DEVELOPMENT OF A MULTIGRADE FILTER FOR SURFACE WATER TREATMENT IN DRINKING PURPOSE

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ABSTRACT

Global water scarcity is becoming an increasing challenge to the global community, particularly in developing countries such as Mexico,Bangladesh,Northern and Southern Africa, India and Northern China; Due to a lack of available resources, knowledge and skills many of these developing countries are unable to upgrade their water supply to sustain the growing population. Most of people in this country use ground water which is more or less safe with respect to surface water. This study aims at developing a multigrade filter unit for surface water treatment which contains sand, gravel and brick chips. From the research it has been found that bacteria removal efficiency was 100% in developed filter unit. Other water quality parameters such as Color and TSS were removed approximately about 100% and 67% for sample 1 and for sample 2 it was found that 77% and 50%. In this study head loss of the developed filter is also determined with respect to depth of filter media. From this research it has been found that head loss of the filter increases with the increase of depth of filter media. At a sand depth of 12 cm head loss was estimated as 7.56 cm and at a depth of 20 cm head loss was estimated as 17.63 cm.

Keywords: Multigrade Filter, Surface water treatment, Head loss

1. INTRODUCTION

Water is the essence of life and access to safe drinking water is a fundamental human need and, therefore a basic human right essential to all. Supply of safe water of appropriate quality is important to the well-being of mankind and development of any country because it supports public health and, therefore, ensures economic growth. The provision of water, sanitation and good hygiene services is vital for the protection and development of human resources (Cocks, N 2009). The supply facilities of drinking water are not enough all over the country.In developing countries, it is often impossible to provide adequate water treatment due to the lack of up-to-date technology and sufficient financial support (Brikke & Bredero, 2003). Underground water flow through soil particles, it is more or less pure. Surface water is sometimes affects by different types of microorganism, which is harmful for the people. Contaminated drinking water is cause of major outbreaks of diarrheal diseases not only in developing but also in developed countries (Barker, J 1998). Approximately over one billion people world-wide lacks access to adequate amounts of safe water and rely on unsafe drinking water sources from lakes, rivers and open well. Nearly all of these people live in developing countries, especially in rapidly expanding urban fringes, poor rural areas, and indigenous communities (Galvis, G. 1999). Much of the global population now consumes untreated, non piped drinking water, usually consisting of small volumes <40 lpcd (liter per capita per day) collected and stored in the home by users. Typically, people collect water from any available source and store it in a vessel in the home for domestic and potable use, often without treatment and protection from further contamination. In many cases, such collected household water is heavily contaminated with faecal microbes and possess risks of exposure to water borne pathogens and thus to infectious diseases (Sobsey, 2003).The greatest risk associated with the ingestion of water is the microbial risk due to water contamination by human and/or animal feces. The effects of drinking contaminated water result in thousands of deaths every day, mostly in children under five years of age in developing countries (WHO, 2004a). Diseases caused by consumption of contaminated water, and poor hygiene practices are the leading causes of death among children world wide, after respiratory diseases (WHO, 2003).Thus lack of safe drinking water supply, basic sanitation and hygienic practices are associated with high morbidity and mortality from excreta related diseases. Because of the magnitude of the health problems associated with water of inadequate quality and quantity, substantial efforts have focused on how to evaluate and maximize the health benefits derived from improved water supplies. In many developing countries, the high incidence of water borne diseases and wide-spread use of untreated and often highly polluted water sources necessitate the accurate assessment of faecal contamination of water.

In pursuit of solution water purification is necessary. There are different types of filtration system. Such as Slow and Rapid sand filtration, direct filtration and Membrane filtration, Multigrade filtration etc . Slow sand filtration systems have become one of the most successful technologies for removing disease-causing organisms. The average removal effectiveness of *E.coli* (indicative pathogen of faecal coliforms) and Total coliform is 99% comprising with previews thesis result, where previews result shows the 100% removal of E.coli and Total coliform (Aminul, 2009).

This study aims at developing a Multigrade Filter (MGF) for surface water treatment in drinking purpose which contains sand, gravel and brick chips. The filtration performance was determined with respect to removal efficiencies of total coliform, faecal coliform, color, TSS, BOD_5 and estimation of filter head loss. The final objective was to find out the problems associated with developed filter and to propose for mitigation measures for improvement.

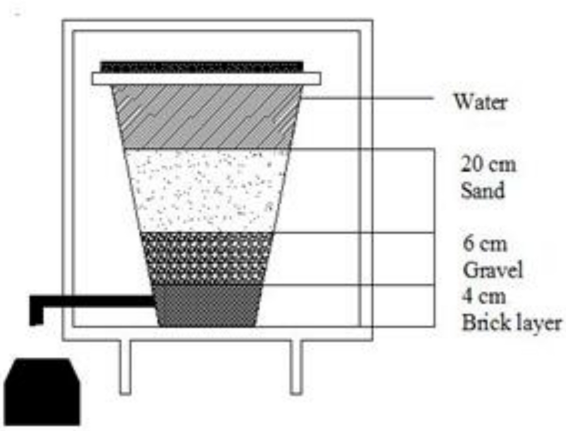
2. MATERIALS AND METHODS

Water samples were collected from two ponds (pond behind Rokeya hall and Khan jahan ali hall) of KUET campus. Raw water quality parameters such as TC, FC, color, TSS and BOD_5 were analysed at KUET environmental laboratory. Multigrade Filter unit was constructed in laboratory. On the developed filter locally available materials such as Coarse Sand, Brick Chips and Gravel were used. Detailed laboratory tests were done to determine the effectiveness of the treatment unit.The performances of the treatment unit were analysed with respect to the removal efficiency of color, TC, FC, BOD_5 and TSS. Head loss of the filter unit was also determined with respect to sand depth. Problems associated with developed filter unit were also identified. Head loss of developed filter unit was measured using the following equations: $H_L = 1.067 C_d \, v^2 D \, f / g d \psi e^4$

2.1 Development Of Multigrade Filter (MGF)

2.1.1 Design of MGF

For the removal of micro-organisms and other contaminants from surface water a MGF was developed under submerged condition using coarse sand, stone chips and brick chips. The developed MGF consists of a bucket (Figure 1 & 2). The layers in bucket are from the top 20 cm coarse sand,then 6 cm gravel and then 4 cm brick chips. The unit is down flow process as raw water passing through the sand. As the sand is always a submerged condition it creates a stable bio- flim slime layer of gelatinous coating formed by the micro-organisms on the sand bed.



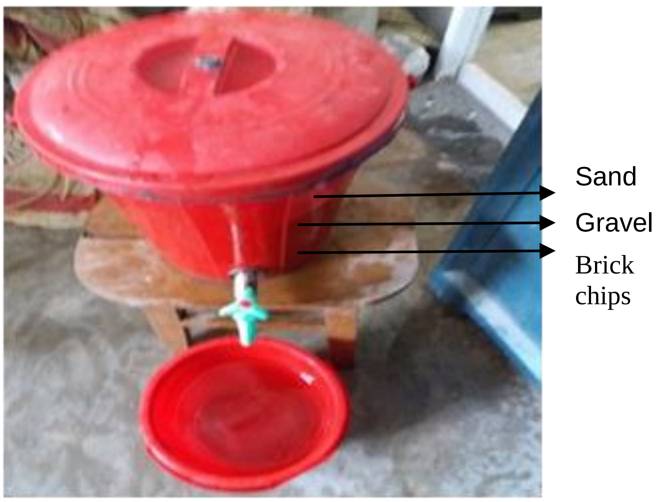


Figure 1: Line diagram of filter unit

Figure 2: Experimental setup of developed filter

2.1.2 Materials Used For MGF

Coarse Sand (CS)

CS is an inactive material used as coarse particulate filter. In the United States, sand is commonly divided into five sub-categories based on size: very fine sand (1⁄16 – 1⁄8 mm diameter), fine sand (1⁄8 mm – 1⁄4 mm), medium sand (1⁄4 mm – 1⁄2 mm), coarse sand (1⁄2 mm – 1 mm), and very coarse sand (1 mm – 2 mm).Locally available CS is collected.Then sieve analysis was done.Then they were thoroughly washed several times and then boiled for disinfection before use.

Gravel

Gravel are composed of sub-angular, hard durable, and dense grains of predominately siliceous material. Gravel are used as flow stabilizing media. Gravel were obtained from local manufacturers. Gravel were also sieved by ASTM standard sieve as BC. Gravel were throughly washed, bolied, clean dried, and screened to meet exacting specifications with strict adherence to quality control.

Brick Chips (BC)

BC are inactive material. BC are from local brick manufacturer which is the crushed aggregated form of brick. They were sieved through ASTM standard sieves. BC were washed several times and disinfected by boiling.

Figure 3: Sand

Figure 4: Gravel

Figure 5: Brick chips

Other materials Plastic bucket

Only food-grade high density polypropylene (HDPP) buckets are used Local plastic moulding industries. Buckets were retrofitted with top cover and outlets for flow controller taps.

Nylon net

Nylon is a generic designation for a family of synthetic polymers, more specifically aliphatic or semi-aromatic polyamides. These chains are naturally very resistant to wear and tear, temperature and chemicals. They can be melt-processed into fibers, films or shapes. Nylon decays very slowly and can take many years to biodegrade. It normally takes between 30 and 40 years to biodegrade. Nylon net is used for separating top layer of the course sand from corresponding 2nd layer.

Figure 6**:** Nylon net

Flow controllers (Tap)

Control flow to maintain optimum residence time. This is fixed in the factory. Moulded plastic or metal taps are avilable in local hardware stores.

2.1.3 Grain Size Analysis Of Sand, Gravel & Brick Chips

Effective size of sand, gravel and brick chips were estimated by sieve analysis. D_{10} of sand is 0.23 mm, $D_{60=}$ 0.87 mm and uniformity coefficient d_{60}/d_{10}=3.91. D_{10} of gravel is 9.9 mm D_{60}= 20.5 mm and uniformity coefficient D_{60}/D_{10} =2.07 .D_{10} of brick chips is 8.5 mm , D_{60}= 20 mm and uniformity coefficient D_{60}/D_{10} =2.35

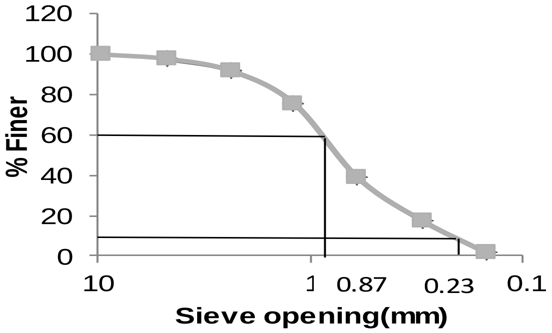


Figure 7: Gradation curve of sand

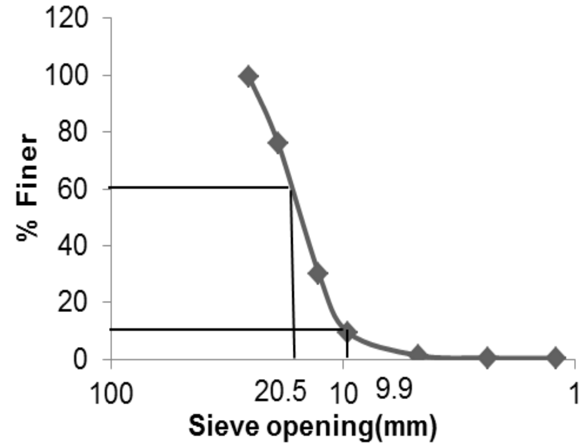


Figure 8: Gradion curve of gravel

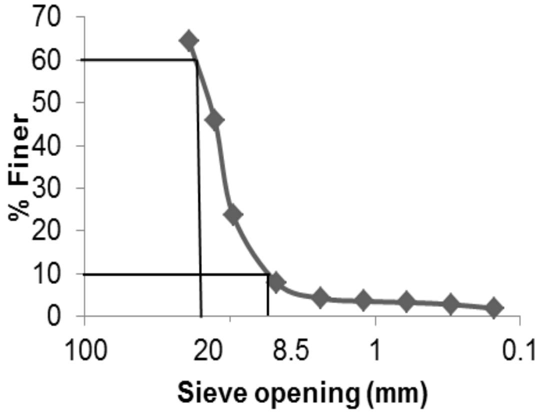


Figure 9: Gradation curve of brick chips

2.2 Filter Head Loss

Head loss rise (HLR) in a filter is a function of the amount of material (particles) accumulated in the interstices and pore space of the filter. The larger the quantity of particulates removed from the separation process, the higher the head loss rise (Kebreab, A. Ghebremichael, 2004).

The loss of pressure (head loss) through a clean stratified-sand filter with uniform porosity was described by Rose:

$H_L = 1.067 C_d\, v^2 D\, f/gd\psi e^4$……………. (1)

Where, H_L = head loss in bed of depth D with face velocity v.

e = bed porosity

d = characteristic diameter of bed particles

ψ = particle shape factor

C_d = Newton's drag coefficient = 24/R

D = bed depth

f = mass fraction of sand particles of diameter d

3. RESULTS AND DISCUSSION

Detailed laboratory test and analysis were carried out through developed filter unit to investigate the change in some drinking water quality parameters. The performances of the treatment unit were analysed with respect to the removal efficiency of color, TC, FC, BOD_5 and TSS.

Table 1: Results summary of raw and filter water

Water quality parameters	BD Standard (ECR'97)	Raw water		Filter water		%Removal	
		Sample1	Sample2	Sample1	Sample2	Sample1	Sample2
Total Coliform(N/ 100mL)	0	12	10	0	0	100	100
Faecal Coliform(N/ 100mL)	0	3	0	0	0	100	_
Color(Pt.Co unit)	15	25	17	0	4	100	77
Total Suspended Solid(mg/L)	10	30	40	10	20	67	50
BOD_5(mg/L)	0.2	3.47	1	0.35	1	90	0

3.1 Total Coliform & Faecal Coliform

Coliform bacteria are described and grouped, based on their common origin or characteristics, as either Total or Fecal Coliform. The Total group includes Fecal Coliform bacteria such as Escherichia coli (E .coli), as well as other types of Coliform bacteria that are naturally found in the soil. Figure 10 shows that total coliform in raw samples were found in 1 and 2 were 12 and 10 N/100mL, respectively which were totally removed from water after fitering through MGF. The results found after filtering satisfied the Bangladesh Standard. Figure 11 shows that in raw water samples 1 and 2 the concentration of feacal coliform were 3 and 0 N/100mL but after filtering feacal coliform was entirely removed

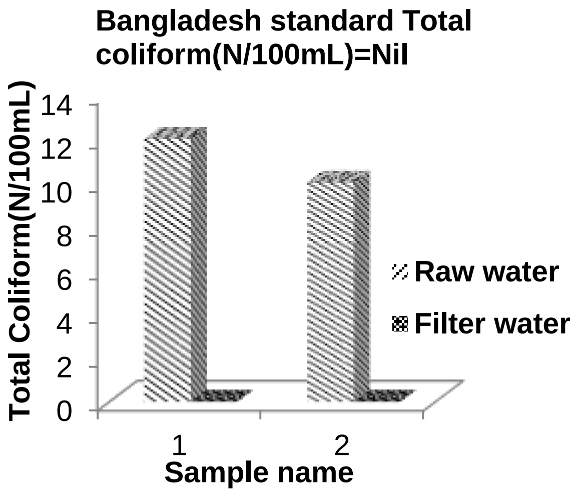


Figure 10: Variation of Total Coliform concentration in raw and treated water

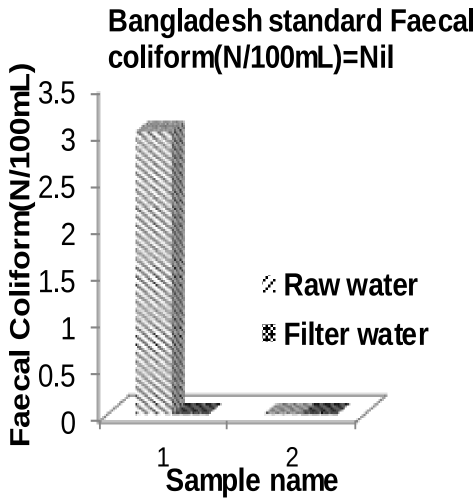


Figure 11: Variation of Faecal Coliform concentration in raw and treated water

3.2 Color

Colour is measured in platinum cobalt units and is an important physical parameter of water. Colour is due to the presence of organic matter; namely humic and fulvic acids as well as iron manganese or highly colored industrial waste (Ahmed & Rahman, 2000) .From figure 12 it is observed that after filtered color of collected sample reduced and below the Bangladesh Standard 15 Pt.Co unit. In raw samples 1 and 2 color were 25 and 17(Pt.Co), respectively and in the filtrated water it became 0 and 4(Pt.Co) respectively.

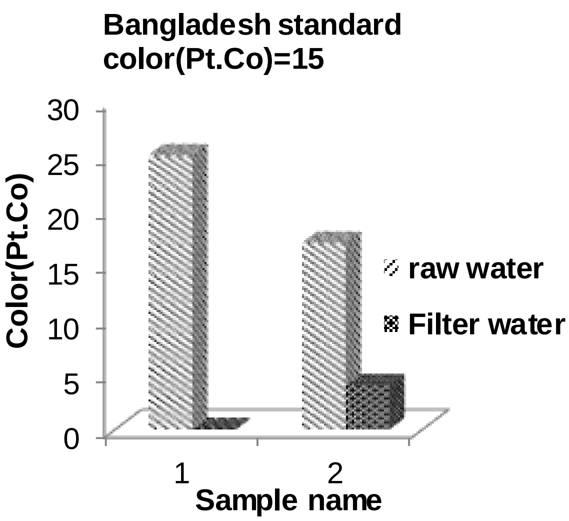


Figure 12: Variation of Color concentration in raw and treated water

3.3 BOD$_5$

Biochemical oxygen demand (BOD, also called biological oxygen demand) is the amount of dissolved oxygen needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. From figure 13 it is observed that BOD$_5$ in raw water sample 1 and 2 were 3.47 and 1 mg/L, respectively and after filtering the concentration becomes 0.35 and 1 mg/L, respectively. In both cases the values exceeds Bangladesh standard limit.

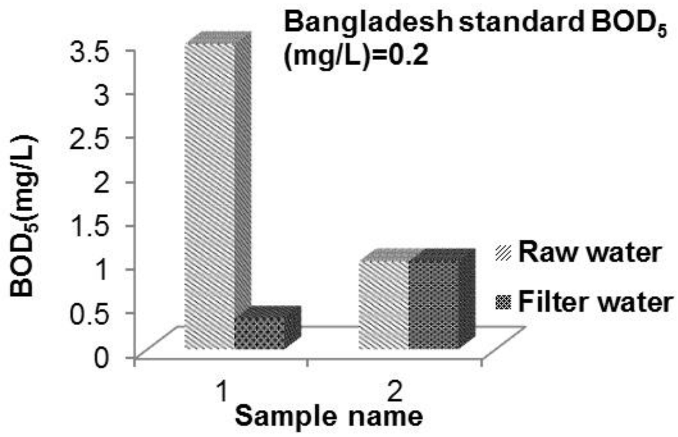


Figure 13: Variation of BOD$_5$ concentration in raw and treated water

3.4 Total Suspended Solid (TSS)

Total Suspended Solids (TSS) is the dry-weight of particles trapped by a filter. It is a water quality parameter used for example to assess the quality of wastewater after treatment in a wastewater treatment plant. From figure 14 it is observed that total suspended solid in raw water sample 1 and 2 were 30 and 40 mg/L, respectively and after filtering it decreases at a concentration of 10 and 20 mg/L, respectively.However in sample 2 TSS concentration decreases after filtering but it exceeds Bangladesh standard limit.

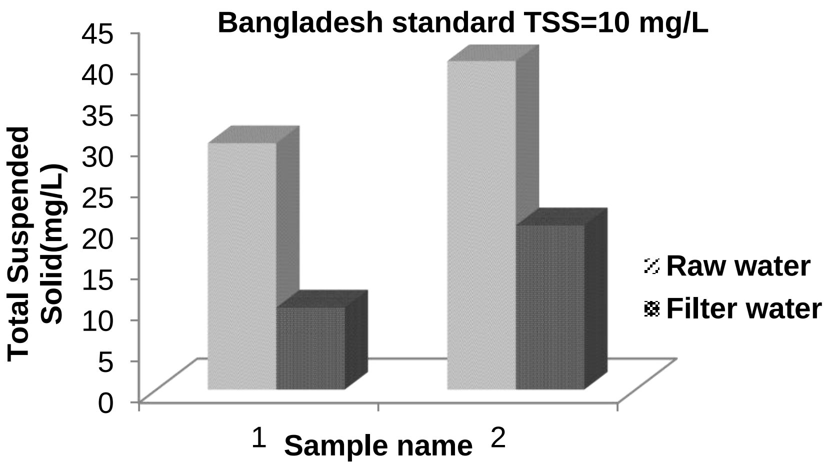


Figure 14: Variation of Total Suspended Solid concentration in raw and treated water

3.5 Estimation Of Filter Head Loss

Head loss rise (HLR) in a filter is a function of the amount of material (particles) accumulated in the interstices and pore space of the filter. The larger the quantity of particulates removed from the separation process, the higher the head loss rise. Head loss was determined with respect to sand depth using equation 1. At a sand depth of 12 cm,14cm, 16cm, 18 cm and 20 cm head loss were estimated as 7.56 cm, 8.27 cm, 10.16 cm, 14.24 cm and 17.63 cm, respectively. From figure 15 it is observed that head loss of developed filter increases with increase of sand depth.

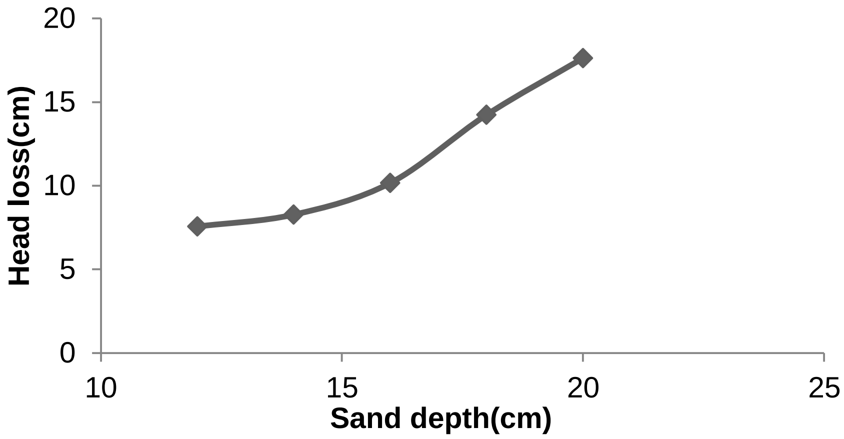


Figure 15: Variation of head loss with respect to sand depth

4. CONCLUSIONS

Color, total coliform, faecal coliform, TSS, BOD_5 concentration of raw water for sample 1 were found to be 25 Pt.Co, 12 N/100mL, 3 N/100 mL, 30 mg/L and 3.47 mg/L, respectively and for sample 2 these were found to be 17 Pt.Co, 10 N/100mL, 0 N/100mL, 40 mg/L and 1 mg/L, respectively. Multigrade Filter unit was constructed in laboratory. The filter unit consists of coarse sand, gravel and brick chips.Total coliform and Faecal coliform removal efficiency was 100% in developed filter unit. Other water quality parameters such as Color and TSS were removed approximately about 100% and 67% for sample 1 and for sample 2 it was found that 77% and 50%. At a sand depth of 12 cm,14cm, 16cm, 18 cm and 20 cm head loss were estimated as 7.56 cm, 8.27 cm, 10.16 cm, 14.24 cm and 17.63 cm, respectively. The main maintaining problem of this type of filter is, hence BOD_5 and TSS concentration reduced after filtering, but the values exceeds Bangladesh standard limit. Another problem is development of filter head loss for clogging of filter materials. For minimizing this problem, the layer of sand in bucket is kept within the lylon net. When the filter is clogged then one has to put the lylon net with Coarse Sand out and washed with water. By doing this simple tasks clogging can be reduced .

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