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Integrated Phytodisinfectant-Sand Filter Drum for Household Water Treatment in Subsaharan Africa

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Abstract: This report details an assessment of an integrated low-technology phytodisinfectant-sand filter drum for household water and waste water treatment for sub-Saharan Africa, using bacterial culture tests, total solids, and turbidity amongst others is presented. A hundred litres of very dirty/turbid water (130.3 NTU) was pretreated with 100 seeds of Moringa olieferaand further filtered through a sand filter drum (120 litres carrying capacity) made of fine, coarse sand, charcoal and gravel. The mean total aerobic mesophilic bacterial counts, *E coli*, coliform, pseudomonas, and yeast counts, as well as turbidity of untreated water drastically reduced to wealth health organization acceptable standards for potable water. The results indicated that the mean values of the same parameters for sand filtered pond water alone was significantly lower than the corresponding mean values obtained for Moringa treated pond water. The findings from this study suggest strongly that an integral of two natural water purification technologies (phytodisinfectant-sand filter drum) could be applied for the treatment of all types of contaminated water rendering it free from pathogens for potable and non potable uses.

Key words: Phytodisinfectant, bacteria, pathogens, turbidity, sandfilter, drum, treatment.

1. Introduction

It is estimated that more than 1.2 billion people lack access to safe drinking water and close to 2.5 billion people lack adequate sanitation while 3 out of every five persons lack clean water [1]. Water remains a strategic resource for the integration of economic, social and environmental concerns and is key to sustainable development [2, 3]. It sustains human productivity and livelihoods and plays a crucial role in integrating world's ecosystems. Water is under increasing and competing demands from agricultural, industrial and domestic uses with increasing pollution threatening this scarce resource. The total volume of water as dictated by hydrological remains constant but contamination of water by geological, industrial and anthropogenic sources remains the greatest deterrent to Man's usage. About 1.6 million people are forced to use contaminated water globally [4, 5]. Uncontaminated water is rarely obtainable in rural Africa, Asia and especially in Subsaharan Africa where the prevalence of waterborne infectious diseases is sharply rising [6, 7]. Water borne diseases contribute to the death of about 4 million children in the developing countries per annum. As such, the world health organization has estimated that up to 80% of all disease and sickness in the world is caused by inadequate sanitation, polluted water or unavailability of water [3]. The need to treat waste water both for domestic use and safe disposal to the environment is obviously exigent. In most developing nations, there are legislation/legal framework established to have industries and factories treat their wastewater before disposal but the cost has been prohibitive for most companies and as such very

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few companies treat their wastewater. Unlike in the Western countries, most companies treat their wastewater although at high cost, high energy inputs with complex and most often technologies that are not ecological [8]. Water scarcity remains intractable in sub-Saharan Africa, especially in rural, semi-urban and even urban areas in these countries [6, 8, 9]. Water management has become a global phenomenon. The beginning of the 21st century has experienced heightened awareness on ecological matters. Humankind has fully come to terms with the rapid urbanization and population growth that is invariably accompanied by adverse environmental problems. There are a number of natural, social and economic activities that affect water quality and availability [3, 10]. There are some water bodies that are naturally defective due to the geology of the area. Besides, there are also natural and artificial water bodies like ponds that contain a lot of nutrients and unacceptable for consumption.

Natural disasters like the Tsunami in last December 2004 have generated a social quagmire and a scandal to the scientific world, as clean water and other embarrassing environmental challenges abound. Furthermore, conflict prone areas around Africa like the Dafur region of Sudan, DR Congo, to name a few, experience acute water crises. It has been estimated that 125 litres of water (potable) is required per person per day, yet, many households cannot actually boast of 25 litres of clean water per person per day. In tandem with this, water purification technologies would have to be reviewed in terms of its simplicity, accessibility (cost) and efficiency [4].

The search for simple, reliable and effective method of water treatment led to the use of plant materials including seeds of *Moringa oleifera* [3, 6, 11, 12]. Standard methods for the treatment of water include coagulation, flocculation, sedimentation and disinfection. These methods are often inappropriate due to prohibitive cost and low availability of chemical coagulants and disinfectants. Dosage and technique poses some local challenges, and for this reasons efforts to establish appropriate chlorination techniques for wells in rural communities is imperative [10]. Regrettably, the available technologies in present day do appear complex and still expensive. No doubt, despite tremendous awareness campaign during the water and sanitation decade of 1981-1990, water and sanitation problems today still remain a major task to reckon with. If the Millennium Development Goals in the water and sanitation sector are something to go by, then the need to focus on integrated low cost water purification systems at grassroots stands unequivocal [2, 4, 6, 8, 13].

For communities perpetually with potable water, there is a need to reflect on how the water is treated, even if the high cost is affordable; is the treatment regime in harmony with nature? Are there some side effects conceivable? Nature, though sometimes harsh is still kind and tender, maybe we fail to get her echoes. Certainly we need an “Adam and Eve water purification type of technology”.

Unfortunately, our flickers of understanding in the way natural systems function erodes our confidence and creates an absurdity about natural systems in favour of the mechanical/chemical systems. The ball has been rolling; the bucket method of water purification using *Moringa oleifera* by Folkard and Sutherland is a case in point [5, 9] although that generates less quantity of fairly pure water perhaps on a daily basis. The integration of phytodisinfectants such as moringa pretreated cum sand filtered water could provide a unique opportunity that overcomes the shortfalls of both techniques. The idea of the sand filter stems from spring water. Spring water is the purest form of water in nature as the water filters through different geological beds [8].

This study was therefore designed to investigate the potential of phytodisinfectants-sand filter system to turbid and wastewater targeted for countries in sub-Saharan Africa. The ultimate purpose is to come up with an affordable wastewater treatment technology that is lowtech, effective and ecological. In this report, an evaluation of the potentials of integrating phytodisinfectants and phytocoagulants using *Moringa oleifera* seed powder and sand filtered treated water is presented.

2. Material and Methods

Mature seeds of *Moringa oleifera* were obtained around homes in Bauchi (Fig. 1). 100 seeds were deshelled and pulverized in clean mortar using a pestle. The powder (from 100 seeds) was sprinkled onto 100 litres of the dirty pond water in a 150 litre capacity drum (see picture) and stirred using a clean wood stirrer and the set up allowed to sit for 30 minutes. It was then filtered off using a muslin sack cloth and the filtered water was then passed through a sand filter drum [9].

The materials used in the construction of the sand filter were locally gotten at a river bed and included: low strong (150 litre carrying capacity) drum (plastic), 1 ½ yards of hose, four clips, three nipples, strainer or sieve, sharp river sand (coarse and fine), charcoal and gravel. All these materials (sand, gravel and charcoal) were carefully washed and rinsed repeatedly in clean water [5, 9].

The laying of the materials in the drum was done in the order; laying of perforated hose connected to the collector tank, then a layer of gravel, followed by a layer of charcoal, then coarse sand (2 mm in size) and two layers of fine sand (0.15-0.30 mm size) on top. A test trial was carried out by flushing the set up repeated with clean water. The moringa pretreated water was then passed through the system. The filtered water was collected in drum 2 and samples taken for analyses. Three pond water samples were collected and subjected to all these treatments.

2.1 Study Site

The pond water (surface) was located in Bauchi metropolis, Nigeria. The pond water is shallow, very turbid and during the dry season, people sometimes

Fig. 1 Pods bearing Moringa seeds.

fetch the water for household chores, stray animals, cows drink from the source.

2.2 pH

The pH of the water samples before and after treatment with biocoagulants and sand filter was measured using a pH meter model pH 1-125. The electrodes of the pH meter were standardized by calibrating in acidic and basic buffers raised on distilled water. pH was taken by inserting the electrodes into test tubes containing wastewater samples and pH read off from the meter screen. The values obtained were consistent with values from HACH DR 2000 [14-16].

2.3 Temperature

Temperature was read off directly from the pH meter.

Total solids and turbidity were analyzed using HACH protocols. The HACH (model 44600) DR 2000 was used for the analysis. The analysis was conducted at the WATSAN laboratory, Bauchi.

2.4 Microbial Analysis and Criteria for Selection of Tests

The microbial analysis was carried out according to protocols specified by Refs. [3, 4, 17]. The MPN technique was avoided due to the fact that it is time consuming, while the membrane filter technique was not considered because of certain limitations such as lack of facility for coliform counts and total aerobic bacterial counts etc., while the presumptive coliform test is also time consuming as limited in other microbial parameters.

A range of tests such as total aerobic mesophilic bacterial counts, pseudomonas aeruginosa counts, as well as yeast counts were considered in addition to the traditional coliform and faecal coliform tests to explore the possibility of taking care of viable but non culturable bacterial. Besides, the traditional indicator tests do not always correlate well with certain groups of pathogens such as *Helicobacter pylori* and *Aeromonas* spp and it is worthwhile considering this, especially in assessing the potential of newly constructed systems for water purification.

2.5 Culture Test

Three samples from a very dirty pond (surface) water with water lilly growing in the water. The sample was collected using sterile Maccathney bottles [11]. 1 mL of the samples each was serially diluted with distilled water (9 mls) three fold; i.e. up to 10^{-3} and 1 mL of each diluent of 10^{-1} and 10^{-3} were plated aseptically onto nutrient agar for total aerobic mesophilic bacterial and pseudomonas counts, MacConkey agar for Total coliform and Eosin Ethylene Blue agar for Escherichia coli counts and potato dextrose agar for yeast/fungi counts [11, 17, 18].

The whole set ups were incubated at 37 ºC for 24 hours, and plates were read off following standard microbiological procedures. The bacterial counts were enumerated using Gallemp colony counter and recorded accordingly while the yeast and pseudomonas colonies were picked, stained using methylene blue and gram stain respectively. The average counts from 10^{-1} and 10^{-3} dilutions were recorded.

3. Results and Discussion

The results are presented in Tables 1-5 and Figs. 1-3. The findings showed conclusively that combining

Table 1 Physico-chemical and microbial assessment of pond (surface) water before purification.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water pond samples 3	Mean values (X)
Temperature (ºC)	27.0	26.0	27.1	27.0
pH	7.6	7.5	7.6	7.6
Turbidity (NTU)	130.3	130.1	130.3	130.2
Total solids (mg/dm^3)	466.0	466.0	466.0	466.0
Total aerobic mesophilic bacterial counts (cfu/mL)	TNTC	TNTC	TNTC	TNTC
Escherichia coli counts (cfu/mL)	5200	4900	5200	5100
Coliform counts (cfu/mL)	7300	7300	7300	7300
Yeast counts (cfu/mL)	2500	2520	2,338	2452.7
Pseudomonas counts (cfu/mL)	1220	900	1,118	1151

TNTC-Too numerous to count.

Table 2 Physico-chemical and microbial assessment of pond (surface) water after pretreatment with *Moringa oleifera* (Lam) seed powder.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature	27.0	27.0	27.0	27.0
pH	7.0	7.0	7.0	7.0
Turbidity (NTU)	30.5	30.9	30.9	30.8
Total solids (mg/mL)	352	352	352	352.0
Total aerobic mesophilic bacterial counts (cfu/mL)	393 *	395	352	352.0
Escherichia coli counts (cfu/mL)	574	574	570	572.7
Coliform counts (cfu/mL)	438	439	436	437.7
Yeast counts (cfu/mL)	755	755	758	756.0
Pseudomonas counts (cfu/mL)	156	151	155	154.0

* Larger colonies with butter-like consistency.

Table 3 Physico-chemical and microbial assessment of pond (surface) water after purification with sand filter drum.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature (ºC)	27.1	27.1	27.1	27.1
pH	7.6	7.6	7.6	7.6
Turbidity (NTU)	24	22	22	22.7
Total solids (mg/dm^3)	327	327	327	327
Total aerobic Mesophilic bacterial counts (cfu/mL)	188	192	189	189.7
Escherichia coli counts (cfu/mL)	13	15	13	13.7
Coliform counts (cfu/mL)	15	17	15	15.7
Yeast counts (cfu/mL)	23	23	25	23.7
Pseudomonas counts (cfu/mL)	10	12	15	12.3

Table 4 Physico-chemical and microbial assessment of pond (surface) water after a combine treatment with *Moringa oleifera* seed powder and sand filter.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature	27.1	27.1	27.1	27.1
pH	7.6	7.6	7.6	7.6
Turbidity (NTU)	4.9	4.6	4.9	4.8
Total solids (mg/mL)	297	300	297	298
Total aerobic Mesophilic bacterial counts (cfu/mL)	10	7	7	8
Escherichia coli counts (cfu/mL)	0	1	0	0.3
Coliform counts (cfu/mL)	5	7	5	5.3
Yeast counts (cfu/mL)	10	11	7	9.3
Pseudomonas counts (cfu/mL)	3	4	4	3

Table 5 Comparing mean values for untreated, Moringa treated, sand filter treated and Moringa-sand filtered ponds (surface) water.

Parameter	Untreated pond/ surface water (X)	Treatment with *Moringa oleifera* (X)	Treatment with sand filter drum (X)	Combine Moringa sand filter drum	WHO values (ranges)
Temperature (ºC)	27.0	27.0	27.1	27.1	-
pH	7.6	7.0	7.6	7.6	6.8-8.5 (9.2)
Turbidity (NTU)	130.2	30.8	22.7	4.5	0-5 (25)
Total solids (mg/dm^3)	466.0	352.0	327	298	500 (1,500)
Total aerobic Mesophilc bacterial counts (cfu/mL)	TNTC	394.0	189.7	8	0-500
Escherichia coli counts (cfu/mL)	5100	572.7	13.7	0.3	0-1
Coliform counts (cfu/mL)	7300	437.7	15.7	5.3	0-10
Yeast counts (cfu/mL)	2452.7	756.0	23.7	9.3	-
Pseudomonas counts (cfu/mL)	151	154.0	12.3	3	-

TNTC–Too numerous to count;

Values in brackets indicate maximum permissible limit.

Moringa oleifera seeds with the sand filter outfit can recover very dirty water for consumption. One moringa seed treats a litre of turbid water. Fig. 1 shows pods bearing moringa seeds. The raw data obtained from pond water showed a very high total aerobic bacterial population and high faecal indicator bacteria suggesting the presence of pathogens. This has been reported earlier by Cheesbrough [18]. Normally, surface water is not usually consumed in Subsaharan Africa but during the dry season when there is acute water shortage; people fetch such water for other non potable domestic uses. These include, laundry, washing of dishes and in some outskirts-in rural places, when the situation grows deplorable, the people treat such water with Alum, boil and use if for drinking. The high *E coli* (5100 cfu/mL) and coliform counts (7,300 cfu/mL) shows how unsafe the pond water is for use in any activity [3]. The use of the pond water for bathing could expose one to skin diseases especially if one has wounds or scratches on the skin [18]. The presence and fairly high pseudomonas aeruginosa counts [19-21] supports this. Generally, surface water in Subsahran Africa is heavily contaminated and this holds true for most streams across Cameroon. This is as a result of a lot of human activities going on in the vicinity of these water bodies [3].

The mean bacterial counts of the pond water when treated with *Moringa oleifera* seeds showed drastic reduction in bacterial counts from too numerous to count to 394 colony forming units per millilitre. This falls within the WHO range (Table 5, Figs. 2 and 3). However, despite a drastic reductionof *E coli* and coliform counts (Table 5) of the pond water when treated with Moringa seed powder, the water cannot still be consumed as suggested by the values, which are far off from the WHO recommended values [5, 9, 13]. This however suggests another round of treatment, without refuting the efficiency of moringa as a coagulant and disinfectant. Moreover, water treated with moringa cannot last for more 48 hours without bacterial re-growth [5, 13]. It was in consideration of this that the integration of a sand filter system to moringa treated water was carried out. When this was done, the total aerobic mesophilic bacterial counts reduced to 8 cfu/mL, *E coli* counts reduced to 0.3 cfu/mL while coliform counts to 5.3 cfu/mL. The values were found to be in the WHO standard values for potable water (Table 5 and Figs. 1-3). The turbidity

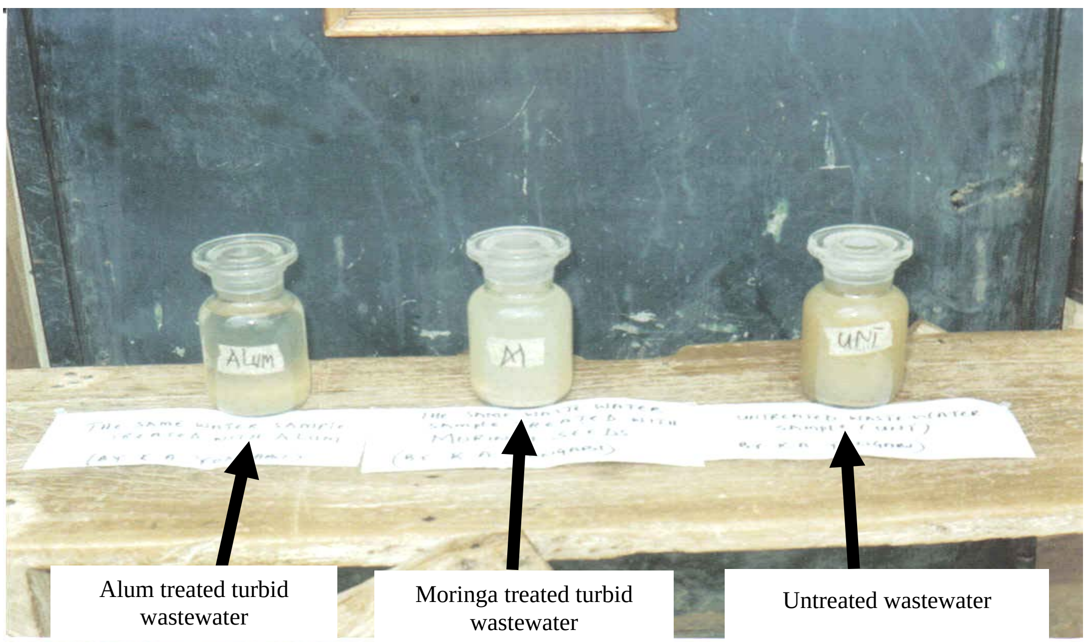

Fig. 2 Turbid water treated with *Moringa oleifera* seeds and alum.

Drum 1: Sand filter drum
A. Control tap

Drum 2: Filtered water storage
B. Clip
C. Colleting tap

Fig. 3 The Moringa-sand filter drum.

as well was drastically reduced within the WHO acceptable level. The results equally indicated that the sand filter is more efficient in purifying water that the seed powder of *moringa oleifera* (Table 3). This is attributed to the fact that sand filter drum is made up of a number of layers of materials with different textures and filtering capacity, fine sand, coarse sand, charcoal and gravel.

Moringa oleifera is rich in nutrients which extracts into the water and later serves as a substrate for bacterial re-growth [11]. Water filtered through the sand filter stores far longer than with Moringa treated water. Despite the comparatively better water treatment potentials of the sand filter. It cannot purify very dirty pond water (the kind of water sample used in this study, Table 5) at one stretch. Without doubts, the sand filter drum has been very efficient in treating well water, borehole, and deep stream water. The CARUDEP (Catholic Arch diocesan Rural Development Programme in Jos, Plateau State of Nigeria) has been installing sand filter drums in many rural communities in Jos, Nigeria for treating the above sources of water. In cases where the water is very turbid (muddy water), they would advise the rural people to either strain the water using a sack cloth or keep in the sun for sedimentation to take place before filtering through the sand filter.

This has worked well, but the option of a pre-disinfection with phytocoagulants particularly seeds of *Moringa oleifera* is not commonly practiced as well as require further studies. It was in view of this that the need arose to evaluate the potentials of an integrated moringa/sand filter drum for purifying all sorts of available water for consumption. The analyse has shown that pond water can be treated effectively using an integrated moringa/sand filter drum. In addition, the system can provide a greater volume of treated water at household than with the Moringa bucket system reported by Folkard and Sutherland and cited by Fuglie [9].

4. Conclusion

The benefits disinfecting water with plant materials while filtering with slow sand filter drum are enormous; the short falls of the two systems are dissolved, greater volume of treated water can store longer, any form of dirty or wastewater can be treated and consumed within a relatively short time. Pathogenic microbes resistant to chlorine as well as the unpleasant effects of Alum and chlorine can be taken care of if this system is used. The techniques are accommodating and the materials needed are cheap, almost all naturally available. Studies are underway in Cameroon to scale up the system for large scale water treatment.

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