Performance of Disc, Conventional and Automatic Screen Filters under Rainbow Trout Fish Farm Effluent for Drip Irrigation System

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Abstract

This study aims to investigate the performance of disc, conventional screen, and automatic screen filters when rainbow trout fish effluent is used for irrigation. The experiments were performed in a fish farm, located in the north-west of Iran. The disc and conventional screen filters were tested at pressures of 150 and 300 kPa, and the automatic screen filter at 200 and 300 kPa. The filtration experiments continued until the backwashing was reached. The results showed that (1) the initial head loss of disc and conventional screen filters was 40 kPa, while for the automatic screen filter was 5 kPa. (2) In the disc filter, with increasing working pressure, the filtered volume significantly (P<0.05) increased from 9.7 to 14.5 m^3 m^{-2} (10 kPa)$^{-1}$, but for conventional and automatic screen filters, it was constant at 5.5 and 7.0 m^3 m^{-2} (10 kPa)$^{-1}$, respectively, and all of them had significant (P<0.05) differences. (3) In the disc filter, with increasing the working pressure, the filtered volume to reach backwashing significantly (P<0.01) increased from 80.9 to 104.4 m^3 m^{-2}, while in the conventional screen filter increased

from 14.1 to 16.4 m^3 m^{-2}. This volume at two working pressures was 29.5 m^3 m^{-2} for the automatic screen filter. These volumes were significantly different (P<0.01) between filters. (4) The mass retention for the disc, conventional, and automatic screen filters were 28.88, 9.11, and 7.72 g min^{-1} m^{-2}, respectively and tended to increase at lower working pressures. Based on this index, the difference in the performance of the filters was significant (P<0.01). (5) Overall, the best performance was for the disc filter, and after that was the automatic screen filters, but the period of time to operate for the filters until backwashing time was less than half an hour, which is not applicable under farm conditions.

Keywords: Aquaculture, Drip irrigation, Emitter clogging, Filtration system, Wastewater.

1. Introduction

Water consumption has increased worldwide by about 1% per year since the 1980s. Agriculture is the largest water user, accounting for 69% of the water used each year globally (WWAP, 2019). Water reuse is on the rise due to limited freshwater resources and has altered the pattern of wastewater management from disposal to reuse and recovery (WWAP, 2017; Demir and Sahin, 2017; Ahmad et al. 2019). The aquaculture industry has been remarkably developed so far, and its effluents have lots of benefits for irrigation in agriculture (Eid and Hoballah, 2014) and contains organic matter, nutrients and suspended solids (Saremi et al. 2013; Piedrahita 2003). The adoption of an integrated agriculture aquaculture system, in which agricultural and aquaculture products are managed in an integrated way, contributes to improved production sustainability, resource productivity, and environmental sustainability (WWAP, 2017).

The most effective system for the reuse of effluent is drip irrigation in which emitter clogging is a challenge that depends on emitter type (Maroufpoor et al., 2020), geometric structure of the emitter (Lequette et al., 2020b; Aminpour et al., 2021), water quality (Capra

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and Scicolone 2001) and filtration efficiency (Tripathi et al., 2014; Ghaffari and Soltani, 2016). So far, various solutions have been proposed to solve this problem in drip irrigation systems such as flushing and lateral drainage, chlorination, and pressure flushing of drippers (Puig-Bargués et al., 2010; Song et al., 2017; Lequette et al., 2020a). A viable strategy to avoid emitter clogging is to use a suitable filter (Ribeiro et al., 2008; Duran-Ros et al., 2014). Based on filtration mechanisms, filters fall into two main categories. In disc and screen filters, classified as mechanical filters, the diameter of the filter pores is lower in size than the diameter of the suspended particles. In the second category, sand filters, physical and chemical mechanisms are involved in the removal of the particles (Adin and Alon, 1986). Disc and screen filters are simple, cost-effective, and easy to use, but sand filters are complex and expensive and are appropriate for farms with high technology (Capra and Scicolone, 2007). All filters reduce the risk of clogging, but the use of unsuitable filters causes increased energy consumption. Filters with smaller pores tend to operate better in water treatment, but the time before a backwashing is needed is shorter, which remains an important issue (Duran-Ros et al., 2014). Disc filters perform better in the removal of the sand particles than clay particles (Khan et al., 2017). Also, for filtration of suspended solids up to a concentration of 50 mg l^{-1}, conventional disc filters, and for concentrations of 50-100 mg l^{-1}, automatic disc filters are effective (Ghaffari and Soltani 2016). An increase in the inlet pressure leads to an enhanced filtration efficiency (Kumar et al., 2017; Duran-Ros et al., 2009a, 2014), but it might lead to no effect in the filtration efficiency of disc filters, screen filters, or a combination of both (Kumar et al., 2017; Duran-Ros et al., 2009a). The performance of disc and screen filters is the same in the use of wastewater treatment plant effluent (Puig-Bargués et al. 2005) However, some studies show better performance of either disc filters (El-Tantawy et al., 2009; Capra and Scicolone, 2001, 2004, 2005, 2007) or screen filters (Duran-Ros et al., 2008, 2009b). These varied performances may be attributed to differences in the type of wastewater or the level of treatment. It was

shown that in using the effluent of multi-stage farms of rainbow trout, the screen filter (125-149 μm) performed better than the sand filter (grain size 3-5 and 5-8 mm) (Manbari et al., 2020).

There has been a wealth of studies on the performance of disc and screen filters in irrigation with freshwater or treated municipal wastewater (Puig-Bargués et al. 2005; Capra and Scicolone, 2007; Ribeiro et al., 2008; Duran-Ros et al. 2009a, 2014; Ghaffari and Soltani 2016; Kumar et al., 2017; Khan et al., 2017). However, the performance of cost-effective disc and screen filters, when using aquaculture effluents has not been reported yet. However, few studies have reported on the performance of cost-effective disc and screen filters, when using aquaculture effluents (Manbari et al., 2020). In this regard, knowledge about its performance is needed to allow proper aquaculture effluent reuse.

The main purpose of this study is to investigate the performances of the disc, conventional screen, and automatic screen filters in the use of the effluent generated by a single-pass raceway system in the rainbow trout fish farm. Also, in this study, the effect of inlet pressure on the performance of these filters is investigated.

2. Materials and methods

2.1. Fish farm effluent

The experiments were conducted in Sanandaj's Mostafavi fish farm, located in Kurdistan province, northwest of Iran. This farm had four ponds for culturing the rainbow trout (*Oncorhynchus mykiss*). The water needed for the farm was supplied from two sources, well and spring, which, after being combined, were distributed by a pipe between fish ponds. The management system of the farm was the single-pass raceway system. Each pond had two outlets. The first outlet (outlet 1) was used to drain excess water as a spillway. The second

outlet (outlet 2) was used to empty the pool floor waste. The water flow from the first outlet was permanent, but the second outlet was opened after feeding the fishes (Fig. 1). The effluents from the ponds were accumulated in a drainage and discharged into a collection reservoir and then pumped to the filtration system. The water entering the fish ponds and the outlet effluent from them were sampled in three non-consecutive replications. The main physical and chemical characteristics of inlet water and outlet effluent are presented in Table 1. Overall, fish farm effluent had higher solid and microbiological load than inlet effluent.

2.2. Filtration system

Three types of filters, including disc, conventional screen and automatic self-cleaning screen filters were studied. The specifications of the filters are listed in Table 2. The conventional screen filter (Abanegn Company, Karaj, Iran) had two inner and outer cartridges. The inner cartridge filtration level was 125 μm, and the outer cartridge filtration level was 149 μm. The filtration cross-section of inner and outer cartridges were 1570 and 2220 cm^2, respectively. The manufacturer has reported an initial head loss of 3.24 kPa in using freshwater. This filter is extensively used in the filtration system of Iran drip irrigation networks. The disc filter (Azud Helix System 2NR, Azud Company, Murcia, Spain) had a maximum discharge of 30 m^3 h^{-1} and a filtration level of 130 μm. The automatic screen filter (ACRV HF-RK-1030A, Acar Maksan Company, Mersin, Turkey) had two filtration stages. In the first stage, the water passed through a screen with large pore diameters to eliminate large suspended particles from the water. Subsequently, for the final filtration stage, the water was directed to the main filter cartridge with a pore diameter of 110 μm. The appropriate performance of the automatic screen filter was in the discharge range of 25-55 m^3 h^{-1}, being the minimum and maximum allowable working pressure 150 and 1000 kPa, respectively. In recent years, in most drip irrigation systems, this filter has substituted the traditional filtration system in the area composed by hydro-cyclone, sand tank and screen filter. For pumping the effluents to the filtration system,

two electro pump and a submersible pump were used. Bypass-pipe was used to adjust the pressure. To measure the pressure and head loss, before and after each of the filters, a Bourdon pressure meter (±5 kPa accuracy) was installed. To measure the outlet discharge of the filters, a flow meter (±0.2-0.5 % accuracy) was used. To adjust the discharge at the filters' outlets, a gate valve was used.
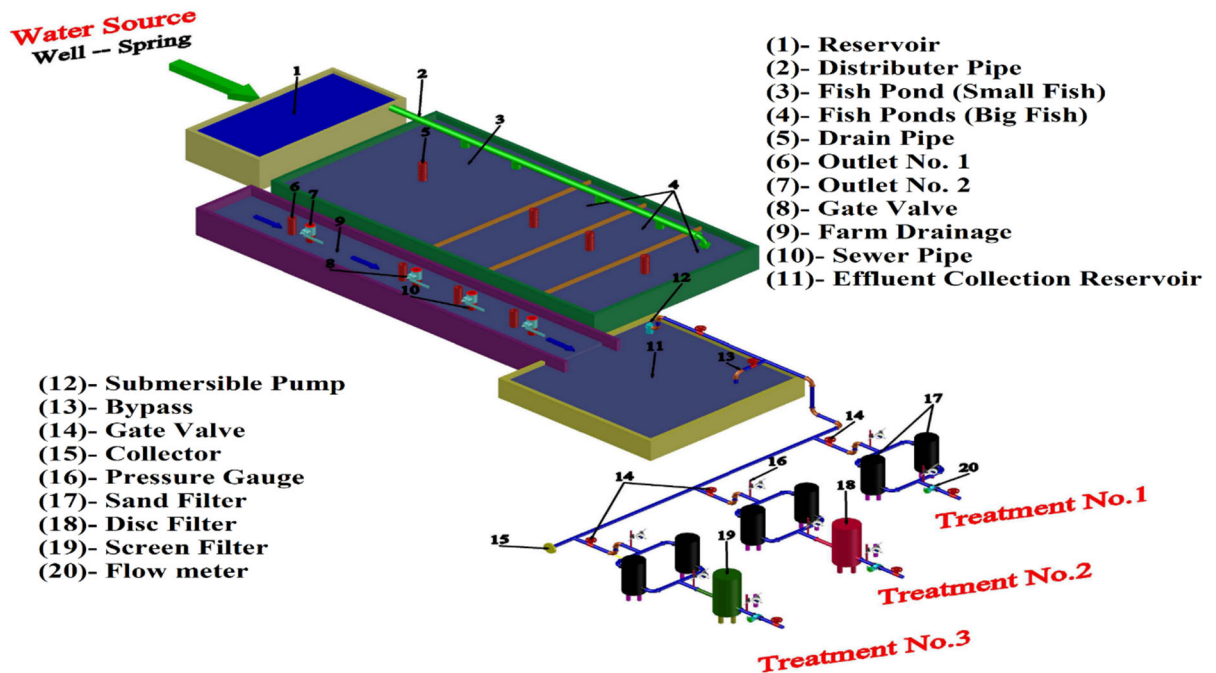

Water Source
Well -- Spring

(1)- Reservoir
(2)- Distributer Pipe
(3)- Fish Pond (Small Fish)
(4)- Fish Ponds (Big Fish)
(5)- Drain Pipe
(6)- Outlet No. 1
(7)- Outlet No. 2
(8)- Gate Valve
(9)- Farm Drainage
(10)- Sewer Pipe
(11)- Effluent Collection Reservoir

(12)- Submersible Pump
(13)- Bypass
(14)- Gate Valve
(15)- Collector
(16)- Pressure Gauge
(17)- Sand Filter
(18)- Disc Filter
(19)- Screen Filter
(20)- Flow meter

Treatment No.1
Treatment No.2
Treatment No.3

Fig. 1 An overview of fish farm and layout of the studied filtration system

Table 1. Means ± standard deviations of the parameters measured for the inlet water and the effluents collected from the fish farm

Property	Parameters	Effluent
Physical	Total suspended solids (mg l^{-1})	10.99 ± 0.21
	pH	7.68 ± 0.12
	Total dissolved solids (mg l^{-1})	384.00 ± 5.29
	Electrical conductivity (dS m^{-1})	0.60 ± 0.02
Chemical	Sodium adsorption rate (meq $l^{-1})^{0.5}$	0.63 ± 0.05
	Total hardness (mg l^{-1})	248.00 ± 7.55
	Na (meq l^{-1})	1.00 ± 0.05
	Ca (meq l^{-1})	4.80 ± 0.13
	Mg (meq l^{-1})	0.16 ± 0.02

			NO$_3$ (mg l^{-1})		0.57 ± 0.05			
			HCO$_3$ (meq l^{-1})		5.20 ± 0.36			
Biological			Number of heterotrophic bacteria (per mL)		2363.60 ± 663.18			

Table 2. Specifications of disc filter, conventional screen filter, and automatic screen filter used in this study

Filter type and model	External dimension (mm)		Grain size (mm)/Filtration Level (μm)	Maximum flow rate (m^3 h^{-1})	Inlet and outlet diameter (mm)	Initial head loss (kPa)	Filtration cross section (cm^2)	Manufacturer
	Diameter	Height						
Sand filter	400	1000	First Layer: 2-3.5 Second Layer: 0.8-1.2 Third Layer: 2-3.5	7.2	50	3.92	1300	Karaj Sazeh Equipment Company-Karaj-Iran
Disc filter	310	595	120	30.0	50	2.65	1198	Azud Company-Murcia -Spain
Screen filter	165	750	125 & 149	18.0	50	3.24	1570 & 2220	Abanegan Company-Karaj-Iran

2.3. Experimental procedures

All experiments were replicated three times under the same conditions. The disc and conventional screen filters were tested at the working pressures of 150 and 300 kPa, and the automatic screen filter at 200 and 300 kPa (Table 3). The discharge of the conventional screen filter at the beginning of the experiment was 12 m^3 h^{-1}, and that of the disc filter and the automatic screen filter were 30 m^3 h^{-1}. The inlet and outlet pressures of the filters were recorded every 5 min, and the experiments continued until the backwashing was reached but if this time was less than 1 h, the experiments would continue for up to 1 h. Disc and conventional screen filters were backwashed only after 1 h of operation, whatever the head loss was more than allowed head loss. However, automatic screen filters were programmed to carry out a

backwashing once the initial head loss increased by 40 kPa. During the experiment, the changes in the filters' discharge were measured using a flow meter (±0.2-0.5 % accuracy). Also, samples of effluent from the filters' outlet were taken three times (beginning, when backwashing was required and 1 h) in each one of the three replications. To measure the suspended solids of samples, ASTM standard (ASTM D5907-13, 2013) and Whatman filter paper, Grade 934-AH were used.

Table 3. Specifications of the experiments on the disc, conventional screen, and automatic screen filters

Treatment	Working pressure (kPa)	Working flow rate (m^3 h^{-1})	Allowed head loss above the initial one (kPa)	Code
Disc	300	30	70	D300
	150	30	70	D150
Conventional screen	300	12	50	S300
	150	12	50	S150
Automatic screen	300	30	40	A.S300
	200	30	40	A.S200

2.4. Evaluation indices

❖ **Filtration volume per filter cross-section unit until backwashing was neeed (V_B)**

Due to the different cross-section of the filters, the filtered volume per cross-section unit of the filter until backwashing was needed V_B (m^3 m^{-2}) was calculated using Equation 1:

$$V_B = \frac{V_1}{A} \tag{1}$$

where V_1 is the volume of water passing through the filter until the filter had to be backwashed (m^3), and A is the filtration cross-section (m^2).

❖ **Filtration volume per filtration cross-section unit and head loss unit (V_{10})**

The head loss of the filters varied depending on the filtered volume. Thus, to compare the volumes of water passing through the filters, these volumes were computed regarding the filtration cross-section and a fixed head loss (10 kPa) using Equation 2:

$$V_{10} = \frac{V_2 \times 10}{\Delta H \times A}$$ (2)

where V_{10} is the filtration volume per filter cross-section unit and head loss of 10 kPa (m^3 m^{-2} $(10\ kPa)^{-1}$), V_2 is the volume of water passing through the filter during 1 h of operation (m^3), and ΔH is the filter's head loss during the operation time (kPa).

❖ **Filtration efficiency**

For measuring the filtration efficiency, $E_{Filtration}$(%), equation 3 was used:

$$E_{Filtration} = \frac{TSS_{in} - TSS_{out}}{TSS_{in}} \times 100$$ (3)

where TSS_{in} is the total suspended solid concentration in inlet effluent to the filter (mg l^{-1}), and TSS_{out} is the total suspended solid concentration in outlet effluent from the filter (mg l^{-1}).

❖ **Mass retention of the filter (q)**

Filtration efficiency of filters varies with their discharge. Therefore, in order to compare the filtration efficiency, it was necessary to calculate the amount of effluent retained mass per unit cross-section of the filter, which is called the mass retention of the filter (g min^{-1} m^{-2}).

$$q = \frac{(TSS_{in} - TSS_{out}) \times Q \times 0.06}{A}$$ (4)

In this equation, Q is the filter's average discharge during the experiment (l s^{-1}).

2.5. Statistical treatment

Data analysis was performed using SPSS software (Ver. 26, IBM, Armonk, NY, USA) and the comparison of means was analyzed using one-way analysis of variance and Duncan test, at 95% and 99% confidence levels.

3. Results and discussion

3.1. Decrease in filters' discharge

Figure 2 shows the decrease in the discharge of each of the filters over the 1 h operation time. The reduction of the filter discharge depended on filter head loss and the changes in the inlet filter working pressure. The maximum discharge reduction at an equal working pressure was observed with the disc filter, which had the highest head loss (233 and 190 kPa) after 1 h of operation. Also, for each filter, the maximum discharge reduction was related to the lower working pressure (150 kPa) due to faster formation of filtration cake. The automatic screen filter worked differently from the other filters. The discharge through this filter was constant during operation time since filtration operation was not interrupted during backwashing. However, during backwashing, its discharge was reduced to the equivalent of backwash discharge.
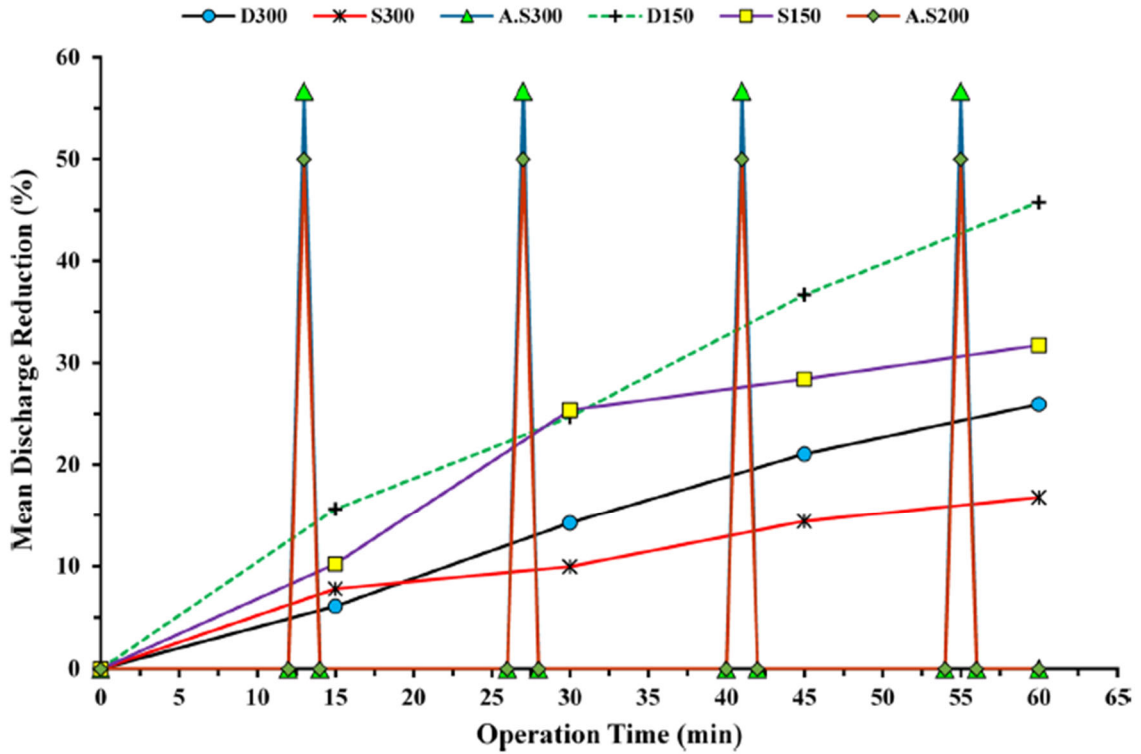
Fig. 2 Discharge reduction of the disc (D), conventional screen (S), and automatic screen (A.S) filters at different operation pressures (150, 200 and 300 kPa) within 1 h of operation.

3.2. Head loss of the filters according to the filtered volume

The initial head loss both disc and conventional screen filters at both working pressures was 40 kPa, while for the automatic screen filter was 5 kPa. The manufacturing companies have reported an initial head loss of 2.65, 3.24, and 1.47 kPa, respectively, with freshwater (Table 2). Thus, when trout fish farm effluent was used, the initial head loss was 15.1, 12.3, and 3.4 times, respectively, than that observed with freshwater. However, according to Bucks et al. (1979) since effluent TSS was below 50 mg l^{-1}, it posed a minor physical risk of emitter clogging. Suspended solids in the effluent of this fish farm are mainly organic (Manbari et al., 2020), and their density is usually between 1.03 to 1.19 g cm^{-3} (Tchobanoglous and Schroeder 1985; Chen et al. 1993; Anon 1995; Patterson et al. 2003).

Figure 3 shows the filtered effluent volume versus the head loss in 1 h of filters' operation. The performance of the automatic screen filter was the same at both working pressures. After reaching a head loss of 40 kPa (over the filter initial head loss) once 6 m^3 were filtered, the automatic screen filter carried out a backwashing. The peak points on Figure 3 indicate the number of automatic backwashings in 1 h. In the other two filters, the evolution of head loss versus the filtered volume was almost linear. Adin and Alon (1986), when using freshwater with different suspended solid loads and constant discharge, concluded that with increasing the concentration of suspended solids, the slope of the head loss regarding filtered volume became steeper. The slopes of the regression equations (Fig. 3) show the amount of head loss per volume unit. For both filters, the filtered volume during 1 h at the working pressure of 300 kPa was about 12 to 15% higher than that observed at 150 kPa (Table 4). The reason was that, since most of the solids in trout fish farm effluent were organic (Manbari et al., 2020), they were deformed as pressure increases and can pass through the filter (Adin and Alon, 1986; Puig-Bargués et al., 2005). In the conventional screen filter, the increase in the filtered volume led to a 9% increase in head loss, which decreased up to 22% in the disc filter. This difference was due to the different performance of both filters and also to the nature of the organic matter in the effluent. In the disc filter, in addition to the surface of the discs, the suspended solids were also trapped inside the grooves of the discs, and an increase in working pressure caused the suspended solids to pass through the grooves and reduce head loss. In the screen filter, the suspended solids are trapped only on the screen surface.

The filtered volume per filtration cross-section of the disc filter was more than three times that of a conventional screen filter, which corresponds to their initial discharge rates (Table 4). At pressures of 300 kPa and 150 kPa, this higher filtered volume increased the head loss by 22% and 71%, respectively, compared to the conventional screen filter (Table 4). Figure 4 shows the average filtered volume per unit of filtration cross-section for a head loss of 10 kPa

(V_{10}). For both screen filters, V_{10} did not change with the increasing of working pressure, but in the disc filter it significantly increased ($P<0.05$) by almost 50% at 300 kPa inlet pressure. At both working pressures, V_{10} for the disc filter was significantly ($P<0.05$) larger than that for the other two filters. This increase in volume compared to the conventional screen filter at low working pressure (150 kPa) was about 80%, while at high working pressure (300 kPa) was 161%. For the automatic screen filter, these ratios varied from 18% to 75%. The value of V_{10} in the automatic screen filter was 27% larger than that for the conventional screen filter, being their difference significant ($P< 0.05$). When using municipal effluent at inlet pressures between 200 and 400 kPa, the disc filter worked similarly but the performance of the conventional screen filter has been reported to be either increasing or decreasing (Duran-Ros et al. 2014).
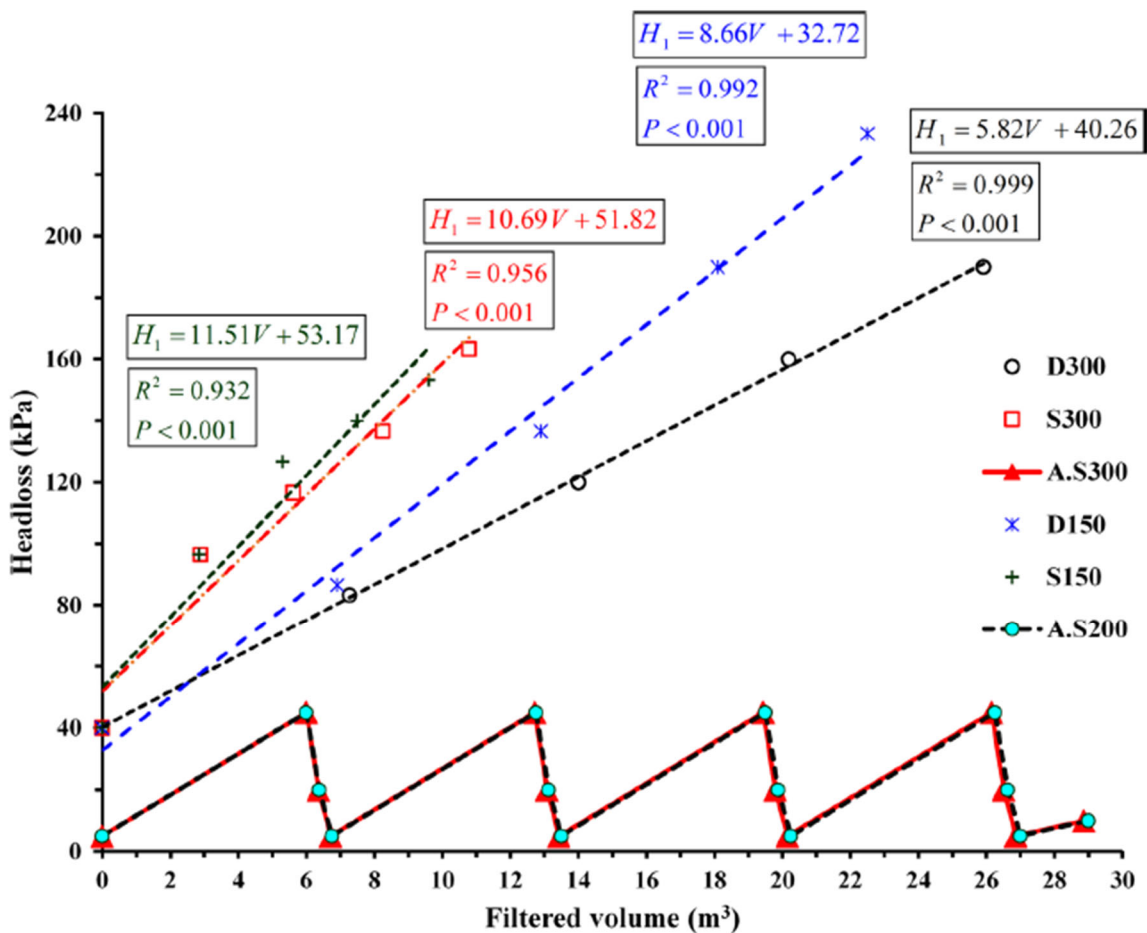
Fig. 3 Head loss of the disc (D), conventional screen (S) and automatic screen (A.S) filters at different working pressures (150, 200 and 300 kPa) per volume of effluent passing through them.

Table 4. Filtered volume and head loss of the disc, conventional screen and automatic screen filters at different working pressures, during one

Filter type	Working pressure (kPa)	Filtered volume (m³)	Filtered volume per unit cross-section area (m³ (m⁻²)	Volume *ratio	Head loss (kPa)	Head loss ratio
Automatic screen filer (A.S)	300	28.87	134.00	1.00	**40.00	1.00
	150	29.00	134.60		**40.00	
Disc filter	300	25.92	216.40	1.15	150.00	0.78
	150	22.51	187.90		193.33	
Screen filter	300	10.78	68.70	1.12	123.33	1.09
	150	9.60	61.20		113.33	
Disc-to-sreen filter ratio	300	2.40	31.50	-	1.22	-
	150	2.35	30.70		1.71	

* Filtered volume ratio from working pressure 300 kPa to 150 kPa; **for the filtered effluent volume 6 m³
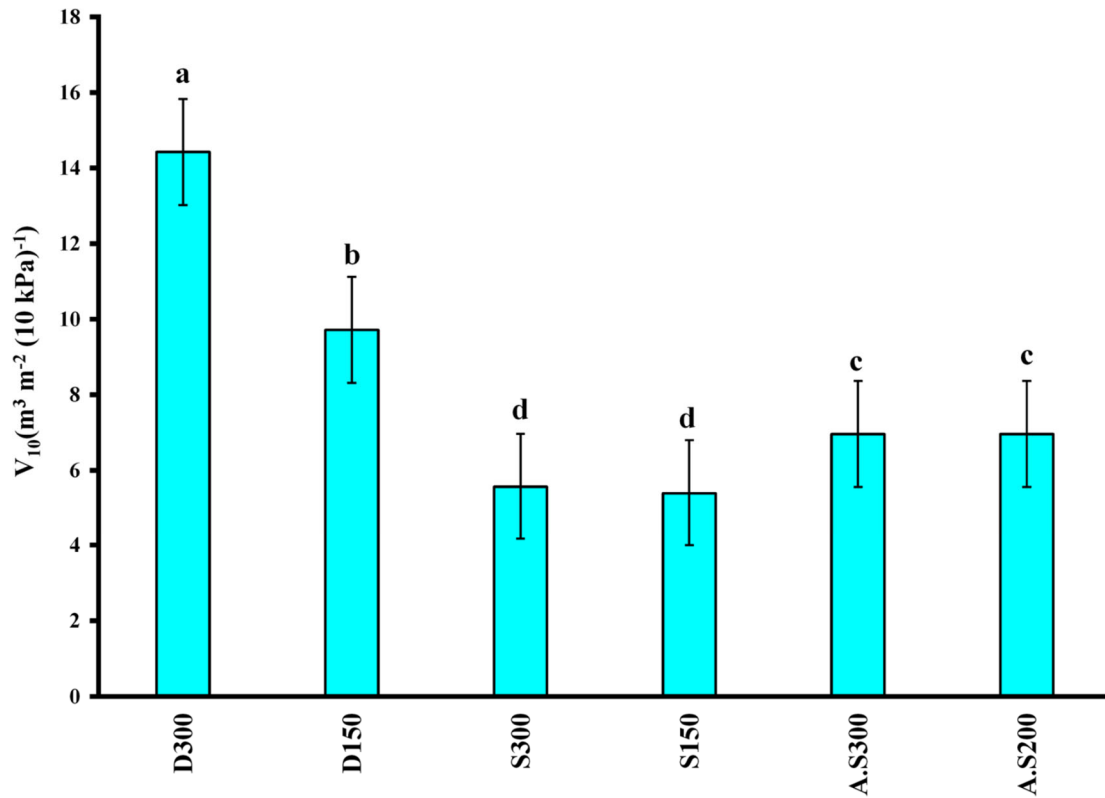
Fig. 4 Average volume ± standard error bars of filtered volume (V_{10}) through the disc, conventional screen, and automatic screen filters at different working pressures per unit of filtration cross-section for a head loss of 10 kPa without including the initial head loss. Columns having at least one letter in common, are not significantly different at 5% level.

3.3. Operating time and filtered volume until backwashing

Figure 5 shows the operating time of the filters until they needed backwashing since filter head loss was 70 kPa (disc filter), 50 kPa (conventional screen filter) and 40 kPa (automatic screen filter) above the initial. The working time of both disc and conventional screen filters at a pressure of 300 kPa was longer than that for 150 kPa. This difference was about 5 min for the disc filter and less than 2 min for the conventional screen filter, which has also been reported in the use of treated municipal wastewater (Puig-Bargués et al., 2005). The duration of the time a filter operates is dependent on the water quality and the type of filter, and when using low-quality municipal wastewater, the filters have a shorter operating time (El-Tantawy et al., 2009; Capra and Scicolone, 2004, 2005, 2007). The disc filter worked longer than the other two filters

at both working pressures, and there were few differences between the operating time of the conventional and automatic screen filters. Capra and Scicolone (2001) reported that the operating time of the screen filter in the use of non-diluted municipal wastewater to reach the backwash was much shorter than that of the disc filter, and in the use of diluted wastewater, both the disc and screen filters had a similar operating time. Also, Puig-Bargués et al. (2005) argued that in the use of a more loaded effluent from a meat industry, the disc filter needed backwashing earlier than the screen filter. These performance differences may be due to the type of suspended solids in the effluent. In general, the operating time of these filters up to the backwash stage is very short and unacceptable in terms of operation. Kumar et al. (2017) also reported that an increase in the inlet working pressure from 250 to 400 kPa significantly diminished the number of backwashes required for disc and screen filters.
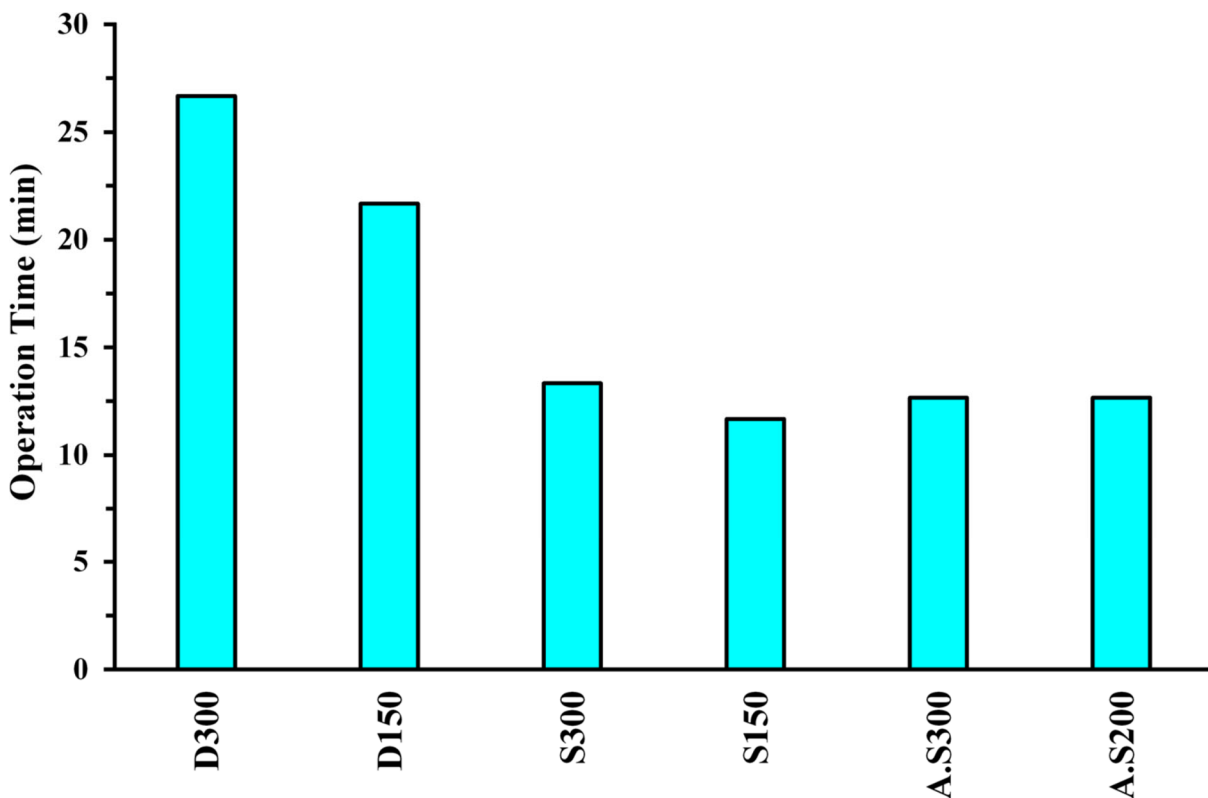
Fig. 5 Average operation time of disc (D), conventional screen (S), and automatic screen filters (A.S) at different working pressures (150, 200 and 300 kPa) until a backwashing was needed.

Figure 6 indicates the filtered volume of effluent passing per filter cross-section (V_B). In the disc filter, with higher working pressure, the volume increase was significant (P<0.01). In the screen filters, there was no significant difference in the volumes at either working pressure. V_B for disc filter was in the range of 2.7 to 3.5 times as much as the automatic screen filter and 5.3 to 6.1 times as much as the conventional screen filter, being these differences significant (P<0.01). V_B for the automatic screen filter was twice that for the conventional screen filter, but there were not significant (P>0.01) differences between both.
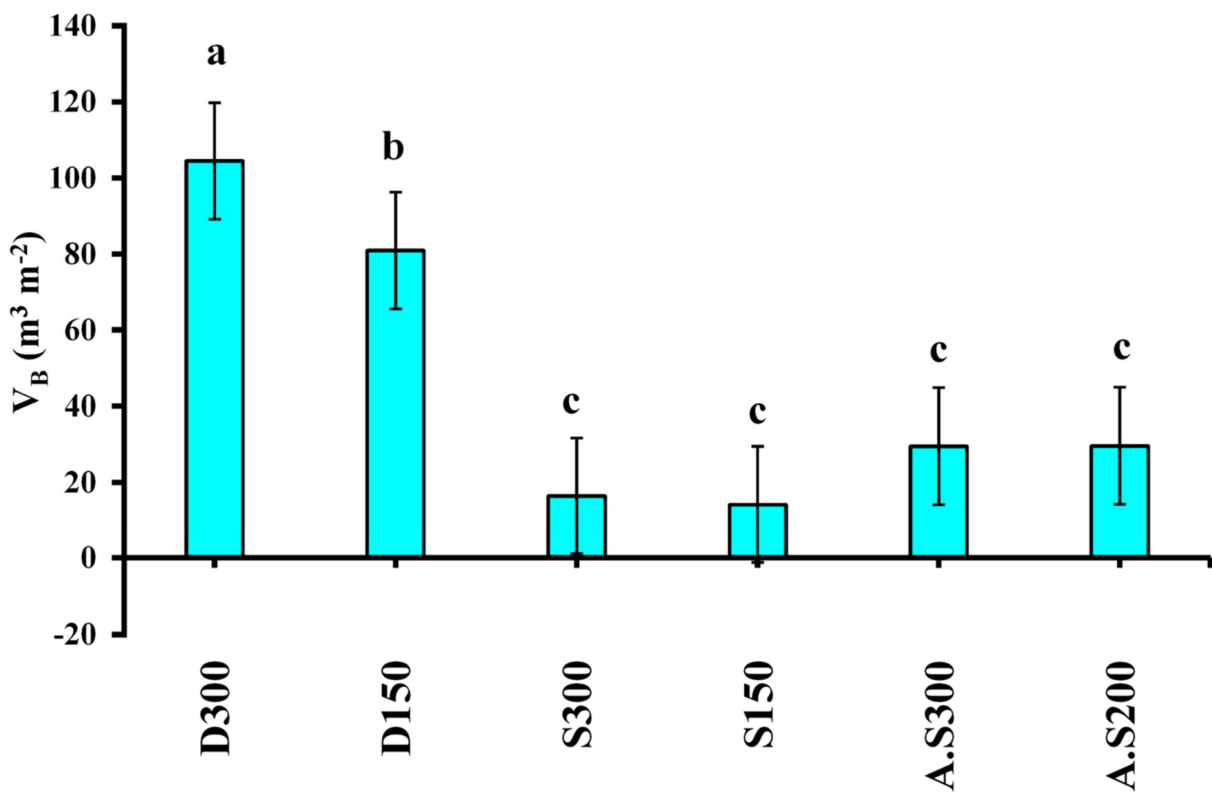
Fig. 6 Average filtered effluent volume per unit cross-section of filtration (V_B) ± standard error bars for disc (D), conventional screen (S), and automatic screen (A.S) filters until backwashing at working pressures (150, 200 and 300 kPa). Columns having at least one letter in common are not significantly different at 1% level.

3.4. Mass retention in the filters (q)

Filtration efficiency regarding total suspended solids (Fig. 7) was -5% to 78%. Negative values, showing an increase in TSS at filter outlet, were observed for the automatic screen filter at 300 kPa during backwashing. The automatic screen filter did not interrupt the filtration operation during backwashing and, therefore, its efficiency dropped considerably. This efficiency reduction may be attributed to the mixing of the suspended solids released during backwashing with those of the filtered effluent, which has been reported by some researchers (Adin and Alon, 1986; Duran-Ros et al., 2008, 2009a, 2009b; Puig-Bargués et al. 2005). For the automatic screen filter, suspended solid concentrations in the backwash output at 300 kPa and 200 kPa were 28.2 mg l^{-1} and 34.6 mg l^{-1}, respectively. A higher concentration of TSS on backwashing water at a working pressure of 200 kPa than at a pressure of 300 kPa implies a higher filtration efficiency at this working pressure.

Figure 8 shows that the mass retention of the filters tended to increase at lower working pressures. For the disc and automatic screen filters, this increase was only significant until backwashing was needed (P <0.01). Conversely, mass retention for conventional screen filter did not show any significant differences regarding pressure. Some researchers reported that using treated municipal wastewater, an increase in working pressure does not lead to any changes in the performance of disc and screen filters (Ravina et al. 1997; Duran-Ros et al. 2009a; Kumar et al. 2017) but Duran-Ros et al. (2014) found higher turbidity reduction in disc and screen filters at higher working pressures.

In conventional screen and disc filters, q increased over time at both working pressures due to the filtration cake. In disc filter, this increase remained significant (P<0.01) after one hour of operation (P <0.01) but was not significant under the other operating conditions (Fig. 8). Puig-Bargués et al. (2005) reported a similar observation for the screen filters in the use of treated municipal wastewater. The maximum value of q relates to the disc filter, which shows a significant difference (P<0.01) in performance compared to the conventional and automatic

screen filters. The q value for both conventional and automatic screen filters was similar (Fig. 9). Some researchers have suggested the use of disc filter for low-quality effluents from wastewater treatment plants and screen filter for diluted effluents (Capra and Scicolone, 2004, 2005, 2007) but, conversely, others did not report noticeable differences of either filter when using urban effluents (Puig-Bargués et al. 2005). Using urban tertiary effluents, Duran-Ros et al. (2009b) found that the best water distribution uniformity was obtained by the emitters protected by a screen filter (83%), while disc filter achieved lower values (59%). Some researchers have also reported that screen and disc filters do not play a pivotal role in removing suspended solids from wastewater (Adin 1987; Adin and Elimelech 1989; Puig-Bargués et al., 2005; Taylor et al., 1995; Ravina et al. 1997; Ribeiro et al. 2008; Duran-Ros et al. 2009a, 2009b). The maximum q value at the working pressure of 150 kPa, and after one hour of operation was 32.7 g min^{-1} m^{-2} for disc filter, and the minimum q value reported for the automatic screen filter at the pressure of 300 kPa and during the backwash time was -1.4 g min^{-1} m^{-2}. Overall, the q values for the disc, conventional, and automatic screen filters were 28.88, 9.11, and 7.72 g min^{-1} m^{-2}, respectively. Therefore, less emitter clogging in the drip irrigation systems using fish trout farm effluent can be expected with disc filter.
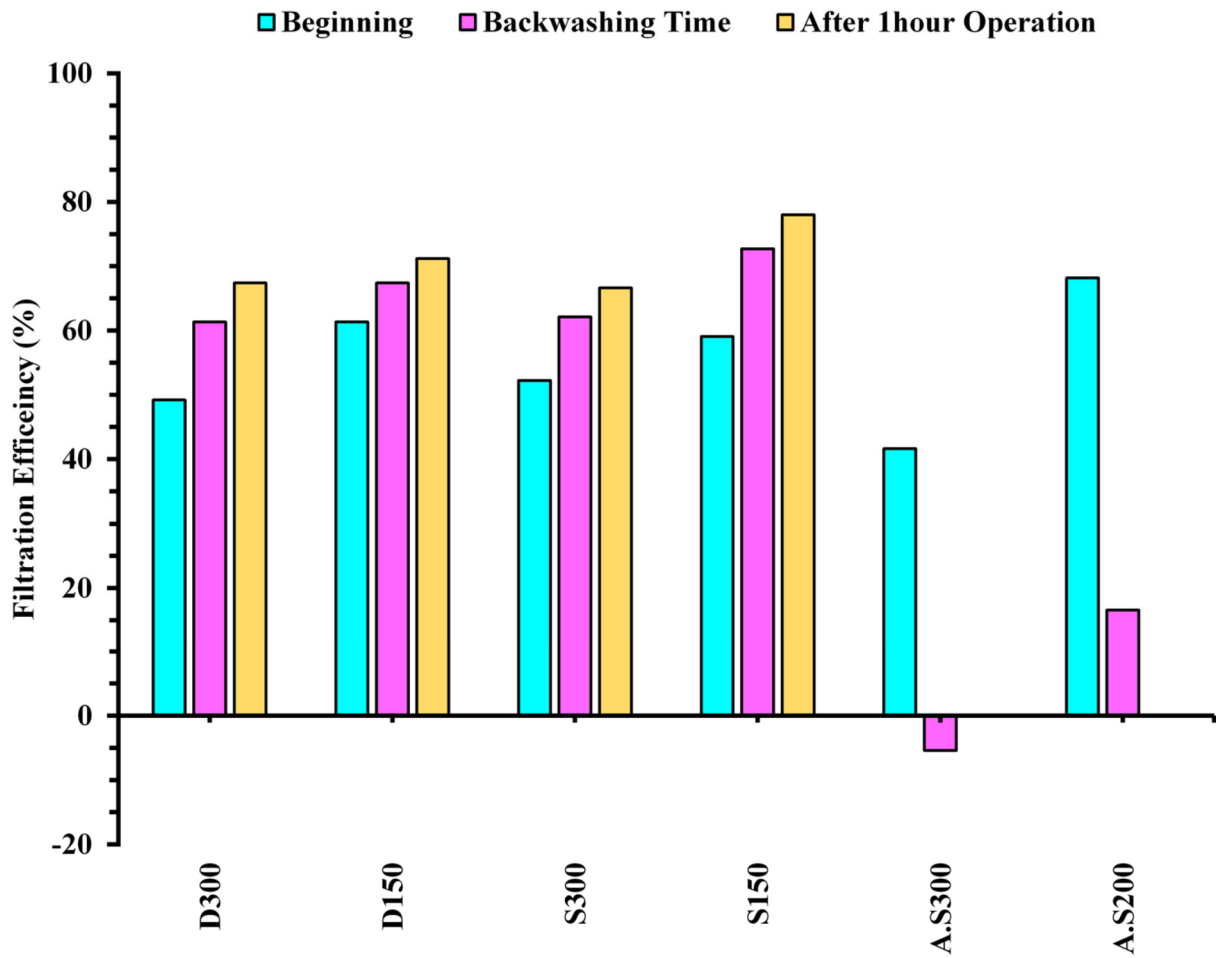
Fig. 7 Filtration efficiency of disc (D), conventional screen (S) and automatic screen (A.S) filters at different working pressures (150, 200 and 300 kPa) and times (beginning of the experiment, when backwashing was needed and after 1 h).
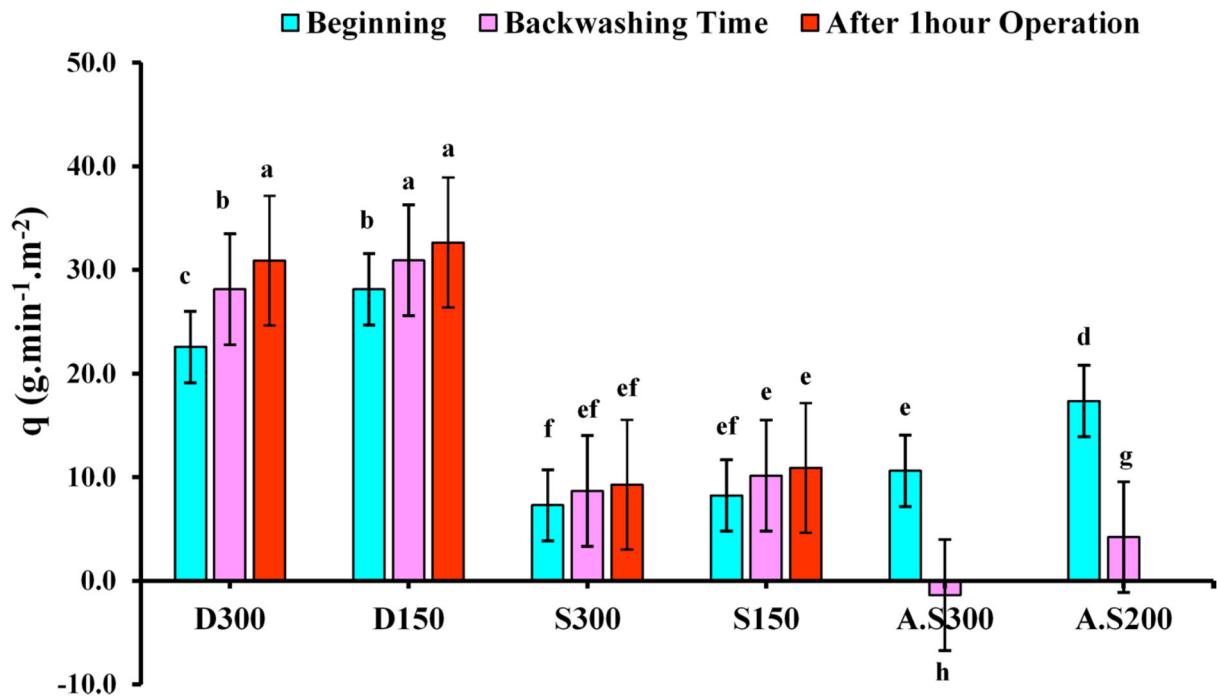
Fig. 8 Average mass retention (q) ± standard error bars for disc (D), conventional screen (S), and automatic screen (A.S) filters at different working pressures (150, 200 and 300 kPa). Columns having at least one letter in common were not significant at 1% level.
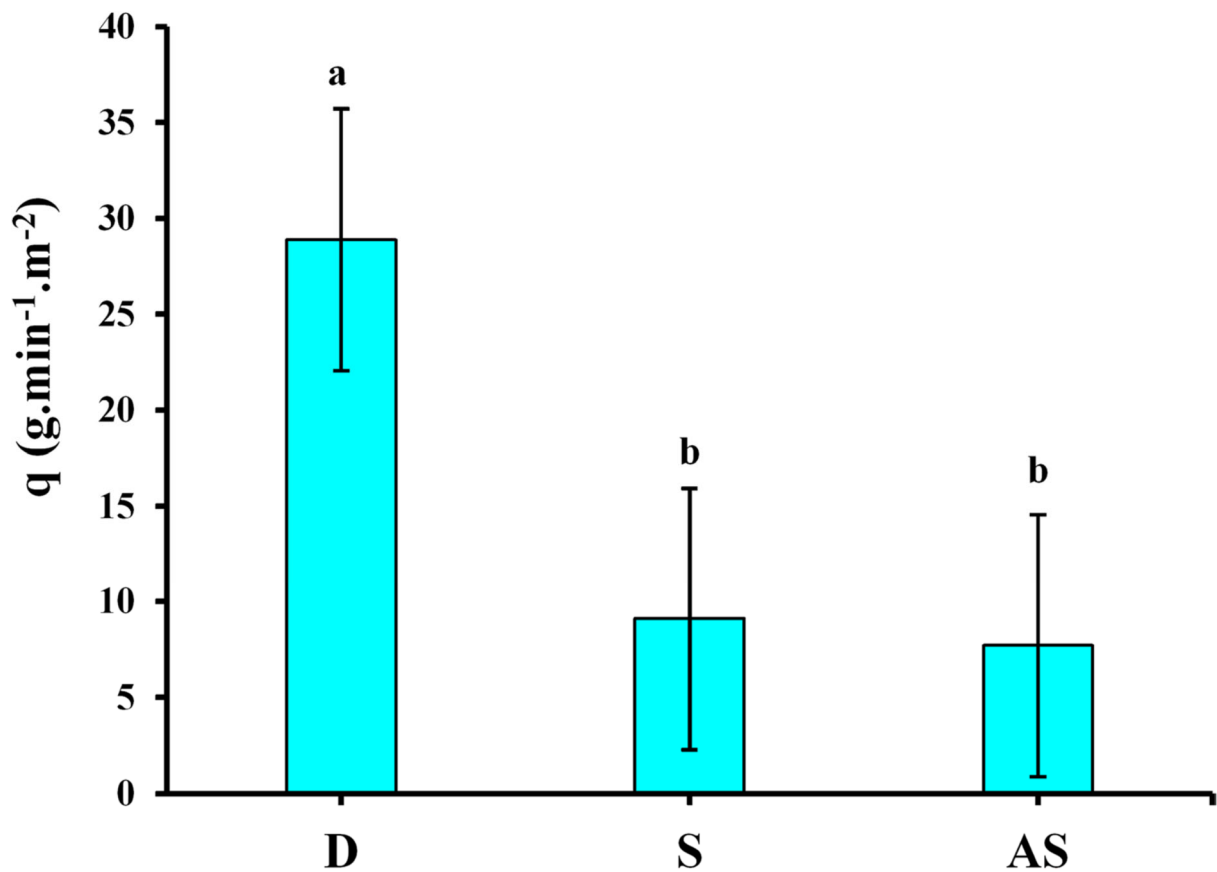
Fig. 9 Average mass retention (q) ± standard error bars for disc (D), screen (S), and automatic screen (A.S) filters for the unit cross section of filtration per minute. Columns having at least one letter in common are not significant at 1% level.

4. Conclusions

This study investigated the performances of the disc and screen filters at working pressures of 150 and 300 kPa and automatic screen filter at working pressures of 200 and 300 kPa in the treatment of rainbow trout fish effluent for an irrigation system. The initial head loss of the both disc and screen filters was found to be 40 kPa, and that for the automatic screen filter was 5 kPa.

Disc filter

The discharge through the disc filter decreased linearly over time. With an increase in the working pressure from 150 to 300 kPa, the filter discharge decreased from 46% to 26% during 1 h operation time. Thus, with an increase in working pressure, V_{10} significantly (P<0.05) increased by 50% from 9.7 to 14.5 m^3 m^{-2} (10 kPa)$^{-1}$ during 1-hour operation. Moreover, changing the working pressure from 150 to 300 kPa, significantly (P<0.01) increased V_B by 29% from 80.9 to 104.4 m^3 m^{-2}. The time of filter operation to reach backwashing was also increased from 22 to 27 min. However, the working pressure increase caused mass retention to decrease at the beginning of the experiment, backwashing time, and after 1-hour operation from 28.1, 30.9, and 32.7 to 22.6, 28.1, and 30.9 g min^{-1} m^{-2}. These reductions were only significant (P<0.01) for the beginning (18%) and at backwashing (10%). Over time. q value significantly (P<0.01) increased, except between backwashing time and one hour of operation at low working pressure.

Conventional screen filter

The discharge also decreased linearly over time with the conventional screen filter. Increasing the working pressure reduced the discharge reduction of the filter from 32% to 17%. For this filter, at both working pressures, V_{10} was 5.5 m^3 m^{-2} (10kPa)$^{-1}$, but although V_B increased from 1.41 to 16.4 m^3 m^{-2}, this increase was not significant (P<0.01). The average time to reach the backwash was 12 min. An increase in the working pressure caused q to decrease at the beginning of the experiment, backwashing time, and after 1 h operation from 8.3, 10.2, and 10.9 to 7.3, 8.7, and 9.3 g min^{-1} m^{-2}, without significant (P<0.01) differences. Although q increased over time, this increase was only significant (P<0.01) between the beginning of the experiment and after 1 h of operation.

Automatic screen filter

The performance of the automatic screen filter at both working pressures was similar. After 13 min and reaching a head loss of 40 kPa (over the filter initial head loss) and a filtered volume of 6 m^3, the backwashing was performed for 2 min, which means that 4 backwashing were carried in 1 h. The outlet discharge was constant, and only during backwashing, it was decreased as low as backwash discharge, which was 50% to 60%. The V_{10} and V_B were 7.0 m^3 m^{-2} (10kPa)$^{-1}$ and 29.5 m^3 m^{-2}, respectively. Also, an increase in the filter's working pressure, the values for q at the beginning of the experiment, and during backwashing decreased from 17.4 and 4.2 to 10.6 and -1.4 g min^{-1} m^{-2}, which was significant (P<0.01).

Comparison of filters' performances

The V_{10} for the disc filter was about 80% and 159% higher than the conventional screen filter and 39% and 107% higher than the automatic screen filter, at low working pressure and high working pressure, respectively, being the difference significant (P<0.05) in all cases. The

values of V_B for the disc filter were also significantly (P<0.01) higher by 474% than conventional screen filter at low working pressure and by 537% at high working pressure, and also by 173% and 254% than the automatic screen filter, respectively. For the automatic screen filter, in comparison to the conventional screen filter, V_{10} was significantly (P<0.05) higher by 27% and V_B was also significantly (P<0.01) higher by 110% at low working pressure and by 80% at high working pressure. The values for q were significantly higher (P<0.01) for the disc filter than the conventional screen filter between the beginning of the experiment and 1 h operation at 150 kPa, increasing by 200 to 250% and at 300 kPa, by 211 to 244%. Disc filter also showed significant (P<0.01) higher q values compared to the automatic screen filter at the beginning of the experiment, at low working pressure by 65%, and at high working pressure by 109%. The q values for the automatic screen filter at the beginning of the experiment was significantly (P<0.01) higher than the conventional screen filter at low working pressure by 113% and at high working pressure by 57%.

Overall, the best performance observed relates to the disc filter, followed by the conventional and automatic screen filter, respectively. However, it should be pointed out the short operating time of the filters until backwashing, which was less than half an hour, and the improper performance of the automatic screen filter while backwashing. Further research is needed to enlarge filtration cycles and improve backwashing performance.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Conceptualization: [Saman Nikmehr, Eisa Maroufpoor]; Methodology: [Abed Mohammad Hasani, Eisa Maroufpoor]; Formal analysis and investigation: [Abed Mohammad Hasani, Younes Aminpour]; Writing - original draft preparation: [Abed Mohammad Hasani, Eisa Maroufpoor, Younes Aminpour]; Writing - review and editing: [Eisa Maroufpoor, Jaume Puig-Bargués]; Funding acquisition: [Eisa Maroufpoor]; Resources: [Abed Mohammad Hasani]; Supervision: [Eisa Maroufpoor, Saman Nikmehr].

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