USE OF *MORINGA OLEIFERA* (LAM.) SEED POWDER AS A COAGULANT FOR PURIFICATION OF WATER FROM UNPROTECTED SOURCES IN NIGERIA

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Abstract

This study evaluated the effectiveness of *Moringa oleifera* (*M. oleifera*) seed powder (MOSP) alone and in combination with household sand filter (MOSP+F) in water purification. Treatment with MOSP+F produced 99.97% reduction in *E. coli* compared with 98.16% reduction obtained from MOSP treatment alone. Water treatment with *M. oleifera* seed powder in combination with household sand filter was found to be more effective for water purification than treatment with *Moringa* seed powder alone. This method should be encouraged in communities without safe water supply.

Keywords: Eschericia coli, Household sand filter, Moringa oleifera, Turbidity, Water treatment

Introduction

Water is essential for human life. Potable water should be free from contaminants. Children bear the greatest health burden associated with unsafe water supplies through preventable diseases like diarrhoea. In developing countries about 2 million people die every year due to diarrhoeal disease; most are children of less than 5 years of age (WHO, 2006). Other water related diseases reported in Nigeria are trachoma, schistosomiasis, ascariasis, trichuriasis, ancylostomiasis (hookworm), malaria and encephalitis (Sridhar and Oloruntoba, 2008)..

Unprotected water sources receive pollutants from surface runoff thus necessitating treatment at the household level. The common methods of household water treatment require coagulation / flocculation followed by sedimentation, filtration and disinfection. Common coagulants are aluminium sulphate, ferric chloride, polyaluminium chlorides and synthetic polymers (Degrémont , 1979). The dosage of coagulant depends on several parameters such as type and concentration of contaminants, pH and temperature. Chemical coagulation may leave certain residuals such as aluminium; this raises a health concern. For centralized treatment, a uniform raw water quality is required for sustainable supply. Most of the urban water pipes in Nigeria are old, leaky and are laid in drains. This may cause back-siphonage, and thus, pollution of the source with its attendant threat to the health of the consumers unless there is further treatment at the household level.

Some household treatment methods are sand filters where clean sand is used as medium (Ingallinelia et al., 1998; Sánchez et al., 2006), chlorine-based chemicals and alum. Slow sand filters are also popular in small communities and in low-income communities. The slow sand filters work through the formation of a gelatinous layer (or biofilm) called the hypogeal layer or *Schmutzdecke* in the top few millimetres of the fine sand layer. The *Schmutzdecke* is formed in the first 10-20 days of operation (National Drinking Water Clearinghouse, 2000) and consists of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae. The *Schmutzdecke* is the layer that provides the effective purification in potable water treatment, the underlying sand providing the support medium for this biological treatment layer. The water produced from a well-managed slow sand filter can be of exceptionally good quality with 90-99% bacterial reduction (National Drinking Water Clearinghouse, 2000).

Another option exists. The use of plant extracts to coagulate suspended matter from drinking water sources is an ancient practice. *Moringa oleifera* (*M. oleifera*) extract was tried in various countries and found very successful in the flocculation of suspended matter in waters. In Nigeria even though this plant is grown in many households, its use is limited for food preparation and medicinal applications. For water treatment, the efficiency is dependent on the turbidity of the raw water, as reported by Katayon et al.,(2004; 2006). *M. oleifera* has also been shown to produce significantly less sludge than aluminium sulphate, which is an advantage especially if the sludge is to be dewatered or treated in some other way before disposal (Ndabigengesere et al., 1995). It can also be used in combination with other coagulants such as aluminium sulphate (Sutherland et al., 1990). The coagulation and flocculation ability of the seeds has been investigated in several studies (Ndabigengesere et al., 1995; Muyibi and Alfugara, 2003). These studies have shown that neither pH nor alkalinity nor conductivity was affected during water treatment, but an increase in COD, nitrate and orthophosphate was observed.

Surface waters have been treated traditionally using herbs as natural coagulants in India for centuries. Ripe seeds of *Strychnos potatorum*, wiry roots of the rhizome of *Vetiveria zizanioides*, seed coats of *Elettaria cardamomum* and leaves from *Phyllantus emblica* were popular (Sadgir, P., 2007). According to Schwarz (2000), the natural coagulant found in *M. oleifera* is present in 6 of the 14 species of *M. oleifera* growing in parts of Africa, Madagascar, India and Arabia. For example, the women of Sudan have used the seeds from the *M. oleifera* for water treatment since the beginning of the 20th century by swirling the seeds in cloth bags with water for a few minutes and allowing it to settle for an hour. Scientifically, the coagulant properties of *M. oleifera* seeds were first confirmed by the German scientist Samia Alazharia Jahn (Schwarz, 2000). The active component, a protein, acts as a cationic polyelectrolyte, which attaches to the soluble particles and creates bindings between them, leading to large flocs in the water. Stirring and mixing was found to accelerate the electrostatic flocculation, and the flocs condense the contaminants (Göttsch., 1992). So far, there has not been much use of natural coagulants such as the seeds of *M. oleifera* in Nigeria. The objective of the present study is to evaluate the effectiveness of *M. oleifera* seed powder (MOSP) and *M. oleifera* seed powder combined with household sand filter (MOSP+F) for household water purification.

Materials and methods

Study design and study location

A laboratory based experimental design was used. Agodi Lake is a surface water source located behind the Agodi Garden, Ibadan North Local Government Area (IBNLGA) (Figure 1). This lake is exposed to pollution from many municipal runoff and industrial sources. Domestic waste and waste from markets and livestock also enter this lake. Ibadan is known for persistent water scarcity and people use water from this source during shortage. The lake also supplies many other human activities such as washing motor vehicles and clothes. All these leave the water body contaminated.

Ibadan North Local Government Area of Oyo state is located on longitude 8°5' East of the Greenwich meridian and latitude 7°23' North of equator. The estimated population is over 3.5 million (Federal Republic of Nigeria, 2009). It comprises 12 wards of many national groups predominantly Yoruba, Igbo, Edos, Urhobos, Itsekiris, Ijaws, Hausas, Fulani. There are also residents from Europe and Asia and elsewhere.

Sampling techniques

A purposive sampling technique was used in collecting samples from the lake. Plastic kegs of 2 litres capacity were used to collect samples for physico-chemical parameters while two kegs of 10 litres capacity were used to collect samples for laboratory-based filtration experiments. Thoroughly washed and sterilized glass bottles were used to collect samples for bacteriological analysis while plastic sample bottles (PTFE) of 60 mL capacity were used to collect samples for heavy metal analysis. The samples were collected by submerging the containers into the water body. Water samples were collected according to recommended standard methods described by the American Public Health Association American Public Health Association, 1998). Water samples collected from this source were subjected to treatments as follows: (i) treated with *Moringa* seed powder and allowed to sediment (MOSP), (ii) treated with *Moringa* seed powder and filtered with sand filter (MOSP+F) and (iii) untreated water sample as control.

Figure 1: The unprotected Agodi lake water source

Moringa oleifera Seed Powder (MOSP)

Matured seeds of *Moringa oleifera* were obtained in Ibadan (Figure 2). The seeds were removed manually from dry fruit and pulverized in clean mortar using a pestle. The seed powder was sieved to obtain a fine powder on a sieve of 0.8 mm mesh size. The seed powder obtained was applied to water samples by preparing a 1 per cent suspension. The insoluble material was filtered using Whatman No 1 filter paper and the clear solution was used.

Figure 2: ***Moringa oleifera*** **seeds**

Jar tests

The equipment used for jar tests was a Janke & Kunkel (UK) jar test apparatus with 4 beakers of 1000 mL capacity each. Each beaker was filled with 1000 mL of the sample water. Varying amounts of coagulant were added to the samples in the 4 beakers and stirred at 100 rpm for 3 minutes. The rapid mix stage helped to disperse the coagulant throughout each container. Then the stirring speed was reduced to 25 rpm and continued mixing for 20 minutes. This 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 stirring too fast. The contents were allowed to settle for about 45 minutes. After sedimentation, samples were collected for water quality assessment. The final turbidity in each container was thereafter measured using HACH DR/2000 (UK) spectrophotometer.

Construction of Household Sand Filter

Household sand filters were constructed with materials which were obtained locally and these include: 16 litres plastic buckets, 1.5 m of hose, clean sharp river bed sand which was subjected to different grain size sieving (coarse 1-1.8 mm and fine 0.3-0.8 mm) and gravel. All these materials (sand and gravel) were carefully washed, rinsed thoroughly with clean water and dried. The construction of the filters in buckets was carried out (Figure 3). Layer of gravel (4.0 mmϕ grain size and 8.4 cm high) at the bottom, followed by a layer of coarse sand (1 - 1.8 mmϕ grain size and 10.3 cm high) and a layer of fine sand (0.3 - 0.8 mmϕ grain size and 20.6 cm high) on top were placed. The set up was flushed repeatedly with clean water. The filter was monitored for a period of 17 days to attain maturity (the development of biological layer- *Schmutzdecke)*. Every day, the old water was removed through the tap at the bottom of the filter. Then, freshly treated water

(MOSP) was decanted back into the filter and allowed to re-circulate for 2 hours. The filter was then filled to capacity and allowed to stand for 3 hours before sample was collected. The filtered water samples were collected for analysis.

Figure 3: Locally made household sand filters

Laboratory Analysis

Preparation of *M. oleifera* coagulant suspension

The jar test was carried out to determine the optimal dosage of the coagulant, MOSP, for the water treatment. Stock solution (1%) was prepared by dissolving/suspending 3.0 g of the MOSP into 300 mL distilled water, filtered through a Whatman No 1 filter paper and the clear solution was used in the jar tests. One (1.0) mL of the stock solution was equal to 10 mg L^{-1} when added to 1,000 mL of water to be tested. From the prepared stock solution of the MOSP, 50 mg L^{-1}, 60 mg L^{-1}, 70 mg L^{-1} and 80 mg L^{-1} concentrations were used for the optimization study. Solution containers were cleaned between batches to remove insoluble seed material. Fresh MOSP solutions were prepared every eight hours.

The filtered water samples were analysed for pH (using Jenway pH meter) and turbidity (using HACH DR/2000 spectrophotometer at wavelength of 450 nm and expressed as NTU). The conductivity was measured using Jenway 470 Conductivity meter. Total Dissolved Solids (TDS) was determined using Jenway 470 TDS meter; total alkalinity by titration with standard acid (HCl, using methyl orange indicator); chloride by titration against $AgNO_3$ using K_2CrO_4 indicator. The titrimetric method (using disodium dihydrogen ethylenediamine-tetra-acetate) was used to determine total hardness (using powdered Eriochrome Black T (EBT) indicator) and calcium hardness (using powdered murexide indicator) [16]. A colorimeter (Jenway 6510, England) at 410 nm was used to determine NO_3-N while an Atomic Absorption Spectrophotometer (Hanna C-100 spectrophotometer (made in UK)) was used for the determination of Iron (Fe), Manganese (Mn), Lead (Pb) and Zinc (Zn) by direct reading (American Public Health Association, 1998).

Total coliforms and (*Eschericia coli) E. coli* were determined using most probable number (MPN) procedure. MacConkey Broth (MB) was used as the culture medium in the presumptive test while Brilliant Green Lactose Bile Broth (BGLBB) was used as culture medium for the confirmed test. The samples were thereafter incubated for 24 h at 37 ^{o}C for total coliforms and at 44 ^{o}C for the *E. coli*.

Data analysis

Data were analysed using the EPI-Info 3.5 statistical package. The mean and the corresponding standard deviation were used to summarize the characteristics of the water samples, while the results were compared with Nigerian Industrial Standard (NIS) for drinking water and World Health Organization (WHO) Guidelines for drinking water quality. A two sided *t*-test was used at 5% level of significance to determine if there were significant variations among the treatments used in the study.

Results

Raw water characteristics

Table 1 presents the results of physico-chemical and bacteriological quality of the raw water used in the study. The source was prone to pollution from dumping domestic and market waste into the water body as well as pollution from surface runoff. Most of the parameters were within the permissible limits specified by WHO and National Industrial Standards (NIS) of Nigeria except for turbidity. Results of bacteriological analysis also show that the source water was grossly contaminated. The total coliforms count and *Eschericia coli (E. coli)*, indicative of faecal pollution, were 2400 ± 130 MPN/100 mL.

Table 1: Physico-chemical and bacteriological quality of raw water used in the study

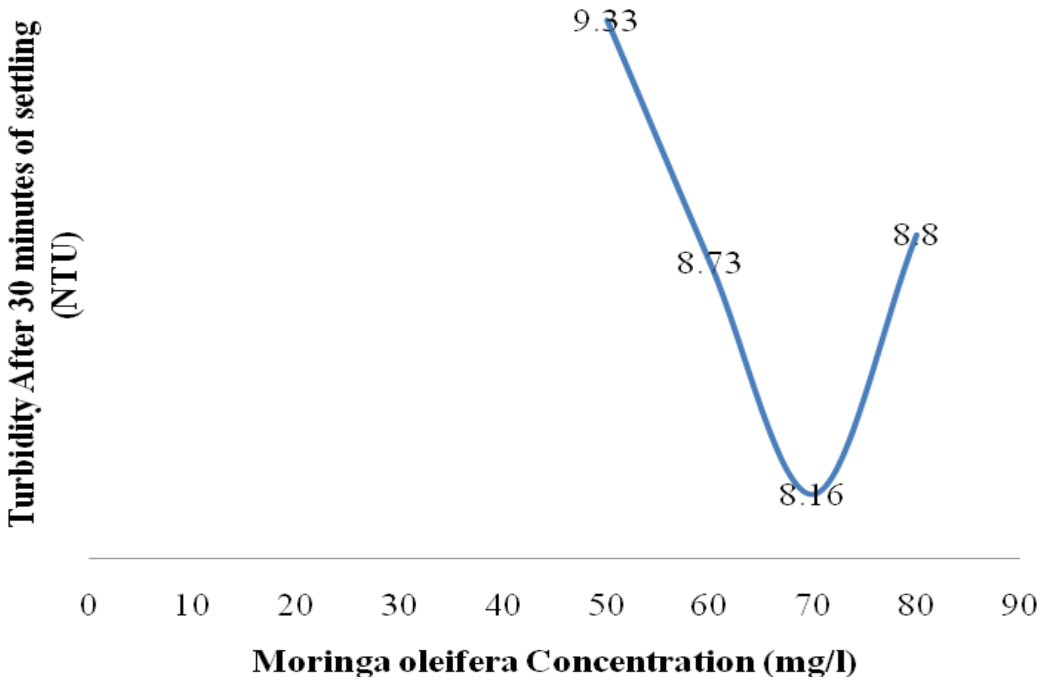
Characteristics	Mean values	WHO Guideline Limits	SON* Standards
pH	7.03 ± 0.2	6.5-8.5	6.5-8.5
Temperature (^{0}C)	28.4 ± 0.0		
Turbidity (NTU)	183.7 ± 0.6	5	5
Conductivity (µS/cm)	400.0 ± 0.6	1000	1000
TDS (mg L^{-1})	239.7 ± 0.6	500	500
Total Alkalinity (mg L^{-1})	74.7 ± 2.3	100	
Chloride (mg L^{-1})	131.1 ± 5.4	250	

Total Hardness (mg L^{-1})	31.5 ± 0.3	100	150
Ca Hardness (mg L^{-1})	23.0 ± 0.3		
NO_3-N (mg L^{-1})	2.8 ± 1.4	10	10
Iron (mg L^{-1})	<0.005	3.0	0.3
Manganese (mg L^{-1})	<0.003	0.4	0.2
Lead (mg L^{-1})	0.002 ± 0.001	0.01	0.01
Zinc (mg L^{-1})	<0.005	3.0	3.0
Total coliforms (MPN/100 mL)	2403 ± 125	10	10
E. coli (MPN/100 mL)	2400 ± 130	0	0

Dosage of MOSP for optimal coagulation

Figure 4 presents the results of jar test and laboratory analysis of the raw water after treating with varying amount of MOSP. The results reveal that the turbidity values were reduced significantly from 183.7 ± 0.6 NTU to 8.2 ± 0.1 NTU. The MOSP dose of 60 to 70 mg L^{-1} was found to be optimal for the reduction of turbidity. It was also observed that more of the larger flocs settled faster at the dosage of 70 mg L^{-1}.

Figure 4: Variation in turbidity with MOSP coagulant dose (at 183.7 ± 0.6 NTU)



Effect of MOSP and MOSP+F treatment on the water

Figure 5 presents the finding on quality of water treated with MOSP+F at different stages of filter maturation. It was revealed that turbidity, total coliform and *E. coli* of the treated water samples reduced appreciably as the filter improved on maturation. Figure 6 presents the results of the quality of water treated with MOSP and MOSP+F at different stages of treatment. The results show that treatment with MOSP alone produced water of acceptable quality while water treated with MOSP+F had better quality. But, turbidity, total coliforms and *E.coli* of water sampled from MOSP+F on day 17 reduced significantly compared to day 1 and day 10. Further, the effect of MOSP and MOSP+F (matured to 17 days) treatments on the water indicated that the physical and bacteriological quality improved significantly (Table 2). The turbidity of raw water reduced from 183.7 NTU to 8.2 ± 0.1 NTU and 4.1 ± 0.2 NTU recorded for MOSP and MOSP+F treated samples respectively. The treatment with MOSP alone gave a percentage turbidity reduction of 95.55% while the MOSP+F method gave 97.75% reduction in turbidity values.

This study revealed that a dose of 70 mg L^{-1} was found effective when the raw water showed a turbidity of 183 NTU. While MOSP alone can be used to clarify water, a combination of MOSP and household sand filter was found to be more effective in the removal of turbidity and reduction of total coliforms and *E. coli*. The reduction is confirmed statistically at 5% level of significance, p = 0.000 (Table 2). Similarly, bacteriological data showed that the MOSP+F treated sample revealed a high percentage reduction in total coliforms 99.94% and *E. coli* 99.97%. Table 2 revealed that the difference between total coliforms and *E. coli* reduction from MOSP and MOSP+F treated samples was statistically significant. This is an indication that the combined (MOSP+F) treatment method had the advantage of reducing microbial load better than the single treatment. The combined method gave the lowest coliform count per 100 mL of the samples as compared to the MOSP treatment method.

Figure 5: Quality of water treated with MOSOP+F at different stages of filter maturation

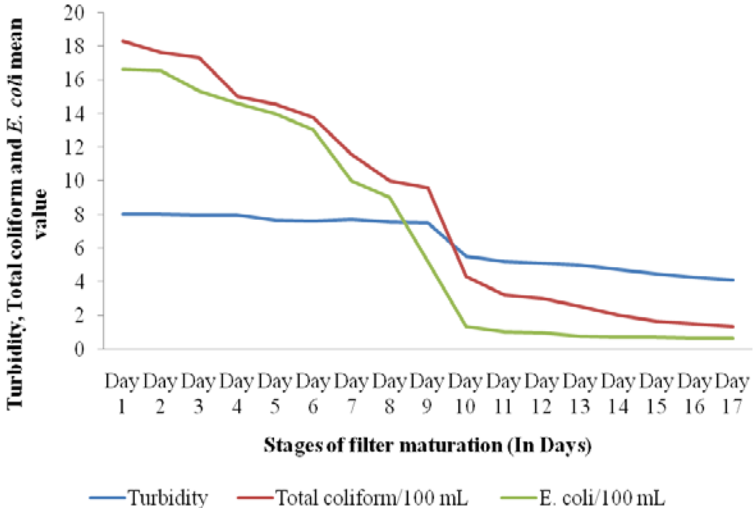


Figure 6: Quality of water treated with MOSP and at different stages of MOSP+F

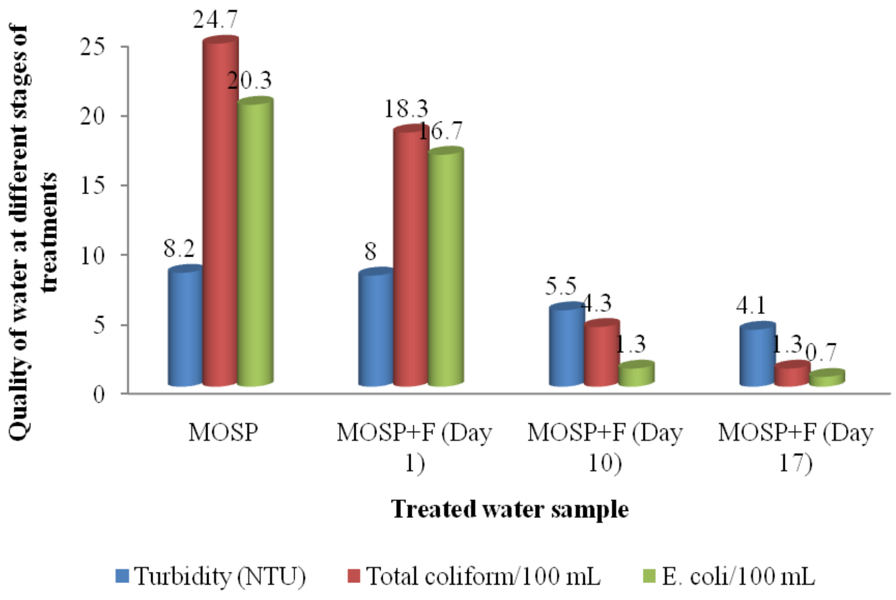


Table 2: Effect of treatment with MOSP and MOSP+F on the physical and bacteriological quality of water after 3 hours of treatment

		pH value	Turbidity (NTU)	Total coliforms (MPN/100 mL)	*E. coli* (MPN/100 mL)
Raw water		7.03 ± 0.2	183.7 ± 0.6	2403 ± 125	2400 ± 130
After Treatment	MOSP	7.06 ± 0.1	8.2 ± 0.1 (95.55%)	24.7 ± 3.2 (98.97%)	20.3 ± 2.6 (99.16%)
	MOSP +F (Day 17)	7.06 ± 0.1	4.1 ± 0.2 (97.75%)	1.3 ± 1.2 (99.94%)	0.7 ± 1.2 (99.97%)
Comparison between MOSP and MOSP+F (Day 17)			t = 19.23 p = 0.000	t = 12.75 p = 0.000	t = 9.02 p = 0.000

(Values in parentheses are percentage reduction)

***SON = Standards Organization of Nigeria**

Note: 0.005, 0.003 and 0.005 are the limit of detection for Iron, Manganese and Zinc (in mgL^{-1})

Discussion

This study showed that the turbidity of the raw water was higher and required flocculation before further treatment. The raw water source was grossly contaminated. Both the total coliform and the *E. coli* counts were higher than the SON and WHO limits, indicating faecal contamination (SON, 2007; WHO, 2006). The presence of a significant number of coliforms in the raw water samples may be as a result of illegal dumping of domestic wastes, roaming livestock, and faecal discharges affect bacterial concentration in runoff (Okonko et al., 2008) This could affect the coliform counts in surface water sources affected by such factors (Sridhar et al., 2009). But the use of plant extracts to coagulate suspended matter from drinking water sources is an ancient practice. *Moringa oleifera* extract was tried in various countries and found very successful in the flocculation of colloids in waters. In Nigeria many households use it for food preparation or as a medicine rather than for water treatment. The plant's efficacy for purifying water may be unknown, or there may be fear of adding an unknown to water. This study revealed that a dose of 70 mg L^{-1} was found effective when the raw water showed a turbidity of 183 NTU. This optimum dose was in line with the study by Folkard *et al* (2000) which had earlier reported *M. oleifera* seed powder dosages between 10-200 mg L^{-1} for turbidities ranging between < 50 and > 150 NTU. While MOSP alone can be used to clarify water, a combination of MOSP and household sand filter was found to be more effective in the removal of turbidity and reduction of total coliforms and *E. coli*. The quality of water after treatment with MOSOP+F was in conformity with WHO Guidelines and SON standards (SON, 2007; WHO, 2006).

It was also demonstrated that treatment with MOSP alone produced water of good quality while water treated with MOSP+F had better quality. Further, turbidity, total coliforms and *E. coli* of water sampled from MOSP+F on day 17 reduced significantly compared to day 1 and day 10. This is an indication that water quality improves as the filter matures. This implies that the *Schmutzdecke* layer needed in the removal of bacteria in the water samples might have been developed, thus improving the water quality. The *Schmutzdecke* is the layer that provides the effective purification in potable water treatment. The underlying sand provides the support medium for this biological treatment layer. The water produced from a well-managed slow sand filter can be of exceptionally good quality with 90-99% bacterial reduction (National Drinking Water Clearinghouse, 2000).

It was found that the pH values of the raw water samples was similar compared to those obtained after treatment with MOSP and MOSP+F (Day 17) respectively. These values were within the acceptable range of 6.5-8.5 (SON, 2007; WHO, 2006). This finding is in agreement with the pH range reported by most authors for drinking water supply [Okonko et al., 2008; Oloruntoba et al, 2006). No significant difference was observed between pH values of raw water and MOSP+F (Day 17) water sample. This is similar to observation by Muyibi and Evison (1994) that, very high doses (400-750 mg L^{-1}) of *Moringa oleifera* used in the complete removal of total hardness in water had no significant increase in pH values. Although pH has no direct effect on health, its indirect action on physiological processes cannot be over emphasized [SON, 2007; Adekunle et al, 2004).

The treatment efficiency is dependent on the turbidity of the raw water, as revealed in previous studies by Katayon et al. (2004; 2006). The study observed that turbidity of the raw water samples was higher than 5 NTU recommended by Standards Organization of Nigeria and World Health Organisation (SON, 2007; WHO, 2006) but turbidity of the MOSP+F (Day 17) treated sample was far below the recommended limits by the two regulatory bodies and that of MOSP treated sample was also reduced. A significant difference in the mean turbidity was obtained with the two treatment methods. This revealed that water treatment with MOSP+F (Day 17) was more effective compared to water treatment using MOSP treatment method only. Although a study carried out in Bauchi, Nigeria by Yongabi (2005) did not indicate the number of days it took the filter to mature, it was concluded that combined *Moringa oleifera* and sand filter when used on the treatment of pond water was more efficient in purification of water than the seed powder of *Moringa oleifera* alone.

In addition, a study by Schwarz found that the process of flocculation removes about 90-99% of bacteria which are normally attached to the solid particles and National Drinking Water Clearinghouse (National Drinking Water Clearinghouse, 2000) reported that the water produced from a well-managed slow sand filter can be of exceptionally good quality with 90-99% bacterial reduction. In this study, a high percentage reduction in total coliforms 99.94% and *E. coli* 99.97% were obtained from water treated with MOSP+F (Day 17). The difference between *E. coli* reduction from MOSP and MOSP+F (Day 17) treated samples was statistically significant. This indicates that the combined MOSP+F (Day 17) treatment method had the advantage of reducing microbial load better than the MOSP treatment alone; and thus gave the lowest total coliform count per 100 mL of the samples as compared to the MOSP treatment method. This is an indication that the combined effect of MOSP and household sand filter produced water which is better in quality compared to the water produced from MOSP treatment alone. The levels of total coliform/100 mL and *E. coli*/100 mL were within SON and WHO limit (SON, 2007; WHO, 2006).

Conclusion

This study revealed that treating highly turbid and contaminated raw water with *M. oleifera* seed powder and further filtration using a matured simple household sand filter is viable for household/community use. This method does not alter the basic mineral composition of the water thus keeping the original appearance and taste. There is need to promote this simple technology, which can provide potable water economically and in culturally acceptable terms

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TABLES

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Figure 4: Variation in turbidity with MOSP coagulant dose (at 183.7 ± 0.6 NTU)
Figure 5: Quality of water treated with MOSOP+F at different stages of filter maturation
Figure 6: Quality of water treated with MOSP and at different stages of MOSP+F