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Bacteriophage Removal Using Upflow Biosand filer: A Laboratory Study

Ghada Heikal[a*], Rabab Wagdy[b], Gamal Eldidamony[c]

[a]*Dr. Ghada El Sayed Heikal, Environmental Engineering Department, Faculty of Engineering, Zagazig University, Postal code 44519, Egypt*

[b]*Dr. Rabab Mohamed Wagdy, Environmental Engineering Department, Faculty of Engineering, Zagazig University, Postal code 44519, Egypt*

[c]*Prof. Gamal El Didamony, Botany Department, Faculty of science, Zagazig University, Postal code 44519, Egypt*

[a]*Email: reemhatem2006@hotmail.com*

[b]*Email: rabab_wagdy53@yahoo.com*

[c]*Email: games5@hotmail.com*

Abstract

Biosand upflow filter of removal bacteria and virus has been carried .Different types of sand and gravels, the variables studied were; Different sand particles, bed height, solution flowrate, different flow rate, different bacteria concentrations, and optimum conditions reduction from 549 to 200 MPN, when using flowrate 0.75 ml/sec, the rate of virus removal was 95% by using contact time 1 hour. The bacteria and virus removal was related to the operating variables.

Keywords: Bacteriophage; Upflow Filter; Virus; Bacteria ; Flow rate.

1. Introduction

The primary goal of water utilities is to safeguard drinking water for consumers. Consequently, drinking water must be of a standard or quality that aligns with many water safety plans. This involves removing contaminants of concern, whether they are biological or chemical, and a range of water treatment methods have been developed over the past century to ensure that these contaminants are removed or minimized in drinking water distribution systems.

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* Corresponding author.

The efficacy of these treatment methods is governed by routine monitoring of specific indicators, including the removal of pathogenic organisms and chemicals of concern (e.g. disinfection by-products, algal toxins, etc.). Access to improved drinking water is unavailable to an estimated 884 million people in the world, most of who live in rural, dispersed, and often remote communities in developing countries [9]. Diarrhea and other waterborne diseases from exposure to microbial pathogens in unsafe water constitute a major threat to health in these settings. The World Health Organization recommends point of use household water treatment (POU) as an intervention to address the need, drawing on appropriate low-cost technologies [5, 8]. The BSF has several advantages as a POU technology in low income developing country rural settings where improved water supplies are often difficult and costly to develop, operate or maintain. Using a concrete or plastic container with a typical sand column of 45-50 cm, the simple yet robust design of BSF units allows construction with local materials and skills found anywhere in the world, making it affordable accessible and durable [2, 3]. There are no recurring costs and operation and maintenance requirements can be performed by the household. Relative to other options, for example, solar and chemical disinfection, ceramic filtration, and flocculants, the BSF's high flow rate and ability to tolerate turbid surface water provide added advantages. An estimated 140,000 locally constructed BSF units were in operation in over 24 countries by 2007, largely through the efforts of decentralized small-scale development organizations [1]. This paper describes an experimental research to systematically investigate and measure the effects of upflow biosand filter (BSF) design and operating factors on its ability to simultaneously remove bacteriophage. Bench-scale model upflow biosand filter (BSF) unit was constructed. The affecting factors and interactions in bacteriophage removal included the flow rate, the height of the used sand, and the influent concentration of bacteriophage was investigated.

2. Experimental Work

2.1 Filter design

A diagram of the experimental upflow Biosand Filter model (BSF) is shown in Fig 1. The container was constructed from 3-inch polyvinyl chloride (PVC) column (8 cm diameter). The PVC column provided with 4 openings at distances 10.5 cm between each other measured from the base of the PVC column. The BSF model consisted of 11 cm crashed stone at the base, followed by 31.5 cm of a single layer of sand of one of the two experimental sands. The experimental work was divided into two stages. First stage contained one run was with coarse sand and the second stage contained several runs were with fine sand which called Sinai sand with two different heights and different boundary conditions of flow rate and the rate of filtration. A single sand layer is commonly used in developing countries to save on costs. 2.5 cm of water were maintained above the sand at all times, ensuring saturated conditions. This configuration was selected to contain approximately 2.0 L of water within the sand column pore.

The influent upflow discharge was measured by (Master Flax Pump) which ranged between (0.34-19.8 l/hr).The rpm of the pump was ranged 0.5, 0.75, 1.25, 1.50, and 1.75 to control the influent discharge and the rate of filtration was ranged 0.8, 1.2, 2.0, 2.4, and 2.8 m/d respectively. The two different heights of the fine sand layer of the second stage were 21, 31.5 cm measured from the top of the crashed stone.

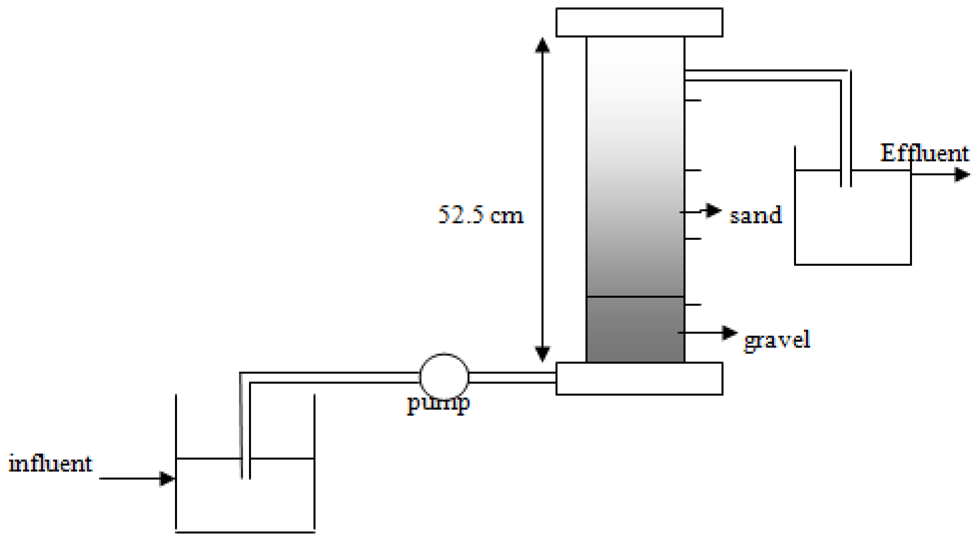

Figure 1: A schematic diagram of the experimental upflow Biosand Filter model (BSF)

2.2 Filter operation

The filter was fed a standard batch of 20L of the influent water mixture per day for approximately 24 weeks, except during 3 days testing. Testing involved feeding 40L test batches over 3 days. Official testing began after 3 days maturation period for the biological zone to establish within the sand.

The influent water was fed into the column upflow discharge from 40L container using the different rates of flow by the master flax pump.

2.3 Sampling and measurements

Following the initial 3-days start up, the effluent sampling were collected 3 samples every two days to determine the average value of the 3 samples.

Samples were analyzed for bacteriophage, influent and effluent water samples for each run were collected from the output of the filter.

Influent samples were collected from 40L beaker feed upflow to the media in the sand filter, samples were analyzed for p.aeruginosa Fecal coliform was enumerated using standard method 9222D .On each test day and for each test batch and filter, several covariates of interest were measured and recorded.

Characteristics of the influent water

The characteristics of the influent water which used in the experimental upflow Biosand Filter model (BSF) is shown in Table (1)

Table 1: The characteristics of the influent water which used in the experimental upflow Biosand Filter model (BSF)

Parameter	**Range**
Temperature °C	20-38.5
Transparency (cm)	65-130
EC (µmohs)	290-1340
pH	7.3-8
DO (mg/l)	1-6
BOD (mg/l)	40-80
COD (mg/l)	70-130
Amonia (mg/l)	2.8-10
Nitrite (µg/l)	4.5-70
Nitrate (µg/l)	25-210

3. Result and discussion

3.1 Effect of sand type

The variation of decreasing the pollutant as a function of sand type by the BSF system is shown in fig (2)

Coarse sand filter it gives no result at 21 cm above the gravel surface , while on using fine sand filter the reduction percent increased gradually until it gives 75% pollutant removal (from 549-200) MPA .

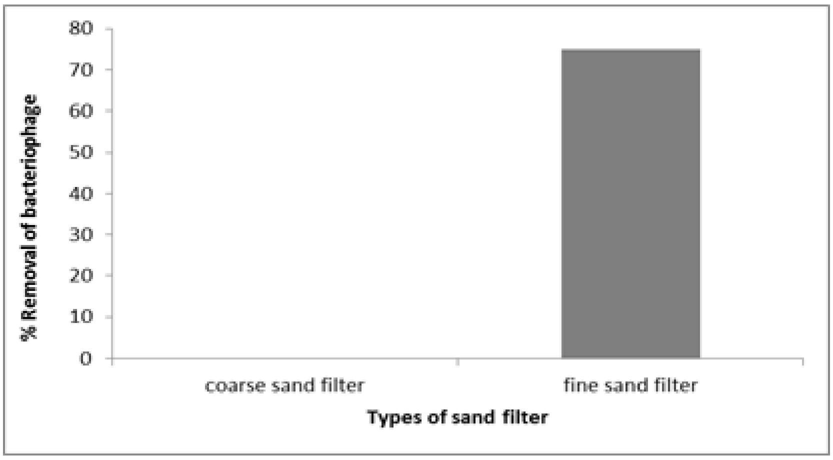

Figure 2: % Removal of bacteriophage at different types of

The above results can be discussed as the most important information to know is that coarse sand does not filter as well as fine sand, and fine sand offers more resistance to the flow of the water than coarse sand between

0.35mm and 0.15 mm effective size with uniformity coefficient of less than 2 is the desired, however all the sand in a layer should be the same effective size, the smaller effective size should be in the top 30 or 40 cm layer of sand.

The gravel of the bottom should be large enough to not pass through the holes in drain pipes and small enough to prevent sand from seeping into them. The drain pipes should be covered by at least 6 inch of gravel, generally the smaller effective size of the sand used the better. If the effective size is too small, however, water will not flow through the filter fast enough, if the effective size is too large biolayer will not form effectively and the filter will not purify water [11] the result agreed with [10] The effect of sand filter characteristics on removal efficiency of organic matter from Grey water.

3.2 Effect of sand height

The heights variation is one of the most important factors influencing the pollutant removal. The effect of the heights variation on pollutant removal is shown on fig (3) for heights (21 cm above the gravel surface) and height (31 cm above the gravel surface). It is observed that the percent of pollutant reduction is gradually increased by increasing heights with maximum value 200 as shown in fig (3), [7] it can be discussed in the light that the changes in the water depths will change the depth of the biozone and removal efficiency of biofiltration. A greater water depth (31 cm) results in lower oxygen diffusion and consequently a thinner biozone and reduce the removal efficiency. With increasing water depth (more than 31 cm) the biolayer moves upwards in the sand bed and thus oxidation and metabolism decrease eventually.

The filter becomes a non living system. Changes in water depth above the sand surface will cause a change in the biological removal efficiency of the filter

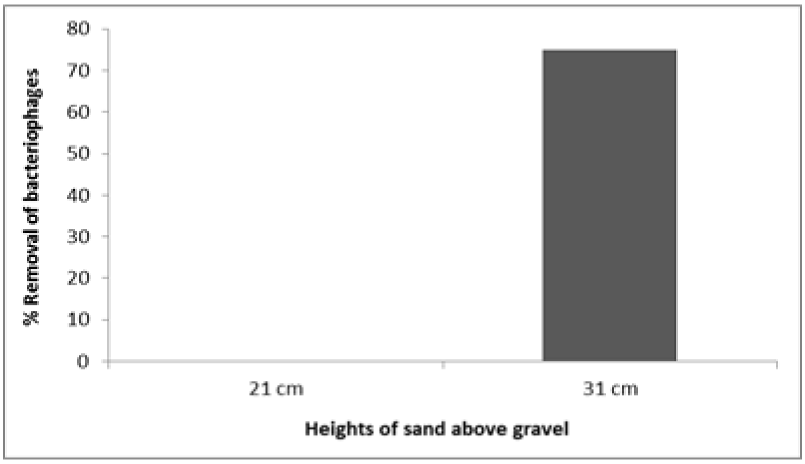

Figure 2: % Removal of bacteriophage at different heights

Results analysis measured such in the first height (21 cm) results shown -ve while removal efficiency increased to a height (31 cm) cm this agreed with

3.3 Effect of flow rate

The variation of flow rate on the decreasing of pollutant is shown in table (2) and table (3). The reduction of pollutant can be discussed as follow.

Table 2: Microbiological analysis of Nile water after passage through sand filter

Sand type	Rate of filtration	MPN	Total coliform cell
Coarse sand	1.5	555	>240
Coarse sand	0.75	520	49
Fine sand	0.75	510	33
Fine sand	0.5	000	2

MPN = Most probable number *

The percentage removal contaminants is inversely proportional to the flow rate through the filter , this due to the biologic reduction of contaminants takes time , the amount of water that flows through the (BSF) is controlled by the size of sand media contained within filter (this result is agreed with [4]) at 680 $l/hr/m^2$. If the rate is too fast, the efficiency of pollutant removal may be reduced, if the flow rate is too slow, there is will be an insufficient amount of treated water, the microorganisms are more confined near the surface of the sand bed in a continuously operated slow sand filter because the oxygen supply is limited by diffusion from the surface because of the thin biologic zone there is a shorter contact time between the biofilm and water during filter runs. Slower filtration rates are therefore required in (BSF) to produce water of similar pollutant quality as continuously operated filter.

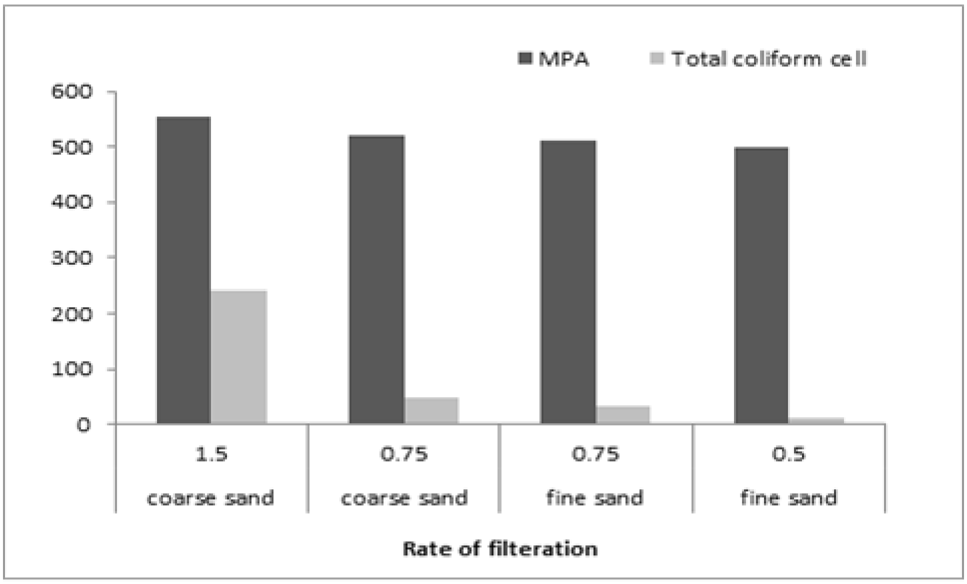

Figure 4: The effect of rate of filteration on the removal of the pollutant

Table 3: shows the comparison between (BSF) and previous work

Parameter	BSF	Previous work
Pollutant		More than 97% [6]
Viruses		80%- 90% [2, 6]

3.4 Bacteria injection

In this case ,the bacteria was injected in the BSF with initial concentration ($1*10^7$) and at 31 cm fine sand height, 1.5 r.p.m , the results shown in table (4), as shown

Table 4: Number of phages active against p.aeruginosa after filtration through sand filter

Contact Time /hr	PFU/ml	% Removal of virus
$t_\circ$= Initial	$c_\circ=1*10^7$	
1	$4.5*10^5$	95.5
2	$2*10^3$	99.98
24	8.3*10	99.99
48	5*10	99.99

*PFU= plague formation unit/ml

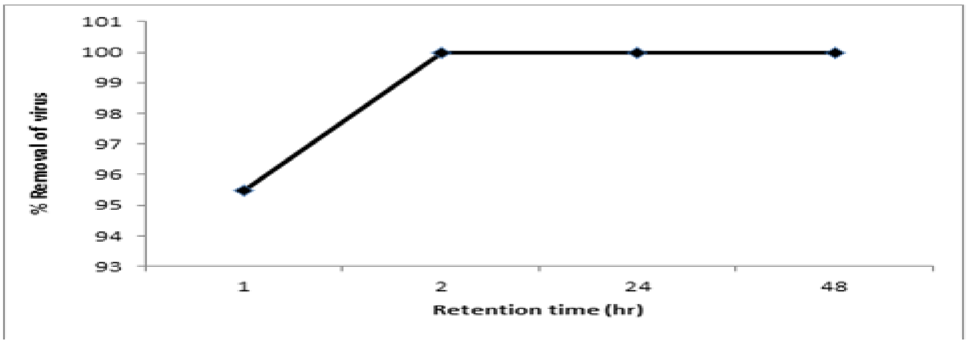

Figure 5: The relation between the % removal of virus depending on retention time

4. Conclusion

- The variation of decreasing the pollutant as function of sand type increased gradually until it gives 75% removal.

- The heights variation is gradually increased until it reached 31 cm height.

- The flowrate for low rate gives zero MPN and total coliform cell of 2 PFU/ml.

- Bacteria injection was injected with initial concentration $1*10^7$ and gives 95% removal of p.aeruginosa after 1 hour using fine sand at 31 cm height.

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