TREATMENT OF CONTAMINATED WATER WITH FILTRATION AND UV DISINFECTION

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ABSTRACT
Disinfection is a challenge in small water supply systems (e.g., rainwater harvesting, pond water), as often a family or small communities do not have necessary facilities to disinfect water properly. Also many commercially available household-level treatment systems are not very effective in removing pathogens. Thus the main objective of the present study was to evaluate the effectiveness of different filtration system (consisting of sand, gravel and activated carbon) and UV disinfection in removing fecal coliform (FC) from contaminated surface water. Effectiveness of filtration columns (147.32cm length) consisting of sand and activated carbon in removing FC was evaluated. A range of laboratory experiments have been carried out in a large tank (152 cm ×48 cm x48 cm) for UV disinfection. The effects of important operational and water quality parameters were assessed for filtration and UV disinfection. UV disinfection could significantly reduce microbial (FC) contamination from highly polluted surface water. The effectiveness of UV disinfection has been found to depend on a number of operational factors including intensity of lamp, exposure time, and distance from the lamp.

Keywords: Filtration; fecal coliform; UV disinfection

INTRODUCTION
In Bangladesh surface water (e.g., pond/river water) and rainwater are important sources of potable water, particularly in areas suffering from arsenic contamination of groundwater and high salinity. However, surface water suffers from high microbial contamination and needs disinfection for potable use. Water from surface water sources (e.g. ponds, lakes, rivers etc.) is often used for drinking purpose through use of pond sand filtration (PSF); however, such systems have not been very successful due to problems related to operation and maintenance **(**BGS and DPHE, 2001; BBS and Unicef, 2015; Hug et al., 2011). The main problem related to use of ponds and rivers for potable water supply is widespread fecal/microbial contamination of these water sources (ITN-BUET, 2015). Recent research works also suggest that many commercially available household-level treatment systems are not very effective in removing coliform bacteria (FC). Thus an effective and low-cost disinfection system that could be implemented in rural areas could significantly improve access to safe potable water in many areas of Bangladesh. The overall objective of the research was to assess the effectiveness of filtration by varying different parameters such as: (i) filter media; (ii) flow rate, and (iii) initial level of contamination (FC) on disinfection efficiency. The performance of UV disinfection has been assessed under different operational (e.g., UV lamp intensity, exposure time) conditions.

METHODOLOGY
Filtration System
Filtration experiments have been conducted in a cylindrical filtration column, 147.32cm in length and 7.62cm in diameter. Two different filter media were used: (1) 30.48cm gravel layer followed by 30.48cm coarse sand layer, and finally 30.48cm of fine sand layer; (2) the above layers with additional 15.24cm layer of activated carbon at the bottom.

UV Disinfection

The experiments for UV disinfection have been carried out in a large acrylic glass tank, 152cm in length, 48 cm width and 48 cm in height. The capacity of the tank is about 355 liters. The tank was fitted with a port for UV lamp at one end, and four sampling ports 30.5 cm away from each other. UV lamps of 6W to 16W intensities were employed in this study. Water from a pond that receive domestic sewage discharge, and amended water (e.g., groundwater amended with polluted water containing microorganisms) were used as raw water in the disinfection experiments. For each set of experiment, the raw water was analyzed for a range of parameters including fecal coliform (FC). Initial FC was varied (by dilution with groundwater) in the disinfection experiments in order to assess its impact on disinfection.

Fig. 1: Filtration system

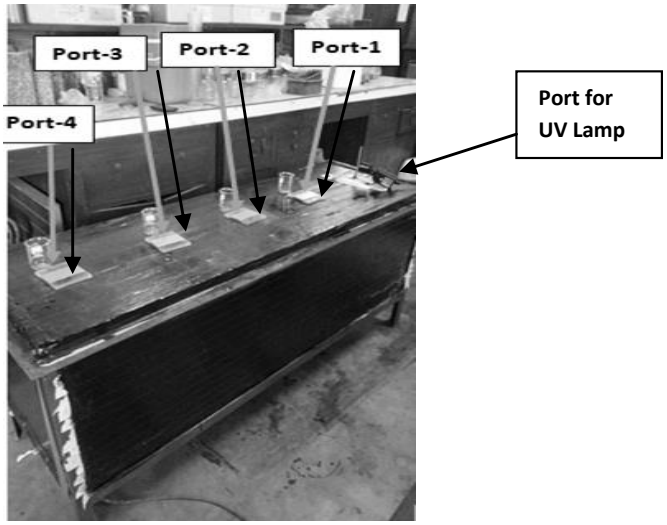

Fig. 2: Experimental set up for UV disinfection

RESULTS AND DISCUSSIONS

Removal of FC by Filtration

The important factors affecting the effectiveness of filtration include: (1) Filter media gradation, (2) Properties of filter media, (3) Inflow Rate, (4) Infiltration Rate, (5) Initial FC concentration, etc. Several experiments were conducted with this filtration system with different initial FC and flow rate. Table 1 shows some of the results of the filtration experiments. It shows that the filter media, with or without activated carbon, have not been very efficient in removing FC from contaminated water.

TABLE 1: REMOVAL OF FC FROM CONTAMINATED WATER IN FILTER COLUMNS

Filter Media	Flow Rate (ml/min)	FC (cfu/100ml)		Efficiency (%)
		Initial	After filtration	
Gravel, Coarse Sand, Find Sand	73	77	25	67.5
Gravel, Coarse Sand, Find Sand	61	85	64	24.7
Gravel, Coarse Sand, Find Sand, Activated Carbon	65	1120	312	72.1

UV Disinfection

Effects of Initial FC Concentration

Table 2 shows the effect of initial FC concentration on disinfection efficiency with a 16W lamp. From an initial concentration of 8000 cfu/100 ml, FC concentration was reduced to 50 cfu/100 ml in Port 1 in 10 minutes; whereas for an initial FC concentration of 9000 cfu/100 ml, the corresponding value is 230 cfu/100 ml. Thus, higher initial FC concentration would reduce disinfection efficiency significantly.

TABLE 2: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY AS A FUNCTION OF EXPOSURE TIME FOR SAMPLES COLLECTED FROM PORT 1 IN DISINFECTION EXPERIMENTS CARRIED OUT WITH 16W LAMP, FOR WATER SAMPLES WITH TWO DIFFERENT INITIAL FC CONCENTRATION (8000 AND 9000 CFU/100ML)

Time of Exposure	Residual FC (cfu/100mL)		Efficiency (%)	
Raw/0 Min	8,000	9,000	0	0
10 Min	50	230	99.4	97.4
20 Min	30	150	99.6	98.3
30 Min	22	56	99.7	99.4
40 Min	12	16	99.9	99.8

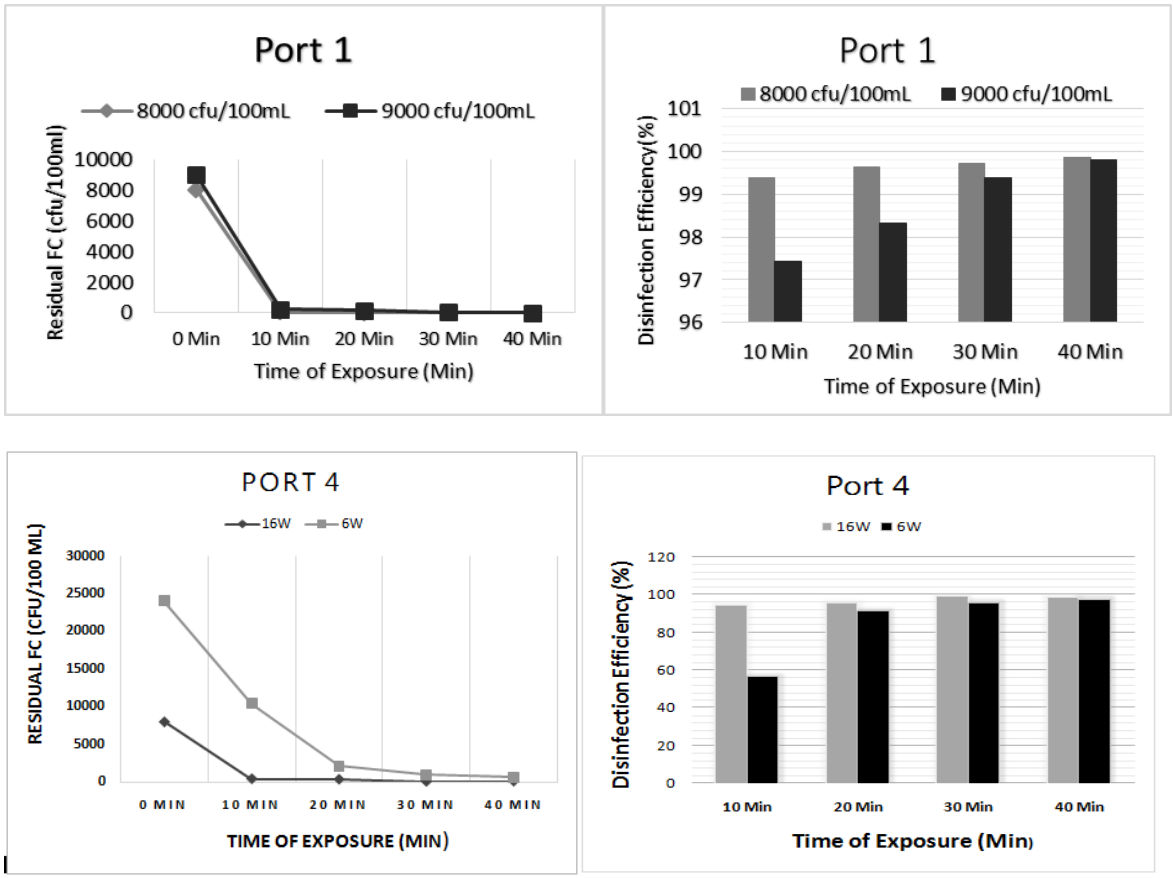

Fig. 3: Effect of Initial FC Concentration at Port 1 and Port 4 for different time exposure with 16W UV lamp

Effects of UV Lamp Intensity on Disinfection

In order to evaluate the effects of UV lamp intensity on disinfection efficiency, a number of experiments were carried out with 6W and 16W UV lamps. Table 3 and Table 4 show the residual FC concentration and disinfection efficiency for water samples collected from Port 1 and Port 4, respectively at different exposure times. Fig. 4 and Fig. 5 graphically show the residual FC concentrations for Port 1 and Port 4, respectively. It should be noted that among the sampling ports

identified, Port 1 receives the highest UV intensity, while Port 4 receives the least; thus these two ports are of highest interest. The figures and tables show that disinfection efficiency depends on UV lamp intensity, and higher intensity UV lamp could achieve higher removal efficiency.

TABLE 3: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY FOR WATER SAMPLES COLLECTED AT DIFFERENT EXPOSURE TIMES FROM PORT 1 OF WATER TANK FITTED WITH 6W AND 16W UV LAMP

Exposure Time	FC (cfu/100 mL)		Disinfection Efficiency (%)	
	6W	16W	6W	16W
Raw/0 Min	24000	8000	--	--
10 Min	600	50	97.5	99.4
20 Min	500	30	97.9	99.6
30 Min	320	22	98.7	99.7
40 Min	120	12	99.5	99.9

TABLE 4: RESIDUAL FC CONCENTRATION AND DISINFECTION EFFICIENCY FOR WATER SAMPLES COLLECTED AT DIFFERENT EXPOSURE TIMES FROM PORT 4 OF WATER TANK FITTED WITH 6W AND 16W UV LAMP

Exposure Time	FC (cfu/100 mL)		Disinfection Efficiency (%)	
	6W	16W	6W	16W
Raw/0 Min	24000	8000	--	--
10 Min	1760	300	92.7	96.3
20 Min	1280	270	94.7	96.6
30 Min	450	185	98.1	97.7
40 Min	350	84	98.5	99.0

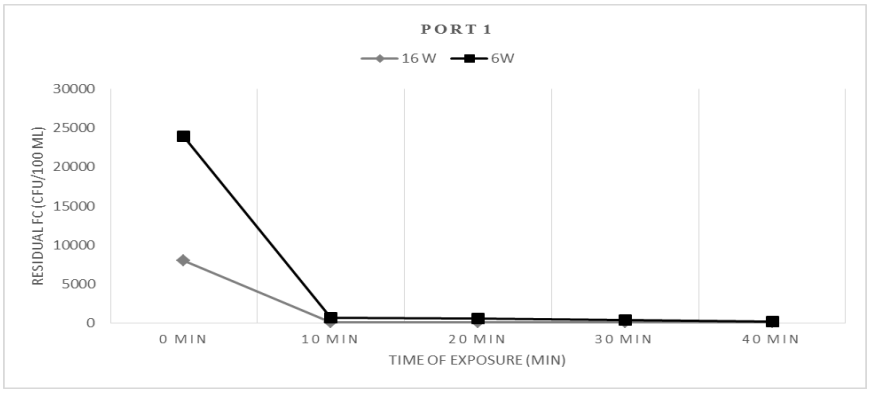

Fig. 4: Residual FC concentration in water samples collected from Port 1 at different exposure times, with 6W and 16W UV lamps

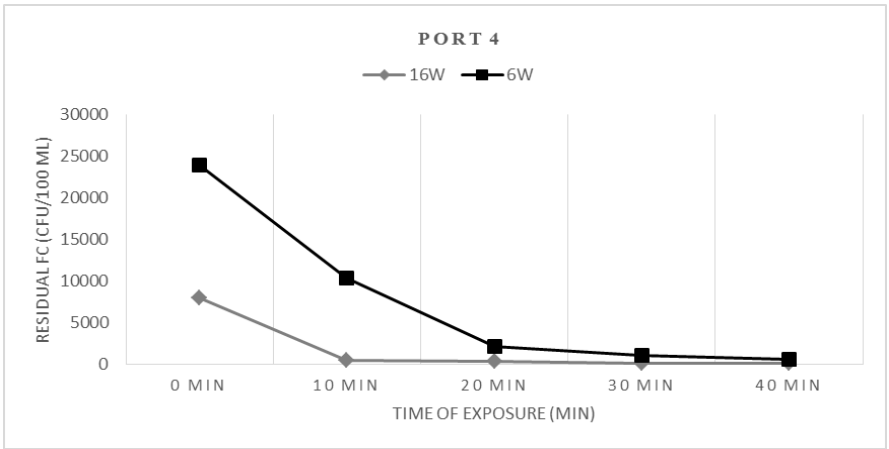

Fig. 5: Residual FC concentration in water samples collected from Port 4 at different exposure times, with 6W and 16W UV lamps

Effect of Exposure Time

Higher exposure to UV radiation would yield higher disinfection efficiency. However, higher exposure means higher power consumption and lower lamp-life, and therefore it is important to estimate the optimum exposure time for a particular condition of UV irradiation and water quality (Das, 2001; Zimmer and Slawson, 2002). Table 5 and Table 6 show that exposure time has a clear effect on disinfection efficiency; higher the exposure time, the better is the disinfection efficiency (Fig. 6 and Fig. 7). However, as discussed earlier, the effect of exposure time is also a strong function of the position of the sampling port with respect to the lamp; Port 1 would require less exposure time of UV radiation compared to Port 4 for achieving the disinfection efficiency.

TABLE 5: RESIDUAL FC CONCENTRATION OF WATER SAMPLES (INITIAL FC: 8000 CFU/100ML) COLLECTED AT DIFFERENT EXPOSURE TIME FROM THE WATER TANK FITTED WITH 16W UV LAMP

Time of Exposure	Residual FC (cfu/100 mL)			
	Port 1	Port 2	Port 3	Port 4
Raw/0 Min	8000	8000	8000	8000
10 Min	50	250	300	420
20 Min	30	160	270	350
30 Min	22	120	155	200
40 Min	12	20	84	96

TABLE 6: RESIDUAL FC CONCENTRATION OF WATER SAMPLES (INITIAL FC: 9000 CFU/100ML) COLLECTED AT DIFFERENT EXPOSURE TIME FROM THE WATER TANK FITTED WITH 16W UV LAMP

Time of Exposure	Residual FC (cfu/100 mL)			
	Port 1	Port 2	Port 3	Port 4
Raw/0 Min	9000	9000	9000	9000
10 Min	230	400	460	840
20 Min	150	280	350	450
30 Min	56	150	180	230
40 Min	16	60	85	120

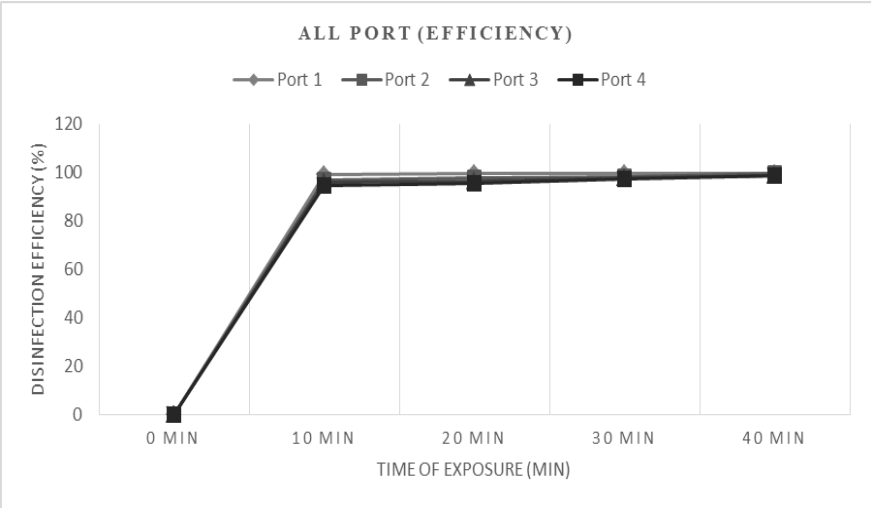

Fig. 6: Effect of exposure time on UV disinfection efficiency of water samples (Initial FC: 8000cfu/100mL) for experiment carried out with 16W UV lamp

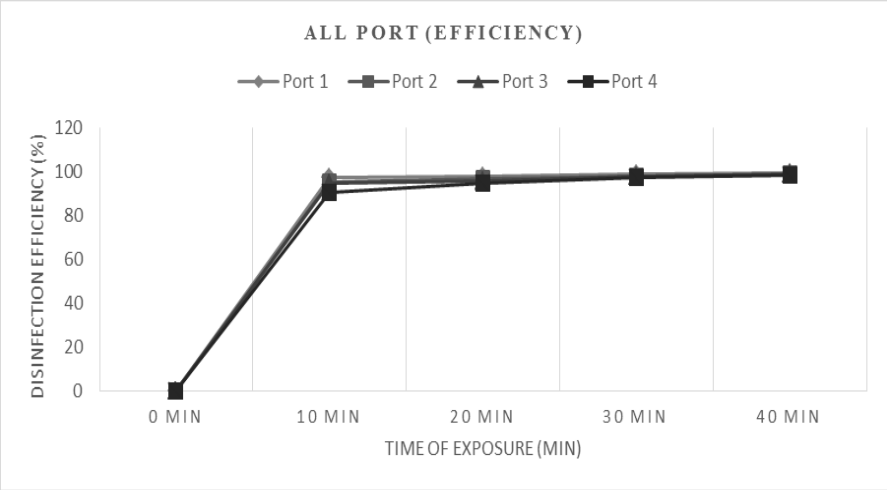

Fig. 7: Effect of exposure time on UV disinfection efficiency of water samples (Initial FC: 9000cfu/100mL) for experiment carried out with 16W UV lamp

CONCLUSIONS

Although FC concentration could not be reduced to zero (which is the national drinking water standard) with UV lamp under the experimental condition used in this study, the results suggest that this could be achieved with appropriate combination of lamp intensity, exposure time and tank dimension for UV disinfection system. Filtration with commonly available filter media (sand, gravel, activated carbon) does not appear to be suitable for removal of FC from water. UV disinfection could potentially be used for treatment of surface (pond/river) water in water scarce areas (e.g., arsenic-affected or salinity-prone areas).

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