Household Slow Sand Filters in Continuous and Intermittent Flows and their Efficiency in Microorganism's removal from River Water

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Abstract

This study aimed to evaluate the efficiency of four household slow sand filter (HSSF) models for the removal of microorganisms from river water throughout the development of their biological layers (*schmutzdecke*). Two models were designed to be operated continuously (HSSF-CC and HSSF-CT) and two intermittently (HSSF-ID and HSSF-IF). Filters were fed daily with 48 L pre-treated river water (24h sedimentation followed by filtration through a non-woven synthetic blanket). Water samples were quantified by coliform group bacteria and analysed by bright field microscopy to visualize the microorganisms. Total coliform reduction was between 1.42±0.59 log and 2.96±0.58 log, with continuous models showing a better performance (p-values < 0.004). *Escherichia coli* reduction varied from 1.49±0.58 log to 2.09±0.66 log and HSSF-IF, HSSF-CC and HSSF-CT presented a similar performance (p-values > 0.06), slightly

better than the one presented by HSSF-ID (p-value=0.04). Microorganisms, such as algae, protozoa and helminths were detected by microscopy in raw water and pre-treated water. Algae were the most significant group in these samples, although they were not visualized by bright field microscopy in the filtered water. Results showed the potential of HSSF in microbiological risk reduction from river water, which increases the range of point-of-use water treatments in rural communities. However, additional studies of the HSSF biological layer must be performed.

Keywords: biosand filter; decentralised treatment; drinking water; microscopy; schmutzdecke

Abbreviations:

HSSF: household slow sand filter

HSSF-CC: household slow sand filter in continuous flow and compact model

HSSF-CT: household slow sand filter in continuous flow and traditional model

HSSF-ID: household slow sand filter in intermittent flow with diffuser

HSSF-IF: household slow sand filter in intermittent flow with float

SSF: slow sand filtration

1. Introduction

It is estimated that 844 million people live without access to drinking water worldwide. This situation causes significant health problems whereby 2.2 million people die from waterborne diseases every year; 90% of them are children younger than

five (WHO, 2017). Drinking water treatment and water networks have been created and improved over time in order to solve water supply problems, however in various cases (e.g. rural communities and low income areas), conventional technologies are expensive and difficult to implement. Based on this, point-of-use technologies for treating contaminated water at a smaller scale have been developed (Kennedy et al., 2013a). Among them, household slow sand filters (HSSFs) have been identified as one of the most promising technologies (Aiken et al., 2011).

1.1. HSSF basic concepts

An HSSF is a small slow sand filter appropriate for households. It is usually made out of concrete or plastic. High concentration of suspended material in the raw water obstructs the intergranular voids, causing a reduction in the filter run and an increase in the frequency of cleaning (Souza Freitas and Sabogal-Paz, 2019). Consequently, the maximum turbidity recommended for HSSF is up to 50 NTU, according to CAWST (2012). For nations with more restrictive drinking water standards, this value must be reduced to 10 NTU (Sabogal-Paz et al., 2020). Young-Rojanschi and Madramootoo (2014) reported 87-96% turbidity removals and 1.67-3.71 log of *Escherichia coli* reductions in HSSFs when raw water with low-turbidity (12.6 ± 7.3 NTU) was treated.

HSSF in intermittent flow can work with filtration rates up to 29 $m^3m^{-2}day^{-1}$, according to the hydraulic load (Elliott et al., 2006). Water is kept in the filter for an interval called pause period (1 to 48 h), which allows time for adsorption, natural die-off of bacteria, pathogen predation and impurity removal (Kennedy et al., 2013b). Users feed the HSSF themselves with up to 20 L after the pause period. An HSSF in intermittent flow can produce up to 80 L day^{-1} (Schmidt and Cairncross, 2009) and the

area occupied inside the house is around 0.1 m^2 (Sabogal-Paz et al. 2020). An HSSF in continuous flow works with filtration rates up to 9.6 $m^3m^{-2}day^{-1}$ and it can produce up to 200 L day^{-1} of filtered water. This filter needs a filtration rate control and more area (approximately 1.0 m^2) inside the house (Maciel and Sabogal-Paz, 2020; Sabogal-Paz et al. 2020).

1.2. Biological layer (*schmutzdecke*)

HSSF has a biological layer that improves the water treatment and its formation in the sand top layer is critical to ensure HSSF efficiency. The biological layer is a stable and efficient ecosystem (Declerck et al., 2009) consisting of complex microbial communities functionally organized and embedded in a gelatinous matrix of extracellular polymers excreted by microorganisms, organic matter, iron and manganese precipitates (Hurlow, 2015). This combination creates an ideal microenvironment that is able to support the survival and growth of microorganisms that collaborate with water treatment (Declerck et al., 2009). According to Characklis and Marshall (1990), bacteria are generally dominant in biofilm due to their low sizes, high growth rates, adaptation capacity, and extracellular polymer production. Nevertheless, protozoa, virus, fungi, and algae may be observed in drinking water biofilms (Snelling et al., 2006). Along this biological layer, several metabolic activities result in partial reduction of the oxygen level causing deaths or inactivation of aerobic organisms, as well as oxidation and absorption of inorganic components. Besides that, biological interactions such as predation, competition and consumption of debris by saprophyte organisms also occur (Galvis et al., 1998), improving the water treatment efficiency during the filtration process through the HSSF.

Schmutzdecke development takes weeks or months according to influent water (Ranjan and Prem, 2018; Maciel e Sabogal-Paz, 2020; Sabogal-Paz et al. 2020), however 30 days is the usual time (CAWST, 2012; Elliot et al., 2008). HSSF ripening depends on the formation of the biological layer and it is directly related to the existence of suspended particles, the bacteria type that is being transported by the influent water, and the microorganisms attached to the sand layer (Prakash et al., 2003).

Slow sand filtration (SSF) or HSSF used as a single water treatment, without the complete formation of the biological layer, is able to remove about 30-70% of the pathogens. When the filter ripening is completed, those removals increase up to 3 log (99.9%) for total coliforms, *E. coli*, virus and *Cryptosporidium* spp. oocysts (Calixto et al., 2020; Elliot et al., 2008; Palmateer et al., 1999; Stauber et al., 2006) and up to 5 log (100%) for *Giardia* cysts (Adeyemo et al., 2015).

Even though water technologies and water monitoring have been improved in recent years, there are still water microbiological risks worldwide due to emergent pathogens (Efstratiou et al., 2017). Among the challenges faced by the HSSF is to operate in a simple way according to the applied hydraulics (i.e., continuous flow or intermittent flow) and maintain its efficiency to remove microorganisms throughout the development of the biological layer. In this context, our study evaluated the HSSF efficiency when it was operated in continuous flow or intermittent flow to remove microorganisms from river water.

2. Materials and Methods

2.1 HSSF characteristics

Four HSSFs constructed with fittings and PVC pipe (cross-sectional area = 0.053 m²) were evaluated. Two filters were operated with continuous flow (HSSF-CC: compact model and HSSF-CT: traditional model) and two filters in intermittent flow (HSSF-ID: with diffuser and HSSF-IF: with float). HSSF schemes are shown in Figure 1 with the complete river water treatment studied.

[Figure 1 near here]

The selection of such HSSF designs aimed at the improvement of currently available models, both in filters operational aspects and filters treatment efficiencies.

HSSF-CC and HSSF-CT differences were the fine sand layer depth (HSSF-CT with 50 cm fine sand layer and total height of 90 cm and HSSF-CC with 25 cm of fine sand layer and a total height of 65 cm). On the other hand, HSSF-ID and HSSF-IF had the same fine sand layer depth, 50 cm. Nevertheless, they owned different devices to distribute the water into the filters. HSSF-ID used a diffuser vessel, which was made out of a bucket with four holes in its bottom, positioned 15 cm above the fine sand top layer. HSSF-IF used a device capable of controlling the maximum hydraulic head (15 cm) inside the filter. This device was made with a bucket with one hole at its bottom equipped with a plastic float.

Filter media materials were the same for the four HSSFs; 50 cm of fine sand for HSSF-CT, HSSF-ID and HSSF-IF, and 25 cm for HSSF-CC. Filling materials characteristics were determined by granulometric tests (ISO, 2017). Fine sand size was 0.17 to 0.56 mm, with effective size (D_{10}), which is the sieve opening through which 10% of the sample passes, of 0.17 mm, uniformity coefficient (CU), which is the ratio between D_{60} and D_{10}, of 2.27 and porosity of 37%. Support media had the same depth

for the four HSSFs and comprised 5 cm layer of coarse sand (0.17 – 0.67 mm), a 5 cm layer of fine gravel (5.0 – 7.0 mm) and a 7.5 cm layer of coarse gravel (7.0 – 12.0 mm). The materials were bought from local supplies in São Carlos City (SP, Brazil). They were washed, sun-dried and sieved using commercial sieves. A non-woven synthetic fabric blanket (specific gravity: ± 0.2 g cm^{-3}, composition: 100% polyester and thickness: 2 mm) was positioned at the fine sand layer top in order to facilitate the HSSF operation and maintenance.

2.2 Water Treatment Proposed

A total of 500 L of raw water from the Monjolinho River (São Carlos/Brazil) was pumped daily into an elevated tank and this water remained undisturbed for 24 h for particle sedimentation to take place. After this period, outlet pipe taps installed in the tank were turned on and the water flowed through two layers of non-woven synthetic fabric blanket (the same blanket used in the HSSF sand layer) filling two 200 L tanks. Therefore, water pre-treatment involved 24h for particle sedimentation followed by water passage through two non-woven blankets (Figure 1). Remaining water from the elevated tank was discharged after the two 200 L tanks were completely filled. Afterwards, a 500 L elevated tank was filled with new raw water and the pre-treatment restarted. Raw and pre-treated water quality for the study is shown in Table 1.

[Table 1 near here]

Pre-treated water from the 200 L tank was pumped into a 310 L elevated tank used to feed HSSF-CC and HSSF-CT. A continuous feeding system was designed to maintain a steady hydraulic head using the float valve that limited the maximum

filtration rate. The filtration rate was regulated by using a needle faucet installed in the filter outlet pipe in order to keep a production of 48 $L.day^{-1}$ of filtered water per HSSF. On the other hand, pre-treated water from the other 200 L tank was used to fill the bucket used to feed HSSF-ID and HSSF-IF. Two feeding intervals were used (5 h and 14 h), therefore each filter was filled three times a day (8:00 am, 1:00 pm and 6:00 pm) with 16 L, producing 48 $L.day^{-1}$ of filtered water.

Filtration rates were kept constant in continuous HSSFs (0.90 $m^3m^{-2}day^{-1}$) by controlling the flow rate using the needle faucet in the exit pipe of the filters; and variable in intermittent HSSFs, reaching its maximum (11.9 $m^3m^{-2}day^{-1}$ for HSSF-ID and 9.0 $m^3m^{-2}day^{-1}$ for HSSF-IF) right after the filters were fed, and falling to zero as the hydraulic head reached its minimum (approximately 5 cm, from the top sand).

2.3 Maintenance of the Water Treatment Systems

The filtration rate has reduced over time due to the particle accumulation and biological layer development. Consequently, when HSSFs were not able to produce 48 $L.day^{-1}$, filters were submitted to maintenance. Initially, the filter faucet was closed and the non-woven blanket was removed, scraped and washed. The sand top layer was carefully suspended by manual mixing and dirty water was removed after sand sedimentation. Finally, the cleaned non-woven blanket was repositioned at the sand top layer.

2.4 Sample collection and analysis

Sample collection started after HSSF maintenance. 1.0 L samples were collected from raw water, pre-treated water, and filtered water every 10 days from day zero of maintenance. Each sample was homogenized and two aliquots (100 mL each) were

collected; the first one was addressed to microscopic analysis by bright field and the other one to the laboratory assays for total coliforms and *Escherichia coli*.

For bright field microscopy, 100 mL were centrifuged at 1500 x *g* for 15 min to obtain the pellet with concentrated microorganisms. Afterwards, one drop of the supernatant and one drop of the pellet of each sample were placed in two different microscope slides, covered with coverslip and analysed under a 40X objective microscope (BX51, Olympus®) to visualize the microorganisms. For total coliforms and *E. coli* quantification, a 100 mL sample was submitted to the Chromocult® Coliform Agar membrane filter method, according to APHA (2012).

2.5. Statistical tests

The analytical datasets obtained were non-normally distributed, according to the Shapiro-Wilk test ($p < 0.05$), therefore the Kruskal-Wallis test was used to compare total coliforms and *E. coli* data from the filtered water and those with the pre-treated water data (95% confidence interval). The Mann-Whitney test was used when the Kruskal-Wallis test indicated that the median values were significantly different to determine which sample was significantly different from another (95% confidence interval). Moreover, the Mann-Whitney test was used to compare raw water and pre-treated water.

3. Results

According to bright field microscopy, microorganisms were detected in raw and pre-treated water, regardless of the collection day (Table 2). Images of microorganisms can be found in the supplementary material of this manuscript.

Among the microorganisms present in raw and pre-treated water, algae was the most significant group, both in variety of genera/species and in number. It was also observed that the organisms identified in the raw and pre-treated water were essentially the same and this pattern was maintained throughout our study. Microorganisms were not visualized by bright field microscopy in the filtered water. Total coliforms and *E. coli* in raw, pre-treated and filtered water are shown in Figure 2.

[Table 2 near here]

[Figure 2 near here]

There were total coliform (0.24 ± 0.26 log) and *E. coli* (0.43 ± 0.45 log) reductions in pre-treated water. The Mann-Whitney test showed that there was a statistically significant difference between raw water and pre-treated water regarding concentrations of total coliforms and *E. coli* ($p = 0.03$ and $p = 0.04$, respectively). For HSSFs, coliform removals were more prominent, with bacterial concentration in filtered water significantly lower than in pre-treated water for all HSSF models ($p < 0.0003$).

The total coliform removal mean values were 2.96 ± 0.58 log for HSSF-CC, 2.92 ± 0.71 log for HSSF-CT, 1.42 ± 0.59 log for HSSF-ID and 1.56 ± 0.56 log for HSSF-IF. According to the Mann-Whitney test, a continuous flow operation presented a reduction in total coliforms significantly higher than the intermittent flow ($p < 0.004$). HSSFs operated under the same flow regime (continuous or intermittent) did not show a significant difference in the efficiency between them.

HSSFs in intermittent flow presented maximum total coliform removals of 2.08 log and 2.27 log in HSSF-ID and HSSF-IB, respectively. HSSFs in continuous flow

reached a maximum reduction of 3.85 log. Furthermore, HSSFs in continuous flow were able to provide filtered water with the absence of total coliforms in 25% of the samples from HSSF-CC and 37.5% from HSSF-CT. On the other hand, HSSFs in intermittent flow did not present this efficiency during the analysed period.

The mean values of *E. coli* removal were 2.08 ± 0.55 log for HSSF-CC, 2.09 ± 0.66 log for HSSF-CT, 1.49 ± 0.58 log for HSSF-ID and 1.62 ± 0.61 log for HSSF-IF. HSSFs in intermittent flow presented maximum *E. coli* removal of 2.18 log and 2.48 log in HSSF-ID and HSSF-IF, respectively, while HSSFs in continuous flow reached a maximum of 2.60 log of removal. Absence of *E. coli* was observed in 50% of the samples from HSSF-CC, 75% from HSSF-CT, 12.5% from the HSSF-ID and 37.5% from the HSSF-IF.

The Mann-Whitney test showed that there was no significant difference between HSSF models, operated in continuous or intermittent flow, for *E. coli* reduction, *i.e.* HSSF-CC and HSSF-CT ($p = 0.87$) and HSSF-ID and HSSF-IF ($p = 0.75$). It was also observed that there was no significant difference in *E. coli* reduction between HSSF-IF and HSSF-CC ($p = 0.08$) and HSSF-CT ($p = 0.06$).

4. Discussion

Several studies have been carried out to evaluate HSSF efficiency from microorganism reduction (Adeyemo et al., 2015; Elliot et al., 2008; Maciel and Sabogal-Paz, 2020; Kennedy et al., 2012; Palmateer et al., 1999; Stauber et al., 2006; Terin and Sabogal-Paz, 2019; Vanderzwaag et al. 2009). However, in the literature, studies reporting the interaction between HSSF and algae or helminths are scarce, due to the fact that it is believed that these microorganisms are easily retained in the filter media (CAWST, 2012). El-Taweel and Ali (2000) reported that the conventional SSF

was capable of eliminating all algae presented in the water. Furthermore, regarding helminths, Okojokwu et al. (2014) and Okojokwu and Inabo (2012) proved the efficiency of this technology removing helminths even from wastewater using an HSSF, in which the concentration of organisms is much higher than in the supply water. In both studies, helminths with different shapes and sizes were included such as *Taenia* spp., *Ancylostoma* spp., *Ascaris* spp. *Trichuris* spp. and *Toxocara* spp. and the filters were able to remove them up to 100% (i.e. > 5 log). It is more usual to find research that addresses the removal of *Giardia* spp. and *Cryptosporidium* spp. by SSF. However, there are still few studies that evaluate HSSF efficiency regarding protozoa. In this context, Adeyemo et al. (2015), Bellamy et al. (1985), Palmateer (1999) and Schuler et al. (1991) registered reduction rates of these two genera of protozoa in water between 92 and 100% (i.e. 1.0 log to > 5 log).

Although *Giardia* spp. and *Cryptosporidium* spp. are usually used as indicators of water quality, mainly due to their worldwide distribution, high survivability in the environment and strong resistance to chlorine, the main disinfectant used in water (WHO, 2017), other protozoan are also commonly found in water sources, as can be observed in this study. However, because they are sometimes less resistant and/or larger than *Cryptosporidium* spp., it is assumed that the technology capable of removing these two main indicators will also be able to remove the others.

Although removal rates were calculated only for *E. coli* and total coliforms, based on the results found herein, it was possible to infer the filters' efficiency against the diversity of microorganisms present in the raw water.

These results can be explained by the effect of the pre-treatment, which favours the particle's retention due to sedimentation and non-woven blanket filtration, associated to the removal mechanisms in HSSF such as diffusion, sedimentation,

adsorption, and biological activity, which improve the water quality (Jenkins et al., 2011).

There was a predominance of algae in raw water (Table 2), which can be attributed to the season in which the research was conducted (October to November – Autumn, 2019) with rainfall, high temperatures and sunlight exposure.

Pre-treatment presented reduced efficiency in removing microorganisms from raw water, since practically the same genus were found in raw and pre-treated water, which facilitated their entry into the HSSFs. Besides that, there was also a low reduction of total coliforms (0.24 ± 0.26 log) and *E. coli* (0.43 ± 0.45 log) due to particle sedimentation.

The biological layer improved the HSSF performance over time, since predatory activities associated with filter ripening; natural death, inactivation and metabolic breakdown can remove or inactivate microorganisms during the filtration process (Elliot et al., 2006; Jenkins et al., 2011). It should be noted that bacteria removal in HSSF has been attributed to grazing by protozoa, and is considered the most important removal mechanism in slow sand filtration (Weber-Shirk and Dick, 1997). It is highlighted that temperature inside the HSSF is usually lower than the human body. Besides that, the lack of food, production and release of chemicals and biological substances from microorganisms create a hostile environment for multiplication and survival of intestinal bacteria with consequent death or inactivation of pathogens, contributing to water treatment (Ranjan and Prem, 2018).

The biological layer on the sand top was not evaluated in our study, since it was not the purpose of our research, however it is expected that the biofilm from HSSF removed most of the existing microorganisms in the pre-treated water. This statement is aligned to the results obtained by Haarhoff and Cleasby (1991), who indicate these

groups (bacteria, algae, helminths and protozoa) as the main integrant of a biofilm from SSF.

Among the types of organisms in the biological layer, algae play a fundamental role, since they form the basis for the food chain. According to Nakamoto et al. (2014), the phytoplankton community established in the filter media top removes impurities and improve the water treatment in slow sand filtration.

The relationship between filter ripening and total coliforms and *E. coli* reductions is mentioned in the literature and it can be visualized in our study. Hijnen et al. (2004) found that HSSFs with a mature biofilm reduced 1-2 logs more of bacteria than filters without established biological layers. Likewise, studies indicate that during the ripening period, bacterial reduction increases exponentially (Wang et al., 2014) and a mature biofilm alone can contribute up to 3-log reduction of total coliforms and *E. coli* (Unger & Collins, 2008).

Filters in continuous flow (HSSF-CC and HSSF-CT) reached higher levels of total coliforms and *E. coli* reduction than HSSF in intermittent flow, as observed by Maciel and Sabogal-Paz (2020) and Young-Rojanschi and Madramootoo (2014). This difference between efficiencies is probably due to the biological layer formed by the low and constant filtration rate in the continuous flow (Souza Freitas and Sabogal-Paz, 2019).

Regarding the difference between HSSF-CC and HSSF-CT, the sand layer depth did not play an important role in the bacteria reduction; possibly due to water treatment by surface action. Therefore, most of the bacteria was retained on the filter media top, a typical behaviour of slow sand filtration treatment.

The main functions of the float valve in HSSF-IF were to equalize and keep the maximum filtration rate, limiting the hydraulic head. This control exercised by the float

valve may explain the *E. coli* reduction closer to the results of HSSFs in continuous flow than HSSF-ID. However, a significant statistical difference among HSSF-IF and HSSF-ID for *E. coli* reduction was a consequence of HSSF-ID maintenance during the analysed period, which partially removed the biological layer in the procedure.

The results obtained for HSSF-CC, HSSF-CT, HSSF-IF and HSSF-ID (Figure 2) are in line with the findings reported by Elliot et al. (2008), who observed *E. coli* removal rates between 0.3-4.0 log (average = 1.9 log), using full scale HSSF in intermittent flow fed with raw water spiked with pasteurized sewage. Equally, Maciel and Sabogal-Paz (2020) reached *E. coli* reduction from 1.26-2.29 log, using full scale HSSF in continuous and intermittent flow regimes, using synthetic water (mixture of kaolinite, well water and *E. coli*). Young-Rojanschi and Madramootoo (2014) obtained *E. coli* removals up to 3.71 log in a bench scale HSSF in continuous flow and up to 1.67 log in a bench scale HSSF in intermittent flow, both fed with raw water spiked with *E. coli.*

Although there are many publications regarding bacteria removal, only a few researchers have considered the impact of surface maintenance on filter performance. However, according to the literature, a drop in filter removal efficiency is expected, and the authors pointed out reductions between 0.02 to 0.52 log (Buzunis, 1995; Duke and Mazumder, 2009; Earwaker, 2006; Ngai et al., 2014; Pincus, 2003). Herein, a direct correlation between disturbance of the HSSF biological layer for maintenance and low levels of E. *coli* and total coliform removal was observed. However, our results showed higher levels than those mentioned in the literature, which can be partially explained by reduced operating times. According to Singer et al. (2017), mature filters that had been in use for a year showed a decrease in *E. coli* removal rates by less than 0.02 log from

baseline after maintenance, while in filters that have been operated for less than three months, the decrease in *E. coli* removal rates can be higher.

5. Conclusions

Microorganisms were observed by bright field microscopy both in the raw and pre-treated water. However, pre-treatment by sedimentation and filtration through blankets showed slight coliform reductions (total coliforms 0.24 ± 0.26 log and E. coli 0.43 ± 0.45 log).

HSSF-CC, HSSF-CT, HSSF-IF and HSSF-ID removed microorganisms, including total coliforms (1.42 – 2.96 log) and *E. coli* (1.49 – 2.09 log). HSSF-CC and HSSF-CT presented a better performance than HSSF-IF and HSSF-ID for total coliforms ($p < 0.004$), due to the constant filtration rate. However, there was no significant difference between HSSF models for *E. coli* reduction, *i.e.* HSSF-CC and HSSF-CT ($p = 0.87$) and HSSF-ID and HSSF-IF ($p = 0.75$). Total coliforms and *E. coli* reductions increased with the filter operation time, indicating a relationship between biofilm ripening and filter efficiency. On the other hand, maintenance activities negatively interfered with the HSSF efficiency.

The proposed household water treatments significantly reduced microorganisms such as algae, helminth, protozoa and bacteria, and this may indirectly reduce users' exposure to waterborne diseases, making them potential options for drinking water supply at a domestic level. However, further studies are recommended to identify target microorganisms responsible for improvements in filter efficiency.

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7. Declaration of Interest Statement

The authors hereby declare previous originality check, no conflict of interest and open access to the repository of data used in this paper for scientific purposes.

8. Supplementary Material

Some microorganisms visualized by bright field microscopy are provided as supplementary material

9. References

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Table 1 – Raw water from the Monjolinho River and pre-treated water quality

Parameter	Raw water	Pre-treated water
	M ± SD	M ± SD
Turbidity (NTU)	60.0 ± 29.6	32.6 ± 19.1
Total coliforms (CFU 100mL^{-1})	12052 ± 6244	7514 ± 4341
Escherichia coli (CFU 100mL^{-1})	1360 ± 1720	373 ± 492

Note: M: mean and SD: standard deviation

Table 2. Microorganisms and algae identified by bright field microscopy in raw and pre-treated water

Biological class	Microorganism	Raw water				Pre-treated water			
		0	10	20	30	0	10	20	30
Algae	*Aulacoseira* spp.	X	X		X	X			X
	Chlorella spp.	X	X		X		X	X	
	Clamydomonas spp.	X			X		X		X
	Cryptomonas spp.		X	X	X				X
	Desmodesmus spp.							X	
	Diatomaceae			X					
	Eudora spp.	X	X		X				
	Euglena spp.					X	X		
	Melosira spp.	X		X				X	
	Navícula spp.				X				X
	Nitzchia spp.				X				
	Phacus spp.	X	X			X	X		
	Rhodomonas spp.	X	X		X	X	X		
	Scnedesmus spp.	X		X	X			X	X
	Sinedra spp.		X						
	Trachelomonas spp.						X		
Helminth	Filarid larvae	X							
Protozoa	*Balantidium* sp.	X					X		
	Entamoeba spp.	X							
	Giardia spp.	X	X		X	X			X
	Heliozoa	X	X	X		X		X	
	Naegleria spp.	X				X			
	Toxoplasma sp.								X
	Vorticela spp.				X				

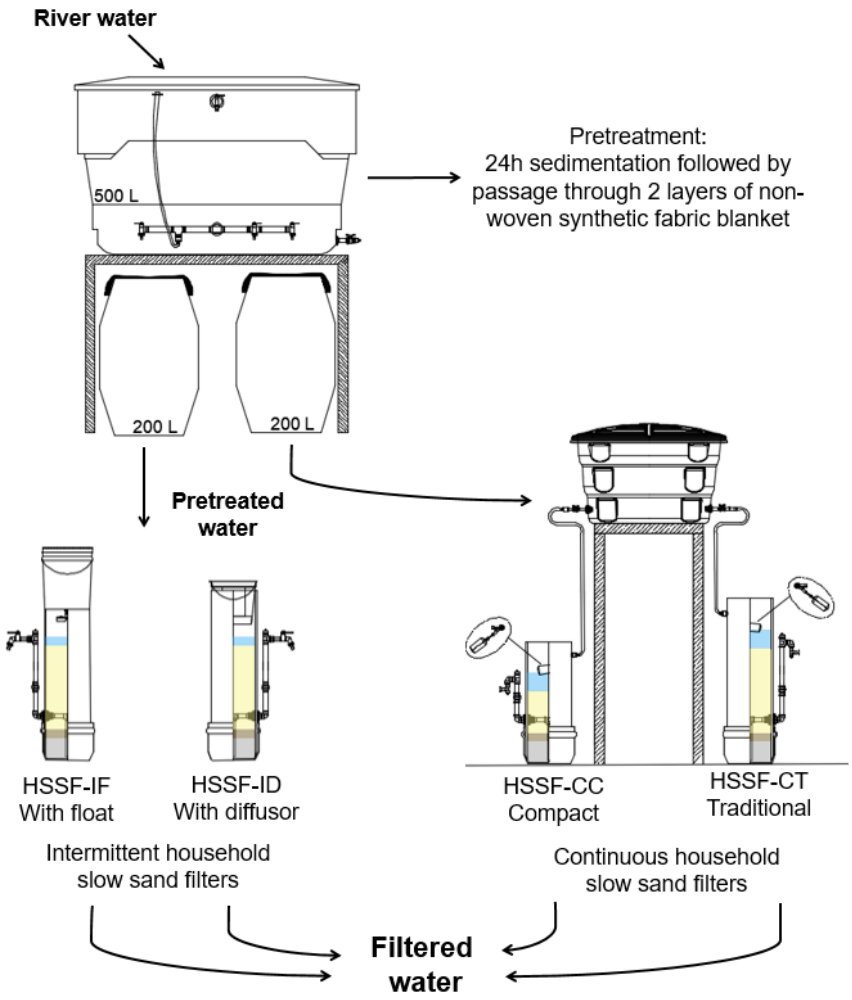

Figure 1 - HSSF schemes with the complete river water treatment studied.

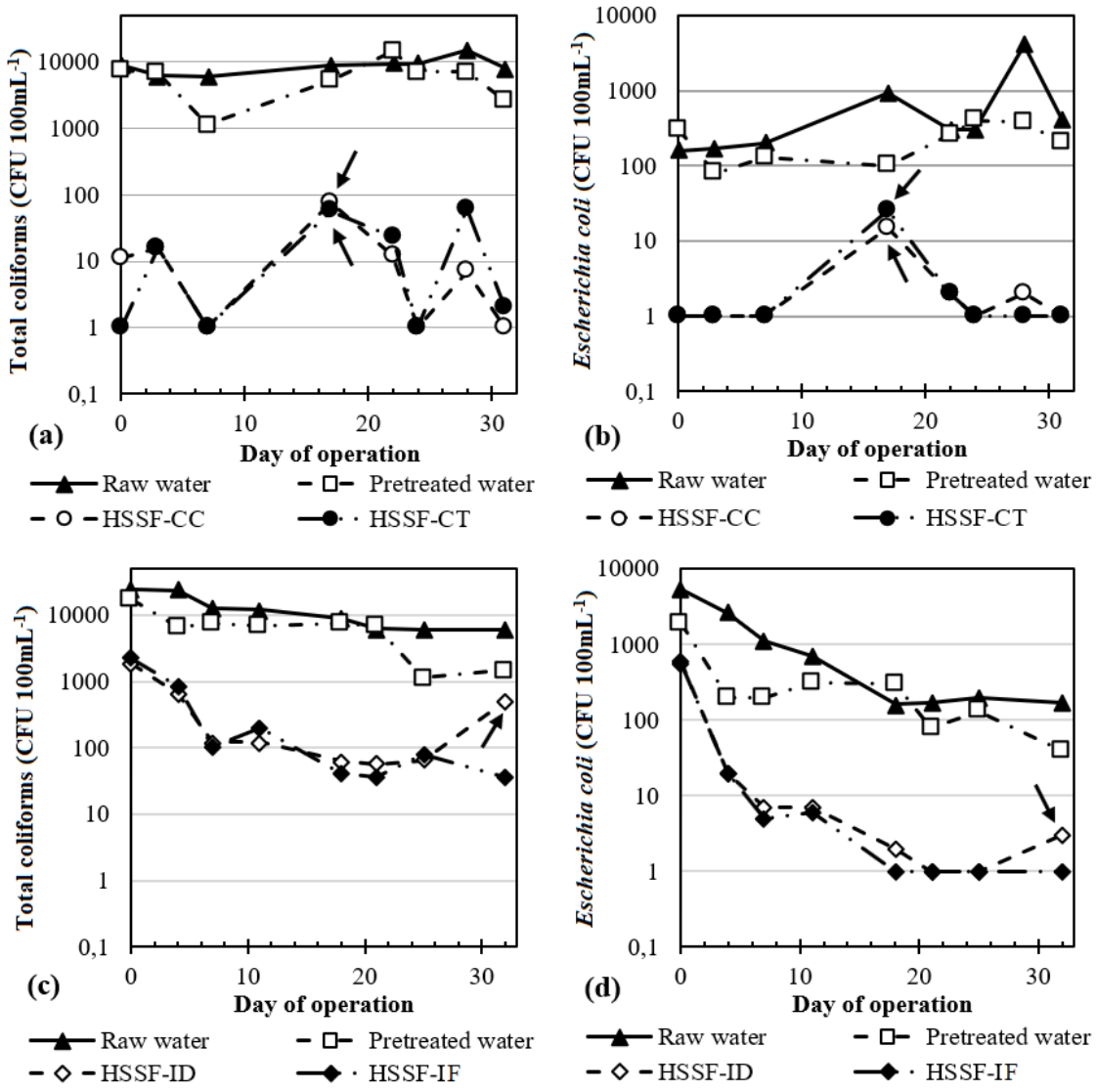

Figure 2 - Total coliforms and *E. coli* in raw, pre-treated and filtered water. HSSF-CC: compact model, HSSF-CT: traditional model, HSSF-ID: with diffuser, HSSF-IF: with float. Arrows indicate maintenance.