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Purification of Domestic Water Using Bentonite Clay Mixed with *Moringa oleifera* Lam. and *Asimina triloba* (L.) Dun. Seeds

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Abstract
The high cost of treated water makes most people in the rural communities to resort to readily available sources which are normally of low quality exposing them to waterborne diseases. It is in this light that this research was carried out to confirm the effectiveness of powder extracted from mature-dried *Moringa oleifera* seeds which are commonly available in most rural communities of Africa, and pawpaw (*Asimina triloba*) mixed with bentonite clay or swelling clay. Laboratory studies using jar test experiments were performed on the medium turbid water to determine water purification ability of *Moringa oleifera* and pawpaw seeds mixed bentonite clay. Results showed that *M. oleifera* seeds mixed with clay had much speed on coagulation than ordinary Moringa seed powder, while the mixture of pawpaw with Moringa and clay was the second in terms of speed of coagulation. Water quality parameters from the treated waters were in an acceptable range as prescribed by UNEP/WHO guidelines. The study then showed that the seed powder of *Moringa oleifera* mixed with bentonite clay and mixture of *M. oleifera* seed powder with pawpaw seed powder can be used to purify domestic water supply which is safe for drinking. This method is a cheap one and can be employed in domestic water treatment.

1. Introduction

Water made up approximately 70% of the earth's surface, but less than 1% is available as freshwater for use by mankind. In most part of the world, freshwater is polluted by micro pollutants, which cause diseases to humans. This is peculiar in the developing countries, where rapidly growing industrialization (accompanied by the indiscriminate release of chemical wastes into the environment), increased population, and unregulated urbanization have heavily contributed to the severe pollution of water and soils. Because of this, more than 70% of the illnesses in developing countries are related to water contamination, with a particular impact on women and children [1].

The scarcity of potable water is a huge problem in many developing countries especially in many parts of Africa like northern Nigeria States of Borno, Taraba and parts of Benue. According to UNICEF, 783 million people worldwide are without improved drinking water, and the World Health Organization estimates that lack of proper drinking water causes 1.6 million deaths each year from diarrheal and parasitic diseases. Part of the problem is that many of these countries must import expensive chemicals to clarify the water, limiting the amount they can afford to produce [1].

Moringa is a plant native to the Sub-Himalayan areas of India, Pakistan, Bangladesh, and Afghanistan, from where the plant has spread to other parts of the world [2-3]. The leaves, bark, flowers, fruit, seeds, and root are used in traditional medicine for treating various ailments such malaria, bacterial infections, diabetic, and antioxidant as well as local water purification. *Asimina triloba*, the pawpaw or common pawpaw, is a species of *Asimina* in the same plant family Annonaceae as the custard-apple, cherimoya, and soursop [2-3]. Both plants contain constituents such as alkaloids, tannins, cardiac glycosides, anthraquinones, and sterols [2-6]. This research was carried out in order to purify domestic water suitable for drinking using *Moringa oleifera* and *Asimina triloba* (pawpaw) mixed with bentonite clay.

2. Materials and Methods

2.1. Materials

In this present study, the following materials were used: Seeds of *Moringa oleifera* and Pawpaw in powdered form, bentonite clay soil, atomic absorption spectrophotometer (AAS), GC-MS (Agilent 7820A Model)beakers, filters, water quality testing apparatus and kits, solvents, reagents, etc. All equipment and solvents used were supplied from standard suppliers.

2.2. Methods

2.2.1. Collection and Preparation Moringa and Pawpaw Seeds

Dried seeds of *Moringa oleifera* and *Asimina triloba* (Pawpaw) were collected from a local source in Donga, Taraba State. They were ground into fine powder using local mortar and pestle and stored in an air-tight polytene bag for further use. Clay soil of *smectite* type also called *swelling clay* or *bentonite* (because of its ability to absorb water) was collected from an area in Bali, Taraba State, properly dried and broken into pieces to remove dirt before use.

2.2.2. Purification of Water by Coagulation Process

Domestic water was fetched from a collection tank of volume 5000 cm^3 at a location in Bali town. The water was poured into a five 250 cm^3 measuring cylinders and labelled according to the experimental design. Cylinders containing domestic water were treated using the following design:

i. Cylinder A (domestic water + moringa seed powder mixed with bentonite clay soil),

ii. Cylinder B (domestic water + pawpaw seed powder mixed with bentonite clay soil),

iii. Cylinder C (domestic water + moringa seed powder + pawpaw seed powder mixed with bentonite clay soil),

iv. Cylinder D (domestic water + moringa seed powder),

v. Cylinder E (domestic water + pawpaw seed powder).

The set-ups were allowed to stand for some times for sedimentation and coagulation. Time of coagulation of dirt in the cylinders was recorded for each treatment. After coagulation, treated waterfrom each cylinder was filtered and the process repeated for three consecutive times. Clean water collected were then taken for analysis of somewater quality parameters following standard procedures [6-10]. Values obtained were then compared with WHO standards for domestic water supply [11].

2.2.3. Determination of Some Water Quality Parameters of Treated Water

The following water quality parameters were determined using standard procedures:

(a) Physical parameters (e.g. density, colour, odour, taste, temperature and pH),

(b) Chemical parameters (e.g. chlorides and calcium),

(c) Microbiological parameter such as total coli form [12],

(d) Heavy metals such as Lead(Pb), Copper (Cu), Zinc (Zn), Arsenic(As), Magnesium (Mg), Boron(B), Manganese (Mn), Iron (Fe), chromium (Cr), Cadmium(Cd), Barium (Ba), and Tin (Sn), [12-15].

A brief explanation on the some of the procedures was outlined below:

Density: This was carried out bymeasuring the mass of the empty graduated cylinder. The cylinder is then filled with water to the 100 mL mark. and weighed to know the mass of the mixture. After this, the mass was subtracted from the mass of the filled cylinder. Finally, the mass of water wasdivided by its volume to get the density of water.

Colour, Taste and *Odour*: These were determined by sensory characteristics of observation, tasting and smelling respective.

Temperature and pH: The temperature was measured using a thermometer by dipping it into beakers containing various water sample and taken their readings while pH was determined using the pH meter after calibrating the probe of the meter.

Chlorides and Calcium: Chloride was determined by Silver nitrate method. Briefly, 100 mL of water was measured into a porcelain dish (pH kept between 5-9). It was stirred, and a small amount of calcium carbonate was added followed by1 mL potassium chromate indicator solution and stirred until a reddish colour was obtained. It was then titrated with silver nitrate solution with constant stirring until only the slightest perceptible reddish coloration persists. The procedure was repeated steps on a 100 mL distilled water blank to allow for the presence of chloride in any of the reagents and for the solubility of silver chromate using the formula below:

Chloride as Cl^{-1} = $(1000(V_1-V_2)$/ volume of water)mg^{-1} [15].

Where V_1 = volume of silver nitrate required by water (mL)

V_2 = volume of silver nitrate required by the blank (mL)

Calcium was determined by EDTA titrimetric method. Briefly, a blank colour comparison was prepared by placing 50 mL of distilled water in a white porcelain dish. The sample for titration was prepared by placing 50 mL of water sample in a white porcelain dish. 2 mL of NaOH solution was added to both the sample and the comparison blank and stirred. The resulting pH was between 12 and 13. 0.2 mg of indicator mixture was added to the blank and stirred, then 2 drops of EDTA was added to the titrant from the burette and stirred until the colour turns from red to purple. The burette reading was recorded. The blank was kept for a colour reference comparison. 0.2 mg of indicator mixture was then added to the water sample. As the sample turns red, EDTA titrant was added slowly, with constant stirring until the colour turns from red to faint purple. EDTA was then added drop by drop until the colour matches the colour comparison blank. The burette reading was taken and the volume of EDTA titrant used was determined by subtracting the burette reading obtained in the above step, using the formula below:

Concentration of Ca = (A x C 400.8 / mL sample) mg^{-1}[15].

Where A= volume of EDTA titrant used

C = is calculated from the standardization of the EDTA titrant:

By formula, *C = mL of standard calcium solution / mL of EDTA titrant*

2.2.4. Preparation of Standards

A stock solution of some heavy metals was prepared by dissolving in volumetric flask 24.62, 1.63 and 1.60 g of Lead nitrate, Copper sulphate and Zinc chloride for Pb, Cu and Zn respectively with 68% of nitric acid. The mixture was shaken and the flask made up to the 1 L mark with the nitric acid for each metal. Calibration solutions of the target metal ions were prepared from the standard stock by serial dilution [15].

2.2.5. Nitric Acid/Perchloric Acid Sample Digestion Procedures for AAS Analysis

In order to ensure the removal of organic impurities from thewater samples and prevent the interference in analysis, the samples were digested with concentrated Nitric acid/perchloricacid. 5 mL of conc. The HNO_3 was added to 100 mL of sampling water into the 250 mL conical flask then heated on a hot plate and evaporated till 20 mL was left. After cooling the flask, 5 mL of conc. HNO_3 solution was added and heated on a hot plate. The digestion was continued till 10 mL was left and finally filtered and diluted with distilled water to 100 mL of volumetric flask and stored in the refrigerator for AAS analysis [15-16].

2.2.6. Digested Water Sample Analysis

The digested water samples were analyzed for the presence of some heavy metals using the Atomic Absorption Spectrophotometer. The calibration used was automatic with two standards. The air acetylene was the flame used and hallow cathode lamp of the corresponding element was the resonance. Line source, the wave length for the determination of three elements were 283.31, 324.7 and 213.9 nm for Lead, Copper and Zinc respectively. The digested samples were analyzed in triplicates with the average concentration of metals being displayed in mg/L by the instruments after extrapolation from the standard curve [15-17].

2.3. Statistical Analysis

Raw data obtained were subjected to statistical analysis by computing varietal means as ± S.E.M.

3. Results

The table below showed how the various treatment groups settled the dirt in each water sample contained in 250 mL capacity cylinders.

Table 1. *Rate of coagulation of various treatment procedure.*

Treatment (mL)	Coagulation rate at 25 min of treatment (min)
Moringa seed/clay	7.4±0.01[a]
Pawpaw seed/ clay	6.1 ± 0.05[b]
Moringa seed/Pawpaw/clay	4.2±0.01[a]
Moringa seed/water sample	6.2±0.05[b]
Pawpaw seed/water sample	14.0±0.07[c]
Alum (control)	9.3±0.01[a]

Figures followed by the same letters are not significantly different at p<0.05, n=3 (one-way ANOVA).

Table 2. *Water quality parameters of treated water.*

Treatment (mL)	Parameter				
	Density	Chloride	Calcium	pH	Odour
	(kg/cm³)	(mgL^{-1})	(mgL^{-1})	-	-
Moringa seed/clay	31.5	0.90±0.001[a]	1.4±0.01[a]	6.76	Odourless
Pawpaw seed/ clay	19.2	2.40 ± 0.01[a]	2.1±0.01[a]	6.77	Odourless
Moringa seed/Pawpaw/clay	16.7	6.00±0.01[b]	5.5±0.2[c]	6.73	Odourless
Moringa seed/water sample	25.6	3.00±0.01[b]	1.3±0.01[a]	6.76	Odourless
Pawpaw seed/water sample	27.1	0.9±0.001[a]	1.5±0.01[a]	6.98	Odourless

Figures followed by the same letters are not significantly different at p<0.05, n= 3 (one-way ANOVA).

Table 3. *AAS analysis of water samples for heavy metals.*

Treatment (mL)	Concentration of heavy metals (µg/mL)									
	As	Cd	Cr	Cu	Pb	Al	Ba	Zn	B	Fe
Moringa seed/clay	0.01	0.01	0.01	0.01	-	0.01	0.01	1.0	0.1	2.1
Pawpaw seed/ clay	0.02	-	0.1	0.1	-	0.2	0.1	1.2	0.1	0.2
MS/Pawpaw/clay	0.0	-	0.0	0.001	-	0.001	0.00	0.01	0.0	0.1
MS/water sample	0.2	0.1	0.001	0.1	-	0.1	0.01	0.8	0.2	0.5
PS/water sample	0.4	0.3	0.6	0.2	0.0	0.3	0.5	1.0	0.2	1.0

Data are means of original values at n= 3, MS (moringa seeds), PS(pawpaw seeds).

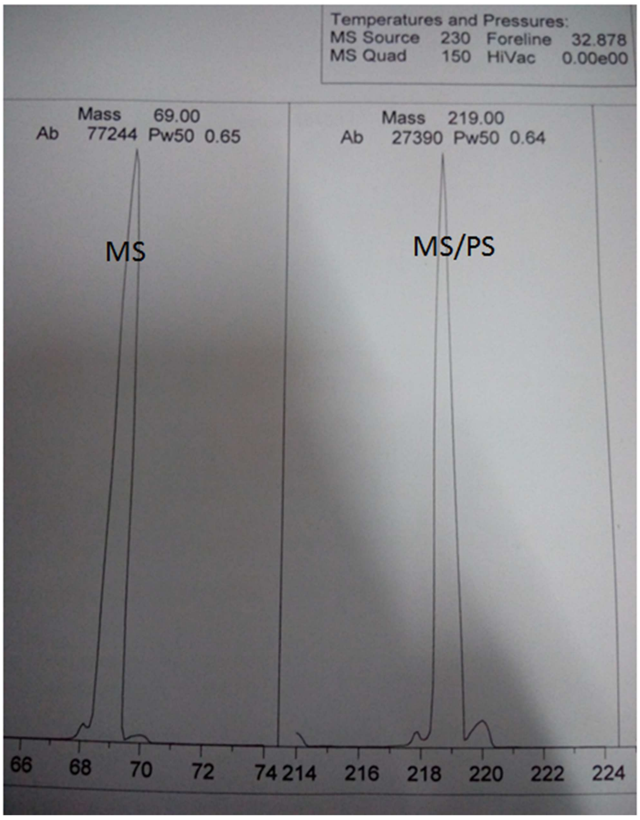

Figure 1. *GC-MS spectra of treated domestic water samples; MS/PS(moringa seeds + pawpaw seeds mixed with clay).*

4. Discussion

One of the benefits of UN Millennium Development Goals is to reduce by half the proportion of people without sustainable access to safe drinking water by the year 2015. The United Nations Convention on the Rights of the Child stipulates that states and their partners have the obligation to provide clean drinking water to all children. The consumption of water containing pathogenic organisms or toxic chemicals and the use of inadequate volumes of water, resulting in poor hygiene, pose serious risks to human health. In addition, the physical condition of water (colour, taste and odour) might render it undrinkable as it can be rejected by end-users. For this reason, water quality assessment and continuous monitoring are of utmost importance [17-19]. In this study, we made concerted efforts in purifying domestic water supplied to the rural populace of Bali, Taraba State Nigeria with a view to obtaining a cheap and safe water treated devoid of diseases. The results of our study revealed that although the various approaches employed in our study yielded significant outcomes yet the combination of Moringa seeds, pawpaw and bentonite clay soil produced the most recommended results. In table 1, MS/PS and clay soil have the shortest sedimentation time of 4.2 ± 0.01^{a} min followed by PS and clay soil with 6.1 ± 0.05^{b}. These values were comparable to the control alum at $p \leq 0.05$ (one-way ANOVA). The shorter time of coagulation and sedimentation in the MS/PS mixed with bentonite clay soil is attributed to superior water treatment potential of this combination over other treated. It is possible to state also that the combination of these three treatment vehicles showed reduced density of 16.7 kg/cm^3, the heavy metal presence of range 0.00-0.10 µg/mL without Pb, As, Cr, Ba and B detected in the sample (Tables 2 and 3). Values of other parameters showed very negligible range which conformed with quality standards of drinking water [17-19]. National drinking water standards often stipulate the maximum permissible concentration of contaminants in the drinking water. In cases where such national standards are not available, the "Guidelines for drinking water quality" published by World Health Organization (WHO) should be followed. Each value given in the guidelines represents the concentration of a constituent that does not result in any significant health risk to the consumer over a lifetime of consumption [20]. The confirmation of this statement was showed by spectra produced by the GC-MS (Figure 1) when compared with pure water (Faro water Nigeria, Ltd).

For many communities in developing countries, however, the use of coagulation, flocculation and sedimentation is inappropriate because of the high cost and low availability of chemical coagulants, such as aluminium sulphate and ferric salts. This research outlined in the application of an indigenous, naturally derived coagulant, namely seed material from the multi-purpose tree *Moringa oleifera* Lam. (*M. oleifera*) and pawpaw seed mixed with clay; which offers an alternative solution to the use of expensive chemical coagulants such as alum.

It was reported recently that defatted papaw seeds can be used for the removal of methylene blue, Pb, and Cd from aqueous solution. The results suggest low adsorption capacity of the pawpaw seeds alone for these pollutants. There is thus a need to further stabilize the adsorbent while maintaining its favourable adsorption capacity [21]. This present study revealed that the seeds of Moringa and pawpaw mixed clay exhibited great coagulation properties in the samples waters, hence the combination presented an efficient and strong adsorbent in water purification. The amount of chloride in Moringa seeds mixed clay is 0.9±0.001[a], calcium is 1.4±0.01[a], while that of pawpaw chloride ion is 2.4±0.01[a] with 2.1±0.01[a] Ca^{2+}. The mixture of both plant's seeds produced a significant amount of Cl^{-1} and Ca^{2+} salts. Other parameters such as temperature, odour, pH, taste, etc, are within UNEP/WHO acceptable standard [22-23].

5. Conclusion

The result of this study showed that seeds of *Moringa oleifera* and pawpaw seeds mixed with bentonite clay soil produced better parameters than any other treatment and followed by the mixture of pawpaw seeds with clay soil. It is therefore concluded that for better and cheep water treatment for consumption in the rural communities, it is better and safe to use bentonite clay soil mixed Moringa seeds (MS) and Pawpaw seeds (PS) which have strong efficiency in domestic water purification. However, our perceived problem in this method of purification is the decontamination of treatment water from germs and other microbial organisms. Therefore, the addition of antimicrobial agents in water during treatment is hereby suggested.

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