Comparison of the Coagulating Efficiency of Moringa Oleifera (Linnaeus) on Wastewater at Lower and Higher Concentration Levels

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Abstract- This research was carried out to evaluate the coagulating effects of Moringa oleifera (Linnaeus) seed powder on wastewater at lower and higher concentration levels using Jar test. 10, 20, 30 and 40 ml of Moringa seed powder-prepared stock solution were used as lower concentration level, while 70, 80 and 90 ml were used as higher concentration level; and results compared. A control experiment was also set up. The pH, Temperature, Total Dissolved Solids, Conductivity and Total Suspended Solids were measured at 24 h post-treatment. Gas Chromatography–Mass Spectrometry was used to reveal chemical components in the ethanolic extract of M. oleifera seed powder. The optimum concentrations for Moringa coagulant at lower and higher concentration levels were 40 and 70 ml respectively. It was observed that 40 ml reduced the Total Suspended Solids of the wastewater from 1240 mg/l to 400 mg/l after 24 h settling interval with removal efficiency of 67.7%. Also, 70 ml reduced the Total Suspended Solids from 1240 mg/l to 360 mg/L after 24 h settling time with removal efficiency of 70.9%. Total Dissolved Solids and Conductivity gradually increased for both concentration levels with increasing concentrations, but were within the World Health Organization recommended standard for drinking water. As observed, both concentration levels did not influence (increase) the temperature and pH of wastewater. The pH values of the treated-wastewater at both concentration levels ranged between 6.7 and 7.8. Findings from this research showed that M. oleifera, a natural coagulant, has greater coagulating efficiency at higher concentration levels.

Keywords - Moringa oleifera, coagulating effect, total dissolved solids, conductivity, total suspended solids, Gas Chromatography–Mass Spectrometry.

1. Introduction

Coagulation is one of the most common ways to reduce the quantity of pollutants present as turbidity, colour and organic matters in water bodies. Coagulation can also be used to reduce the quantity of metallic ions in water. Coagulants have been classified into two (based on their origin), namely inorganic such as aluminum-sulphate and poly-aluminum-chloride or synthetic organic polymers such as polyacrylamide derivatives, according to Bhatia et al [4, 5]. Separation of these colloidal particles can be achieved by the introduction of synthetic coagulant, which leads to slow agitation (flocculation) and thereby causing the coagulation of colloidal particles, so that they can be separated by sedimentation [23]. The common methods of water purification using synthetic materials such as aluminum sulfate (Alum) and calcium hypochlorite are not efficient because these materials are imported and they thus make the cost of water relatively expensive in most economically developed countries; and not readily affordable for most rural populations. Therefore, some people try to get water from different sources such as dams, mining sites, streams, rivers, and lakes. Water from these sources is usually turbid and contaminated with microorganisms and may cause various water-borne diseases. Bearing in mind the problem of environmental pollution, the use of botanicals for wastewater treatment has recently been adopted. Although, wastewater and water from rural sources are known for all the above-mentioned factors (shortcomings), remediating them via the removal of microorganisms, suspended particles and presence of high turbidity is possible by the employment of plant-based products [14, 22].

Different botanicals (plant parts) have been screened as water additives, in other to produce potable water, and they are found to be potential natural coagulants based on the remarkable coagulating properties reposed in them. Notable plant species studied with promising coagulating effects were Moringa oleifera (Linn.), Cactus latifaira and Prosopis jaliflora [13]. So far, many researches have revealed the ability of M. oleifera seed powder in reducing water effluent to a recommendable level. As a result of this, the seed was used as a primary coagulant for turbidity removal on raw and synthetic-turbid water. Records showed that it was 80 – 99% efficient for water purification [18].

Among all the biological materials that have been tested over the years, powdered M. oleifera seeds has been shown to be one of the most effective botanicals which serves as a primary water coagulant and with similar performance to that of alum (conventional chemical coagulant) [17]. From their reports, the powder has antimicrobial properties. Studies have also shown Moringa to be free of mammalian toxicity [15], and its use as a coagulant has been recommended in developing countries [8, 18, 21]. The use of Moringa seeds have an added advantage over the chemical treatment of water because it is bioactive, eco-friendly, biodegradable, and had been reported edible (medicinal) to humans [13].

The cost of this natural coagulant would be less expensive compared to the conventional coagulant (alum) for water purification, since it is available in most rural communities in Nigeria where treated water is a scarce resource. It is in this light this research was carried out to confirm the effectiveness of powdered extract of matured and dried M. oleifera seeds, which is commonly available in most communities in the country. However, there is dearth of information reported on the use of Moringa seed powder as a coagulant in water treatment, in Nigeria, particularly Akure, Capital City of Ondo State. Therefore, this research focused on evaluating and comparing the coagulating effects of Moringa powdered seeds on wastewater both at lower and at higher concentration levels.

TCO film when used as a window for light to pass through to the active material beneath, serves as an ohmic contact for carrier transport out of the photovoltaic. It also acts as a transparent carrier for surface mount devices used between laminated glass and light transmissive composites. Transparent materials possess bandgaps with energies corresponding to wavelengths which are shorter than the visible range of 380 nm to 750 nm. As such, photons with energies below the bandgap are not collected by these materials and thus visible light passes through. However, applications such as photovoltaic may require an even broader band gap to avoid unwanted absorption of the solar spectra.

2. Materials and Methods

2.1. Study Design and Study Location

The study area was located at Apatapiti layout, Stateline Road, Federal University of Technology Akure (FUTA) Southgate, Akure, Ondo State, Nigeria. Apatapiti settlement is a very rocky part of Akure South Local Government (ASLG) with low underground water level. Akure, the capital city of Ondo, Nigeria, lies about 7°23’ North of the equator and 5°19’ East of the Meridian. The water sample used for this research was taken from an unprotected pond at Apatapiti area immediately after a heavy rainfall.

2.2. Sampling Techniques

A purposive sampling technique was used in collecting sample (wastewater) from the pond. A rubber keg of five (5) litres was used to collect sample for the experimental set up. The sample was collected by submerging the container into the pond and subjected to treatments as follows: (i) treated with Moringa at lower concentrations (ii) treated with Moringa at higher concentrations (iii) untreated wastewater as control.

2.3. Measurement of Physicochemical Parameters

The Temperature, Total Dissolved Solids (TDS), Electronic Conductivity (EC) and pH were measured using a microcomputer meter of model HI 9811-5. The probe was inserted into the sample in the beaker and the key for each parameter was selected. The value displayed on the screen was recorded in appropriate units. Total Suspended Solids was measured by filtering the water (control and treated) using a Whatman No. 1 filter paper of a known weight. The filter paper was then dried in the oven at 35 - 40ºC to remove the water element, and was later re-weighed to determine the weight added by the suspended solids.

The Total Suspended Solids was measured to determine the turbidity of the water in mg/l instead of using the turbidity meter. Total Suspended Solids (TSS) was calculated as follows:

Total Suspended Solids (mg/L) = $(A - B)\ x\ \frac{1000}{C}$

Where: A = weight of filter paper and the residue in mg;

B = weight of filter paper in mg; and,

C = volume of sample filtered in ml.

2.4. Preparation of Coagulant from Moringa oleifera Seed Powder

Matured seeds of M. oleifera (Linnaeus) were obtained in Ibadan, Nigeria. The seeds were removed manually by cracking the dry fruit. It was then pulverized using clean mortar and pestle. The seed powder was sieved with a sieve of 0.8 mm mesh size to obtain a fine powder. The fine seed powder obtained was applied to wastewater by preparing a stock solution of one (1) percent suspension. This was done by weighing 2.5g of the seed powder to 250ml of distilled water and then mixed thoroughly, so that 1ml of the solution will contain 0.01g. One (1.0) ml of the stock solution was equal to 2.5 mgL-1 when added to 250 mL of sample (wastewater) to be tested. The insoluble M. oleifera seed powder was later filtered using Whatman No. 1 filter paper and the clear solution was used.

2.5. Extraction of M. Oliefera Seed Powder

The crude extract of ground M. oleifera seeds was obtained by cold extraction using standard methodology. Fifty gram (50 g) of M. oleifera powder was soaked for 72 h in round-bottomed glass jar containing 150 ml ethanol. The mixtures were stirred occasionally with a glass rod. After 72 h, filtration was done using muslin cloth. Substantial amount of ethanol was removed using a rotary evaporator according to [24]. The resulting extract was air-dried for one to three weeks till all traces of solvent were thoroughly removed. The crude extract was kept in a dark bottle, preserved temporarily in the refrigerator [2] and taken out for GC-MS analysis.

2.6. Jar Test

The equipment used for Jar test was Janke and Kunkel (UK) apparatus with nine (9) beakers of 250 ml capacity each. Each beaker was filled with 250 ml of the wastewater. Varying amounts of coagulant (stock solution) were added to the four (4) beakers containing the wastewater and stirred vigorously for about three (3) minutes. The prepared seed extract was added at different concentration levels: 10 ml, 20 ml, 30 ml and 40 ml as lower concentration; and 60 ml, 70 ml, 80 ml and 90 ml as higher concentration.

The set up was mixed thoroughly at high speed for five (5) minutes to enable total dispersal of coagulant and slowly for 15 minutes to aid effective flocculation of the colloidal particles. The rapid mix stage helped to disperse the coagulant throughout each container. The slower mixing speed helped in promoting floc formation by enhancing particle collisions, which led to larger flocs. This speed is slow enough to prevent shearing of the floc due to turbulence caused by rapid stirring.

After thorough mixing, the contents were allowed to settle for 24 h. Thereafter, the pH, Temperature, Total Dissolved Solids and Conductivity were measured and recorded. Also, the Total Suspended Solids was determined by filtering the treated water.

2.7. Gas Chromatography – Mass Spectrometry (GC-MS) Anatlsis

The crude extract of M. oleifera seed powder was initially purified through liquid-liquid chromatography with sodium sulphate on separating funnel packed with silica gel. Gas Chromatographic Analysis of one (1) µl M. oleifera extract was analyzed using Agilent 7890A Gas Chromatograph (GC) system (Agilent Technologies, USA) with a Mass Spectrometer (5975C VLMSD) and Injector (7683B series). The carrier gas was Helium. The capillary column used was HP-5MS and the dimensions were: 30 cm in length, 0.320 mm internal diameter, and film thickness was 0.25 µm. The GC oven temperature was set at 80oC for two min. The temperature increased steadily at 6oC per min to 240oC and was held for 6 mins. The run time of each sample was 36 mins. The peak of each chemical component was expressed based on its retention time and abundance. The identification of components was achieved by searching the mass spectra database (NIST Library), checking for direct similarities with identified components in the system [1].

2.8. Statistical Analysis

All statistical data subjected for analysis were carried out on Microsoft Excel 2010.

3. Results and Discussion

The values of physicochemical parameters for sampled wastewater before treatment were shown in table 1 below:

Table 1: Values of physicochemical parameters of sampled wastewater at zero (0) and 24 h post-treatment

Duration (h)	pH	Temp (^{O}C)	E. Conductivity (µs/cm)	TDS (mg/L)
0	7.5	27.0	220.0	100.0
24	7.3	25.1	190.0	80.0

LEGEND:

h: Hour; Temp: Temperature; TDS: Total Dissolved Solids; E. conductivity: Electronic Conductivity.

Table 2: The Suspended Solids of sampled wastewater at 24 h post-treatment

Initial weight of filter paper (mg)	Final weight of filter paper (mg)	Suspended solids (mg/L)
890.0	1200.0	1240.0

3.1. Effect of Coagulants on Constituent Parameters

The treatment efficiencies of stock solution (Moringa seed powder) at lower and higher concentration levels are presented in tables 3, 4, 5 and 6. At the varying concentrations of the coagulant (stock solution), slight changes were observed on pH, TDS, EC, Temperature, and TSS for treated samples.

Table 3: Physicochemical qualities of the wastewater at 24 h post-treatment at lower concentrations of the coagulant (Moringa seed powder)

Duration (h)	Parameters	Control	*M. oleifera* seed powder			
		Grafik Alanı	10ml	20ml	30ml	40ml
24	pH	7.3	7.1	7.0	6.9	6.8
	Temp (°C)	25.1	25.1	25.1	25.1	25.0
	E. Conductivity (µs/cm)	190.0	230.0	230.0	250.0	270.0
	TDS (mg/l)	80.0	100.0	110.0	130.0	130.0

Table 4: Suspended Solids of the wastewater at 24 h post-treatment at lower concentrations of the coagulant (Moringa seed powder)

Moringa concentrations	Initial weight of filter paper (mg)	Final weight of filter paper (mg)	Suspended solids (mg/L)
10 ml	890.0	1050.0	640.0
20 ml	890.0	1050.0	640.0
30 ml	910.0	1020.0	440.0
40 ml	900.0	1000.0	400.0

Table 5: Physicochemical qualities of the wastewater at 24 h post-treatment at higher concentrations of the coagulant (Moringa seed powder)

Duration (h)	Parameters	Control	*M. oleifera* seed powder			
			60ml	70ml	80ml	90ml
24	pH	7.30	6.90	6.80	6.68	6.70
	Temp (°C)	25.10	25.20	25.20	25.10	25.20
	E. Conductivity (µs/cm)	190.00	330.00	310.00	310.00	300.00
	TDS (mg/l)	80.00	150.00	140.00	140.00	150.00

Table 6: Suspended Solids of the wastewater at 24 h post-treatment at higher concentrations of the coagulant (Moringa seed powder)

Moringa concentrations (ml)	Initial weight of filter paper (mg)	Final weight of filter paper (mg)	Suspended solids (mg/L)
60 ml	910	1010	400
70 ml	900	990	360
80 ml	910	1010	400
90 ml	890	1100	440

3.1.1. Effect of Coagulants on PH

Treatments with varying concentration levels of Moringa did not influence pH of water at both lower and higher concentrations. The pH values ranged between 7.8 and 6.7. These pH values were within the World Health Organization (WHO) standards for drinking water.

The effectiveness of M. oleifera as a coagulant lies in the presence of water-soluble cationic proteins in the seeds. This suggests that in water, the basic amino acids present in the protein of Moringa would accept a proton from water molecule, resulting in the release of a hydroxyl group [18]. Thus, Moringa extract at any concentration levels, maintains the water in its neutral state.

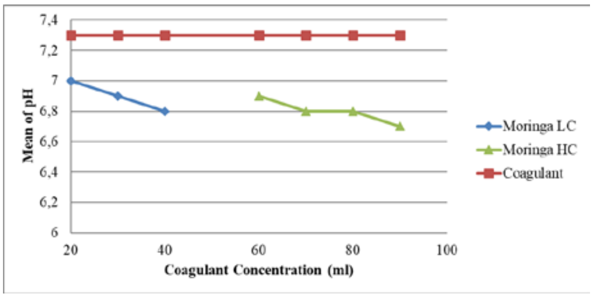

Fig. 1: Effect of higher and lower concentration levels of Moringa coagulant on pH after 24 h interval

3.1.2. Effect of Coagulants on Electronis Conductivity

Electronic Conductivity (EC) is a measure of total dissolved solids (TDS) in water, which varies considerably in different geographical regions, owing to differences in the solubility of minerals. Hence, there is no standard value for it, but higher levels in drinking water may be objectionable to consumers [27].

Treatments with Moringa seed powder influenced the conductivity of water slightly. Increasing concentrations of Moringa resulted to an increase in conductivity of the water. The increase in conductivity with Moringa treatment may be due to anionic polyelectrolyte in the seeds, while increase in sulphate ions and the dissolution of aluminium ions resulted to producing high dissolved solids which increased the conductivity [20]. However, at 70ml to 90ml, there was a decrease in the electronic conductivity of water as a result of decrease in their respective TDS values. This gives rise to the possibility of decreasing electronic conductivity of water at higher concentration levels of M. oleifera.

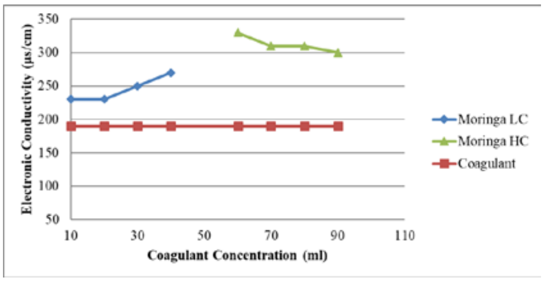

Fig. 2: Effect of higher and lower concentration levels of Moringa coagulant on Electronic Conductivity after 24 h post-treatment

3.1.3. Effect of Coagulants on Total Dissolved Solids

Total dissolved solids (TDS), is a measure of the combined content of all inorganic and organic substances contained in a liquid, molecular, ionized or micro-granular suspended forms. These originated from natural sources, sewage, urban run-off, industrial wastewater, and chemicals used in the water-treatment process, and the nature of the piping or hardware used to convey the water.

The concentration levels for TDS gradually increases as the lower concentration levels increased. A slight decrease in the TDS of water samples for 70ml and 80ml was also observed. An important aspect of TDS in respect to the quality of drinking water is its effect on taste. It was reported that water with TDS levels less than 600 mg/l is generally considered to be good and palatable [26]. Furthermore, since the TDS values of water treated with Moringa seed powder at both lower and higher concentration levels were below 200mg/l, the water could be classified as palatable since the recommended guideline value of TDS in drinking water is 1000 mg/l based on taste [27].

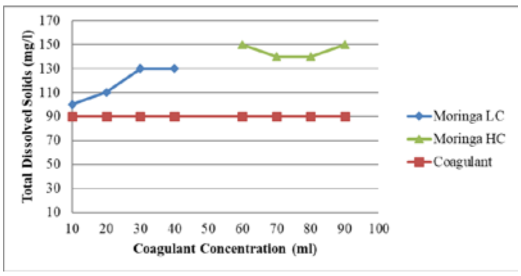

Fig. 3: Effect of higher and lower concentration levels of Moringa coagulant on Total Dissolved Solids after 24 h post-treatment

3.1.4. Effect of Coagulants on Temperature

Temperature is a measure of the degree of coldness or hotness of a body. The coagulant at lower and higher concentration levels showed no significant effect on temperature as it remained almost constant in all the treatment (ml). Hence, the treatment of water with Moringa at any concentration levels has no effect on the temperature of the water.

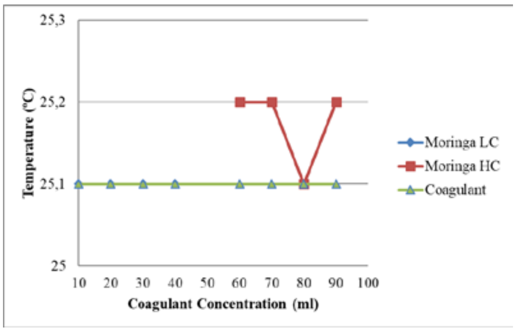

Fig. 4: Effect of higher and lower concentrations of Moringa coagulant on Temperature after 24 h post-treatment

3.1.5. Effect of Coagulants on Total Suspended Solids

Before the treatment of water samples, the value of the total suspended solids was observed to be above the recommended standards for drinking water. The total suspended solids recorded could be attributed to sediments, organic detritus, surface runoffs, characteristics of parent rock and anthropogenic activities such as farming in the immediate surroundings of sampled water sources. This has been reported to contribute to the increase in turbidity [25]. According to the reports of Department of Water Affairs and Forestry [9], high level of total suspended solids in water causes problems with water purification process such as flocculation and filtration, and is mostly associated with the possibility of microbial pollution. The optimal concentration recorded for lower concentration levels of Moringa coagulant for treating wastewater was 40 ml. This concentration reduced the total suspended solids of the wastewater from an initial of 1240 mg/l to 400mg/l after 24 h settling interval. This shows that at this volume, Moringa has a removal efficiency of 67.7%. As for higher concentration levels, the optimal concentration of Moringa coagulant for treating wastewater was 70 ml. This concentration reduced the total suspended solids of the wastewater from an initial of 1240 mg/l to 360mg/l after 24 h settling interval. This shows that at this volume, Moringa has a removal efficiency of 70.9%. These total suspended solids values obtained after seed coagulation were within the WHO acceptable total suspended solids value of 500mg/l for safe drinking water [27].

The coagulation effect of M. oleifera is caused by the destabilization of negatively charged colloids by cationic polyelectrolytes [11]. The likely processes involved in this coagulation activity are adsorption and neutralization of charges, or adsorption and bridging of destabilized particles [3].

For higher concentration levels of Moringa seed - treated water samples, the total suspended solids increased with increasing concentrations beyond the optimal volume (70 ml). This was due to re-stabilization caused by reversal of colloidal charge due to adsorption. This can be explained by the possible saturation of the polymer bridge sites in the Moringa protein, which resulted in the re-stabilization of the destabilized particles, as a result of insufficient number of particles, to form more inter-particle bridges [7]. This was also observed by [6] during coagulation of synthetic turbid water using extracts of Moringa seeds.

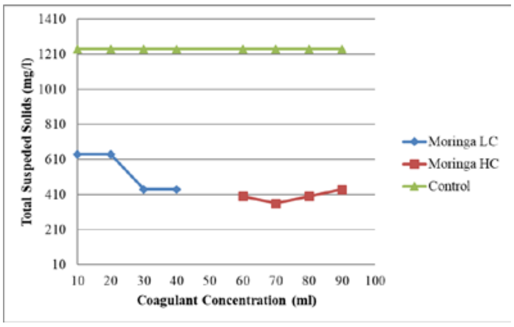

Fig. 5: Effect of higher and lower concentration levels of Moringa coagulant on Total Suspended Solids after 24 h interval

4. Chemical components of ethanolic extracts of M. oleifera seed powder

Chromatogram of ethanolic extract of M. oleifera seed powder is shown in figure 6. GC-MS analysis revealed varied chemical components present in the extract. Thirteen (13) chemical components were identified in ethanolic extract of M. oleifera seed (Table 7). Out of the identified chemical components, Hexadecanoic acid, ethyl ester (22.325%) and 11-Octadecenoic acid, methyl ester (18.091%) were the most abundant components.

As reported and substantiated by different authors, extracts from all parts of Moringa plant have shown pharmacological properties. Remarkably, the seeds have been a good antimicrobial agent against fungi [10] and bacteria [13]. In addition, the seeds are capable of reducing 99.9% of the bacteria suspended in water after a 1-to-2 hour post-treatment [17].

As a natural coagulant, aqueous seed extract of Moringa has been employed as traditional water purifier in Africa and South Asian countries, owing to its higher levels of active cationic proteins with molecular mass between 6 and 16kDa and alkaline isoelectric points, as reported by [13, 18, 19], with a coagulation efficiency similar to that of alum in samples with high turbidimetry [13].

As against the use of alum, the crude extract of. M. oleifera seeds can be a strong alternative for water treatment, especially in developing countries to reduce costs and expand water supplies in rural areas [16]. In agreement with the findings of this research, it was reported by [12] that grounded seeds of M. oleifera are efficient in water treatment and purification. In view of this, he reported that three ground seeds is enough for purifying a litre of water.

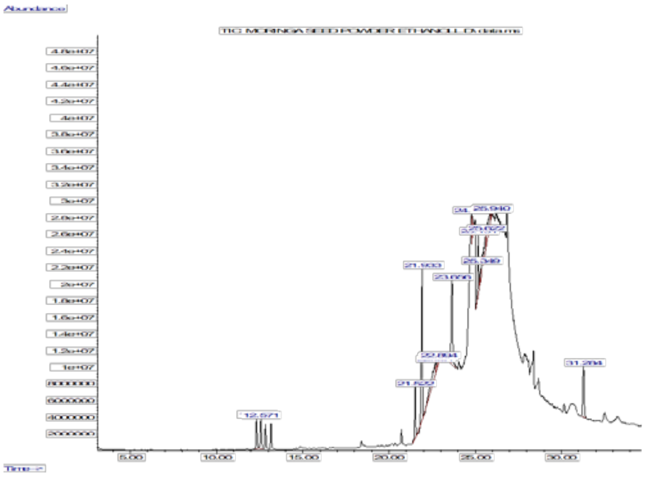

Fig. 6: Chromatogram showing the peaks of chemical components identified in ethanolic extract of Moringa oleifera seed powder

Table 7: Names of chemical components identified in ethanolic extract of Moringa oleifera seed powder

RT (mins)	Name of components	CAS no.	% of total
12.320	1-(1, 5-dimethyl-4-hexenyl)-4-methylBenzene	000644-30-4	4.314
12.571	5-(1, 5-dimethyl-4-hexenyl)-2-methyl-1, 3-Cyclohexadiene	000495-60-3	4.789
21.522	Ethyl 9-hexadecenoate	054546-22-4	6.676
21.933	Hexadecanoic acid, ethyl ester	000628-97-7	22.325
22.681	n-Hexadecanoic acid	000057-10-3	7.331
22.779	cis-13-Octadecenoic acid	013126-39-1	1.679
23.656	11-Octadecenoic acid, methyl ester	052380-33-3	18.091
24.809	(E)-9-Octadecenoic acid ethyl ester	006114-18-7	3.217
25.191	Octadecanoic acid, ethyl ester	000111-61-5	7.443
25.349	9-Octadecenoic acid, (E) -	000112-79-8	1.619
25.622	Oleic Acid	000112-80-1	4.492
25.840	cis-Vaccenic acid	000506-17-2	6.177
31.284	Docosanoic acid, ethyl ester	005908-87-2	9.842

*RT – Retention Time

*CAS no. – Chemical Abstracts Service Registry Number

5. Conclusion

Findings from this research, showed that Moringa oleifera seeds, a natural coagulant, has greater Total Suspended Solids removal at higher concentration levels than at lower concentration levels. Also, higher concentration levels of Moringa seed powder do not increase the pH and temperature of treated wastewater. Since, in all the volumes (ml) used as higher concentration levels, the values of the parameters recorded are not beyond the recommended (standard) values; thus, it can be concluded that M. oleifera seed powder has greater coagulating efficiency at higher concentration levels.

As revealed by Gas Chromatography – Mass Spectrometry (GC-MS) analysis obtained, there were qualitative and quantitative variations in phytochemical constituents (chemical components) found in M. oleifera seeds extract.

Considering the lack of toxic compounds in M. oleifera seeds, and its excellent coagulating (purification) ability, employing this plant material in water treatment could establish an additional source of food (water) fortification, and also serves as an alternatives to obtaining hygienic drinking water, most remarkably in rural areas where there is dearth of potable water.

6. Recommendation

From this research, it could be recommended that further work on components of M. oleifera seeds extract be done to identify the most effective bioactive components, out of the array of components revealed by GC-MS analysis obtained, which possesses the coagulating properties and aided in the water treatment and purification. It is therefore necessary to screen all the pure forms of compounds present in the extract, in other to identify the individual contributions of the chemical constituents that might be responsible for the coagulating effect reported in Moringa oleifera seed powder. It is also necessary to research further on mixing two or more individually-screened chemical constituents together for any synergistic or antagonistic effects (coagulating properties) that might result from them.

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