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Performance Evaluation of a Constructed Biocoagulant Sand Filter System for Water Treatment in Rural Community

Ukpong, Cletus[*], Antia, Orua[**], Iron, Udeme[***]
[*](Department of Civil Engineering, University of Uyo, Uyo, Nigeria
[**] (Department of Agricultural and Food Engineering, University of Uyo, Uyo, Nigeria
[***] (Department of Civil Engineering, University of Uyo, Uyo, Nigeria
Corresponding Author: Antia, Orua[**]

ABSTRACT
This paper examines some major physico-chemical parameters and microbial quality of a typical community water; in an effort to develop a water treatment system that may provide adequate clean water per day for rural community with no standard facilities. This may also encourage government intervention in communities for provision of water that is safe for drinking, bathing, and recreational purposes for the inhabitants of such community. In this work, the water from Itung Ikot Effanga Mkpa River in Calabar, Cross River State, Nigeria was taken as a case study. A three system was constructed for this study. The result of treating the water sample at temperature of $27.1 \pm 0.57\ ^0$C showed that the physico-chemical parameters such as hardness, pH, total solids, turbidity, total dissolved solids, colour, acidity, chloride, alkalinity and microbial parameters such as *E.coli* and *Coliform* counts considered were found to be within the limit acceptable by the World Health Organization (WHO) for portable water; when *Moringa oleifera* seed powder was combined with sand filter and used as a biocoagulant sand filter system.

Keywords: Biocoagulant (*Moringa oleifera* seed powder), Microbial Quality, Physico-chemical parameters, Sand Filter, Water.

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I. INTRODUCTION

Water is essential for human life and so its safety and access for drinking is a serious concern. Approximately each person requires about 125 litres of clean water per day. Unfortunately, many households cannot have even up to 25 litres of water per day per person. In addition, water is greatly needed for industrial, agricultural and domestic, etc purposes. Human activities and settlement hinge on the availability of water. The increasing risk of water contamination from human activities arises from both 'diffuse' (general agricultural), point source (manure and silage storage) and septic tank system. The anthropogenic activities affect the quality of water from natural sources coupled with the predisposing geographical factors which makes effective disposal of human waste impossible. It has been estimated by World Health Organization (WHO) that about 80% of sickness and diseases are attributed to inadequate water of good sanitary standard. Some health burdens are associated with diseases such as diarrhea, trachoma, schistorso-miasis, malaria, ascariasis, ancylostomiasis (hook worm), trichuriasis and encephalitis, etc [1, 2, 3a,b]. Therefore, good quality water is necessary for cooking, bathing and laundering. However, water source that is unprotected would receive the pollution in surface run off and therefore would require treatment at homes. Usually, some methods acceptable as standard approach to treat water are sedimentation, reverse osmosis, coagulation, disinfection, flocculation, membrane filtration and ultra violet rays. In the treatment of water for supply in community, these methods are in most cases in appropriate because of the high cost associated with the treatment coupled with scarcity of disinfectants and some chemical coagulants. The common method of rural water treatment requires coagulant/ flocculation, followed by sedimentation, filtration and disinfection. Coagulants commonly used are aluminum sulphate, synthetic polymers, ferric chloride and poly-aluminum chlorides. The coagulant dosage depends on some parameters namely type and concentration of contaminant, temperature and pH. One of the methods of communal water treatment used could be sand filter where the medium used in passing clean water is sand. The working of the slow sand filter is based on the use of hypogeal layer which is a formulation of gelatinous layer (bio coagulant). The hypogeal layer will be in few millimeters from the top of the layer of fine sand. In this set up, it is possible to have about 90 – 99% reduction of bacteria if the slow sand filter is well managed. However, an ancient method of coagulating suspended matter in the source of drinking water was by the use of biocoagulant extract. Generally, to maintain the sustainability of treating water at low cost the utilization of rich biodiversity of plant is imperative. In flocculating suspended matter in water, it has been found that *Moringa oleifera* is good enough. The utilization of *Moringa oleifera* seed has been the focus for the past three decades as it has been associated with low cost, biodegradability, abundance and high efficacy in the treatment of water [4, 5, 6, 7, 8, 9]. The use of *Moringa oleifera* in water treatment is advantageous as it produces significant less sludge when compared with aluminum sulphate. More so, the aluminum sulphate may leave behind certain residue like aluminum which could cause health challenge when consumed. Thus, the evaluation of low technology biocoagulant sand filter including seed coagulant of *Moringa oleifera* is essential [10a,b, 11, 12, 13].

It is necessary to note that the use of *Moringa oleifera* coagulant agent obtained from the use of sodium chloride (NaCl) is more potent that using distilled water. This may be attributed to the salting-in mechanism of which increase in the strength of salt ion would influence protein solubility and protein-protein dissociation [14]. In an effort to have good quality water treatment in some communities, a case study of water at Itung Ikot Effanga Mkpa River in Calabar, Cross River State, Nigeria was examined. In this study, it is imperative to monitor the physico-chemical and microbial quality of water supply and then develop simple and efficient biocoagulant aided water treatment system. This may provide the impetus for sustained government intervention.

II. MATERIALS AND METHODS

2.1 Materials

In this study, the following are some materials used: pH meter (model: Mettle Toledo MP), turbidmeter (Model:HANNAA Instrument H 193703), Whatman filter paper, oven, desiccator, weighing balance, Lovibond comparator, indicators such as phenolphthalein, methyl orange, 10 ml plastic measuring tube, 25 ml glass container, Manver hardness indicator, EDTA (ethylene diamine tetracetic acid, calcium indicator and 8N-potassium hydroxide solution and Elenmeyer flask.

2.2 Sourcing of Water

The water from Itung Ikot Effanga Mkpa River, Calabar, Cross River State, Nigeria was obtained as a typical water from a community for this study.

2.3 Microbial and Physico-chemical Evaluation of Water

The water sample was tested for the following based on method prescribed by [15, 7, 16], pH, turbidity, total dissolved solids, total solids, colour, acidity, alkalinity, chloride, hardness, *E. coli* and *Coliform* count. The tests were carried out in triplicate and average value taken and result compared with WHO standard for potable water.

2.4 Formulation of Biocoagulant Using *Moringa oleifera*

The seed of *Moringa oleifera* was shelled and the seed crushed to powder form by using dry head blender. The powder was sieved by the use of 0.8 mm mesh. About 0.3 kg of this powder was mixed using small quantity of clean water in order to make it as paste. Ten (10) litres of turbid water was used in mixing the paste thoroughly by stirring. The paste was allowed to stay for five (5) minutes. This is to enable the extraction of coagulant protein from the waste before it is used. Muslin cloth was used to filter the insoluble material into a bucket for use in treating water.

2.5 Equipment

2.5.1 Components and Principles

The major components of the slow sand filter are sand and gravel. The size range of sand used was between 0.15 mm and 0.35 mm with average sand size of about 0.2 mm. The depth of the fine sand is about 1.2 m and is supported on three gravel layers. The coefficient of uniformity of the fine sand was between 0.35 to 1.7 mm. Usually, in the slow sand filter system the filtration rate is between 2.5 to 6.0 m^3/ day. Its efficiency may depend on the ratio of the filter bed surface, the sand particle size distribution. Also, the depth of the bed is traditionally within the range of 0.5 to 1.5 m for sand filter that is good. However, the filtration is more efficient as the depth of the filter bed increases. In this study, fine sand having 0.05 to 0.5 mm particle distribution size is integrated with 0.001 m to 0.1 mm particle size range of powder made from the *Moringa oleifera* seed.

2.5.2 Construction of Water Treatment System

Three systems were constructed as shown in Fig. 1 to 3 for rural water supply carrying a capacity of ten litres of water for evaluation using the surface water from Itung Ikot Effanga Mkpa River.

Figure 1: Surface water treatment with sand filter

Figure 2: Surface water treatment with *Moringa oleifera*

Figure 3: Combined treatment with *Moringa oleifera* and sand filter

2.5.3 Biocoagulant Sand Filter System Operation
When the insoluble part of the *Moringa* seed powder filtered after the coagulant protein is extracted to the water; it is then mixed with clean sand to constitute a biocoagulant sand filter system. Water would be poured into the system and the set up would be left undisturbed for the production of potable water to commence.

III. RESULTS AND DISCUSSION

The results obtained from analysis of raw surface water and when it was treated with *Moringa oleifera*, sand filter and a combination of sand filter and *Moringa oleifera* in the constructed water treatment system using temperature of $27.1 \pm 0.57\ ^0C$ are presented in Table 1 and 2 together with acceptable values by World Health Organization (WHO).

Table 1: Microbial quality of untreated and treated surface water compared with WHO standard

Parameters	**Untreated Surface Water**	**Treated Surface Water**			**WHO Acceptable Values Ranges**
		Using *Moringa oleifera*	**Using Sand Filter**	**Using Combined *Moringa oleifera* and Sand Filter**	
Echerichia coli count (MPN/100ml)	5.4	0.8	0.5	0.3	0 - 1
Coliform count (MPN/100 ml)	25	7	4	2	0 - 10

Table 2: Physico-chemical parameters of untreated and treated surface water compared with WHO acceptable values

Parameters	**Untreated Surface Water**	**Treated Surface Water**			**WHO Acceptable Values Ranges**
		Using Moringa Oleifera	**Using Sand Filter**	**Using Combined Moringa Oleifera and Sand Filter**	
pH	8.2 ± 0.05	7.6 ± 0.11	7.9 ± 0.05	7.2 ± 0.05	6.8 - 8.5
Turbidity (NTU)	12.0 ± 0.02	5.5 ± 0.57	3.2 ± 0.57	2.5 ± 0.57	0 - 5
Total solids (mg/l)	510 ± 0.57	420 ± 0.28	384 ± 0.28	315 ± 0.57	500
Total dissolved solid (mg/l)	713 ± 0.58	351 ± 0.58	215 ± 0.28	211 ± 0.52	500
Colour	Light brown	Colourless	Colourless	Colourless	Colourless
Acidity (mg/l)	0.8 ± 0.57	0.26 ± 0.76	0.42 ± 0.28	0.10 ± 0.57	0.3
Alkalinity(mg/l)	130 ± 0.1	126 ± 0.57	118 ± 0.57	100 ± 0.28	200
Chloride (mg/l)	12 ± 0.57	7 ± 0.57	6.5 ± 0.57	5.0 ± 0.57	250
Hardness (mg/l)	190 ± 0.58	110 ± 0.58	105 ± 0.28	100 ± 0.57	500

From Table 1, the *E.coli* (500 cfu/ml) and *Coliform* count (7300 cfc/ml) show respectively high values for the untreated surface water as 5.4 MPN / 100 ml and 25 MPN /100 ml. The indication of pathogenic bacteria is present could be based on the presence of Coliform bacteria. The use of surface water having high *E.coli* and *Coliform* count for bathing implies that the skin might be exposed to diseases if one has wound or scratches on the skin. Generally, surface water is heavily contaminated and this is as a result of heavy human activities that are going on in the water bodies' vicinity. The surface water treatment with *Moringa oleifera* gave a value of 0.8 MPN/ 100 ml for E. coli while that of Coliform was 7 MPN/ 100 ml. Usually water treated with *Moringa oleifera* cannot last for more than 48 hours without bacteria re-growth. However, using sand filter for surface water treatment resulted in having *E. coli* and *Coliform* count of 0.5 and 4 MPN/ 100 ml, respectively. The efficiency of sand filtration system usually depends on the quality of water source (degree of pollution) and the source of supply should contain less Coliform bacteria. The combination of *Moringa oleifera* seed with sand filter outfit shows a recovery of high quality water consumption in terms of *E. coli* and *Coliform* count. This is indicated by the drastic reduction in the mean values of bacterial count of the surface water. These values fall within the acceptable range by WHO. This implies that it is likely that the *Moringa oleifera* sand filter combined system could provide a greater volume of water treated for members of the rural communities to use for their consumption coupled with reduction in health risk. From Table 2, the pH values for untreated and treated water were within WHO acceptable range. However, the pH decreased when treated singly with *Moringa* and sand filter; but partially increased when treated with combined *Moringa* and sand filter. The increase may be due to *Moringa oleifera* action as a coagulant of which its potency lies in the water soluble cationic protein in the seeds. This implies that in water, the basic amino acid present in *Moringa oleifera* protein would accept a proton from water. This would result in the release of hydroxyl group to make the solution basic. The turbidity values were best obtained when *Moringa* and sand filter treatment were combined to treat water to acceptable range by WHO. The total solids (TS) and total dissolved solids (TDS) present in treated water were within WHO acceptable standard with a better treatment obtained using combined *Moringa* and sand filter. More so, the initial brown colour of surface water was completely removed after treatment using *Moringa* seed powder. The *Moringa oleifera* seeds therefore show absorbent properties. The acidity was observed to decrease and was within the acceptable limit by WHO. This may likely be that the *Moringa oleifera* contains water-soluble protein of lower molecular weight which carries a positive charge. Hence, the seeds when crushed and water added to it would cause the protein in it to produce positive charge that would act like magnets to attract predominantly negative charged particles. Moreover, at various stages of treatment, the alkalinity was observed to reduce after the treatment using *Moringa oleifera* seed powder; as against when treated with sand filter alone and when combined *Moringa* with sand filter of which the alkalinity was slowly increased. The decrease in alkalinity may be as a result of insoluble products precipitation during the reaction between *Moringa* and water. This is similar to the precipitation during softening of water using lime / soda ash. The extract of *Moringa* seed extract seems to have a natural buffering capacity. It was also observed that *Moringa* seed extract reduced the chloride ion level. This may be because the cations from the seed would combine with the negatively charged chloride ions present in the water and result in the neutralization of the chloride ions to range between 5 – 9 mg/ l in surface water sample. These values are within the WHO standard limit. The hardness of treated water decreased comparably with untreated water. This may be because; *Moringa oleifera* is polyelectrolyte and may remove hardness in water by adsorption and bridging of inter- particle. Also, to note is that surface water have higher value of hardness because it contains magnesium, calcium and other hardness-causing substances. Therefore, it is likely that the *Moringa oleifera* seed powder dosage would be required to be increased as the hardness of water increases.

IV. CONCLUSION

In this study, it may be concluded that a well-constructed biocoagulant water treatment system that utilizes *Moringa oleifera* seed powder and sand filter can be used effectively to treat water to acceptable WHO standard in rural areas that have no standard facilities.

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