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Effectiveness of *Moringa oleifera* seed as a coagulant in domestic wastewater treatment

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An investigation on the effectiveness of *Moringa oleifera* seed for the treatment of domestic sewage was carried out in 15 litres plastic pots. Completely randomized design (CRD) experimental design was adopted. The treatments included: the control culture (no *Moringa* seed), 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g *Moringa oleifera*. Physical, bacteriological and chemical properties of domestic sewage were investigated before and after treatment. The turbidity value was reduced drastically for the treatments. Water hardness was reduced from 64.2 mg/l to 36 mg/l for the treatments. Alkalinity was reduced from 148 mg/l to 114 mg/l for the treatments, total solids were reduced from 1280 mg/l to 1129 mg/l for the treatments, suspended solids were reduced from 384 mg/l to 306.3 mg/l for the treatments, dissolved oxygen was reduced from 124.8 mg/l to 112.7 mg/l for the treatments, dissolved solids were reduced from 896 mg/l to 820.3 mg/l for the treatments, and acidity was increased from 0.84 to 2.02 for the treatments. The pH value was reduced from 9.6 to 7.5 for the treatments. BOD was reduced from 96.5 mg/l to 80.2 mg/l for the treatments and COD was reduced from 81.6 mg/l to 72 mg/l for the treatments. Generally, the results showed that the higher the quantity of *Moringa oleifera* seed applied to sewage, the better the purification of the sewage.

Keywords: *Moringa*, coagulant, treatment, total solid, dissolved solids, wastewater

Introduction

An increase in population has led to an increase in pollution and degradation of the environment, raising huge challenges for policymakers in most developing countries around the world. Since this increase is faster than infrastructural development, demand for freshwater in these regions is extremely high. Also, watersheds are converted into residential facilities and farmlands, leading to depletion of water resources (Goundern 1997). The quality of freshwater is threatened because of pollution by domestic, industrial and agricultural wastes. The amount of domestic and industrial wastewater that flows into the world's rivers is increasing at an alarming rate.

The purpose of adding coagulants to acidic drainage waters is to increase the flocculation in the water. As flocs density increases, inter particle contact increases due to Brownian motion, promoting agglomeration of colloidal particles into larger flocs for enhanced settling (Qasim et al. 2000). The removal of turbidity in water treatment is essential because naturally suspended particles are transport vehicles for undesirable organic and inorganic contaminants, taste, odour and colour-imparting compounds and pathogenic organisms (Raghuwanshi et al. 2002). The turbidity of water often results from the presence of colloidal particles that have a net negative surface charge. Thus, electrostatic forces prevent them from agglomerating, making it impossible to remove them by sedimentation without the aid of coagulants. In recent years, there has been considerable interest in the development of natural coagulants such as *Moringa oleifera*. By using natural coagulants, considerable savings in chemicals and sludge handling costs may be achieved. *Moringa oleifera* seed kernels are biological coagulant consisting of significant quantities of low molecular weight water-soluble proteins, which in solution carry an overall positive charge. *Moringa oleifera* coagulant is safe and very effective in removing impurities. Apart from its turbidity removal properties (Sotheeswaran, Nand, Matakite, & Kanayathu, 2011), *Moringa oleifera* has being reported to have antimicrobial properties in water (Amagloh and Benang 2009). It also has been reported as having the ability to remove metals from water (Nand, Maata, Koshy, & Sotheeswaran, 2012). A number of studies have pointed out that the introduction of natural coagulants as a substitute for metal salts may ease the problems associated with chemical coagulants. Earlier studies have found *Moringa* to be non-toxic and recommended its use as a coagulant in developing countries. The use of *Moringa* has an added advantage over the chemical treatment of water because it is biological and has been reported as edible. According to Muyibi and Evison (1995), hardness removal efficiency of *Moringa oleifera* was found to increase with increased dosage. Using natural coagulant such as the seeds from the *Moringa oleifera* tree instead of aluminum sulphate might provide advantages, such as lower costs of water production, less sludge production and the ready availability of reagents. Several chemical coagulants have been used in conventional water treatment plants for potable water production that include inorganic, synthetic organic polymer and naturally occurring coagulants (Okuda et al. 2000). Generally, alum (aluminum sulphate), and its synthetic polymeric derivatives are widely used in water treatment (Najm et al. 1998). The seeds from *Moringa oleifera* have been proven to be one of the most effective primary coagulants for water treatment, especially in rural communities in comparison with other plants material used over the years (Doer 2005; Onwuliri and Dawang 2006). Folkard et al. (1993) reported that while aerating well water in rural areas of Sudan for the reduction of carbon dioxide prior to softening, numerous complaints of red water in hot water systems were received, even when aeration was continued and carbon dioxide neutralized with lime in the regular plant treatment process. These complaints ceased and did not reoccur when *Moringa* seeds were used. Palada and Chang (2003) described the morphology of the plant. Suspensions of ground seed of the *Moringa* tree are used as primary coagulants. Coagulating the solid matter in water so that it can be easily removed also removes a good portion of the suspended bacteria. The primary objectives of this study are to investigate the effectiveness of using *Moringa oleifera* in the treatment of domestic water and to determine the effects of treating domestic wastewater with *Moringa oleifera* in terms of physical, chemical and bacteriological properties.

Materials and methodology

The study was conducted under a controlled environment in order to eliminate interference from human activities, rainfall and solar intensity.

Experimental design

The experiment was design based on completely randomized design (CRD) and was replicated three times. Domestic sewage water was collected into twelve two-litre capacity plastic containers. The first three plastic containers contained control cultures with no *Moringa oleifera* (seed extract), the second three contained 2 g of *Moringa oleifera*, the third three contained 4 g of *Moringa oleifera* and the final three contained 6 g of *Moringa oleifera*. Each container was weighed before the addition of domestic water and after the addition of the sewage water in order to determine the weight of the container and the sewage.

Samples

The containers were cleaned thoroughly before taking the sample to avoid contamination. The initial volume of each sample was recorded at the collection point. After collection, the containers were properly stored in a cool dry place and the analysis of the sewage commenced two hours after collection. The following parameters were determined: temperature, water hardness, volume of sewage consumed, odour, conductivity, total solids, suspended solids, dissolved oxygen, dissolved solids, chemical oxygen demand (COD), biological oxygen demand (BOD), pH, *E.Coli* (Escherichia coli) and faecal coliform.

Results and discussion

The experiment was conducted over seven weeks (7 April to 26 May 2014). The volume of domestic sewage consumed at the beginning of the experiment was 180 litres.

Hardness

Initial hardness of all samples at the point of collection was 64 mg/l. At the end of the experiment, the following results were obtained: 57.8 mg/l for the control, 40.6 mg/l for the 2 g of *Moringa oleifera*, 36.0 mg/l for the 4 g of *Moringa oleifera* and 33.6 mg/l for the 6 g of *Moringa oleifera* as shown in Figure 1. The result showed that the higher the quantity of *Moringa oleifera* applied, the higher the hardness that was removed. As a result of this fact, 6 g of *Moringa oleifera* had the highest potency in reducing hardness of water.

	Control	2g of *M.O*	4g of *M.O*	6g of *M.O*
POC	64.2	64.2	64.2	64.2
Week one	63.5	53.8	52.1	49.57
Week two	61.8	52.83	46.73	43.3
Week three	61.8	49.3	42.43	40.8
Week four	59.6	47.17	38.67	36.2
Week five	58.9	46.17	38.67	35.47
Week six	58.1	42.3	35	34.83
Week seven	57.8	40.6	36	33.6

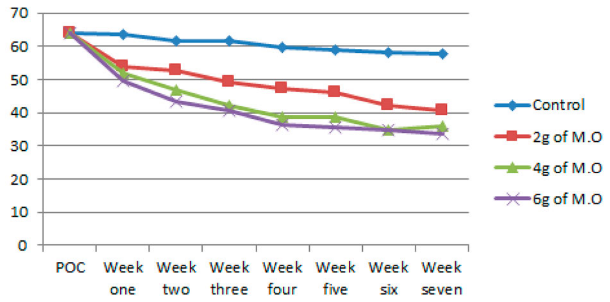

Figure 1: Hardness.

Alkalinity

Alkalinity at the collection point was 148 mg/l for all treatments. Figure 2 shows that it decreased to 136.8 mg/l, 113.3 mg/l, 114.0 mg/l and 114.2 mg/l for the first week for the control culture and for 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g *Moringa oleifera*, respectively.

Total solids

Figure 3 shows that the total solid at the point of collection was 1280 mg/l which indicates a high presence of solid particles in the domestic sewage. The average drop of total solid for the control culture after the seventh week of experiment was 1169.2 mg/l, and 1138.3 mg/l for the 2 g of *Moringa oleifera*, 1129.0 mg/l for the 4 g of *Moringa oleifera* and 1107.3 mg/l for the 6 g of *Moringa oleifera*, respectively. From the ANOVA statistical analysis done, the concentration (Fcal = 25.267) and with significant difference ($P = 0.000$).

	Control	2g of *M.O*	4g of *M.O*	6g of *M.O*
POC	148	148	148	148
Week one	144.97	134.17	127.93	124.3
Week two	144.6	131.15	129.17	124.97
Week three	142.03	126.83	123.83	121.03
Week four	139.3	123.83	119.6	117.83
Week five	138.9	120.77	117.9	116.6
Week six	137.53	118.3	116.3	114.9
Week seven	136.37	113.3	114	114.2

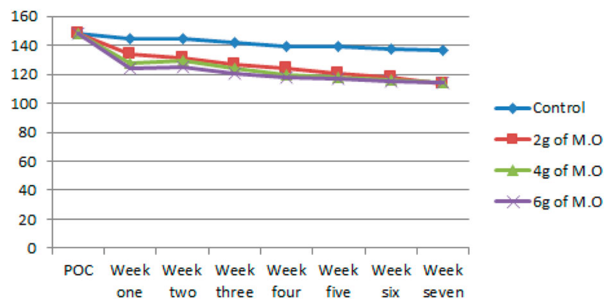

Figure 2: Alkalinity.

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	1280	1280	1280	1280	2000
Week one	1230	1187.67	1171.3	1136.67	2000
Week two	1187.8	1165.3	1151.67	1123.67	2000
Week three	1185.8	1159.3	1137	1112.13	2000
Week four	1181.5	1159.77	1136.5	1110.06	2000
Week five	1176.8	1153.67	1135	1111	2000
Week six	1176	1146.3	1132.7	1109.6	2000
Week seven	1169.2	1138.3	1129	1107.3	2000

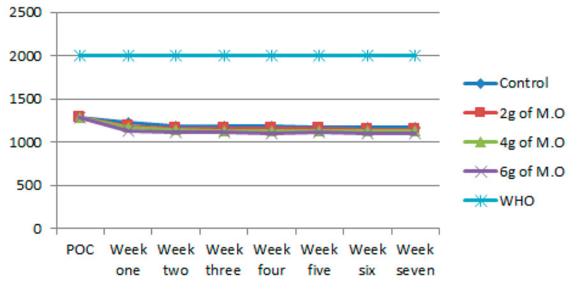

Figure 3: Total solids.

Suspended solids

The suspended solid from the point of collection after seven weeks of analysis on all the experimental design was 384 mg/l. From Figure 4, it can be seen that the suspended solid dropped to an average of 359 mg/l for the control culture, 317 mg/l for the 2 g of *Moringa oleifera*, 306.3 mg/l for the 4 g of *Moringa oleifera* and 304.67 mg/l for the 6 g of *Moringa oleifera*. The total average for all the treatment during the course of the analysis was 321.82 mg/l.

Dissolved oxygen

There was an observed rapid increase in the dissolved oxygen of the 2 g of *Moringa oleifera* and 4 g of the *Moringa oleifera* as seen in Figure 5. There was formation of small organisms in the water during the course of the experiment. The suitability of the water for the organisms proves that the water was conducive to their growth and development. This shows that the treated water can be used for plant irrigation. The control culture had the highest DO 110 mg/l after seven weeks, while 2 g *Moringa oleifera* had 118.2 mg/l.

	Control	2g of *M.O*	4g of *M.O*	6g of *M.O*	WHO
POC	384	384	384	384	220
Week one	381.3	340.83	323.16	317.5	220
Week two	375.3	341.33	322.1	317	220
Week three	373.3	337.83	318.37	312.37	220
Week four	367.7	331	312.2	307.57	220
Week five	365	326.67	310	308.9	220
Week Six	361	321.67	308	307	220
Week Seven	359	317.3	306.3	304.67	220

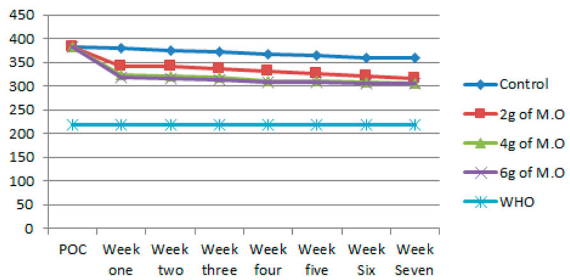

Figure 4: Suspended solids.

	Control	2g of M.O	4g of M.O	6g of M.O
POC	124.8	124.8	124.8	124.8
Week one	123.2	127.5	126.1	121.83
Week two	121.73	132	125.17	117.83
Week three	118.3	130.33	124.3	117.5
Week four	115.53	128.67	119.03	114.5
Week five	112.7	125.67	118.17	113.27
Week six	110.6	122.5	115.67	111.83
Week seven	110	118.17	112.67	111.43

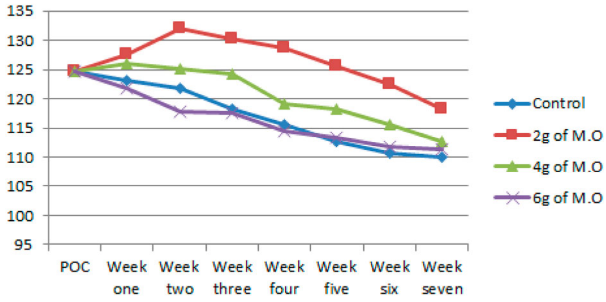

Figure 5: Dissolved oxygen.

Dissolved solids

The dissolved solids at the point of collection was 896 mg/l, which showed that the pollution level was minimal, though above that required by WHO. The dissolved solids at the end of the experiment were 829 mg/l for the control culture, and 825 mg/l for the 2 g of *Moringa oleifera*, 820.3 mg/l for the 4 g of *Moringa oleifera* and 818.3 mg/l for the 6 g of *Moringa oleifera*, respectively It can be observed from Figure 6 that the 6 g of *Moringa oleifera* was the most effective in the treatment.

Acidity

From the results of the analysis carried out shown in Figure 7, it can be observed that the acidity at the collection point was 0.8 mg/l. The average acidity of the wastewater after treatment was 2.32 mg/l, 2.29 mg/l, 2.02 mg/l and 3.12 mg/l for the control culture, 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g of *Moringa oleifera*, respectively.

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	896	896	896	896	500
Week one	880	857.83	840.83	831.67	500
Week two	872.3	851.67	838.17	829.17	500
Week three	856.3	849	832	829	500
Week four	847	839.67	826.57	823	500
Week five	837	835.7	825.67	821.6	500
Week six	836	831.5	822.03	819.93	500
Week seven	829	825.7	820.3	818.3	500

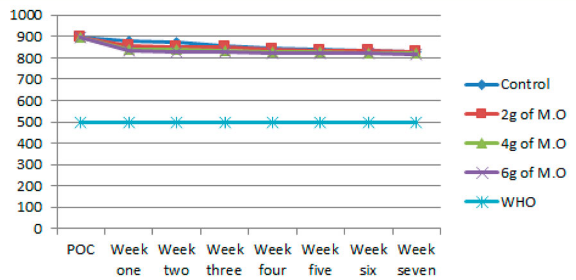

Figure 6: Dissolved solids.

	Control	2g of *M.O*	4g of *M.O*	6g of *M.O*	WHO
POC	0.84	0.84	0.84	0.84	1.02
Week one	1.84	1.45	1.61	1.64	1.02
Week two	1.56	1.49	1.63	1.69	1.02
Week three	1.59	1.52	1.57	1.93	1.02
Week four	2	1.82	1.86	2.16	1.02
Week five	2.2	1.97	1.88	2.8	1.02
Week six	2.23	2.03	1.95	2.98	1.02
Week seven	2.32	2.29	2.02	3.12	1.02

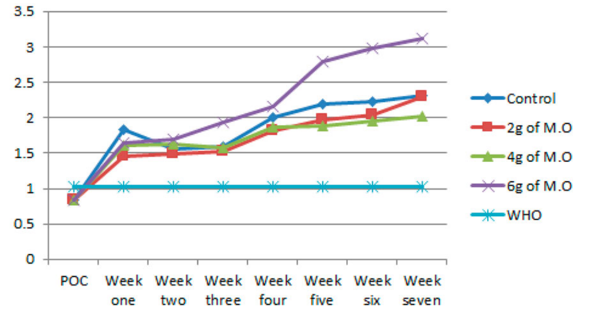

Figure 7: Acidity.

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	5.94	5.94	5.94	5.94	5
Week one	5.91	5.86	5.79	5.72	5
Week two	5.86	5.81	5.77	5.67	5
Week three	5.83	5.76	5.74	5.64	5
Week four	5.78	5.74	5.72	5.61	5
Week five	5.76	5.7	5.67	5.58	5
Week six	5.73	5.68	5.62	5.56	5
Week seven	5.69	5.64	5.6	5.52	5

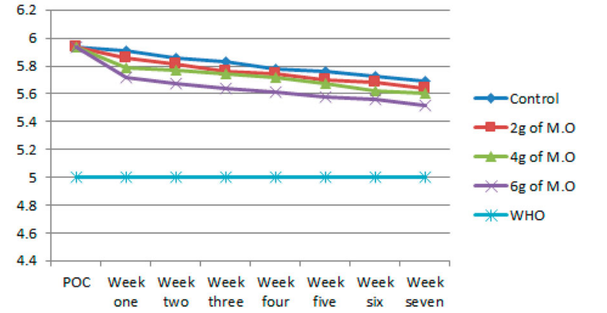

Figure 9: Turbidity.

Conductivity

The conductivity (k,) at the point of collection was 1868 µs^{-1}. The average reduction of conductivity after seven weeks of analysis for the control culture, 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g of *Moringa oleifera* was 1841.7 µs^{-1}, 1828 µs^{-1}, 1828.3 µs^{-1} and 1820 µs^{-1}, respectively (Figure 8). The treatment with 6 g of *Moringa oleifera* had the least conductivity.

Turbidity

The turbidity at the point of collection was 5.94NTU. From Figure 9, it can be seen that the turbidity level reduced rapidly for the control culture, 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g of *Moringa oleifera* during the process of the experiment. The average turbidity after the analysis for all the experiments was 5.62NTU, which is close to the WHO standard of 5NTU.

pH

The pH of the domestic sewage at the point of collection was 9.6 and after treatment the pH value dropped to an average of 9.21, 7.8, 7.57 and 7.1 for the control, 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g of *Moringa oleifera*, respectively (Figure 10).

Biochemical oxygen demand (BOD)

Initial BOD of influent was recorded to be 96.5 mg/l, but after seven weeks of treatment the following BOD readings were obtained: 93.9 mg/l, 82.37 mg/l, 80.2 mg/l and 79.3 mg/l for the control, 2 g of *Moringa oleifera*, 4 g of *Moringa oleifera* and 6 g of *Moringa oleifera*, respectively The result shows that a higher concentration of *Moringa oleifera* is required for better removal of BOD as seen in Figure 11. The data was further subjected to analysis of variance in Table 1. The result from the analysis of variance reveals that the removal of BOD by

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	1868	1868	1868	1868	1400
Week one	1865	1858	1851.3	1848.3	1400
Week two	1860.7	1856.3	1849	1845	1400
Week three	1858.3	1849	1842	1838.7	1400
Week four	1853	1843	1835.7	1831	1400
Week five	1849	1842	1833.7	1826.3	1400
Week six	1843.7	1837	1831	1822.6	1400
Week seven	1841.7	1828	1828.3	1820	1400

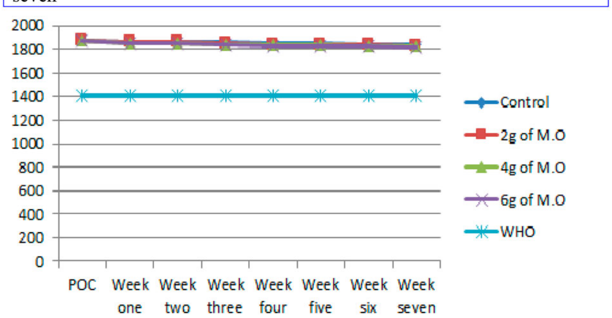

Figure 8: Conductivity.

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	9.6	9.6	9.6	9.6	7.6
Week one	9.38	9	8.9	8.5	7.6
Week two	9.39	8.97	8.6	8.2	7.6
Week three	9.33	8.7	8.4	7.97	7.6
Week four	9.28	8.56	8.1	7.8	7.6
Week five	9.26	8.3	7.9	7.5	7.6
Week six	9.24	8	7.8	7.2	7.6
Week seven	9.21	7.8	7.5	7.1	7.6

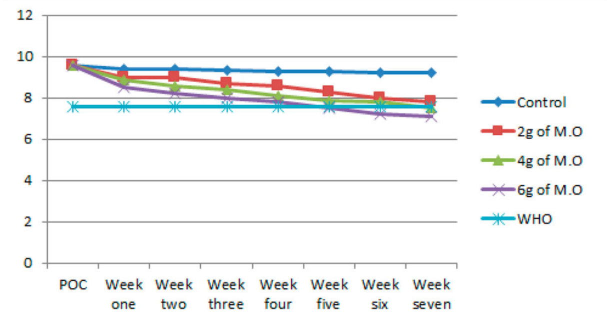

Figure 10: pH.

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	96.5	96.5	96.5	96.5	50
Week one	96	93.2	91.97	90	50
Week two	95.7	92	90.83	88.2	50
Week three	95.2	88.67	88.6	86.9	50
Week four	94.9	88.17	86.3	84.8	50
Week five	94.6	85.17	84.1	83.5	50
Week six	94.2	84.7	82	80.9	50
Week seven	93.9	82.37	80.2	79.3	50

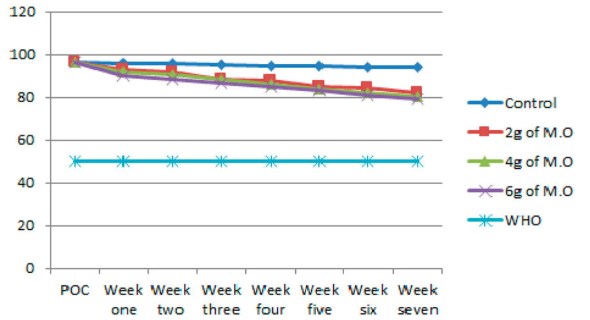

Figure 11: BOD.

Table 1: ANOVA for BOD.

	SS	df	MS	F	Sig.
Treatments	423.236	3	141.079	11.070	0.00
Errors	305.864	24	12.744		
Total	729.100	27			

Moringa oleifera was significantly different at $p > 0.05$ level of significance.

Chemical oxygen demand (COD)

The COD of the influent of all the cultures was 51.5 mg/l. After the treatment, the following results were obtained: 78.3 mg/l, 76.4 mg/l, 72.0 mg/l and 68.1 mg/l for the control, 2 g of *Moringa oleifera,* 4 g of *Moringa oleifera*, and 6 g of *Moringa oleifera*, respectively, as shown in Figure 12. The ANOVA result in Table 2 reveals that the

	Control	2g of M.O	4g of M.O	6g of M.O	WHO
POC	81.6	81.6	81.6	81.6	100
Week one	81.3	79.4	76.87	75.5	100
Week two	80.7	78.9	76.37	74.7	100
Week three	80.3	78.6	75.3	74	100
Week four	79.3	78.3	74.97	73.2	100
Week five	79	77.9	74.3	71.4	100
Week six	78.6	77.5	73.4	69.5	100
Week seven	78.3	76.4	72	68.1	100

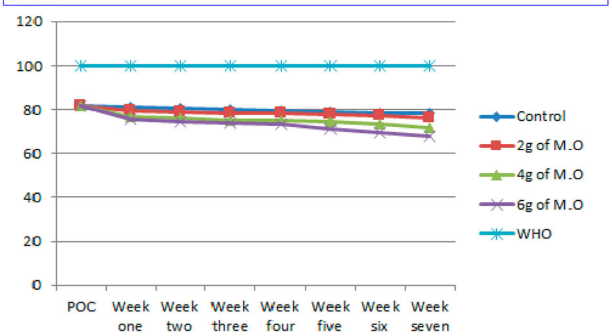

Figure 12: COD.

Table 2: ANOVA of COD.

	SS	df	MS	F	Sig.
Treatments	227.679	3	75.893	23.802	0.00
Errors	76.526	24	3.189		
Total	304.205	27			

Table 3: Average bacterial count.

Description	Colonies on nutrient agar (cc)	Coliform organisms in 100 cc	E.coli per 100 cc
Point of collection	> 300	180+	Very high
Sample with 2 g of *Moringa oleifera*	> 300	180+	Very high
Sample with 4 g of *Moringa oleifera*	> 300	180+	Very high
Sample with 6 g of *Moringa oleifera*	> 300	180+	High

effect of concentration of *Moringa oleifera* is statistically significant at $p > 0.05$.

Bacteriological parameters

Bacteria count

During the period of the experiment, there was an increase in formation of organisms in the domestic sewage over the first four weeks. At the end of the experiment, there was slight reduction of *Coliform* counts for both the 4 g *Moringa oleifera* treatment and the 6 g *Moringa oleifera* treatment, but a greater reduction in the 2 g *Moringa oleifera* treatment sample due to the high competition for nutrients between the introduced microorganism and the *faecal Coliform* present in the sewage. However, the total *faecal Coliform* count for all the treatments was greater than 300 cfu/ml due to the large population of *faecal coliform*, but the control culture had the lowest *faecal* count. Table 3 provides a comparison of the average *faecal Coliform* count of the various *Moringa oleifera* treatments, control culture and the controlled environment, with reference to standard values, which exceeded the minimum permissible values, indicating a very high presence of different bacteria colonies, in comparison with the permissible standard of the World Health Organization.

Conclusion

Moringa oleifera is an environmentally friendly natural coagulant most suitable for the treatment of water containing undesirable heavy metal concentrations. Based on the experimental test results, the following conclusions can be drawn:

i *Moringa oleifera* is an eco-friendly technology and economically advantageous.

ii *Moringa oleifera* is 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.

iii *Moringa oleifera* seeds present a viable alternative coagulant to alum in treating water for rural dwellers since they are environmentally friendly and cheaper.

Water coagulation with alum is usually very acidic and thus dangerous for human consumption, as it is liable to harm the gastrointestinal tract.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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