Performance of sand filter with disc and screen filters in irrigation with rainbow trout fish effluent[1]

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Abstract

Drip irrigation is the most suitable system for reusing effluents in agriculture, but emitter clogging is still its major drawback. Adequate filtration is needed to prevent emitter clogging, but little information is available about the performance of different filter types when using fish farm effluent. The purpose of this study was to evaluate the performance of three filtration treatments for rainbow trout effluent in drip irrigation systems: 1-sand filter (T1), 2-sand filter followed by a disc filter (T2), and 3-sand filter

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[1] Performance du filtre à sable avec des filtres à disque et à crible dans l'irrigation avec les effluents de truite arc-en-ciel

followed by a screen filter (T3). The treatments were tested with a constant discharge of 14.4 m^3/h at two working pressures of 300 and 150 kPa until reaching the backwashing threshold. For each filter, the following were computed: filtered volume per cross-section until reaching the backwashing threshold (V_B); filtered volume per cross-section unit and head loss (V_{10}), suspended solid removal efficiency (E_F); and filter mass retention (q). T2 at 300 kPa had a significantly ($P<0.01$) higher V_B, whereas T1 and T3 only showed a V_B of 53 and 45% at 300 kPa and 48 and 47% at 150 kPa, respectively, higher than that obtained by T2. The results suggest that using a combination of sand and disc filters at an operation pressure of 300 kPa is the best option when using rainbow trout effluent.

Keywords: Drip irrigation, Filtration, Emitter clogging, Unconventional waters, Aquaculture.

Résumé

L'irrigation au goutte à goutte est le système le plus approprié pour réutiliser les effluents en agriculture, mais le colmatage des émetteurs reste son inconvénient majeur. Une filtration adéquate est nécessaire pour éviter le colmatage des émetteurs, mais peu d'informations sont disponibles sur le rendement des différents types de filtres lors de l'utilisation des effluents des fermes piscicoles. Le but de cette étude était d'évaluer la performance de trois traitements de filtration des effluents de truite arc-en-ciel dans des systèmes d'irrigation goutte-à-goutte: filtre à 1-sable (T1), filtre à 2-sable suivi d'un filtre à disque (T2) et filtre à 3-sable suivi d'un filtre à filtre (T3). Les traitements ont été testés avec une décharge constante de 14,4 m3/h à deux pressions de travail de 300 et 150 kPa jusqu'à atteindre le seuil de backwashing. Pour chaque filtre, on a calculé: Volume filtré par unité de section et perte de charge (V_{10}), efficacité de l'élimination des solides en suspension (EF_s); T2 à 300 kPa avait un V_B significativement plus élevé (P< 0,01), tandis que T1 et T3 montraient seulement un V_B de 53 et 45% à 300 kPa et 48 et 47% à 150 kPa, respectivement, plus élevé que celui obtenu par T2. Les résultats suggèrent que l'utilisation d'une combinaison de filtres à sable et à disques à une pression de fonctionnement de 300 kPa est la meilleure option lorsqu'on utilise des effluents de truite arc-en-ciel.

Mots-clés: irrigation au goutte à goutte, Filtration, colmatage des émetteurs, eaux non conventionnelles, Aquaculture.

1 Introduction

Reuse of treated wastewater is increasingly occurring in areas with water scarcity and increasing demand for irrigation water (Marinho et al., 2013; Weerasekara, 2017). In addition to conserving potable water resources, effluent reuse reduces costs (De Melo Ribeiro et al., 2019; Elnwishy et al., 2008) and provides nutrients for agriculture (Elnwishy et al., 2008).

The aquaculture industry needs a high volume of water in the production process and, therefore, yields a high amount of effluent (De Melo Ribeiro et al., 2019). Global fish consumption increased by an average annual rate of 3.1% from 1961 to 2017, which is almost double the annual growth of the world's population (1.6%) for the same period and is higher than the 2.1% yearly growth of other animal protein foods (FAO, 2020). Thus, integrating aquaculture with agricultural systems can be considered one of the ways to improve food security (Elnwishy et al., 2008). Rainbow trout is one of the major species produced in world aquaculture, achieving a production of 848100 tons in 2018 (FAO, 2020). A traditional flow-through system for trout will typically use approximately 30 m^3 of water per kg of fish produced per year (Klontz, 1991). Approximately 1.2 kg of feed is consumed per 1 kg of trout production, and since 52% of the feed will be released as solids in the effluent, it will produce 0.624 kg of total suspended solids (Klontz, 1991), which are mainly organic (Manbari et al., 2020). Thus, rainbow trout production provides a notable volume of effluent that has a high solid load. However, despite its many benefits, if effluent reuse is not correctly managed, it could be dangerous to human health and the environment due to the risk of pathogen and pollutant dissemination and accumulation (Becerra-Castro et al., 2015).

Drip irrigation is the most suitable irrigation system for the reuse of effluents in agriculture (Pandey et al., 2010; Li et al., 2015), but its main drawback is emitter clogging, which is exacerbated when effluents are used (Capra and Scicolone, 2007; Pandey et al., 2010; Maroufpoor et al., 2021).

Therefore, using a filtration system to remove suspended solids (Nieto et al., 2016; Wen-Yong et al., 2015) and thus preventing emitter clogging is required (Manbari et al., 2020; Nieto et al., 2016).

Sand, screen, and disc filters are the most common filters used in drip irrigation systems (Capra and Scicolone, 2005; Tripathi et al., 2014; Hasani et al., 2022). Sand filters are the most effective filters for preventing emitter clogging when effluents are used (Trooien and Hills, 2007; Solé-Torres et al., 2019) since they avoid both physical and biological clogging (Shortridge and Benham, 2018). Various mechanisms, including mechanical and chance contact straining, impaction, interception, adsorption, flocculation, and sedimentation, are involved in suspended solid removal by sand filters (Galvin, 1992). The type of mechanism and its degree of impact, in addition to the type and size of particles in the porous filter medium, also depends on the type of suspended solids. Moreover, the type and size of sand particles considerably affect the filter performance (Keller and Bliesner, 1990). The sand filter efficiency decreases with increasing sand particle diameter (Shortridge and Benham, 2018) and increasing pollutant load of the treated effluent (Nieto et al., 2016; Wen-Yong et al., 2015). Small particles can pass through the filter and be released during filter and backwashing operations (Elbana et al., 2012; De Souza et al., 2021). Sand particle size also has a key effect on sand filter head loss (Arbat et al., 2011; Mesquita et al., 2012). On the other hand, screen and disc filters retain particles mainly on their surface and, therefore, they are less effective than sand filters. They are, however, cheaper and easier to manage than sand filters (Capra and Sciolone, 2005).

The performance of sand, screen and disc filters in using all types of urban and industrial wastewater for irrigation has been extensively studied (Adin and Sacks, 1991; Puig-Bargués et al, 2005; El-Tantawy et al, 2009; Capra and Scicolone, 2007). However, to date, there has been very little research on the performance of these filters when using fish farm effluents. Since filter performance is greatly affected by the composition and type of particles of the effluent (Puig-Bargués et al., 2005), it is necessary to analyse their specific operation when using effluent from rainbow trout fish farms. In Iran, multilayer sand filters filled with silica sand are widely used for freshwater filtration for irrigation of fields since farmers are satisfied with their performance (Daee et al., 2019; Dashti et al., 2021). Manbari et al. (2020), using a common sand filter in Iran for irrigation with rainbow trout effluent, found that its performance was very poor, which was attributed to the sand particle size and the type of suspended solids in the fish effluent. With this in mind, Wen-Young et al. (2015) achieved increased removal efficiencies when a disc filter was placed after a sand filter. This could be a strategy that is worth investigating.

Therefore, the purpose of this study was to investigate the performance of a multilayer sand filter working alone or combined with disc and screen filters when using rainbow trout effluent. Moreover, the effect of inlet pressure on the performance of these filters was studied.

2 Materials and Methods

2.1 Experimental setup

The filtration system consisted of three treatments: 1- sand filter, 2- sand filter followed by a disc filter, and 3- sand filter followed by a screen filter. The inlet effluent to the filters was supplied from the Mostafavi rainbow trout (*Oncorhynchus mykiss*) farm (Sanandaj, Kurdistan, Iran). This farm had a single-pass raceway system so that the effluent of each pool, instead of being drained to other ponds, was conveyed to the field drain (Figure 1). The sand filter (400 mm external diameter, Karaj Sazeh Equipment Company, Karaj, Iran) with a maximum discharge of 7.2 $m^3\ h^{-1}$ had three sand layers. The sand size of the first and third layers was 2-3.5 mm, and that of the middle layer was 0.8-1.2 mm (Table 1). This sand filter arrangement is common in the area. Two sand filters were installed in parallel. Therefore, the maximum discharge of this treatment was 14.4 $m^3\ h^{-1}$. 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 screen filter (165 mm external diameter, Abanegan Company, Karaj, Iran) had a maximum discharge of 18 $m^3\ h^{-1}$ and had two cartridges, one internal and the other external. The internal cartridge had a filtration level of 125 μm, and the external cartridge had a filtration level of 149 μm. The external diameter of all three filters' inlet and outlet pipes was 50 mm. Some specifications of the filters from the manufacturer's catalogues are listed in Table 3.

A 2.3 kW submersible pump was used to pump water from the effluent collection pond into the filtration system. A gate valve was installed at each filter outlet to adjust the discharge. A bypass pipe was used to adjust the inlet pressure. At each filter inlet and outlet, a Bourdon pressure meter (±5 kPa accuracy) was installed. In addition, a flow meter (±0.2-0.5% accuracy) was used to measure the flow across each filter.

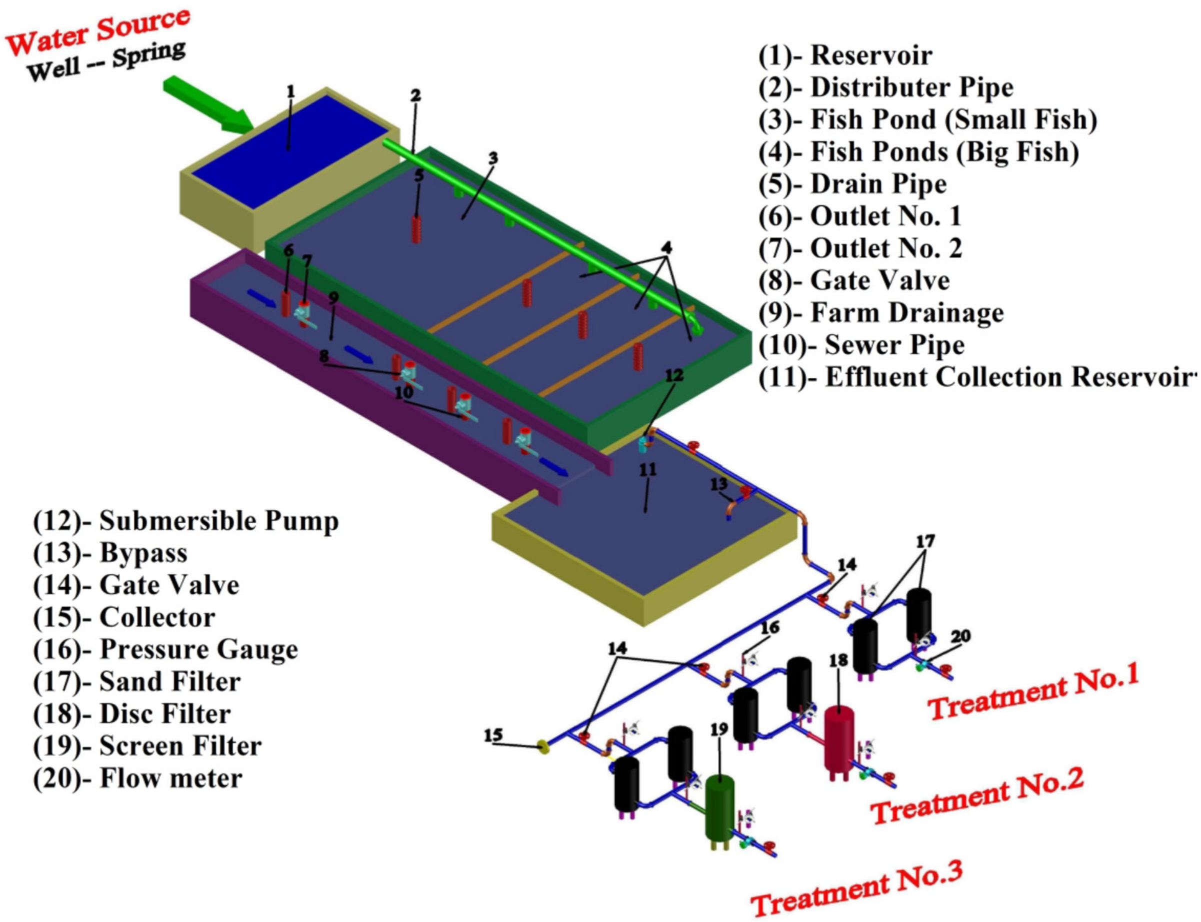

Figure 1. An overview of the fish farm and layout of the studied filtration system.

Table 1. Specifications of the sand filter, screen filter and disc 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

Table 2 shows some of the physical and chemical properties of the studied water and effluent. Samples were taken from effluent in three replications for three nonconsecutive days. The parameters mentioned were measured following standard methods (Adams 2017; Rice et al. 2005).

Table 2. Means ± standard deviations of the parameters measured for the inlet water and the effluents collected from the fish farm.

Property	**Parameters**	**Effluent**	**Clogging risk (**Pitts et al. 1990; Ayers and Westcot 1994; Couture 2004**)**	
			Inlet Water	**Effluent**
Physical	Total suspended solid**s** (mg l^{-1})	10.99 ± 0.21	Minor	Minor
Chemical	pH	7.68 ± 0.12	Moderate	Moderate
	Total dissolved solids (mg l^{-1})	384.00 ± 5.29	Minor	Minor
	Electrical conductivity (dS m^{-1})	0.60 ± 0.02	n.c.	n.c.
	Sodium adsorption rate (meq l^{-1})$^{0.5}$	0.63 ± 0.05	n.c.	n.c.
	Total hardness (mg l^{-1})	248.00 ± 7.55	Moderate	Moderate
	Na (meq l^{-1})	1.00 ± 0.05	n.c.	n.c.
	Ca (meq l^{-1})	4.80 ± 0.13	n.c.	n.c.
	Mg (meq l^{-1})	0.16 ± 0.02	n.c.	n.c.
	NO_3 (mg l^{-1})	0.57 ± 0.05	n.c.	n.c.
	HCO_3 (meq l^{-1})	5.20 ± 0.36	n.c.	n.c.
Biological	Number of heterotrophic bacteria (per mL)	2363.60 ± 663.18	Minor	Minor

n.c. not classified

2.2 Experimental procedure

The treatments were tested at two working pressures (150 and 300 kPa) until backwashing was needed and in three replications (Table 3). In local irrigation projects, a pressure of 150 kPa is usually considered the minimum required pressure of the filtration system, and a pressure of 300 kPa is one of the most common pressures of the filtration systems since it is the pressure required for filter backwashing. According to the recommendations of sand filter manufacturers, a pressure of 100 to 250 kPa is required considering the filter flow and the sand particle size to ensure proper sand filter backwashing. In addition, 50 kPa was considered for system head losses at both pressures. The discharge of all treatments was 14.4 m^3 h^{-1}. Discharge and pressure changes of each treatment were recorded during the experiments. The time to reach the backwash step for all filters compared with the filter clean state was when the head loss reached 50 kPa. All inlet and outlet effluent samples from the filters were taken in three replications for each treatment. Moreover, samples of effluent from the filters' outlet were taken every hour during the filter operation in each of the three replications. The total suspended solids of the effluent at the filter inlet and outlet were determined following the ASTM standard (ASTM D5907-13, 2013).

Table 3. Specifications of the experiments on the sand, sand + disc, and sand + screen filters.

Treatment	Working pressure (kPa)	Working flow rate (m^3 h^{-1})	Allowed head loss above the initial one (kPa)	Code
Sand filter	300	14.4	50	T1 (300)
	150	14.4	50	T1 (150)
Sand filter+ Disc filter	300	14.4	50*	T2 (300)
	150	14.4	50*	T2 (150)
Sand filter + Screen filter	300	14.4	50*	T3 (300)
	150	14.4	50*	T3 (150)
Disc filter in T2	300	14.4	50	D300
	150	14.4	50	D150
Screen filter in T3	300	14.4	50	S300
	150	14.4	50	S150

*** When each of the filters reached a head loss of 50 kPa, above the initial head loss, the treatment was washed.**

2.3 Assessment of treatment performance

Four indicators, which are defined in Table 4, were used to evaluate and compare the studied treatments' performance.

Table 4. Evaluation indices for the assessment of filtration performance.

Evaluation indices	Equation	Parameters
Filtered volume per filter cross-section unit until backwashing (V_B)	$V_B = \frac{V_1}{A}$ $\quad (m^3\ m^{-2})$	**V_1 : volume of water passing through the filter until a backwashing was carried out (m^3)** **A : filters' filtration cross-section (m^2).** **ΔH : filter's head loss during its operation (kPa)** **TSS_{in} : total suspended solid concentration at filter inlet (mg l^{-1})** **TSS_{out} : total suspended solid concentration at filter outlet (mg l^{-1})** **Q : average filter flow rate during the experiment (l s^{-1})**
Filtered volume per filtration cross-section and head loss unit (V_{10})	$V_{10} = \frac{V_1 \times 10}{\Delta H \times A}$ $\quad \left(m^3 m^{-2} (10\ kPa)^{-1}\right)$	
Suspended solids removal efficiency (E_F)	$EF_s = \frac{TSS_{in} - TSS_{out}}{TSS_{in}} \times 100$ $\quad (\%)$	
Mass retention of the filter (q)	$q = \frac{(TSS_{in} - TSS_{out}) \times Q \times 0.06}{A}$ $\quad \left(g\ \min^{-1} m^{-2}\right)$	

2.4 Statistical treatment

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

3 Results and Discussion

3.1 Head loss and volume of water passing through the treatments

The initial head losses of T1, T2, and T3 at a pressure of 300 kPa were 10, 25 and 50 kPa, respectively, and those at 150 kPa were 40, 60, and 80 kPa (Table 5). The disc and screen filters had an initial head loss of 15 and 40 kPa at 300 kPa, respectively, and 20 and 40 kPa at 150 kPa. Therefore, the screen filter at both pressures had the highest initial head loss compared to the disc filter. Thus, at both pressures, the highest initial head loss was found with T3 and the lowest with T1, whose ratio was five at 300 kPa and two at 150 kPa. Moreover, the initial pressure loss of all treatments at the working pressure of 150 kPa was greater than that at 300 kPa. The highest increase was observed with T1 (4 times), and the lowest was observed with T3 (1.6 times). The initial head loss of the disc filter at 150 kPa was greater than the initial head loss at 300 kPa, but the initial head loss in the screen filter was the same at both pressures. Therefore, the lowest increase in the initial head loss was observed with T3. Hasani et al. (2022) reported that the initial head loss of disc and screen filters using rainbow trout effluent that worked independently was 40 kPa. In their research, farm fish effluent was directly conveyed to the filters, but the effluent was previously filtered through a sand filter in the present study. Therefore, when filters are fed with the sand filter effluent, the initial head loss of the disc filter is reduced by half or less, but the initial head loss of the screen filter remains constant. This is due to the difference in the geometric structure of these filters. In the screen filter, the suspended materials accumulate on the cartridge, but in the disc filter, in addition to the accumulation of solids on the body of the discs, they can also become stuck inside the grooves of the discs, and therefore, filter clogging is lower and head losses are smaller. High initial head loss requires higher working pressure and, consequently, higher energy consumption.

For both the T2 and T3 treatments, the disc and screen filters reached the maximum allowable head loss of 50 kPa faster than the sand filter. In addition, the screen filter had a head loss higher than the disc filter during its operation. Therefore, the longest operating time was related to T1 at both pressures, and the shortest was related to T3 (Table 5). Moreover, the head loss during filter operation was higher at 150 kPa than at 300 kPa, which was similar to what happened with the initial head loss. At 300 kPa, the organic particles may be compressed, and then friction is reduced as the cross section decreases. Therefore, the operating times of the treatments at 300 kPa were longer than those at 150 kPa. The longest working time was obtained with T1 at 300 kPa (21 h), and the shortest was obtained with T3 at 150 kPa (9 h). The head loss changes of the treatments at both working pressures (except for T3 at 300 kPa) had an almost uniform trend over time (Figure 2). Assuming an irrigation time of 7 to 10 h for each irrigation event, the allowable operating time of treatments T1 and T2 includes two to three irrigation events, while treatment T3 will have only one irrigation event, and then the filters will need to be backwashed. This operation time can be acceptable for T1 and T2 treatments but is too short for T3 treatment. Manbari et al. (2020) reported a minimal head loss in a sand filter (with 3-5 mm and 5-8 mm grain sizes) in the treatment of rainbow trout effluent. In the present study, however, the sand sizes were smaller (0.8-1.2 mm and 2-3.5 mm), and consequently, pressure loss and solid removal were higher, as has been previously reported (Duran-Ros et al., 2009).

The filtered volume of each filter per unit area (V_B) allows a better comparison of filter treatment performance before the backwashing step (Figure 3). In the T2 and T3 treatments, V_B was calculated per unit area of disc and screen filters since these were the limiting filters. The V_B values of the treatments were significantly different from each other ($P<0.01$). T2 had the highest $V_{B,}$ so its ratio to the T1 and T3 treatments at a pressure of 300 kPa was 1.9 and 2.2, respectively, and at a pressure of 150 kPa, it was 2.1 (Table 5). A high V_B reduces the frequency of filter backwashing, which is very important for the farmer. In addition, the V_B was significantly higher ($P<0.01$) for each treatment at 300 kPa than at 150 kPa. The highest increase was observed with T1 (30%), and the lowest increase was observed with T3 (10%). The higher V_B observed at 300 kPa is explained by the smaller head loss observed at this pressure and by longer filtration cycles, which caused an increased volume of water to be filtered.

For further investigation, the filtration volume of disc and screen filters per unit area per 10 kPa head loss was calculated (V_{10}). The V_{10} values for the disc filter at 300 kPa and 150 kPa were 402 and 342 m^3 $(m^2.10\ kPa)^{-1}$, respectively, and for the screen filter were 179 and 160 m^3 $(m^2.10\ kPa)^{-1}$ (Figure 4). Therefore, the V_{10} of the disc filter was approximately 2.1 to 2.3 times higher than that of the screen filter, which was a significant difference ($P<0.01$). Moreover, the effect of pressure on V_{10} was also significant ($P<0.01$), with V_{10} being greater with increasing pressure. Therefore, the maximum head loss per unit volume of filtration (1 m^3) from the unit area of filters (1 m^2) was observed with the screen filter. In addition to the physical and chemical characteristics of the effluent, the head loss of filters depends on the geometric features of the filter pores, including their diameter and shape, in addition to the specific characteristics of the media materials. Duran-Ros et al. (2014), using urban wastewater treatment plant effluents, reported that as the pressure increased, a 130-µm disc filter would treat a larger volume of water for a constant head loss.

Table 5. Operating time and volume of water passing through the treatments until reaching the backwash stage (head loss of 50 kPa).

Treatment	**Initial head loss (kPa)**				**Operation time (h)**	**Operation time ratio***	**Head loss (kPa)**				**V_B (m^3 m^{-2})**	**Volume ratio***
	Sand filter	**Disc filter**	**Screen filter**	**Treatment**			**Sand filter**	**Disc filter**	**Screen filter**	**Treatment**		
T_1 (300)	10	-	-	10	21	1.35	50	-	-	50	1067.8	1.3
T_1 (150)	40	-	-	40	15.5		50	-	-	50	812.7	
T_2 (300)	10	15	-	25	18	1.20	42	50	-	92	2007.8^a	1.2
T_2 (150)	40	20	-	60	15		47	50	-	97	1709.7^a	
T_3 (300)	10	-	40	50	10	1.11	25	-	50	75	895.4^b	1.1
T_3 (150)	40	-	40	80	9		35	-	50	85	802.0^b	

* Ratio from working pressure 300 kPa to 150 kPa, **a**: Per unit of disc filter cross-section; **b**: Per unit of screen filter cross-section

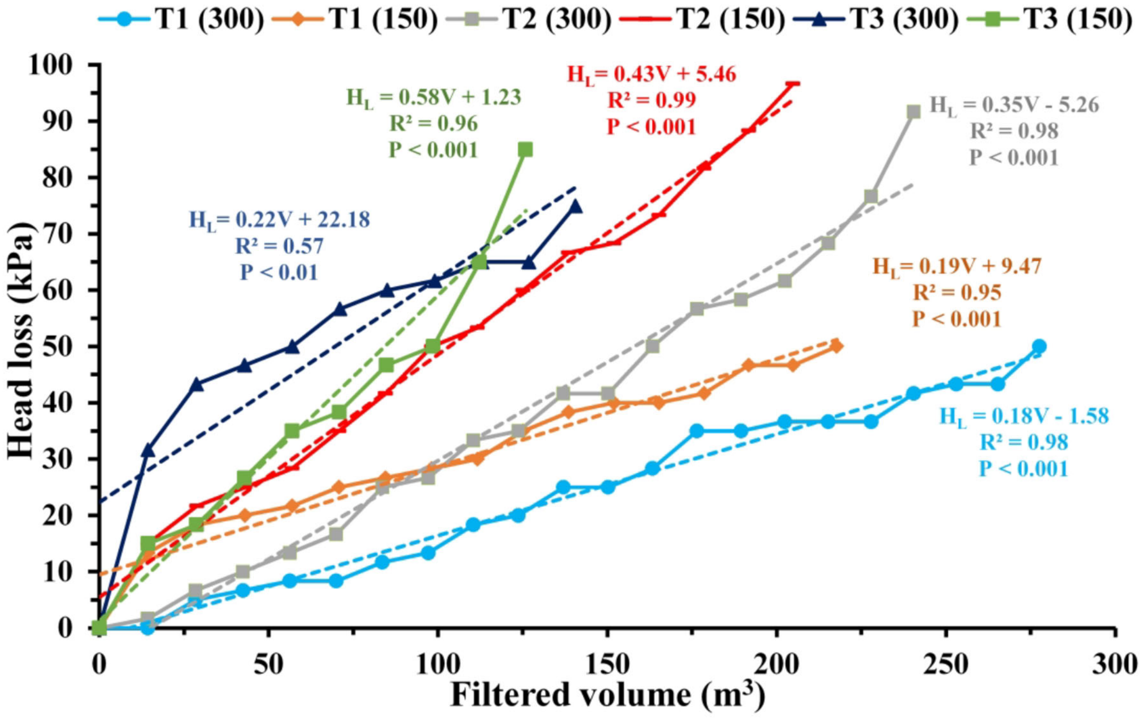

Figure 2. Head loss of the T1, T2, and T3 treatments at working pressures (150 and 300 kPa) per volume of effluent passing through them.

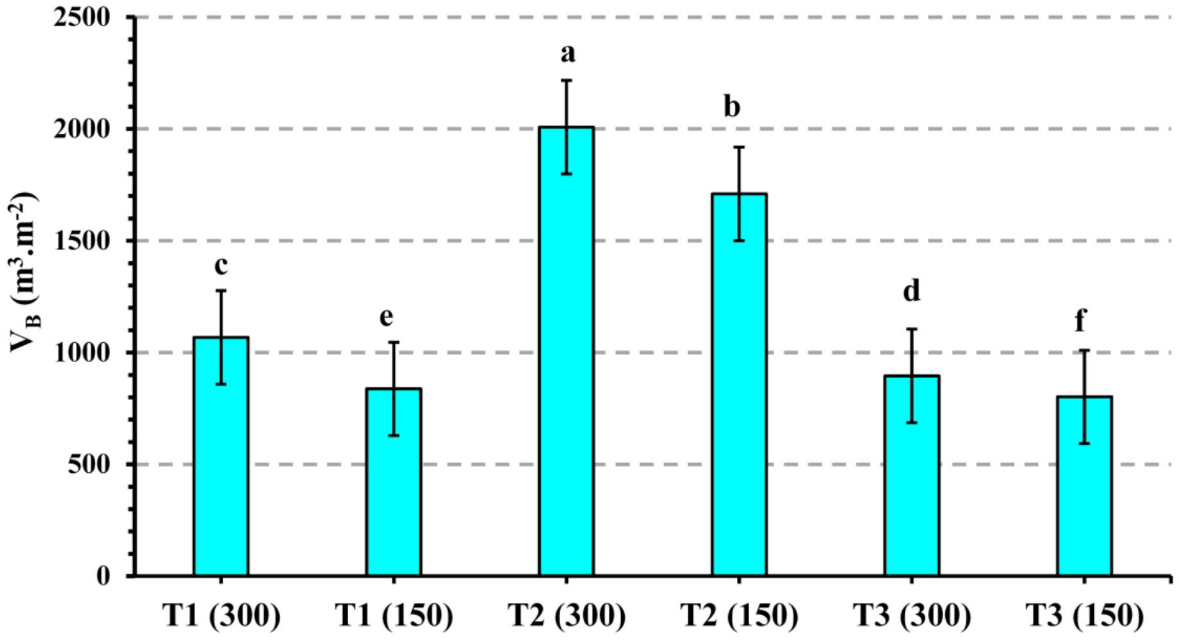

Figure 3. Average filtered effluent volume per filter cross-section unit (V_B) ± standard error bars for the T1, T2 and T3 treatments until backwashing at working pressures (150 and 300 kPa).

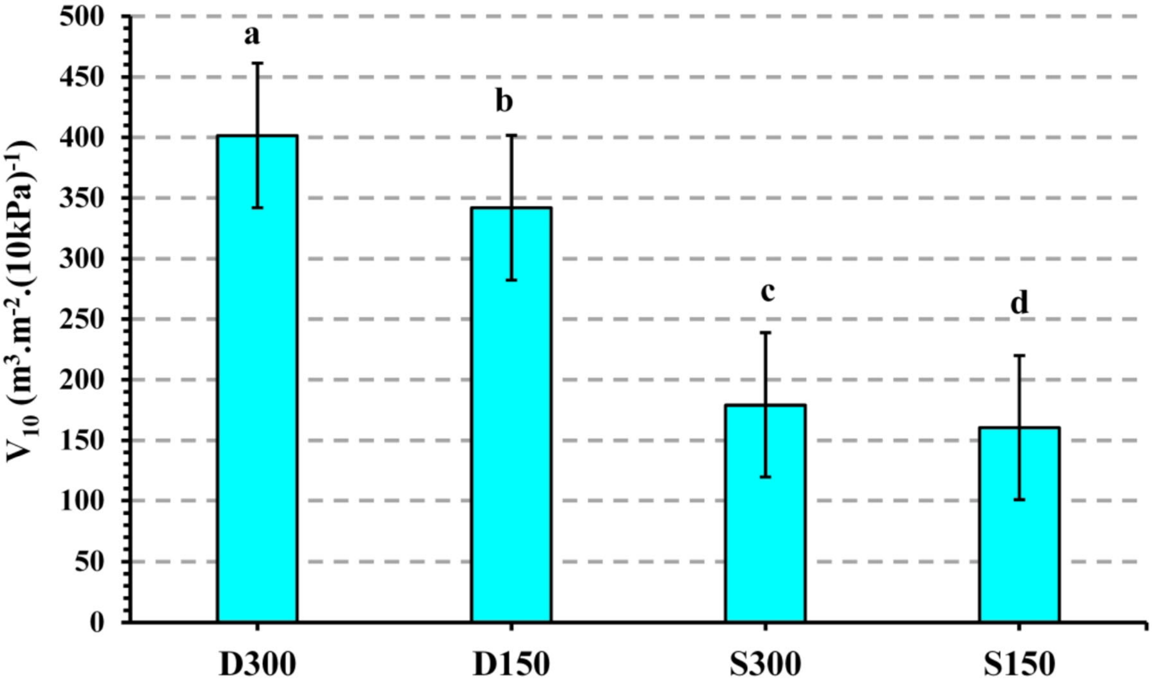

Figure 4. Average filtered effluent volume per filtration cross-section unit to reach 10 kPa head loss (V_{10}) ± standard error bars for disc filter (D) and screen filter (C) until backwashing at working pressures (150 and 300 kPa).

3.2 Filtration efficiency and mass retention

Figure 5 shows the suspended solid removal efficiency of the different treatments. The suspended solid removal efficiencies (EF_s) of T1, T2, and T3 ranged from 49-57%, 65-68%, and 71-74%, respectively. The solid removal efficiency achieved by the sand filter working alone (T1) using trout fish effluent was higher than that reported by Duran-Ros et al. (2009) (47.3%), Tripathi et al. (2014) (-27.5-19.5%) and Wen-Yong et al. (2015) (11.4-34.3%) with urban effluents, which are more widely used around the world. Several authors have also found that more solids can be trapped if a secondary filter, such as a screen or disc filter, is placed after a sand filter. When a disc filter was placed after a sand filter, solid removal efficiencies increased up to 0.4-36% (Tripathi et al., 2014) and 30-80% (Weng-Yong et al., 2015). In the present experiment, solid removal efficiencies with the sand and disc filter (65-68%) and trout fish effluent were between those values previously observed with urban effluents. Manbari et al. (2020) observed suspended solid removal efficiencies for a screen filter placed after a sand filter of 23% and 43% with fresh water and trout fish farm effluent, respectively. In the present work, with a smaller grain size, the efficiencies increased considerably. These results confirm that screen filters are only advisable with diluted or previously filtered effluents (Capra and Scicolone, 2005).

The mass retention index (*q*) was calculated to better compare the treatments. The q value for the T1, T2, and T3 treatments varied in the ranges 5.1-5.6, 7.9-8.7, and 8.4-8.7 ($g.min^{-1}.m^{-2}$), respectively (Figure 6). The q values of the T2 and T3 treatments were approximately equal, and both were 1.5 times significantly greater ($P<0.01$) than T1. These results show that more solid mass is trapped using a secondary filter, and therefore, greater prevention against clogging is guaranteed. Moreover, increasing the working pressure from 150 to 300 kPa caused more suspended solids to pass through the sand filter, resulting in a decrease in q in T1 but, conversely, an increase in treatments T2 and T3 since this suspended solid was controlled by disc and screen filters. These changes were not significant for any treatment ($P>0.01$).

In the T2 and T3 treatments, disc and screen filters were placed after the sand filter, respectively. As the effluent passed through the sand filter, the concentration of suspended solids was reduced by 49 to 57%. This meant that the effluent at the disc and screen filter inlets had half the TSS of the initial effluent. Therefore, the possibility of retaining the suspended solids in disc and screen filters was reduced, which, in turn, lowered its specific suspended solids removal efficiency. The E_F of the disc and screen filters varied between 26-31% and 38-42%, respectively (Figure 7). However, as previously discussed, the use of these additional filters allows more mass retention in the filters and should reduce the chance of emitter clogging.

Moreover, the q values for disc and screen filters (Figure 8) ranged from 2.3-3.6 and 2.8-3.6 $g.min^{-1}.m^{-2}$, respectively, which did not differ significantly at the same working pressure ($P>0.01$). In both filters, changing the working pressure from 150 kPa to 300 kPa significantly ($P<0.01$) increased q due to the higher TSS in disc and screen filter inlets. Hasani et al. (2022) found that when using trout fish farm effluent directly, disc and screen filters tended to decrease q with increasing pressure. This pattern was also observed for the sand filter working alone (T1).

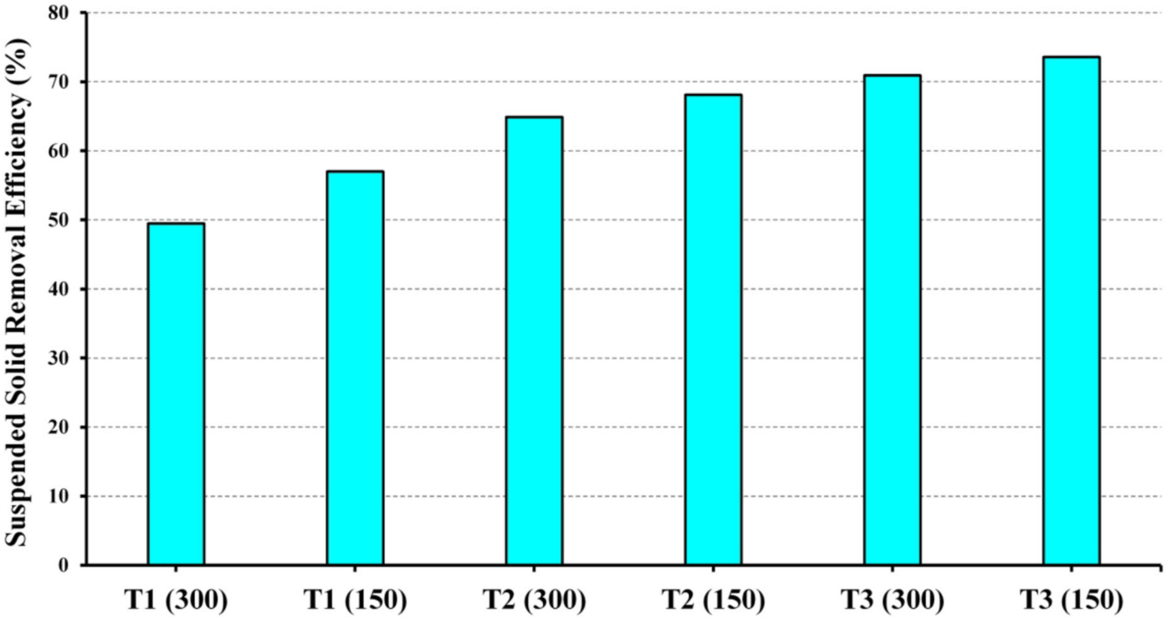

Figure 5. Suspended solid removal efficiency T1, T2 and T3 treatments until backwashing at working pressures (150 and 300 kPa).

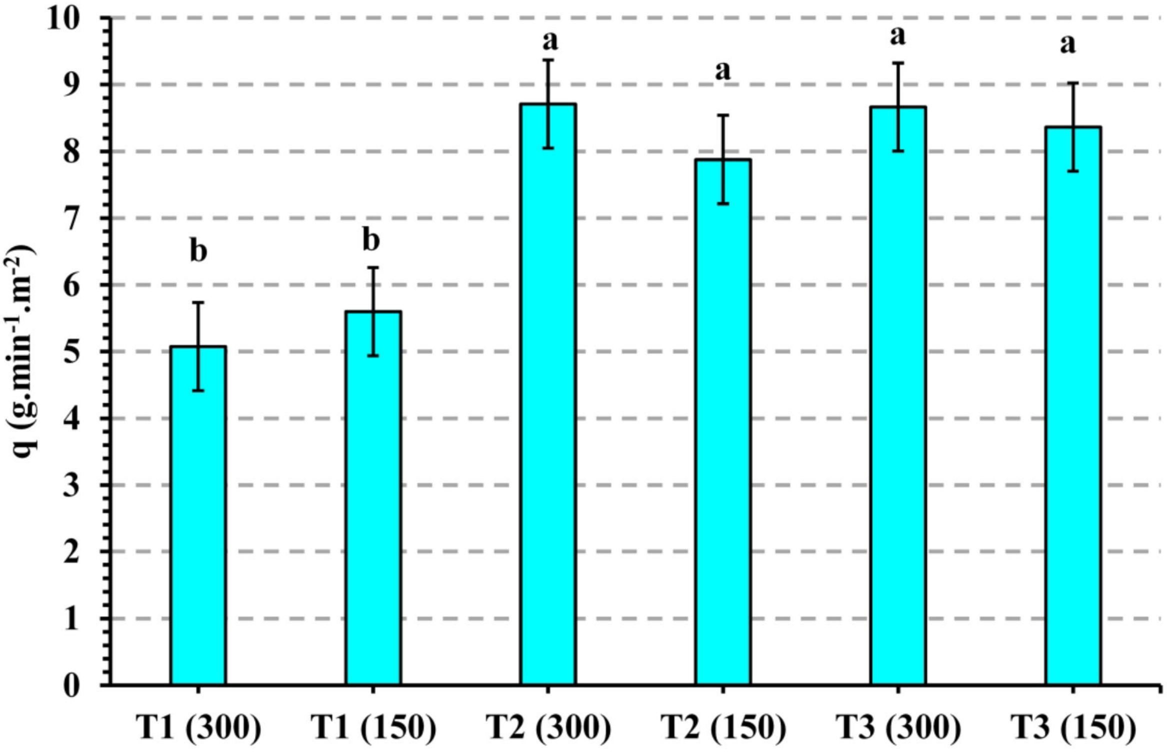

Figure 6 Average mass retention for the T1, T2 and T3 treatments until backwashing at working pressures (150 and 300 kPa).

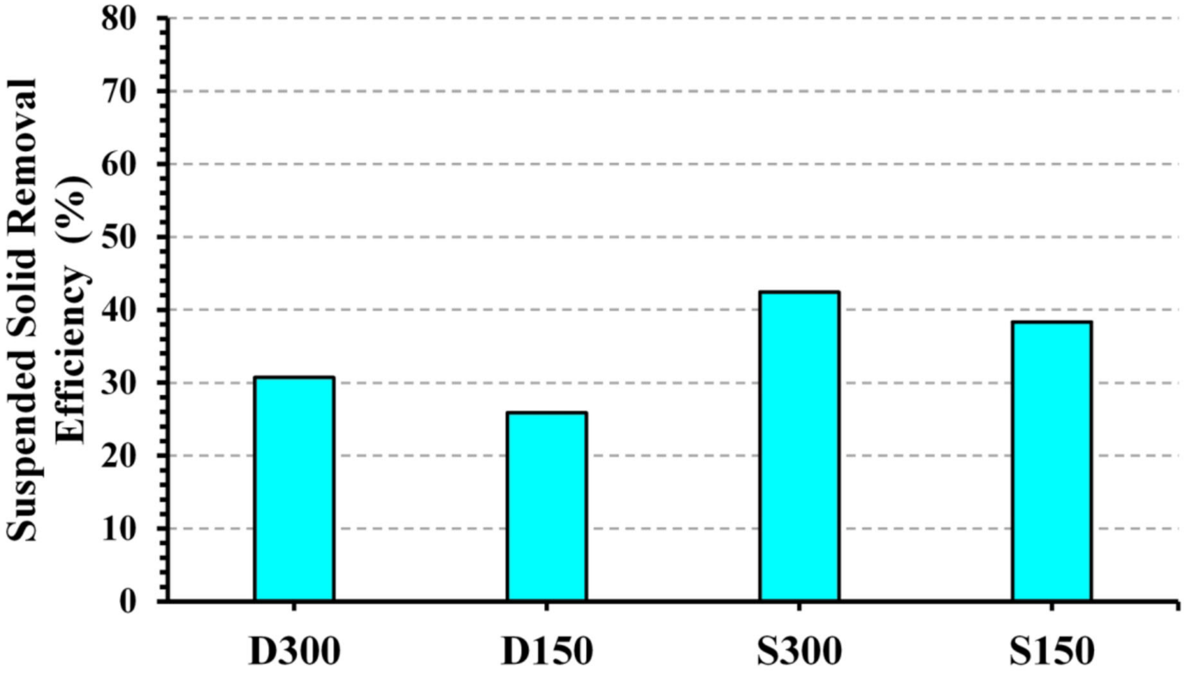

Figure 7. Suspended solid removal efficiency of disc (D) and screen (C) filters until backwashing at working pressures (150 and 300 kPa).

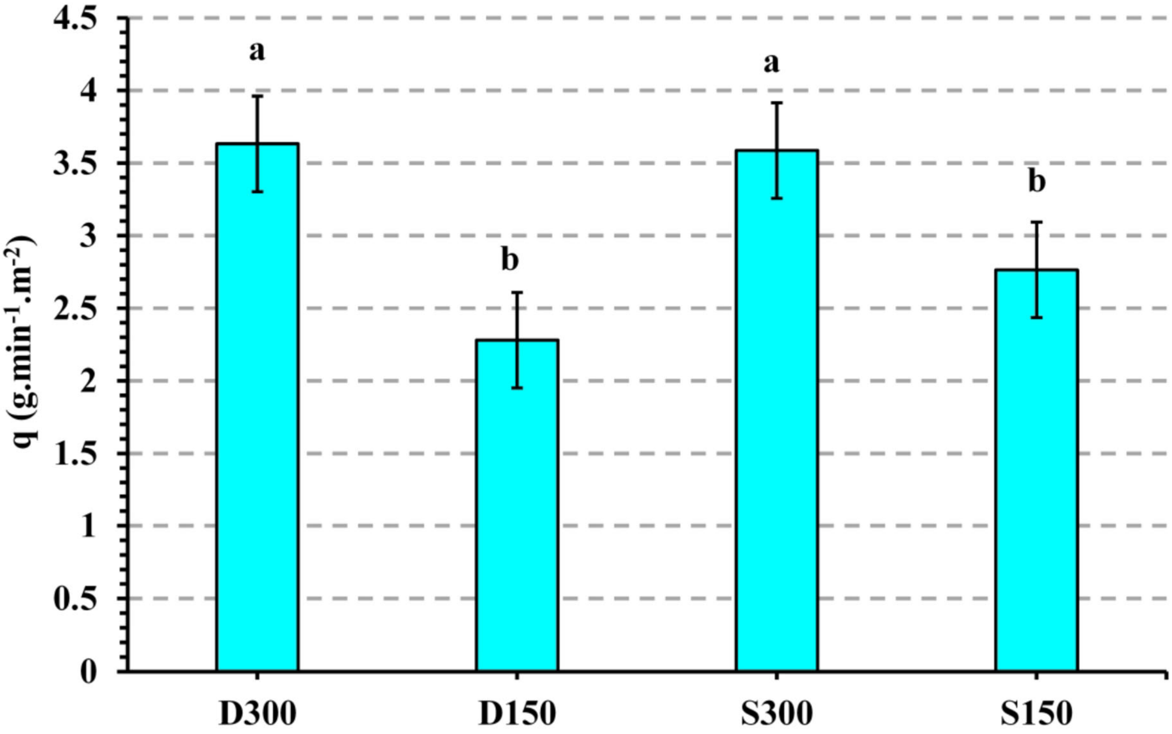

Figure 8. Average mass retention for disc filter (D) and screen filter (C) until backwashing at both working pressures (150 and 300 kPa).

4 Conclusion

Sand filter followed by a disc filter (T2) treatment had the highest fish trout effluent filtered volume per filter cross-section until backwashing (V_B). V_B was 2007.8 m^3 m^{-2} at a working pressure of 300 kPa, which was significantly higher ($P<0.01$) than at 150 kPa (1709.7 m^3 m^{-2}). This treatment showed V_B 1.9 and 2.2 times significantly higher ($P<0.01$) than those of the sand filter alone (T1) and the sand filter followed by a screen filter (T3) at a working pressure of 300 kPa, respectively. The combination of sand and disc filters allowed operation times of 18 h. The suspended solids removal increased in the sequence of T3 (71-74%) > T2 (65-68%) > T1 (49-57%). On the other hand, the mass retention (q) of the T2 and T3 treatments was approximately equal (8.4 g.min^{-1}.m^{-2}), both being a significant 1.5 times higher ($P<0.01$) than that of the T1 treatment. In summary, the most suitable treatment for rainbow trout effluent treatment is a sand filter followed by a disc filter (T2 treatment) at a working pressure of 300 kPa.

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

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

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