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Purification and removal of *Ascaris* and *Fasciola hepatica* eggs from drinking water using roughing filters

Jafar Nouri, Amir Hossein Mahvi†, Reza Saeedi, Kavoos Dindarloo, Mohammad Rafiee and Sina Dobaradaran

Department of Environmental Health Engineering, School of Public Health and Center for Environmental Research, Medical Sciences/University of Tehran, P.O. Box 14155-6446, Tehran, Iran

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Abstract−The performance of a horizontal roughing filter (HRF) and a downflow roughing filter (DRF) in the removal of *Ascaris* and *Fasciola hepatica* eggs was investigated. The experiments were performed at three filtration rates of 0.5, 1.0 and 1.5 m/h and different influent concentrations of *Ascaris* and *Fasciola hepatica* eggs. Alteration of the filtration rate in the range of 0.5-1.5 m/h did not have significant influence on the effectiveness of the roughing filters. The HRF had higher efficiency in the removal of both *Fasciola hepatica* and *Ascaris* eggs in comparison with the DRF, so that the average efficiencies of the HRF for the removal of *Fasciola hepatica* and *Ascaris* eggs at filtration rate of 1.0 m/h were determined to be 89.0 and 57.3%, respectively, whereas the same values of the DRF were 77.2 and 52.5%, respectively. The straining was confirmed to be the main mechanism of helminth eggs removal by the roughing filters, because *Fasciola hepatica* eggs with larger size were removed more effectively than *Ascaris* eggs. The results of this study indicate that the roughing filters, especially the HRF, had promising performance in the removal of helminth eggs and could be used for water and secondary effluent treatment.

Key words: Water, *Ascaris*, *Fasciola hepatica*, HRF, DRF

INTRODUCTION

The degree of microbial pollution is a key parameter in explaining the quality of raw water. Infectious diseases caused by pathogenic bacteria, viruses, and protozoa or by helminth parasites are the most common and widespread health risks associated with drinking water [1-3]. The unsafe drinking water contaminated with soil or faeces could act as a carrier of parasitic infections, such as Cryptosporidiosis (*Cryptosporidium parvum*), Giardiasis (*Giardia lamblia*), balantidiasis (*Balantidium coli*) and certain helminths (species of *Fasciola*, *Fasciolopsis*, *Echinococcus*, *Spirometra*, *Ascaris*, *Trichuris*, *Toxocara*, *Necator*, *Ancylostoma*, *Strongyloides* and *Taenia solium*). Helminth parasites infect a large number of people and animals worldwide. For most helminths, drinking water is not a significant route of transmission. There are two exceptions: *Dracunculus medinensis* (guinea worm) and *Fasciola* spp. (*F. hepatica* and *F. gigantica*) (liver flukes). Dracunculiasis and fascioliasis both require intermediate hosts to complete their life cycles but are transmitted through drinking water by different mechanisms. Other helminthiases can be transmitted through water contact (schistosomiasis) or are associated with the use of untreated wastewater in agriculture (ascariasis, trichuriasis, hookworm infections and strongyloidiasis) but are not usually transmitted through drinking water [3]. Depth filtration has been an effective water treatment process for the removal of helminth parasites and preventing the spread of parasitic infections [3,4].

Depth filtration involves the removal of particulate material suspended in a liquid by passing the liquid through a filter bed comprised of a granular or compressible filter medium [5,6]. The efficient design of filtration systems continues to be important in the control of water and air pollution [7]. One of the depth filtration types is roughing filtration. Roughing filters also contribute to improvement of microbial water quality. Several studies have also shown that a roughing filter is a simple, efficient and cheap water treatment technology compared to the conventional system [8-10]. This is in terms of technical labor requirement, operation and maintenance costs and treatment efficiency and effectiveness. Cost analysis shows that the initial installation cost of roughing filter is higher than that of a conventional system; however, this disadvantage of high initial costs is outweighed by the low cost of operation and maintenance [11,12]. Roughing filters are categorized by their flow patterns. These include upflow roughing filters, downflow roughing filters and horizontal roughing filters. A typical roughing filter consists of a series of graded gravel beds, with the first bed having the coarsest material and the final bed having the finest material. Typical roughing filters have gravel of different sizes in one, two, or three compartments. If three beds are used, the size of gravel in the middle bed would be intermediate between the sizes in the first and last beds. Typical filtration rates for roughing filters are between 0.3 and 1.5 m/h and typical gravel sizes may be as large as 40 mm and as small as 3 mm [2,13,14]. Collins et al. [15] operated pilot-scale roughing filters and noted that the most influential design variable for kaolin removal was filter length or depth. For algae removal the most important variable was hydraulic loading rate. For every kind of particle, a longer residence time in the roughing filter was related to improved removal.

The objective of this paper was to study the performance of the horizontal roughing filter (HRF) and downflow roughing filter (DRF) in the removal of *Ascaris* and *Fasciola hepatica* eggs. The effect of filtration rate on the efficiency of the filtration systems was investigated. The experiments were performed in 2007 in Tehran, Iran.

†To whom correspondence should be addressed.
E-mail: ahmahvi@yahoo.com

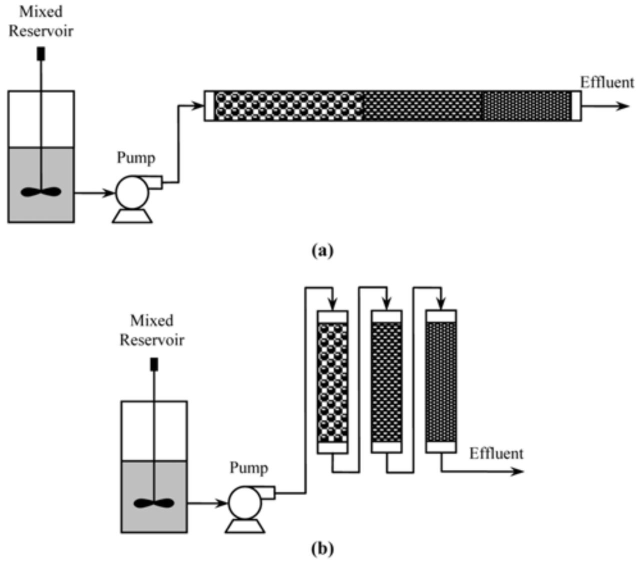

Fig. 1. Experimental setup of the roughing filters used in this study: (a) HRF and (b) DRF.

MATERIALS AND METHODS

The present investigation employed the HRF and DRF in pilot-scale for evaluation of the performance of these systems in the removal of *Ascaris* and *Fasciola hepatica* eggs. The experimental setup of the filtration processes is shown in Fig. 1. Each pilot plant consisted of three compartments. In the HRF, the lengths of first, second and third compartment were 2.5, 2.0 and 1.5 m, respectively, and the width and depth of each compartment was 0.1 m. Also, the depth, length and width of each compartment in the DRF were 2.0, 0.1 and 0.1 m, respectively. The grain sizes of sand in the first, second and third compartment of the pilot plants were 12-18, 8-12 and 4-8 mm, respectively.

The experiments were conducted by pumping a synthetic flow to the roughing filters with a peristaltic pump. The synthetic water samples were prepared by use of tap water and concentrated samples of parasite eggs. The concentrated samples were prepared using the faeces of infected humans by *Ascaris* or *Fasciola hepatica*. To investigate the effect of filtration rate on the performance of the roughing filters in the removal of helminth eggs, field experiments were performed at three filtration rates of 0.5, 1.0 and 1.5 m/h. Also, the experiments were performed at different influent concentrations of helminth eggs to determine the influence of helminth egg concenration on the performance of the roughing filters. The filters were operated over 2 weeks in different experimental runs. In each experimental run on the pilot plants, the samples were collected from influent and effluent of the roughing filters. Each sample was examined to determine the concentration of *Ascaris* or *Fasciola hepatica* eggs (egg numbers/mL). All of the examinations were performed according to the instructions of Standard Methods [16].

RESULTS

The operating and performance data of the HRF and DRF during experimentation are summarized in Table 1. In these experiments, the influent concentration of helminth eggs was in the range of 8-300 egg/mL. The removal efficiencies of *Fasciola hepatica* eggs by the HRF at different filtration rates are illustrated on Fig. 2. The efficiencies of the HRF in the removal of *Fasciola hepatica* eggs at filtration rates of 0.5, 1.0 and 1.5 m/h were determined to be in the ranges of 80.3-100, 71.5-100 and 66.9-99.8%, respectively. Fig. 3 shows the efficiencies of the HRF in the removal of *Ascaris* eggs at different filtration rates. The removal efficiencies of *Ascaris* eggs by the HRF at filtration rates of 0.5, 1.0 and 1.5 m/h were in the ranges of 43.3-86.2, 35.2-81.5 and 29.8-75.0%, respectively. Fig. 4 shows the removal efficiencies of *Fasciola hepatica* eggs by the

Table 1. The operating and performance data of the HRF and DRF

Filtration rate (m/h)	Average removal efficiency of the HRF (%)		Average removal efficiency of the DRF (%)	
	Fasciola hepatica	*Ascaris*	*Fasciola hepatica*	*Ascaris*
0.5	91.3	60.7	82.1	57.3
1.0	89.0	57.3	77.2	52.5
1.5	85.4	52.3	73.6	46.4

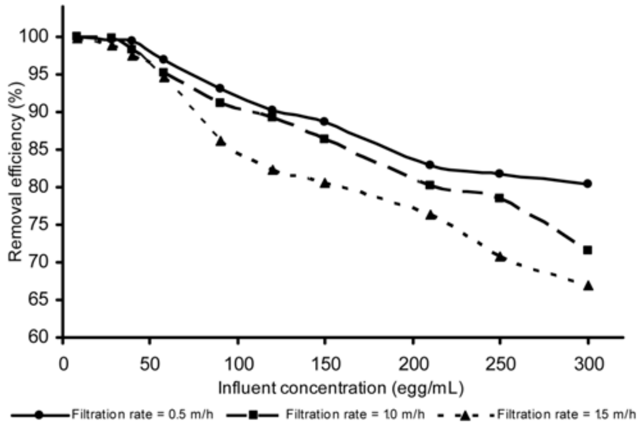

Fig. 2. The removal efficiencies of *Fasciola hepatica* eggs by the HRF at different filtration rates.

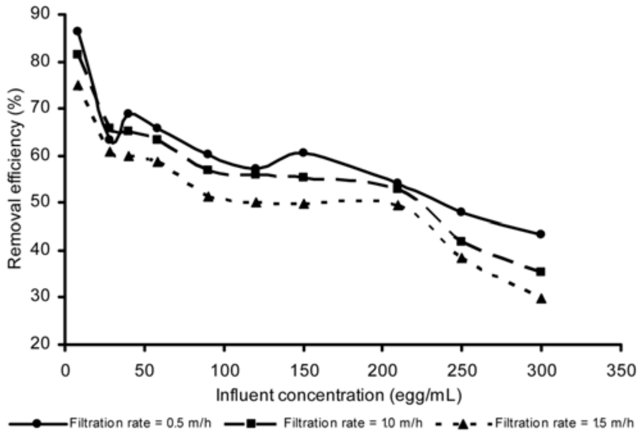

Fig. 3. The removal efficiencies of *Ascaris* eggs by the HRF at different filtration rates.

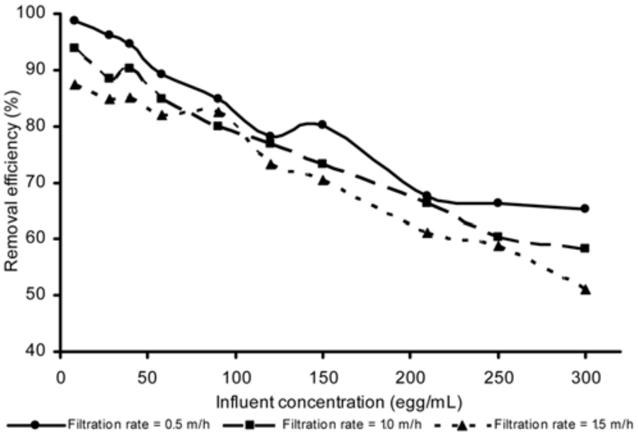

Fig. 4. The removal efficiencies of *Fasciola hepatica* eggs by the DRF at different filtration rates.

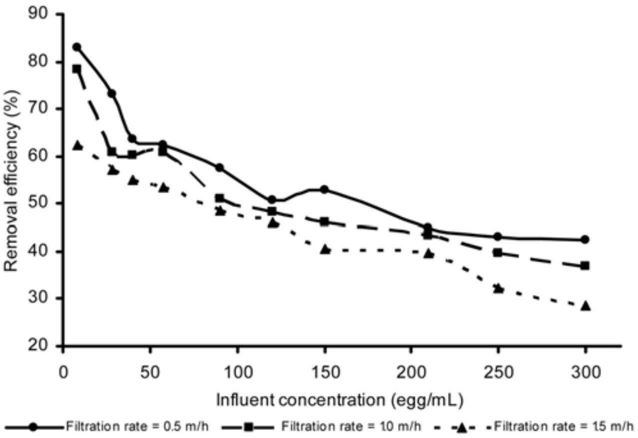

Fig. 5. The removal efficiencies of *Ascaris* eggs by the DRF at different filtration rates.

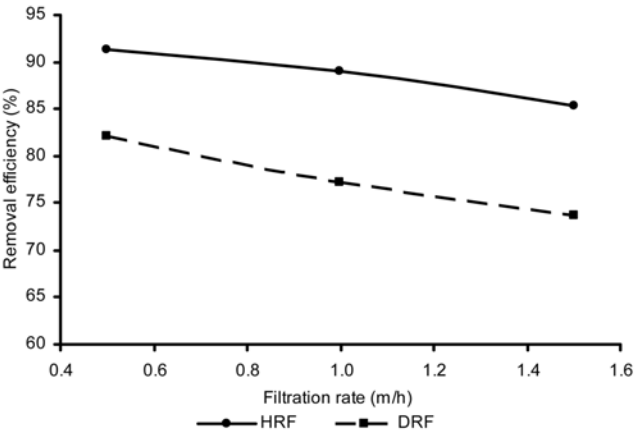

Fig. 6. Comparison of the HRF and DRF in the removal of *Fasciola hepatica* eggs.

DRF at different filtration rates. The removal efficiencies of *Fasciola hepatica* eggs by the DRF at filtration rates of 0.5, 1.0 and 1.5 m/h were obtained to be in the ranges of 65.3-98.6, 58.2-93.8 and 51.2-87.5%, respectively. The efficiencies of the DRF in the removal

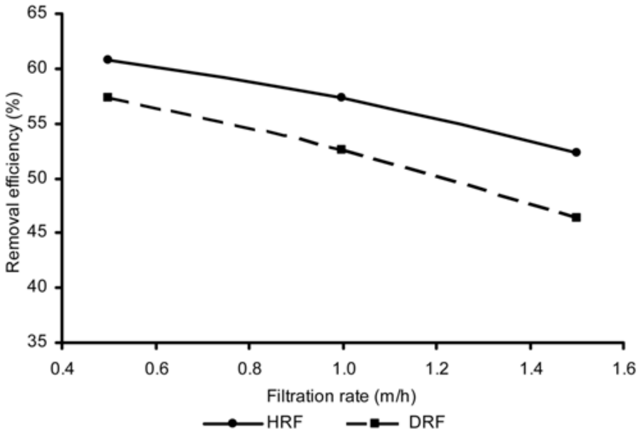

Fig. 7. Comparison of the HRF and DRF in the removal of *Ascaris* eggs.

of *Ascaris* eggs at different filtration rates are represented in Fig. 5. The efficiencies of the DRF in the removal of *Ascaris* eggs at filtration rates of 0.5, 1.0 and 1.5 m/h were in the ranges of 42.3-82.8, 36.8-78.3 and 28.7-62.5%, respectively. Figs. 6 and 7 show comparison of the HRF and DRF in the removal of *Fasciola hepatica* and *Ascaris* eggs.

DISCUSSION

The principal particle removal mechanisms, believed to contribute to the removal of material within a granular medium filter, are identified as straining, sedimentation, adhesion, flocculation, adsorption and biological processes [6,17].

As illustrated on Figs. 2-5, the removal efficiencies of the helminth eggs decreased by increasing of their influent concentrations. Also, by increasing of the filtration rate in the range of 0.5-1.5 m/h, the removal efficiencies of the helminth eggs in the roughing filters decreased, but the variation of the removal efficiencies was not significant in the range of filtration rates. According to Figs. 6, 7, the HRF had higher efficiency in the removal of both *Fasciola hepatica* and *Ascaris* eggs as compared with the DRF. Also, the roughing filters had higher removal efficiencies for *Fasciola hepatica* eggs than for *Ascaris* eggs, so that the average removal efficiencies of the HRF at filtration rates of 0.5, 1 and 1.5 m/h for *Fasciola hepatica* eggs were determined to be 91.3, 89.0 and 85.4%, respectively, whereas the same values for *Ascaris* eggs were obtained 60.7, 57.3 and 52.3%, respectively. The average sizes of *Fasciola hepatica* and *Ascaris* eggs were 110 and 50 μm, respectively. This observation showed that *Fasciola hepatica* eggs with larger size were removed more effectively than *Ascaris* eggs; therefore straining was identified as the principal mechanism that was operative in the removal of helminth eggs. The performance of granular medium filters in the improvement of microbial quality of water was also investigated in other studies. Jimenez et al. [18] investigated the performance of sand and synthetic medium filters for the removal of helminth eggs from primary effluent. The average influent concentration of helminth eggs was 1.2 egg/L, and both filters produced effluent concentrations ranging from 0 to 0.52 egg/L; the removal efficiencies of the sand and synthetic filters were similar. El-Taweel and Ali [19] observed that the removal efficiencies of total coliforms, fecal coliforms and fecal streptococci by a roughing filter were 93, 92 and 85%, respectively. The average removal efficiency of *E. coli* by a multistage filter (HRF with slow sand filter) was obtained about 90% [12].

Since helminth eggs are resistant to common disinfectants and UV radiation, the standard application of disinfectants is not completely effective for removing these infective agents. For this reason, reduction of helminth egg content of water previous to disinfection is desirable [20]. The results of this study indicate that roughing filtration, especially horizontal roughing filtration, was a feasible method for the removal of helminth eggs and improvement of microbial quality of water and secondary effluent. A similar experiment has already been done for the removal of parasite eggs from raw water which resulted in high removal efficiency by the authors [21].

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