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***Corresponding Author:**
Daniel E. Omonigho

Email:
eoziengbe@biu.edu.ng

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Effect of *Moringa oleifera* Seeds on the Microbiological and Physicochemical Parameters of Industrial and Kitchen Effluents

Ikponmwoba P. Osarugue, Daniel E. Omonigho*, Olisaka N. Frances, Uwadiae Eseosa

Department of Biological Sciences, Benson Idahosa University, Benin city, Nigeria.

Abstract:
This study was carried out to determine the effects of *Moringa oleifera* seeds on the microbial and physiological parameters of industrial and kitchen effluents. Different concentrations of the Moringa seeds (1%, 2%, 4%, and 8%) were prepared and used to treat known volumes of domestic and kitchen effluents using alum (1%) as the control for a 4 day treatment period. Phytochemical screening, coagulation, and microbiological studies were carried out using standard methods. The results revealed the presence of several phytochemicals including Flavonoids, alkaloids, cardiac, glycosides, saponins, reducing sugars, terpenoids, and coumarins in both the ethanol and aqueous extracts of the Moringa seeds. Coagulation studies revealed that the pH of the industrial effluent treated with 1% alum (control) and 1% Moringa increased from day 1 (pH3.75) to day 4 (pH4.0). Conductivity values showed that the industrial effluent treated with 8% Moringa had the highest conductivity value on day 1 (2470Ω/m) while 1% Moringa treated group had the lowest value on day 4 (1000Ω/m). Microbial studies revealed that lowest values for the heterotrophic count (83 x 10^2), coliform count on MAC agar (124 x 10^2) and coliform count on EMB agar (130 x 10^2) for the industrial effluent. Industrial effluent treated with 1% Moringa had the lowest MPN value of 7 on day 4. The results showed that *M. oleifera* seeds have good coagulation abilities and can be used in water treatment processes. However, further research into optimum parameters required for efficient treatment of effluents should be encouraged.

Keywords: *Moringa oleifera* seeds, phytochemicals, coagulation, conductivity, bacterial count.

INTRODUCTION

In many developing countries, access to clean and safe water is a major problem due to limited clean and safe water sources (Yung, 2003). This has caused great dependence on surface water either from rivers or rain-fed wells which is vulnerable to various forms of pollution generated from different sources mainly households, agriculture and industries (Abaliwano *et al*., 2008; Azeem and Rashid, 2019). Hence the continuous treatment of wastewater is more suitable and ideal to serve as an alternative source to clean and safe water.

In recent times, there have been studies on the use of indigenous natural plants as coagulants and antimicrobial agents in water treatment to remove turbidity and microbial load of wastewater (Anwar *et al.,* 2007; Yung, 2003; Sattar *et al.,* 2018; Iqbal and Ashraf, 2018; Iqbal *et al.,* 2019; Sultana *et al.,* 2019a; Sultana *et al.,* 2019b). One of such plant seed suggested to be of use in wastewater treatment is *Moringa oleifera.*

The plant is the most widely cultivated species of a monogeneric family, the *Moringaceae*, that is, native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan (Alo *et al.,* 2012). It is being grown in West, East, and South Africa, tropical Asia, Latin America, the Caribbean, Florida and the Pacific Islands (Jed, 2005). Almost every part of the plant (leaves, flowers, seeds, roots, and bark) can be used as food or with medicinal and therapeutic purposes (Anwar *et al.*, 2007), it has been reported to contain phytochemicals such as flavonoids, tannin and essential oils (Nascimento *et al.,* 2000). *M. oleifera* seeds are also used as a primary coagulant in drinking water clarification and wastewater treatment due to the presence of a water-soluble cationic coagulant protein able to reduce the turbidity of the water treated (Ndabigengesere *et al.,* 1995). Seeds are powdered and added to the water straight or after preparing crude extracts (Ndabigengesere *et al.,* 1995).

Sutherland et al. (1994) have reported that crushed *M. oleifera* seed has been a viable replacement coagulant for chemicals such as aluminum sulfate (alum). This is because there are constraints encountered in the use of chemical coagulants (e.g. alum), such as scarcity of foreign currency for importation and inadequate supply of chemicals. Although aluminum is the most commonly used coagulant in the developing countries, studies have linked it to the development of neurological diseases such as pre-senile dementia or Alzheimer's disease due to the presence of aluminum ions in the drinking water (Jekel, 1991). Many researchers have reported *M. oleifera* various uses and as a coagulant specifically for the last two decades (Broin *et al*., 2002; Suarez *et al*., 2003; Alo *et al.,* 2012). They have found that the *M. oleifera* seed is a non-toxic and good coagulant in water treatment. *M. oleifera* seed has also been found to have antibacterial activity. The ability of *M. oleifera* coagulant to remove bacteria from water has been carried out by different researchers with positive results (Broin *et al*., 2002; Suarez *et al*., 2003). The health implication and high cost of treating wastewater with aluminum sulfate (alum) have necessitated this research into a cheap, natural and more efficient coagulant for use in treating both domestic and industrial wastewater.

This study was conducted to ascertain the effects of *M.olifera* seeds on the microbial and physiological parameters of industrial and Kitchen effluents. The main objectives were to identify phytochemicals present in *M. oleifera* seeds and determine the coagulation potential as well as the antibacterial potential of the crushed seeds when applied to industrial and domestic wastewater.

MATERIALS AND METHODS

Sample Collection

Seeds of *M. oleifera* used in this study were purchased from New Benin Market, Benin City, Edo State, Nigeria.

Preparation of *M. oleifera* seed powder

The *Moringa* seeds were dried at ambient temperatures for a period of five days before milling. The white kernels were milled into a fine powder using a Starlite blender (Model SL-999) and were sieved through a small mesh to get the fine powder. The powder was collected into a sterile bottle with a cap and stored at 4ºC until further analysis.

Phytochemical screening

A hundred (100) grams each of the crushed *M. oleifera* seeds were soaked in 300ml of ethanol and 500mL of water respectively for 72 hours with constant stirring. The mixture was filtered muslin cloth and the filtrate concentrated with a rotary evaporator then the extract was collected and stored in airtight universal containers at 4ºC till further analysis.

Preparation of extracts for phytochemical screening

One gram of the aqueous and ethanol extracts was weighed and mixed with 10mL distilled water in a sterile conical flask and used for phytochemical screening. Test for flavonoid, cardiac glycosides, saponins, steroids, terpenoids, alkaloids, coumarins, and reducing sugar was carried out as described by Kamba and Hassan (2008).

COAGULATION AND ANTIBACTERIAL STUDIES

Collection of water sample

The domestic wastewater used for this study was collected from Bala's Kitchen, Ben mag's cafeteria, Benson Idahosa cafeteria, located within Benson Idahosa University, Ugbor road, Benin City, Edo State while the industrial wastewater was collected from Guinness Nigeria PLC, Agbor Road, Benin City, Edo State. The effluent sampled was obtained from the wastewater disposed into the environment by the brewery. The wastewater was transported to the laboratory for further processing.

Preparation of *M. oleifera* seed solution and water treatment

Different concentrations of *Moringa* seed mixture were made by dissolving 20g, 40g, 80g, and 160g of the *Moringa* seed powder weighed on a weigh balance into 2000ml of wastewater each contained in a flask to obtain 1 %, 2%, 4% and 8% concentration of the solution respectively (Schwarz, 2000). The mixture was mixed properly for 1 minute by swirling the container. The treated water was then allowed to stand undisturbed for 4 days. 300 mL was collected from the top of the water and subjected to post-treatment analysis every day for 4 days. (Suleiman and Evison, 1994; Doerr, 2005). Commercially available alum was used for this study as control and the powder was obtained from the Oba market, Benin City, Edo State. 1% solution of alum was made by adding 10g of alum into 1 liter of the raw water sample and shaken for 60 seconds. The treatment procedure was the same as described above with the *Moringa* solution. The alum was totally soluble in the water.

Microbial analysis of the water sample

The microbial analysis was performed to determine the microbiological quality of the water sample. These tests which include the total viable counts, i.e., the total heterotrophic, total coliform count and the estimation of the most probable number (MPN) of fecal coliform bacteria were conducted prior to treatment and after the incorporation of the *M. oleifera* seed solution into the water sample.

Total viable count

One mL of the treated water sample was cultured on molten freshly prepared Nutrient

agar, MacConkey agar and Eosin Methylene Blue (EMB) Agar every day for 4 days using the spread plate method. After this, the culture plates were incubated at 37ºC. The number of colonies on each agar plate were enumerated and recorded after a 24 hour incubation period.

Most probable number (MPN)

Five (5) MacCartney bottles each containing ten (10) mL of double-strength macConkey broth and ten (10) MacCartney bottles each containing five (5) mL single strength MacConkey agar broth was freshly prepared and autoclaved. Before dispensing, the effluent samples were thoroughly mixed by inverting the bottle several times for proper homogenization. To the MacConkey agar bottles containing the double strength MacConkey agar broth, ten (10) mL of the effluent samples were added each and mixed while to the single strength, one (1) mL of the effluent sample was added to five bottles and 0.1mL was added to the remaining five bottles. The inoculated broths were then incubated at 37ºC for 24 hours with the bottles loosely capped. After the incubation period, the results were read and interpreted using Cheesbrough (2000) standards.

Physicochemical analysis of the water sample

The water sample physicochemical parameters were determined prior to and after treatment with *M. oleifera* seed solution using specific methods. The parameters determined were:

Determination of turbidity

The turbidity of the water sample was determined using a turbidimeter (Hach USA). The meter was switched on and then calibrated with distilled water. Five (5) mL of the water sample was poured into a cuvette holder with the vertical line on the cuvette aligning with the horizontal mark on the instrument. The value of the turbidity was then read on the crystal liquid display (CLD) as soon as the ready signal was seen on the screen (APHA, 2005).

Determination of conductivity

These parameters were determined using a multimeter analyzer (HACH, USA) that has a software application that can inter-change to read different parameters when the 'mode' button is pressed. The instrument was switched on and calibrated with distilled water. Then five (5) mL of sample to be determined was poured into a test tube, the sensor (electrode) of the instrument was now inserted into the test tube and the mode button pressed for the reading of each parameter. The value for conductivity was read from the crystal liquid display (CLD) as soon as the instrument indicates a ready signal (APHA, 2005).

Determination of pH

This was done using a pH meter (search tech, USA). The instrument was calibrated with buffers 4, 7 and 9 before usage. Five (5) mL of the effluent samples were dispensed into a clean test tube and the electrode of the instrument inserted into the sample before the start button pressed, the reading was taken as displayed directly on the crystal liquid display panel of the instrument (APHA, 2005).

Determination of Biological Oxygen Demand

Two hundred (200) mL of distilled water was aerated using an air pump. Seeding of the effluent was carried out by mixing one hundred (100) mL of the aerated water with one hundred (100) mL of the effluent sample (this is referred to as percentage dilution). Determination of the Dissolved Oxygen (DO_1) using Winkler's method on a 100ml portion of the seeded water was carried out. An incubation bottle was filled to the brim with the remainder of the diluted water sample. The bottle was screw-capped and incubated in the dark for 5 days at 20 ºC. On the 5^{th} day, the DO value was determined. The BOD value was the result of the difference between

the respective DO values divided by the percentage dilution (Ademoroti, 1996).

Calculation:

$$\text{BOD mg/mL} = \frac{(DO_1 - DO_5)}{\text{Percent dilution}}$$

$$\text{Percentage dilution} = \frac{\text{Amount of aerated water (mL)}}{\text{Amount of effluent (mL)}}$$

Determination of total dissolved solids (TDS)

TDS was measured according to the method by Ademoroti, (1996). Fifty (50) mL of the samples was placed pre-weighed 50ml beaker and evaporated to dryness. The beaker was weighed after drying and the TDS calculated thus:

$$\text{TDS} = \frac{\text{Weight of beaker before drying- Weight of beaker after drying} \times 1000}{\text{Sample volume}}$$

Determination of total suspended solids (TSS)

TSS was measured according to the method by Ademoroti (1996). 50ml of the samples were filtered through a pre-weighed Whatman 11cm filter paper and dried. The weight of the filter paper after drying was obtained and the TSS calculated thus:

$$\text{TSS} = \frac{\text{Weight of beaker before drying- Weight of beaker after drying x 1000}}{\text{Sample volume}}$$

RESULTS

The phytochemical results of the aqueous and ethanolic extract of *M. oleifera* are represented in Table 1. Flavonoids, alkaloids and cardiac glycosides were present in both aqueous and ethanol extracts. Tannins and reducing sugars were the only phytochemicals absent from the ethanolic extract. Saponins, terpenoids, and coumarins were also absent in the aqueous extract but moderately present in the ethanol extract.

Table 1. Phytochemical screening of the aqueous and ethanol extracts of *M.olifera* seeds

Test	Aqueous	Ethanol
Flavonoids	+	++
Tannins	+	-
Cardiac Glycosides	++	+
Saponins	-	++
Terpenoids	-	++
Alkaloids	+	++
Coumarins	-	++
Reducing Sugar	++	-

Key: +=present, ++= moderately present, +++= highly present, -= absent

The physicochemical results of the treatment of Industrial effluent with dose-dependent concentrations of *M.olifera* are represented in Table 2. For pH and electrical conductivity, there was a significant difference between the different treatment doses and control ($p<0.01$) within the treatment period (4 days). There was however no significant difference for Biological Oxygen demand (BOD), turbidity, Total Dissolved Solids (TDS) and Total suspended solids (TSS) between the different treatment concentrations and control ($p>0.05$) for the treatment period (4 days).

Table 2 showed mean changes in the physicochemical analysis of industrial wastewater treated with varying concentrations of *M. oleifera* over a four day treatment period. Turbidity, conductivity, BOD and TDS and TSS all increased in a dose-dependent manner with 1% moringa having the lowest values for these parameters. pH did not follow this trend as 1% Moringa had the highest pH value (4.48) while 8% of Moringa had the lowest. Compared to control, pH was higher in all Moringa groups than the control. Conductivity, turbidity, and TDS values were higher in control than all the groups except 8% Moringa. For BOD, the values obtained for moringa groups were all lower than control. For TSS, control was lower than all Moringa groups except 1% Moringa.

Turbidity, conductivity, BOD and TDS and TSS all increased with an increase in Moringa concentration with 1% Moringa having the lowest values for these parameters. pH did not follow this trend as 1% Moringa had the highest pH value (4.420) while 2% of Moringa had the lowest. Compared to control, conductivity, turbidity, and BOD values were higher in control than the Moringa concentration groups while pH, TDS, and TSS were lower in control compared to the Moringa groups (Table 3).

Most probable number of the industrial and domestic effluents treated with varied concentration of *M. oleifera* seeds increased in a dose-dependent manner within the 4 day treatment time with domestic effluent treated with 1% alum (control) having the highest MPN value of 110 on day 1 and the industrial effluent treated with 1% Moringa having the lowest MPN value of 7 on day 4. 1% Moringa had the lowest count for both effluent throughout the 4 day period. As compared to control, the counts for all the varied concentrations of Moringa were lower for domestic effluent compared to control for the 4 day treatment period. The counts of all Moringa groups for industrial effluent was lower compared to control for day 1 and 2 only (Table 4).

The bacterial count showed that 1% concentration of Moringa had the lowest count for all parameters compared to the other Moringa concentrations while 4% Moringa had the second-lowest counts for coliform counts (EMB) and heterotrophic count. 8% Moringa had the highest count in all the microbiological parameters analyzed for. Compared to control, 1% Moringa was the only concentration of Moringa lower than control in all microbiological parameters analyzed except for coliform count (MCA and EMB) (Table 5).

Most probable number of the industrial and domestic effluents treated with varied concentration of *M. oleifera* seeds increased in a dose-dependent manner within the 4 day treatment time with domestic effluent treated with 1% alum (control) having the highest MPN value of 110 on day 1 and the industrial effluent treated with 1% Moringa having the lowest MPN value of 7 on day 4. 1% Moringa had the lowest count for both effluent throughout the 4 day period. As compared to control, the counts for all the varied concentrations of Moringa were lower for domestic effluent compared to control for the 4 day treatment period. The counts of all Moringa groups for industrial effluent was lower compared to control for day 1 and 2 only (Table 6).

DISCUSSION

The results of this study showed that ethanol and aqueous extracts possessed good phytochemical components. Several reports have suggested that Moringa seeds are rich in phytochemicals, vitamins, minerals, amino acids, antioxidants, anti-inflammatory nutrients and omega 3 and 6 fatty acids (Fahey, 2005).

The Moringa treated groups for both effluents had lower counts for the total heterotrophic count and coliform counts compared to the control (1% alum).

Table 2. Mean changes in the physicochemical analysis of industrial wastewater treated with varying concentrations of *M.olifera*over a four day treatment period.

Physico chemical Parameter	1% Alum	1% Moringa+Kitchen Effluent	2% Moringa +Kitchen Effluent	4% Moringa+Kitchen Effluent	8% Moringa+Kitchen Effluent	P-value	Significant level
	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E		
pH	3.88±0.16^{b}	4.48±0.09^{a}	4.28±0.03^{a}	4.32±0.037^{a}	4.28±0.037^{a}	0.002	P<0.01*
EC(µS/cm)	1846.40±241.94^{a}	1181.60±42.16^{b}	1286.80±20.59^{b}	1315.80±24.656^{b}	1924.20±216.618^{a}	0.004	P<0.01*
Turbidity(NTU)	2.10±0.24	1.32±0.42	1.68±0.33	2.04±0.24	2.38±0.17	0.147	P>0.05
BOD(Mg/l)	2.68±0.4	1.40±0.75	2.00±0.616	2.00±0.60	2.16±0.57	0.689	P>0.05
TDS(Mg/l)	351.20±138.41	260.20±123.76	302.40±104.85	349.80±108.15	397.80±118.33	0.939	P>0.05
TSS(Mg/l)	6.600±1.12	6.200±1.15	8.800±2.51	15.400±6.46	13.800±2.53	0.226	P>0.05

Key: EC= electrical conductivity, BOD= biological oxygen demand, TDS= total dissolved solids, TSS= total suspended solids. a,b= values showing statistical difference. **Note**: Values are represented as mean ±SE.

Table 3. Mean changes in the physicochemical analysis of domestic wastewater treated with varying concentrations of *M.olifera* over a four day period.

Parameter	1% Alum	1% Moringa+Kitchen Effluent	2% Moringa +Kitchen Effluent	4% Moringa+Kitchen Effluent	8% Moringa+Kitchen Effluent	P-value	Significant level
	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E		
pH	3.520±0.196^{f}	4.420±0.080^{g}	4.100±0.055^{g}	4.140±0.050^{g}	4.180±0.037^{g}	0.000	P<0.001***
EC	1640.200±393.795^{f}	460.800±91.681^{j}	608.600±126.469^{i}	711.600±154.232^{h}	1108.600±253.431^{g}	0.012	P<0.05*
Turbidity	1.700±0.084	0.840±0.271	1.000±0.228	1.160±0.196	1.240±0.178	0.067	P>0.05

BOD	2.080±0.235	0.960±0.464	1.020±0.449	1.200±0.402	1.280±0.385	0.305	P>0.05
TDS	81.800±23.338[g]	96.800±29.280[i]	138.800±35.013[h]	172.600±40.708[e]	276.800±62.884[f]	0.021	P<0.05*
TSS	7.600±1.435	9.200±1.594	14.000±1.581	16.400±2.159	17.800±2.538	0.004	P<0.01**

Key: EC= electrical conductivity, BOD= biological oxygen demand, TDS= total dissolved solids, TSS= total suspended solids. f,g,h,i= values showing statistical difference. **Note**: Values are represented as mean ± standard error.

Table 4. Changes in the most probable number (MPN) of industrial and domestic waste treated with varied *M. oleifera* seeds over a four (4) day period.

		1% Moringa	2% Moringa	4% Moringa	8% Moringa	Control (1% Alum)
Day 1	Industrial effluent	16	20	29	43	75
	Domestic effluent	20	25	41	75	110
Day 2	Industrial effluent	13	16	22	31	43
	Domestic effluent	16	20	29	43	75
Day 3	Industrial effluent	9	14	38	41	31
	Domestic effluent	13	16	22	31	43
Day 4	Industrial effluent	7	11	32	29	22
	Domestic effluent	9	14	20	25	31

Table 5. The mean changes the microbiological analysis of industrial effluent treated with varying concentrations of *M.oliferaover* a four day treatment period.

Parameter	1%	2%	4%	8%	Control (1Alum)	P-value	Significant level
	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E		
Heterotrophic count	317.75±37.46	428.75±50.17	574.00±95.48	667.50±127.68	667.50±127.68	0.078	P>0.05
Coliform count on EMB	358.50±114.05	520.75±165.99	370.00±116.17	600.00±197.60	329.50±101.39	0.620	P>0.05
Coliform count on MCA	303.25±41.294	424.25±80.08	542.00±118.62	581.25±130.59	272.50±34.33	0.101	P>0.05
Fecal coliform count	$12.83±1.62^{t}$	$15.25±1.88^{t}$	$27.40±3.84^{s}$	$32.00±4.83^{r}$	$37.40±10.44^{q}$	0.019	P<0.05*
Most probable number (MPN)	13.37±39	16.25±1.33	28.39±3.35	35.00±4.37	39.03±10.47	0.018	P<0.05*

Key: Values are represented in mean ±standard error. **Note:**P<0.05- High significant difference* P>0.05- Low significant difference*

Table 6. The Mean change in the microbiological analysis of the domestic effluent treated with varying concentrations of *M.oliferaover* a four day treatment period.

Parameter	1%	2%	4%	8%	Control (1Alum)	P-value	Significant level
	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E	$\bar{X}$±S.E		
Heterotrophic count	231.00±103.271	305.00±84.956	368.60±71.898	452.80±56.268	285.60±90.411	0.405	P>0.05
Coliform count on EMB	$305.60±101.316^{n}$	$401.20±78.112^{n}$	$461.40±64.836^{n}$	$655.00±65.606^{m}$	$368.60±90.384^{n}$	0.060	P>0.05
Coliform count on MCA	$303.60±84.037^{n}$	$374.00±65.406^{n}$	$374.20±70.928^{n}$	$704.60±114.199^{m}$	$346.00±74.383^{n}$	0.020	P<0.05*
Fecal coliform count	119.60±105.115	123.00±104.26	130.40±102.466	142.80±99.675	159.80±96.035	0.999	P>0.05*
Most Probable Number (MPN)	217.10±103.115	134.00±213.37	145.60±131.777	153.13±73.153	163.75±81.000	0.735	P>0.05*

Key: Values are represented in mean ±standard error.**Note:** P>0.05-Low significant difference. P<0.05-Highly significant difference

Various researchers have reported the efficacy of *M. oleifera* in reducing bacterial populations more than alum (Broin *et al.,* 2002; Alo *et al.,* 2012). Antioxidants and phytochemicals have been linked with antimicrobial attributes. The leaf of Moringa has been reported to be an effective source of natural antioxidants due to the presence of flavonoids and phenolics (Siddhuraju and Becker, 2003). Flavonoids, tannins, and alkaloids were present while coumarins, saponins, and terpenoids were absent. These phytochemicals present in the seed extract in varying concentrations may be responsible for changes in the microbiological as well as physical parameters of the wastewater in this research. Various researchers have reported other active agents found in Moringa seeds which possess antimicrobial properties, they include 4-(4'-*O*-acetyl-α-L-rhamnopyranosyloxy), benzyl isothiocy-anate 4-(α-L-rhamnopyranosyloxy)benzyl isothiocy-anate, niazimicin, pterygospermin, benzyl isothiocyanate and 4-(α-L-rhamnopyranosyloxy) benzyl glucosinolate (Abrams *et al.,* 1993; Akhtar and Ahmad, 1995; Anwar and Bhanger, 2003).

There was no significant difference between the fecal coliforms count of different treatment concentrations and control ($p<0.05$) within the treatment period (4 days) in this work. Several researchers have reported the efficacy of the aqueous extracts of Moringa seeds in inhibiting the growth of *Enterobacter* sp. (16.50mm), *Vibro* sp. (15.9mm), and *Staphylococcus aureus* (16.5) *invitro* (Kudi *et al.,* 1999; Peixoto *et al.,* 2011).

The pH values of the treated water for both alum and Moringa seed treated wastewater showed a lot of variations. The slight decrease in pH on the first day of treatment following treatment with *Moringa* seed solution may be due to hydrogen ions of the weak acidity of *M. oleifera* solution formed with the wastewater. This phenomenon however improved with an increase in treatment time suggesting a balance with the hydroxide ions in the effluents. Compared to the control (1% alum), there was a decrease in the pH of alum over the treatment period. There was however a significant difference for pH between the different treatment concentrations of *M. oleifera* seeds and control ($p<0.01$) within the treatment period (4 days) for both industrial and domestic effluents. This is in agreement with the report of Alo et al. (2012) who opined that pH and conductivity are not significantly affected following coagulation of effluent with Moringa seeds as compared to alum which adversely affects the pH and conductivity of the effluent sample.

There was also a significant difference between the conductivity values of the different treatment concentrations of *M. oleifera* seeds and control ($p<0.01$) within the treatment period (4 days) for both industrial and domestic effluents. This can be explained by the fact that alum coagulant contains amounts of aluminum, sodium, potassium and sulfate ions which readily dissolve in water and increase its ionic content (Alo *et al.,* 2012). This can also be correlated with the high values for total dissolved solids present in the alum treated water compared to the moringa treatment groups. High conductivity values suggest high metal content in water which could be detrimental to human health (Alo *et al.,* 2012). The *M. oleifera* seeds reduced the conductivity in the treated groups as compared to control (Alum).

Turbidity, total suspended solids and BOD values in the Moringa treated groups were lower compared with control. This can be correlated with the lower counts for heterotrophic, coliform and most probable number of the Moringa treated effluents compared to control. Overall, the Moringa seeds treated the domestic effluent better with 1% Moringa being the most efficient dosage. This observation is in contrast with the research of Muyibi *et al.,* (1999) who reported that *M. oleifera* treats effluents better with an increase in dosage. However, Egbuikwem and Sangodoyin, (2011) reported that the dose of Moringa efficient in treating effluents is

dependent on its turbidity. In their research, low turbidity water requires low doses of Moringa. High doses of Moringa used in treating low turbidity water may increase bacterial growth, total solids and turbidity as the Moringa seeds also contain some ingredients that are proteinous. As observed in this study, the turbidity and BOD values were quite low in both effluents used. This may be the reason why the lowest dosage of Moringa was the most effective.

CONCLUSION

From the results obtained, *M. oleifera* seeds treated both industrial and domestic wastewater better than commercially used alum. It can, therefore, be concluded that Moringa seeds are better coagulating agents than alum. However, further research into optimum dosage and temperature for the treatment of effluents should be encouraged to optimize the use of Moringa for better treatment results.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Abaliwano, J.K., Ghebremichael, K.A., Amy, G.L., 2008. Studies on National Water Coagulants in Sudan, with Special Reference to *M. oleifera* Seeds. Water Mill Working Paper Series. 5: 1-22.

Abrams, B., Duncan, D., Hertz-Piccioto, I., 1993. A prospective study of dietary intake and acquired immune deficiency syndrome in HIV-seropositive homosexual men. J. Acquired Immune Deficiency Syndrome., 8: 949-958.

Ademoroti, C.M., 1996. Standard methods for water and effluent analysis. Foludex press limited. Ibadan. pp 22-28.

Akhtar, A.H., Ahmad, K.U., 1995. Anti-ulcerogenic evaluation of the methanolic of some indigenous medicinal plants of Pakistan in aspirin-ulcerated rats. J. Ethnopharmacol., 46: 1-6.

Alo, M., Anyim, C., Elom, M., 2012. Coagulation and antimicrobial activities of *Moringaoleifera* seed storage at 3°C temperature in turbid water. Adv. App. Sci. Res., 3(2): 887-894.

Anwar, F., Bhanger, M.I., 2003. Analytical characterization of *Moringa oleifera* seed oil grown in temperate regions of Pakistan. J. Agric. Food Chem., 51(22): 6558-63.

Anwar, F., Latif, S., Ashraf M., Gilani, A.H., 2007. Moringa oleifera: A food plant with multiple medicinal uses. J. Phytochem. Res., 21: 17-25.

APHA, 2005. Standard Methods for the Examination of Water and Wastewater. 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Azeem, M., Rashid, A., 2019. Determination of Heavy Metals in Vegetables Grown in Sewage Irrigated Fields of Shakargarh, Pakistan. Int. J. Altern. Fuels. Energy., 3(3): 36-40.

Broin, M., Santaella, C., Cuine, S., Kokou, K., Peltier, G., Joet, T., 2002. Flocculent activity of a recombinant protein from Moringa oleifera Lam. seeds. App. Micro. Biotech., 60(1-2): 114-119.

Cheesbrough, M., 2000. District Laboratory Practice in Tropical Countries. 2nd Ed., Cambridge University Press, Cambridge, UK. pp 143-145.

Doerr, B., 2005. Moringa Water Treatment. An ECHO technical note, ECHO, USA. pp 15-16.

Egbuikwem, P., Sangodoyin, A., 2013. Coagulation efficacy of *Moringa oleifera* seed extract compared to alum for removal of turbidity and *E. coli* in three different water sources. Eur. Int. J. Sci. Technol., 2(7): 13-20.

Fahey, J.W., 2005. Moringa oleifera: A review of the medical evidence for its nutritional, therapeutic and prophylactic properties. J. Life T., 1: 1-33.

Iqbal, M.N, Ashraf, A., 2018. Environmental Pollution: Heavy Metals Removal from Water Sources. Int. J. Altern. Fuels. Energy., 2(1): 14-15.

Iqbal, M.N., Ashraf, A., Iqbal, A., 2019. Phytoremediation Potential of Plants: Green Technology for the Clean-up of Heavy Metals in the Soil. Int. J. Altern. Fuels. Energy., 3(3): 41-43.

Jed, W.F., 2005. Role of phenolic acids in the expression of barley (Hordeumvulgare) autotoxicity. Allelopathy. J. Trees Life., 5: 1-15.

Jekel, M.R., 1991. Operation of Water Treatment Plants. Water Utili. 39(3): 243–250.

Kamba, A.S., Hassan, L.G., 2008. Phytochemical screening and antimicrobial activities of *Euphobia balasamifera* leaves stems and roots against some pathogenic microorganisms. African J. Pharm. Sci. Pharm., 1(1): 57-64.

Kudi, A.C., Uhoh, J.U., Eduvie, L.O., 1999. Screning of some Nigerian medicinal plants for antibacterial activity. J. Ethnopharmacol., 67: 225-228.

Muyibi, S.A., Evison, L.M., 1995. Optimizing physical parameters affecting coagulation of turbid water with *Moringa oleifera* seeds. J. Wat. Res., 29: 2689–2695.

Nascimento, G.G., Locatelli, J., Freitas, P.C., Silva, G.L., 2000. Antibacterial activity of plant extracts and phytochemicals on antibiotic-resistant bacteria. Braz. J. Micro., 31: 247-256.

Ndabigengesere, A., Narasiah, K.S., Talbot, B.G., 1995. Active agents and mechanism of coagulation of turbid waters using *Moringa oleifera*. J. W. Res., 29: 703–710.

Peixoto, J.R., Silva, G.C., Costa, R.A., 2011. In-vitro antibacterial effect of aqeous and ethanolic Moringa leaf extracts. A. Pac. J. Trop. Med., 4: 201-204.

Sattar, M., Kashif, S.R., Hareem, T., Ali, T., Alam, S., Shuaib, M., 2018. Removal Efficiency of Aloe vera (*Aloe barbadensis* Miller) and Basil (*Ocimum basilicum*) for Heavy Metals from Polluted Soil by Phytoremediation. Int. J. Altern. Fuels. Energy., 2(2): 21-33.

Schwarz, D., 2000. Water Clarification using *Moringa oleifera*. Technical Information W1e.https://sswm.info/sites/default/files/reference_attachments/SCHWARTZ%202000%20Water%20Clarification%20Using%20Moringa%20Oleifera.pdf

Siddhuraju, P., Becker, K., 2003. Antioxidant properties of various solvent extracts of total phenolic constituents from three different agroclimatic origins of the drumstick tree (*Moringa oleifera* Lam.) leaves. J. Agric. Food Chem., 51(8): 2144-2155.

Suarez, M., Entenza, J.M., Doerries, C., Meyer, E., Bourguin, L., Sutherland, J., Manson, I., Moreillon, P., Mennod, N., 2003. An antitumor promoter from *Moringa oleifera* Lam. J. Mut. Res., 81(1): 13-20.

Suleiman, A., Evison, L.M., 1994. Studies on the antiulcer activity of *Moringa oleifera* leaf extract on gastric ulcer models in rats. J. Phytochem. Res., 29(4): 463–465.

Sultana, T., Fariha, A., Nawaz, M., Alam, S., Iqbal, M.N., Ashraf, A., Kashif, S.R., 2019a. Phytoremediation Efficiency of Sunflower (*Helianthus annuus*) and Bryophyllum (*Bryophyllum pinnatum*) in Removing Heavy Metals from Polluted Soil. Int. J. Altern. Fuels. Energy., 3(3): 31-35.

Sultana, T., Sarwar, Y., Rana, T., Sharif, S., Alam, S., Iqbal, M.N., Ashraf, A., Athar, A., 2019b. Removal of Heavy Metals from Contaminated Soil using Plants: A Mini-Review. PSM Biol. Res., 4(3): 113-117.

Sutherland, J.P., Folkard, G.K., Mtawali, M.A., Grant, W.D., 1994. *Moringa olefira* as a natural coagulant. 20th WEDC conference, Affordable water supply, and sanitation, Colombo, Srilanka. pp. 297-299.

Yung, K., 2003. Biosand Filtration: Application in the Developing World CE401 project. Civil Engineering Department. The University of Waterloo. Canada.