 1) obtained for total hardness, the value (Fcal=0.595).

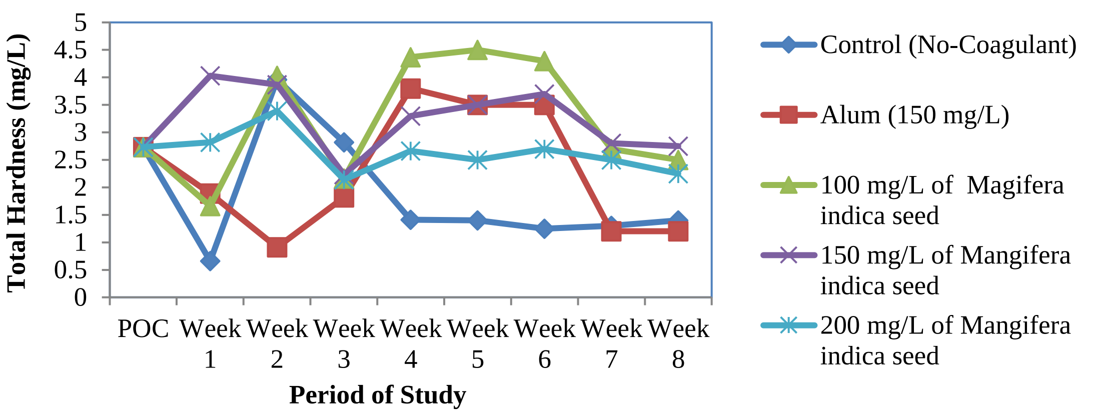

Figure 1. Effects of Coagulation on Total Hardness

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Table 1. Statistical Analysis of parameters using ANOVA (Analysis of Variance)

Property	Sum of Squares			Mean Square		F	Significance
	Treatment	Errors	Total	Treatment	Errors		(p at 95%)
Total Hardness	2.89	30.35	33.24	0.72	1.21	0.59	0.67
Total Solids	6.34×10^8	2.24×10^8	8.58×10^8	1.58×10^8	1.12×10^8	14.15	0.00*
Suspended Solids	5.70×10^7	7.66×10^8	8.23×10^8	1.43×10^7	3.83×10^7	0.37	0.82
Dissolved Solids	6.13×10^5	7.16×10^6	7.77×10^6	1.53×10^5	3.58×10^5	0.43	0.79
Turbidity	215.13	1.10×10^4	1.12×10^4	53.78	548.77	0.10	0.98
Temperature	0.14	21.62	21.76	0.035	0.865	0.04	1.00
Calcium Hardness	1.05	12.59	13.64	0.26	0.50	0.52	0.27
Magnesium Hardness	4.00	18.10	22.10	1.00	0.72	1.38	0.27
Lead	0.003	0.003	0.006	0.001	0.001	7.73	0.001*
Zinc	0.215	0.310	0.525	0.054	0.012	4.334	0.008*
Total Viable Count	1052.33	6951.67	8004.00	263.08	347.58	0.76	0.56
Total Coliform Count	3424.44	1425.00	4849.44	856.11	71.25	12.02	0.00*
E. coli	0.69	2.67	3.36	0.17	0.13	1.30	0.34

*Significant at $p \leq 0.05$ shows insignificant differences existed when the mean values of the treatments are compared (p=0.669).

Total Solids

Figure 2 shows that the total solid at the point of collection was 11800 mg/L and this shows high level of solid particles in the domestic waste water. The average drop of total solid for the control culture after the fourth week of experiment was 4750 mg/L, 5250 mg/L for Alum, 4500 mg/L for 100 mg/L, 5500 mg/L for 150 mg/L and 2000 mg/L for 200 mg/L of *M. indica* seeds. Figure 2 shows that the treatment containing 200 mg/L of *M. indica* seeds best. From the ANOVA test result in (Table 1), shows that the Fcal=14.147with significant difference (p=0.000). Hence, Duncan test (Table 2) was performed which shows 100 mg/L of *M. indica* seeds performed best.

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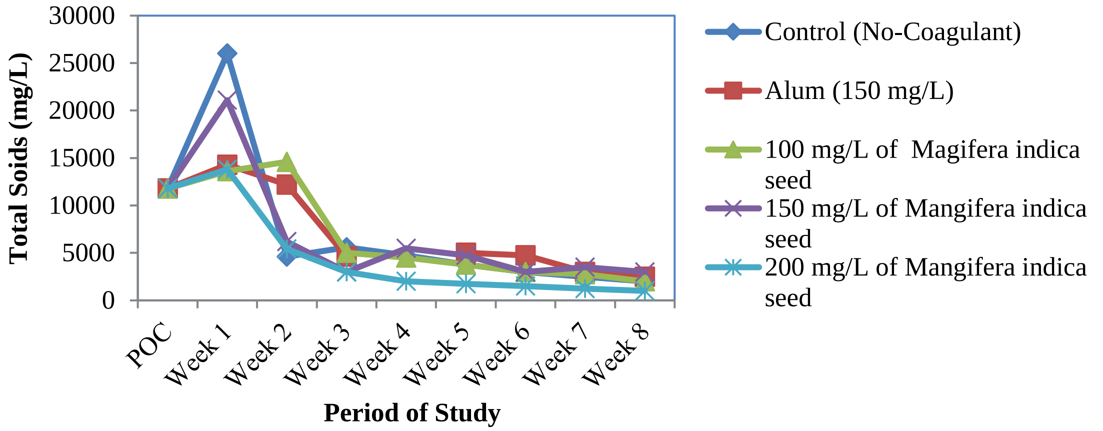

Figure 2. Effects of Coagulation on Total Solids

Table 2. Duncan Multiple Tests

	Treatments				
	Control	**150 mg Alum**	**100 mg *M. indica* seeds**	**150 mg M. *indica* seeds**	**200 mg *M. indica* seeds**
Total Solids	11800.00[b]	17760.00[b]	18100.00[a]	4070.00[c]	4312.50[c]
Lead	0.01[c]	0.01[c]	0.027[b]	0.032[a]	0.033[a]
Zinc	0.01[c]	0.010[c]	0.027[b]	0.032[a]	0.033[a]
Total Coliform Count	40.00[b]	24.80[b]	31.33[b]	51.80[a]	5.25[c]

Suspended Solids

Figure 3 shows that the total suspended solids level of the waste water was observed to be far above the WHO standard from point of collection with 10300 mg/L and it reduced to 3000 mg/L after the fourth week, while it was 2500 mg/L for the alum treatment, 2000 mg/L for 100 mg/L, 3250 mg/L for 150 mg/L and 500 mg/L for 200 mg/L of *M. indica* seeds treatment. It was observed that 200 mg/L of *M. indica* seeds treatment shows higher level of efficiency. The ANOVA test result in (Table 1), shows the values with (Fcal=0.372) and the insignificant difference at (p=0.825).

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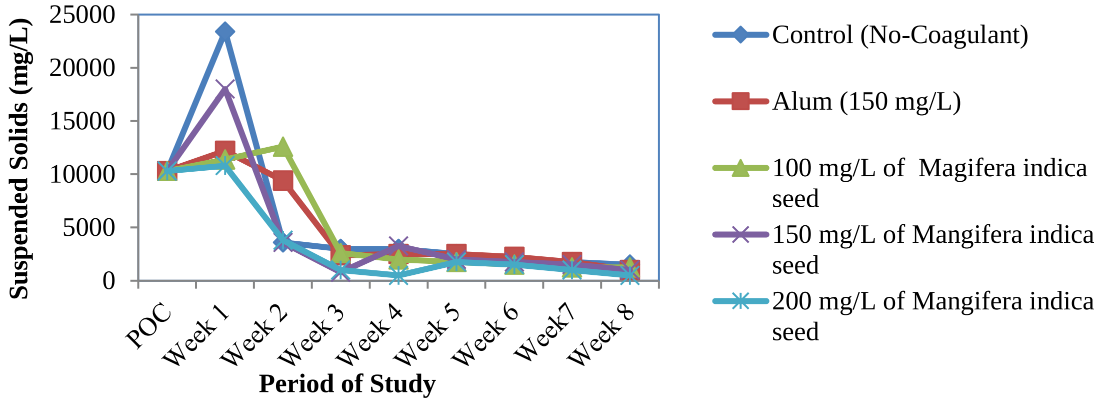

Figure 3. Effects of coagulation on Suspended Solids

Dissolved Solids

The dissolved solid at the point of collection (Figure 4) was 1500 mg/L this shows that the water is very polluted. At the end the value increased to 1750 mg/L for the control, 2750 mg/L for the Alum treatment, 2500 mg/L for the 100 mg/L, 2250 mg/L for the 150 mg/L and same value of 1500 mg/L for the 200 mg/L of *M. indica* seeds comparing with WHO [12] standard of 500 mg/L none of treatment was able to meet the standard. The ANOVA test result (Table 1) shows Fcal. =0.428 and insignificance difference of at p= 0.787.

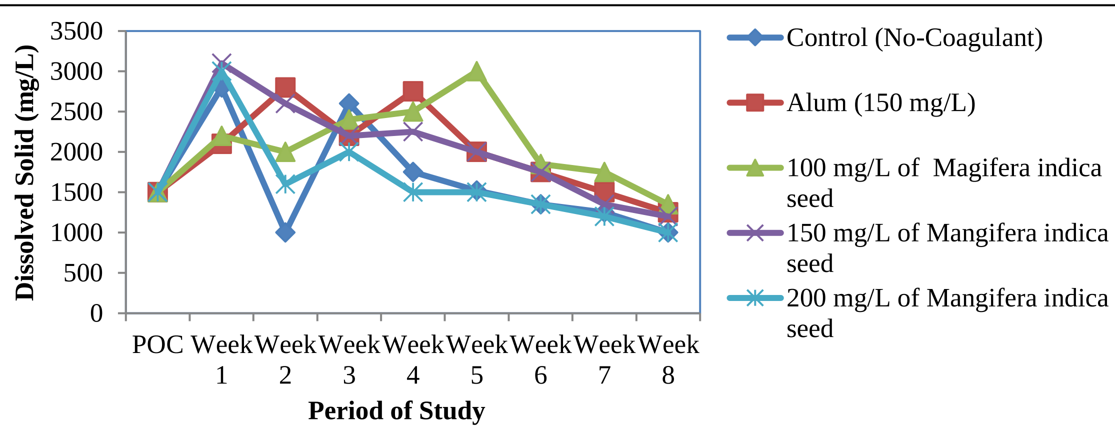

Figure 4. Effects of Coagulation on Dissolved Solids

Turbidity

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and other microscopic organisms. Figure 5 show that turbidity at point of collection was 013NTU. Turbidity at the end of the fourth week for the control was 001 NTU, for the control was 006 NTU, for the 100mg/L of *M. indica* seeds was 005 NTU, for the 150mg/L of *M. indica*

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seeds was 007 NTU and that of 200mg/L of *M. indica* seeds was 002 NTU comparing with WHO [12] standard of 5 NTU, the control performs best followed by 200 mg/L of *M. indica* seeds. The ANOVA result analysis (Table 1), shows the mean values with (Fcal=0.098) and insignificant values of (p=0.982).

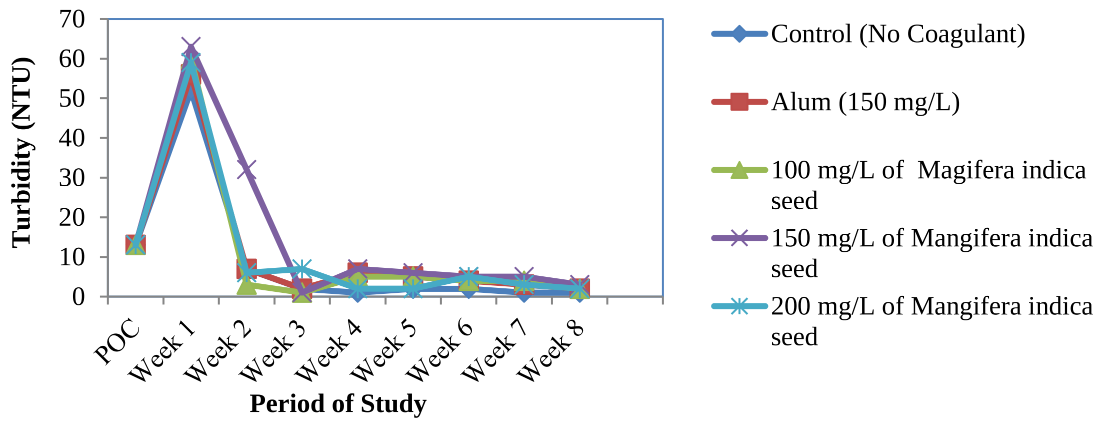

Figure 5. Effects of coagulation on Turbidity

Temperature

Temperature does not affect coagulation normally but it can influence microbes' formation. Figure 6 shows that the highest temperature (26^0C) was recorded at the second week for the control and the least temperature (22.5^0C) was recorded at first week for the control. The temperature at the point of collection was 24^0C. At the fourth week and fifth week, the temperatures were the same for all the treatments as 24^0C and 25^0C respectively. The ANOVA results (Table 1) shows that (Fcal) =0.040 and insignificant at p=0.997.

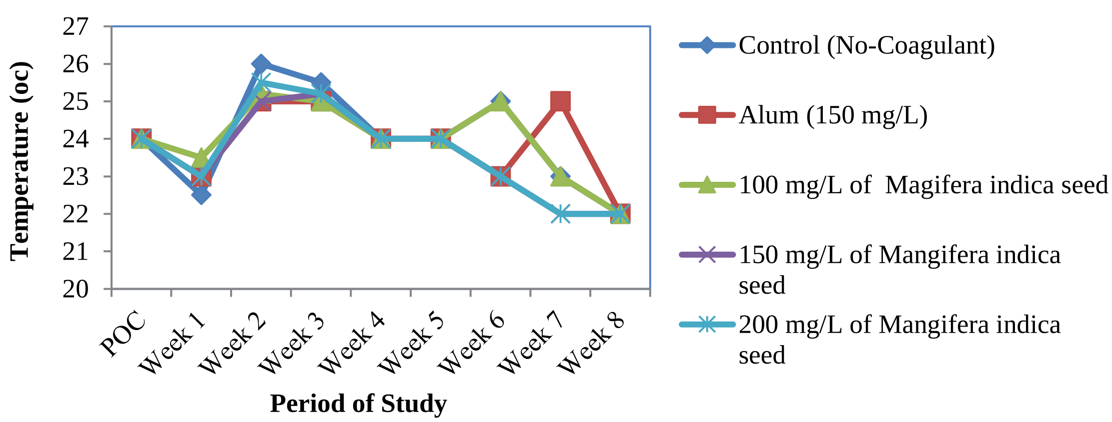

Figure 6. Effects of coagulation onTemperature

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Calcium Hardness

Figure 7 show that Calcium hardness at the point of collection was 1.50 mg/L. At the end of the period of study, the value remains at 1.50 mg/L for both control and 100 mg/L of *M. indica* seeds treatment. The value increased to 3.25, 2.25, 2.75 mg/L for alum, 150 mg/L of *M. indica* seeds and 200 mg/L of *M. indica* seeds treatment, respectively. The ANOVA result (Table 1) shows that (Fcal) is 0.521 and insignificant difference at p=0.721.

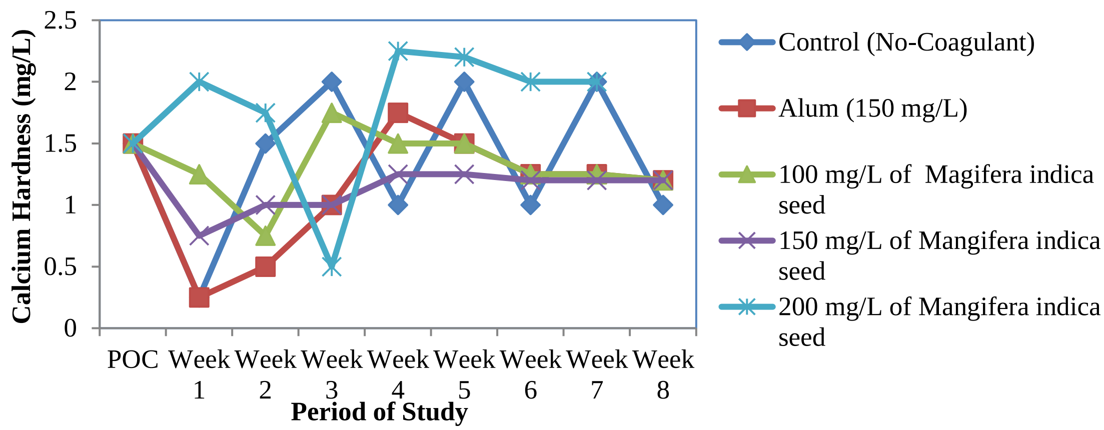

Figure 7. Effects of coagulation on Calcium Hardness

Magnesium Hardness

Figure 8 show that Magnesium hardness at the point of collection was 1.23 mg/L. At the end of the period of study, the value reduced to 0.82 mg/L for both 100 mg/L of *M. indica* seeds treatment and 200 mg/L of *M. indica* seeds treatment. The value increased to 1.64, 2.05, 2.05 mg/L for the control, alum and 150 mg/L of *M. indica* seeds respectively. The ANOVA result (Table 1) shows that (Fcal) is 1.382 and insignificant difference at p=0.269.

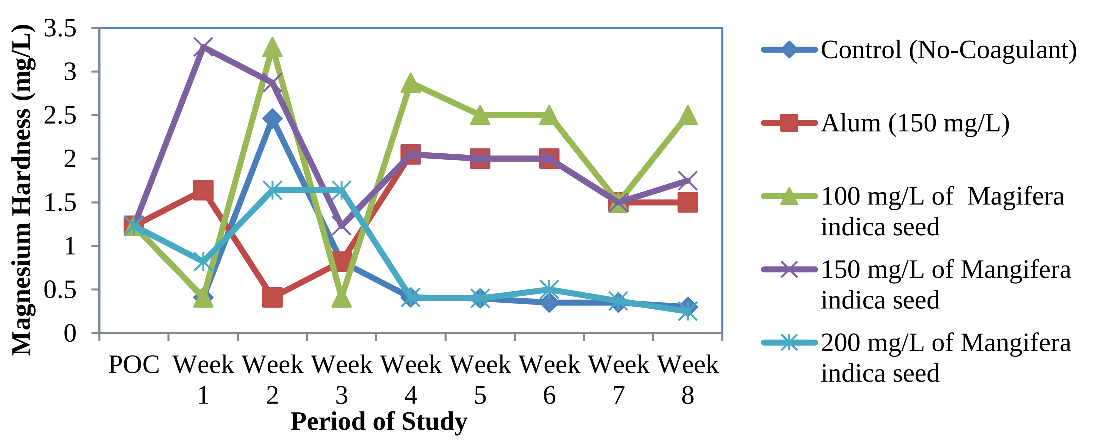

Figure 8. Effects of coagulation on Magnesium Hardness

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Lead

Lead as a heavy metal above WHO [12] standard of 0.01 mg/L causes cancer and tooth moth. Figure 9 shows that at the point of collection lead level was 0.01 mg/L and the value was maintained for the control and alum treatment throughout the period of study. The value increased to 0.04 mg/L for 100 mg/L of *M. indica* seeds, 150 mg/L of *M. indica* seeds and 200 mg/L of *M. indica* seeds. The peak value of 0.07 mg/L was recorded at the first week for 150 mg/L of *M. indica* seeds. From the ANOVA result (Table 1), Fcal was 7.727 and significant at p=0.001*. Duncan test was performed which shows 150 mg/L of *M. indica* seeds and 200 mg/L of *M. indica* seeds performed best.

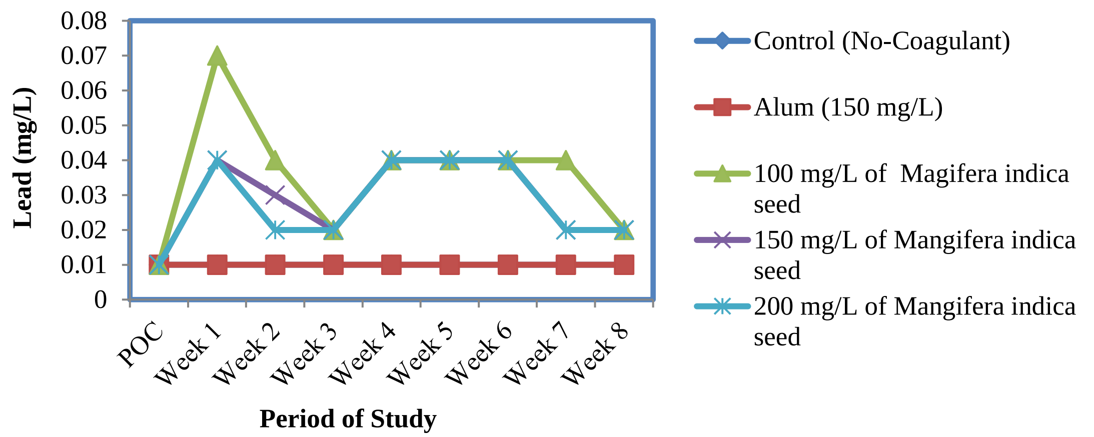

Figure 9. Effects of coagulation on Lead

Zinc

The level of zinc at the point of collection was 0.20 mg/L (Figure 10). The highest level (0.69 mg/L) was recorded at the first week of 100 mg/L and the lowest level (0.12) was recorded at the third week of 150 mg/L of *M. indica* seeds. Maximum permitted level according to WHO [12] standard is 3 mg/L. Figure 10 shows that all the treatments are below the maximum permitted level for the period of study. Table 1 gives (Fcal.) to be 4.334 and significant at p=0.008. Duncan test (Table 2) was performed this shows that 100 and 150 mg/L of *M. indica* seeds were comparable.

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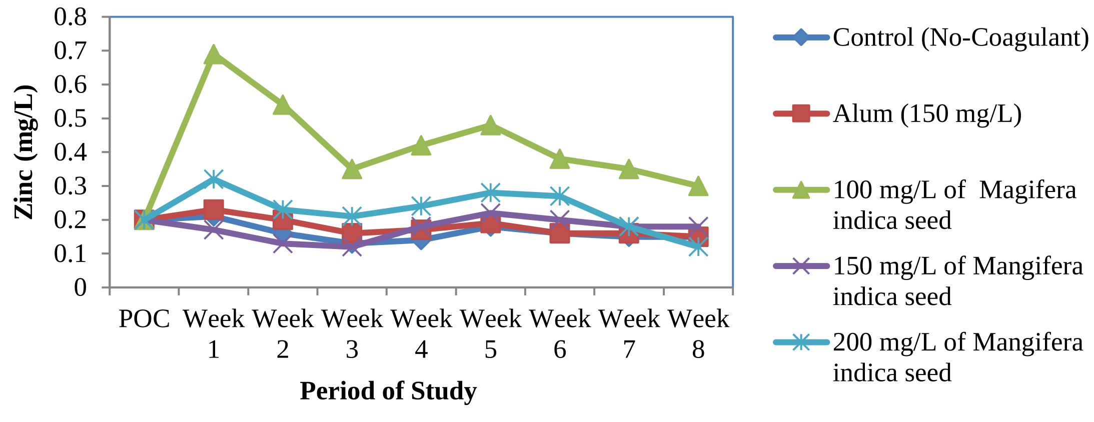

Figure 10. Effects of coagulation on Zinc

Total Viable Counts (TVC)

Figure 11 show that the TVC at the point of collection was 50 CFU/ml. By the fifth week, the Total Viable Counts (TVC) reduced in the control to 43 CFU/ml, 22 CFU/ml in the Alum treatment, 22 CFU/ml in the 100 mg/L seeds, 14 CFU/ml in the 150 mg/L of seeds and 28 CFU/ml in the 200 mg/L of seeds. From the result, 150 mg/L of *M. indica* seeds performs best in reducing the Total Viable Count. The ANOVA result analysis (Table 1), shows the mean values with (Fcal=0.757) and insignificant values of (p=0.565).

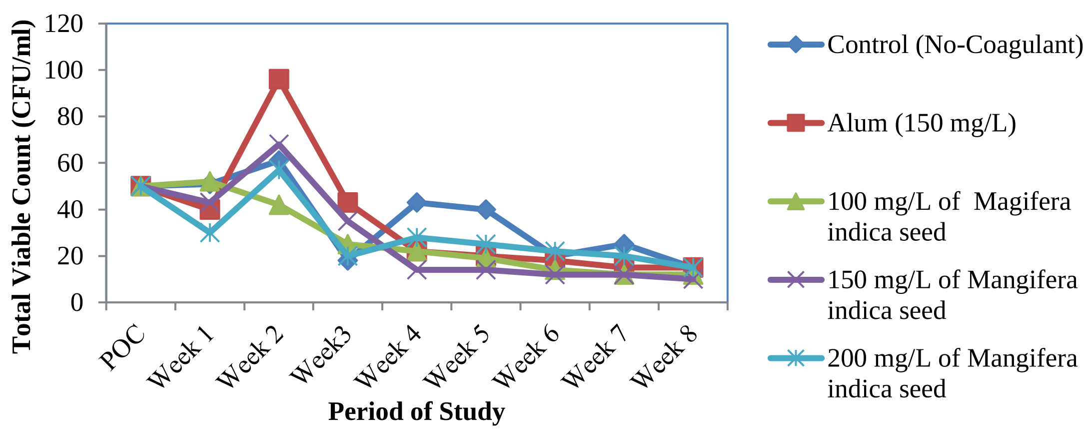

Figure 11. Effects of coagulation on Total Viable Count

Total Coliform Count (TCC)

The TCC at the point of collection was 40 CFU/ml (Figure 12). By the fifth week, the Total Coliform Counts (TCC) reduced in the control to 5 CFU/ml, 4 CFU/ml in the Alum treatment, 5 CFU/ml in the100 mg/L of seeds, 4 CFU/ml in the 150 mg/L of seeds and 8 CFU/ml in the 200 mg/L of seeds. From the result, 150 mg/L of seeds and the Alum treatment performs best in reducing the Total Coliform Count.

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The ANOVA result analysis (Table 1), shows the mean values with (Fcal= 12.016) and significant values of (p=0.000*). Hence Duncan test (Table 2) was performed which shows that 150 mg/L of seeds performed best.

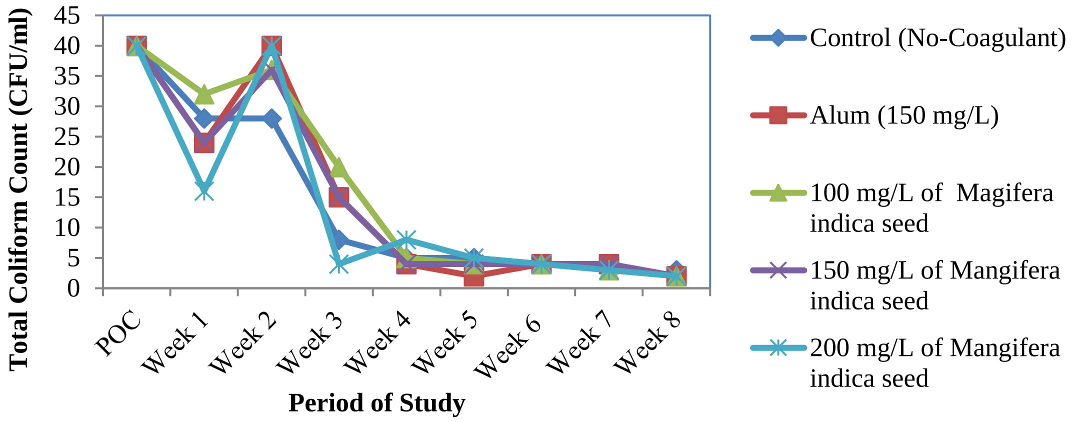

Figure 12. Effects of coagulation on Total Coliform Count

Escherichia Coliform (*E. coli*)

Table 1 shows that the *E. coli* was present (+ve) in the waste water at the point of collection and through-out the period of study it was present in the control, alum treatment and 150 mg/L of seeds. *E. coli* was absent (-ve) in the 2nd and 3rd week for the 100 mg/L of seeds. *E. coli* was also absent (-ve) in the1st and 2nd week for the 200 mg/L of seeds. WHO [12] standard for *E. coli* is –ve which shows absence in portable water because it is dangerous to human health hence 200 mg/L of seeds performed best in removal of *E. coli*.

DISCUSSION

The study shows that 150 mg/L of *M. indica* seeds performed best in reduction of Total Coliform Counts, Lead and Zinc while 100 mg/L of *M. indica* performed best in reduction of Total Solids, while the dosage of 200 mg/L of seeds reduced significantly turbidity, Magnesium hardness and *E. coli*. The dosage of 150 mg/L alum was most effective for *E. coli*. Apart from *E. coli*, the dosage of 200 mg/L of seed and 150 mg/L of alum are not as effective as that of 100 and 150 mg/L of seeds.

CONCLUSION

The study shows that *M. indica* is effective in purifying domestic sewage. *M. indica* is an effective natural coagulant which can be used in improving the physicochemical characteristics of water in terms of turbidity, total dissolved solids, suspended solids, alkalinity, and conductivity etc. Thus *M. indica* seeds present a viable alternative coagulant to alum in treating water for rural dwellers since alum has side effects like Alzheimer's disease and *M. indica* is environmentally friendly and cheaper without side

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effects. While water coagulation with alum are usually very acidic and thus dangerous for human consumption as it is liable to harming the gastrointestinal tract. *M. indica* seed is cheaply available and often disposed as waste by people after eating the fruit, instead of constituting environmental nuisance the seed can used profitably.

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