Determination of the Filter Potential of Luffa Sponge (*luffa aegyptiaca)* in Water Quality Analysis

Adie D.B
Igboro S.B
Daouda N

Department of Water Resources and Environmental Engineering
Ahmadu Bello University, Zaria – Nigeria

Eladere E

Department of Civil Engineering
Kaduna Polytechnic, Nigeria

Abstract

Surface water is unprotected and exposed to the vagaries of weather and environmental pollution and therefore, the possibility of contamination. The main target of water treatment is the removal of chemical and bacteriological contamination and inactivation of disease causing organisms. A filter model with luffa sponge as filter media was tested for its effectiveness in the purification of water. The experimental work was conducted on selected luffa sponge in a plate form inserted in a Perspex plastic filter model that has been designed for this purpose. The filter medium (luffa sponge) was placed in the four separated chambers starting from the more porous to the least one in the direction of flow. The system was operated in series. Each compartment was separated by a cascade and the sponges were held in place to avoid the deformation of the filter media. The filter bed was provided with an under drain system for flushing after a certain running time. It was observed that luffa sponge has high hydraulic efficiency and that the horizontal filter is more efficient than the vertical filter. However, it only has a moderate TSS removal capacity due to its high porosity value. It was calculated that the filter media performance efficiency was 18.15% for turbidity removal, 48.33% for TSS, 10% for hardness, 0% for alkalinity, 16% for chloride, 16.66% for ammonia nitrogen and 80% for bacterial removal. The study showed that the luffa aegyptiaca (cylindrica) sponge possesses a great potential for heavy metals removal in water as well as hardness and microbiological reductions. Because of these advantages and the fact that it performed poorly in the reduction of parameters of importance in potable water quality, it is concluded that the luffa sponge filter media can be considered as a preliminary wastewater roughing filter, but cannot adequately be used as a filter media for potable water supply. However, the size of the sponge limits the filter size and its fibrous nature offers high degree of porosity

1. Introduction

Surface water is unprotected and exposed to the vagaries of weather and environmental pollution and therefore, the possibility of contamination. The main target of water treatment is the removal of chemical and bacteriological contamination and inactivation of disease causing organisms (Mukhopadhay et al., 2008)

Water is essential for life and socio-economic development of man. It is also life sustaining for animals and plant. The water required has to be adequate both in quality and in quantity. The properties of water are strikingly different from those of other substances in both its physical, biological and chemical nature. Therefore, the requirement for potable water, taking into cognizance these factors, is of consideration in the design of all the water supply units including the intakes, treatment plant and pipeline of the distribution system. Water quality problems are responsible for 30,000 deaths daily (WHO and UNICEF, 2006) and over 25,000 kinds of water borne diseases have been identified (UNICEF, 2006).

Water is treated for a number of reasons of which the removal of disease germs is the most important. The need for treatment arises because of the presence in water of bacteria, colour, taste, odour, hardness, floating material, suspended solids and dissolved metallic salts. Potable water should also have good appearance. It should also be suitable for domestic uses like cooking; washing etc. The degree of treatment required depends upon the type of impurities carried by water. Surface water may be from lakes, rivers or canals.

Water bodies are being overwhelmed with bacteria and waste matter. Among toxic substances, reaching hazardous levels are heavy metals (Robinson, 1998). Heavy metals occur in immobilized form in sediments and as ores in the nature. However due to various human activities like ore mining and industrial processes the natural biogeochemical cycle is disrupted causing increased deposition of heavy metals in the terrestrial and aquatic environment. The heavy metals are of public health concern as they are non-biodegradable and persistent. Through a process of biomagnification they further accumulate in food chains. Thus, their treatment becomes inevitable and in this endeavor, biosorption seems to be a promising alternative for treating metal contaminated waters.

Biosorption can be defined as "a non-directed physico-chemical interaction that may occur between metal radio-nuclide species and microbial cells" (Hima et al., 2007). It is a biological method of environmental control and can be an alternative to conventional contaminated water facilities. It also offers several advantages over the conventional treatment methods such as activated sludge process, lagoons, etc. Other advantages include cost effectiveness, efficiency, minimization of chemical/biological sludge, requirement of additional nutrients, and generation of biosorbent with possibility of metal recovery. Biosorption process involves a solid phase (sorbent or biosorbent; usually a biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be adsorbed (sorbate, a metal ion) (Hima et al., 2003)

In filtration, water is passed through a filter medium in order to remove the particulate matter not previously removed by sedimentation. There are several functions involved; one is simply the building up of floc layer on the surface of the filter which in itself acts as a filter media. The second is the penetration of the floc into the bed where tubes of penetration and further branch tubes are developed through which the water flows, leaving behind the particle of suspended matter. Luffa sponges are the fibrous interiors of the fruits of luffa plant (*luffa cylindrica*). The luffa plant has oval leaves of five to seven lobes, dentate, accumulate and dark green. They are 10 to 30 cm long and 5 to 25 cm wide. The fruits are regularly cylindrical, sometime striped and pale green in colour. When they are dried, a network of fibers is released and forms the luffa sponge that is about 30 to 60 cm long and 8 to 10 cm wide Luffa fibers have various industrial uses, more especially as engine filters and as shock and sound absorbers.

Luffa sponge products are available in the cosmetic and pharmaceutical industries. The popularity of luffa for personal hygiene products is due to the gentle exfoliating effect the fibers have on the skin. Many environmentally conscious consumers appreciate that luffa product are biodegradable, natural and a renewable resource (Mazali et al., 2005; Bal and Lallam, 2004). It is chemically composed of 60% cellulose, 30% hemicelluloses and 10% lignin. The mature, dry fruit consist of a hard shell surrounding a stiff, dense network of cellulose fibers, adopted for support and dispersal of hundred of flat, smooth black seeds. In addition, studies have proved that luffa sponge have an aspect of biosorption of heavy metals, high fidelity calcium carbonate and hydroxyapatite. Inorganic replicas of the fibrous network of the dried fruit of *luffa cylindrica* have been replicated, utilizing a facile synthetic route. Luffa sponge has a highly complex macroscopic architecture template and is an inexpensive sustainable resource (Iqbal and Edyvean, 2004).

The aim of the research is to determine the effectiveness of *luffa cylindrica* as a filter material, especially in regards to its physical, chemical, biological properties and its ability to reduce dissolved heavy metals in water by adsorption.

For this purpose a filter model with luffa sponge as filter media was tested for its effectiveness in the purification of water. The experimental work was conducted on selected luffa sponge in a plate form inserted in a Perspex glass filter model that was designed for this purpose.

2. Materials and Methods

2.1 Materials

(a)Water quality test

Series of tests were carried both on the influent and effluent at each chamber outlet. Physical, chemical and Biological test were carried out in the laboratory using standard methods (APHA, 1995). Equipments such as Thermometer, Lovibond Comparator, Turbidimeter, pH meter and digital conductivimeter were used. Other equipment are Oven, Autoclave and Incubator were also used. While glassware employed are Burettes, pipettes, reflux flask, conical flask, measuring cylinders, volumetric flask, test tubes and evaporation dish were used. In addition Buffer solution, potassium dichromate and other reagents were also used.

(b) Filter model and design

A pilot filter model was constructed to investigate the efficiency of luffa sponge in the filtering process. The model structure was made from fiber glass sheeting. The model consisted of 4 chambers each with dimension of 8.5 cm ×18cm ×14cm.

The filter medium (luffa sponge), was placed in three locations in the four separated chambers starting from the more porous to the lesser one in the direction of flow (i.e. 3. 6. and 9 sponges respectively). The Luffa sponge obtained was cut to size and light pressed to shape to fit into the compartment provided

The system was operated in series. Each compartment was separated by a cascade and the sponges were held in place to avoid the deformation of the filter media. The filter bed was provided with an under drain system for flushing after certain running time. This is to facilitate sludge extraction by observing the filter resistance. A constant flow rate was maintained in all the compartments. The suspended solid (SS) concentration of raw water for the chambers at the inlet and the outlet was measured. Raw water from Kubanni River was used because of its suspended and dissolved solid content which is greater than 40mg/l. According to Weglin's (1996) guideline the water sample is of medium range concentration, since 100-300 mg/l is recommended for river water.

2.2 Methods

(a) Sampling technique

A systematic sampling technique is adopted in the selection of dried luffa sponge. The sponge was cut longitudinally, soaked in boiling water for 30 minutes, thoroughly washed under tap water, and left for 24 hours in distilled water, changed three to four times. The luffa sponges were oven dried at 70º and autoclaved for 20 minutes.

(b) Filter media characteristics

(i) *Porosity:* The sponge pore sizes were measured under dried condition. The values are obtained from the formula.

$$\text{Porosity} = \frac{\textit{total volume of void}}{\textit{total volume of sample}} \qquad (1)$$

(ii) *Specific gravity*

This is calculated from equation (2)

$$\text{Specific gravity} = \text{weighed sample mass/sample volume} \qquad (2)$$

(iii) *Filtration flow:* This was determined based on filtration rate. This was determined by obtaining the inflow and outflow rates during the filtration process.

(iv) *Retention time*: This is the time it takes for the water to complete one batch filtration process. This was determined by:

$$T^* = \frac{AD}{Q} \qquad (3)$$

Where, A= surface area of the tank (m^2); Q = flow through tank,(m^3/s); D=dept of the tank (m).

(c) ***Chemical test***

These following tests were conducted under chemical analysis:

(i) Total suspended solid: TSS test results were used as a measure of performance of treatment process.

This was determined by the use of membrane filters to assess the amount solid particles in water samples.

Suspended solid (mg/l) = w_1惘w_2 (4)

Where, w_2 =weight of evaporated dish (mg/l)

W_1 =final weight of evaporated dish and residue (mg/l)

(ii) Alkalinity: The alkalinity of the samples was obtained from the formula:

$$\text{Total alkalinity}=\frac{|a-b|\times N\times 50{,}000}{ml\ of\ sample\ used} \quad (5)$$

Where:

A = Volume of acid used for blank

N = Normality of acid used 0.02

B = Volume acid used for sample.

(iii) Chloride in water: The Mohr's method was used to determine the chloride amount in water.

$$\text{Cl (mg/l)} = \frac{A\times N\times 3545}{ml\ of\ sample\ taking\ for\ analysis} \quad (6)$$

Where,

A= ml of titrant for sample

N=Normality of silver nitrate solution (N=0.0282)

d) Determination of Ammonia Nitrogen

(iv) Determination of Hardness: This was determined by the use of total hardness given by the formula:

$$\text{Mg/l } Caco_3 = \frac{A\times B\times 1000}{ml\ sample} \quad (7)$$

Where, A = ml of titrant; B = ml $CaCo_3$ equivalent to 1.00 ml EDTA titrant.

(v) Dissolved Oxygen/ Biochemical Oxygen Demand: Determined by:

BOD_5 = [D_o惘D_5] ×P (8)

Where;

D_o = zero day dissolved oxygen

D_5 =5 days dissolved oxygen, and

$$P = \text{fraction for dilution} = \frac{final\ volume\ used}{initial\ volume\ taken} \quad (9)$$

(d) Microbial and biological examination

The Serial Dilution Technique and Most Probable Number (MPN) method was used for the analysis. This method involves dilution of water samples in order to reduce by a known amount, the number of bacteria to make counting possible. In each of the tubes, the dilution is 10 times greater than the one before it and this also applies to the number of bacteria in the water. Depending on the volume of water incubated (0.1 or 1ml), the number of bacteria per given volume was calculated.

(e) Data Analysis

The conceptual filter theory for evaluating the efficiency of the filter is used. This method was based on the filtration theory described by Weglin (1996).

According to the available filter theories and Fick's law, the filter efficiency can be expressed by the filter coefficient λ or,

$$\frac{dc}{dx} = -\lambda c \quad (10)$$

Where c = solid concentration, λ= filter coefficient or coefficient of proportionality

x = filter depth.

From eqn. 9, it can be stated that the removal of the suspended particles is proportional to the concentration of the particles present in water.

The total length of the filter can be described as the number of parallel plates and act as a multistage reactor. This allows the performance of the luffa sponge filter to be ascertained on the basis of the results obtained from the small filter cells. The total suspended solids concentration after length Δx of the filter cell can be expressed:

$$C_{outlet} = \sum C_{inlet}\, e^{-\lambda i \Delta x} \quad (11)$$

Where,

λ_i = Filter efficiency of each filter cell,

Δx = Length of experimental filter cell

C_{inlet} and C_{outlet} = Concentration of particles in the inlet and outlet of the filter.

After evaluating the filter depth (length), the filter efficiency can be predicted. According to Weglin (1996), the effluent quality for the n number of compartment is given by,

$$C_e = Co \times E_1 \times E_2 \times E_3 \times \ldots\ldots \times E_n \quad (12)$$

Where, C_o = concentration of TSS in the influent.

C_e =concentration of TSS in the effluent.

$E_1, E_2 \ldots\ldots\ldots E_n$ = filtration efficiency for each compartments (1, 2, 3 …n; respectively)

The basic expression for the above relationship is given by;

$$C_e = C_o e^{-\lambda l} \quad (13)$$

The filter efficiency is given by: $E = \frac{Ce}{Co} = e^{-\lambda l}$ (14)

3. Results and Discussion

Table 1 shows the summary of laboratory results carried out. Filtrate 1 had 3 sponges installed in each compartment; filtrate 2 had 6 sponges in each compartment, while filtrate 3 had 9 sponges installed. The peak reduction shows the percentage reduction in parameter value between raw water and filtrate water quality using the stated number of sponges.

Figures 1 to 3 shows results of the change in turbidity against the number of sponges, variation of bacteria colony with respect to the number of sponges and the variation of total suspended solids with respect to sponge number respectively.

Luffa sponge has a moderate TSS removal capacity due to its high porosity value. It was calculated that the filter media performance efficiency was 18.15% for turbidity removal, 48.33% for TSS, 10% for hardness, 0% for alkalinity, 16% for chloride, 16.66% for ammonia nitrogen and 80% for bacterial removal.

Table 1: Summary of laboratory test results in the experiment

Parameters		Concentration/intensity				Peak Reductions
		Raw	Filtrate1 (3 sponges)	Filtrate2 (6 sponges)	Filtrate3 (9 sponges)	
Physical	pH	7.85	7.86	8.00	8.47	
	EC	130μmhos/cm	130μmhos/cm	140μmhos/cm	140μmhos/cm	
	TSS	120mg/l	100mg/l	86mg/l	62mg/l	48.33%
	Color	15NSA	15NSA	10NSA	5NSA	66.66%
	Turbidity	39.10NTU	36.10NTU	36NTU	32NTU	18.15%
Chemical	Hardness	42mg/l	36mg/l	-	-	10%
	Chloride	88.62mg/l	74.44mg/l	-	-	16%
	Ammonia Nitrogen	12NAB	10NAB	-	-	16.66%
	Alkalinity	2mg/l	2mg/l			0%
	BOD	0.2mg/l	0.2mg/l	0.17mg/l	0.15mg/l	25%
Heavy metal	Chromium	0.82mg/l	-	-	0.28mg/l	65.85%
	Cadmium	0.13mg/l	-	-	0.091mg/l	30%
	Zinc	0.41mg/l	-	-	0.151mg/l	63.17%
	Nickel	0.3mg/l	-	-	0.08mg/l	73.3%
Biological	MPN	50	40	30	10	80%

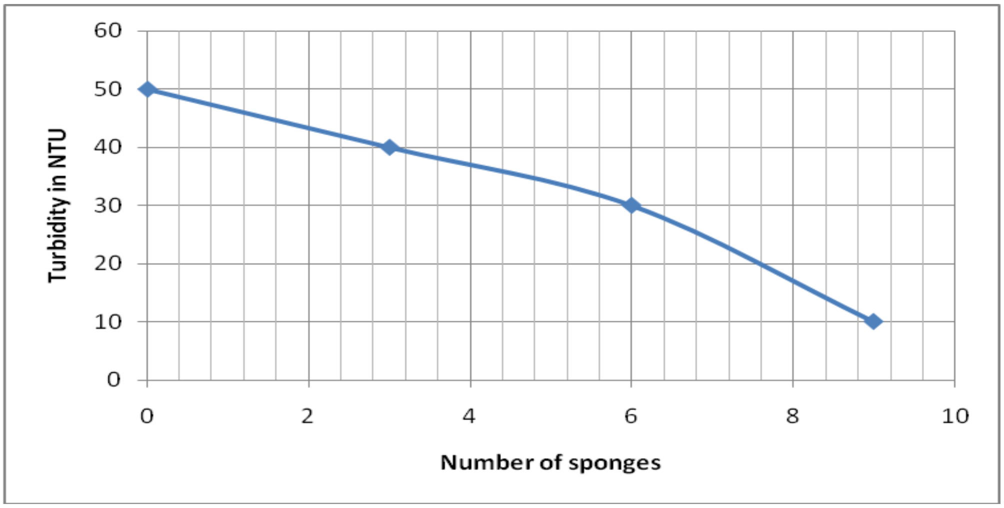

Figure 1: Variation of turbidity with respect to number of sponges

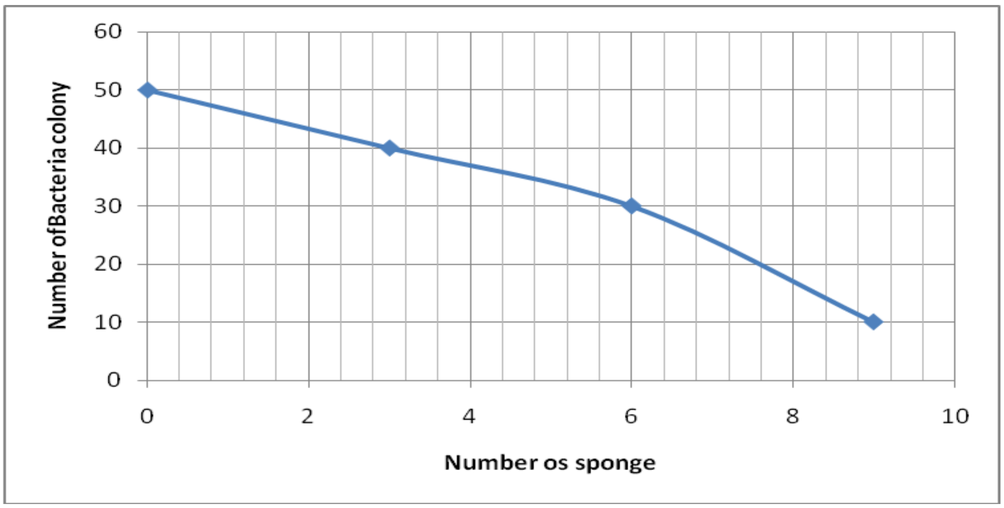

Figure 2: Variation of bacteria colony with respect to number of sponges

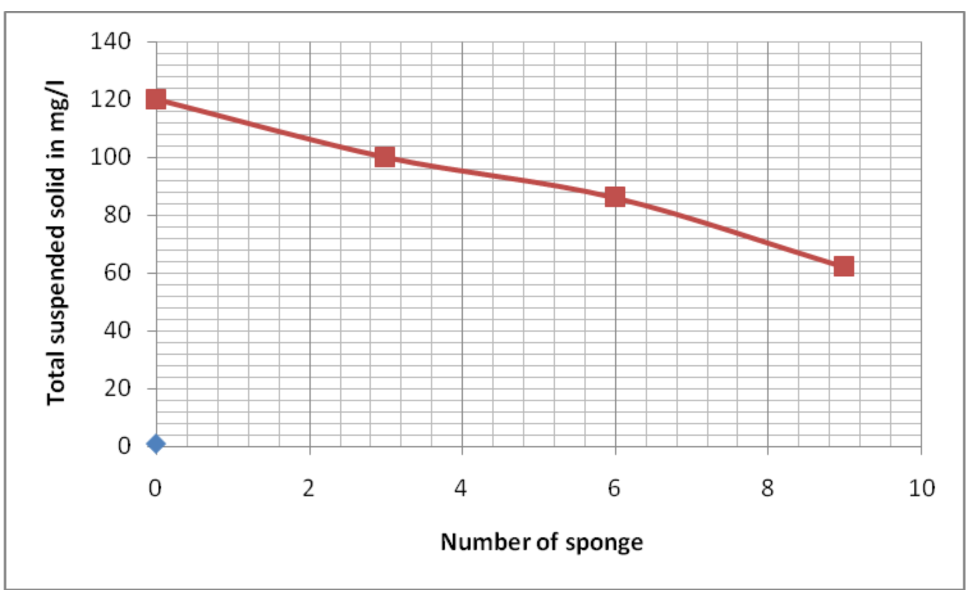

Figure 3: Variation of total suspended solids with respect to number of sponges

The results show that the luffa sponge has a very good capacity of purifying water from harmful micro-organism and heavy metals. The medium range of total suspended solid removal capacity and the insignificant BOD removal show us that the luffa sponge can be better used in wastewater pre-purification than in potable water supply; this is because of its low percentage removal of turbidity, as well as hardness, alkalinity, chloride and ammonia nitrogen. These parameters have great importance in potable water quality. The alkalinity property of the luffa sponge can serve as pH regulator for very acidic wastewater.

4. Conclusion

The study showed that the *luffa cylindrica* sponge possess a great potential for heavy metals removal in water as well as hardness and microbiological reductions. Because of these advantages and the fact that it performed poorly in the reduction of parameters of importance in potable water quality, it is concluded that the luffa sponge filter media can be considered as a preliminary wastewater roughing filter, but cannot adequately be used as a filter media for potable water supply. However, the size of the sponge limits the filter size and its fibrous nature offers high degree of porosity.

References

APHA (1995): Standard methods for the examination of water and waste waters. American Public Health Association, U.S.A.

Bal K.E, Bal Y and Lallam A. (2004): Gross morphology and adsorption capacity of cell-fibres from the fibrous vascular system of loofah (luffa cylindrical). Textile es. Journal. 74: 241 - 247

Hima K.A, Srinivasa r.R, Vijaya S.S., Jayakumar S, Bondili S V, Suryanarana V. and Venkateshwar P. (2007) Biosorption: An eco-friendly alternative for heavy metal removal. African Journal of Biotechnology. Vol.6, No 25, pp 2924 – 2931.

Iqbal M and Eduvyean R.G.J (2004): Alginate coated loofa sponge discs for the removal of cadmium from aqueous solutions. Biotechnol Letters 26: 165 - 169

Mazali I.O and Alves O.L (2005): Morphosynthesis: High fidelity inorganic replica of the fibrous network of loofa sponge (luffa cylindrical). Annals of Brazilian Academy of Sciences: 77: 25

Mukhopadhay B, Majunder M, Barmannath R., Roy Kumar P. and Mazunder A (2008): Verification of filter efficiency of horizontal roughing filter by Weglin's design criteria and artificial neural network. Drinking Water Engineering Science Discussions. No1, PP 117 – 133.

Robinson P.K (1998): Immobilized algal technology for wastewater treatment. In Water Treatment with Algal. Wong Y.S and Tam F.Y (ed.) pp 1-16. Berlin: Springer-Verlag.

UNICEF (2006): Progress for Children. A Report Card on Water and Sanitation. UNICEF, New York

Weglin M (1996): Surface water treatment by roughing filters. A design, construction and operation manual. Gallen Switzerland

WHO and UNICEF (2006): Meeting the MDG Drinking Water and Sanitation Targets. The urban and rural challenge of the decade. Joint Monitoring Programme, Geneva and New York