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RESEARCH PAPER

Rotary Drum Filter Effectiveness in Suspended Solids Removal from Trout Farm Discharges - A Case Report

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Abstract

Utilization of micro-screen filters for mitigation of aquaculture impacts on receiving water bodies has been widened in recent years. However, there are limited practical data on treatment efficiencies of rotary drum filters (RDF) in farms with high production capacities and flow rates. The present study aimed to assess effluent suspended solids treatment efficiencies of RDFs with 200 µm mesh size in 8 flow-through rainbow trout farms. The average concentrations of total suspended solids (TSS) were between 2.6±1.1 mg/L and 6.0±4.3 mg/L in farm outlet waters. The average treatment efficiencies of RDFs for total suspended solids were between 18 and 32%, while they were between 28 and 53% for farm-derived suspended solids. Treatment efficiency of RDFs did not relate linearly to inlet and outlet total suspended solids concentrations as well as farm-derived suspended solids (FSS) ($P>0.05$). The results indicate that relatively low TSS concentrations resulting from rainbow trout aquaculture in flow-through farms can reduce treatment efficiency of RDFs. The study also shows that the average treatment efficiency of RDFs with a mesh size of 200 µm in removal of FSS may reach up to 40%.

Introduction

Increasing aquaculture production has contributed to a degradation of the quality of surface waters. This is particularly crucial in areas where environmental carrying capacity has already been exploited by various human activities (FAO, 2006). The serious efforts have been directed towards mitigation of aquaculture impacts on the environment by improvement of feed quality, feeding and farm managements, and waste treatments (Bergheim *et al.*, 1998; MacMillan *et al.*, 2003; Subasinghe *et al.*, 2009). Waste minimization is acceptable as the first strategy to reduce the loading from flow-through fish farms while waste treatment, is mainly based on solid removal from the effluent, is the second strategy (Boyd, 2003; Brinker and Rösch, 2005; Sindilariu, 2007).

Various methods are applied in removal of total suspended solids (TSS) derived by aquaculture (Sindilariu, 2007; Lekang, 2013). Micro-screens are one of the most used tools for primary treatment of the effluents in flow-through farms due to minimal requirements for labor and floor space (Bergheim *et al.*, 1998). Rotary drum filters (RDFs) are mostly preferred in flow-through as well as recirculating farms (Ali, 2013; Dolan *et al.*, 2013; Lekang, 2013). Nevertheless, treatment efficiency of RDFs can show huge variations depending on many factors including farm practices, feed characteristics, particle size distribution, filter mesh size, hydraulic/solids loading rate and TSS concentration of the effluent (Cripps, 1995; Kelly *et al.*, 1997; Cripps and Bergheim, 2000; Brinker and Rösch, 2005; Dolan *et al.*, 2013).

The treatment efficiencies of RDFs have been largely studied in recirculated aquaculture systems

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(Summerfelt and Penne, 2005; Tal *et al*., 2009; Martins *et al*., 2010; Ali, 2013; Suhr *et al*., 2013) or in flow-through farms with relatively lower flow rates (Bergheim *et al*., 1998; Cripps and Bergheim, 2000; Brinker and Rösch, 2005; Sindilariu *et al*., 2009a). Although some studies have compared treatment efficiencies of RDFs installed at several flow-through farms (True *et al*., 2004; Sindilariu *et al*., 2009b), there are limited data on their efficiencies in farms with high inflow rates.

Eşen River is one of the main running waters of the western Mediterranean basin in Turkey. The catchment of the river is a significant land-based rainbow trout production site. The detailed information of the river and aquaculture activities in the catchment was previously provided (Koçer *et al*., 2013; Koçer and Sevgili, 2014). This study aimed to determine treatment efficiencies of RDFs for TSS and farm-derived suspended solids (FSS) in an intensive rainbow trout (*Oncorhynchus mykiss*) production site including 8 flow-through farms.

Materials and Methods

Study Site and Rotary Drum Filters

This study was conducted at nine farms which are located along a reach of the Eşen River with an actual production capacity of 5,100 tons/year (Figure 1). In this site, the upper located farms take directly headwater, while the lower located farms use river water receiving the discharges from one or more farms. These flow-through farms were installed RDFs with micro-screens of 200 µm mesh size in 2012 depending on their outlet rates between 1.0 and 5.0 m^3/s (Table 1).

Sampling and Data Processing

The study was carried out at 8 out of 9 farms during a period between February 2013 and January 2014. The composite water samples were taken every 2 hours during daytime from 09 am to 09 pm and

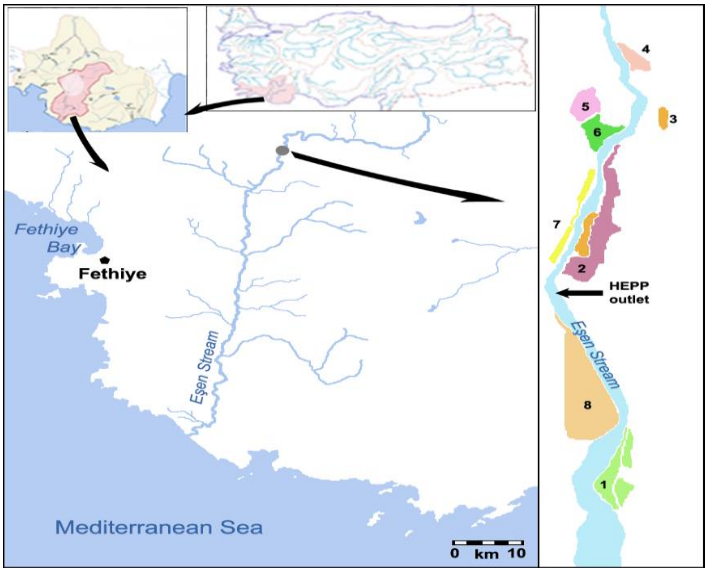

Figure 1. Eşen River (plot on left) and a schematic view of the flow-through trout farms (plot on right) (HEPP, hydroelectric power plant).

Table 1. Characteristics of 8 rainbow trout farms and rotary drum filters during study period (H, hatchery; G, on-growing)

Farms	Culture type	Production capacity (tons/year)	Inflow rate (m^3/s)	Filter area (m^2)
1	H + G	900	4.5	3.2
2	H + G	800	2.5	2.0
3	G	250	1.1	2.4
4	H + G	300	1.2	2.4
5	H + G	2500	5.0	3.2
6	H + G	100	1.0	2.4
7	G	200	1.0	2.4
8	H + G	50	1.0	2.4

were collected monthly from farm inflows (inlet, C_1) and drum screen inflows (outlet, C_2) as well as drum screen outflows (discharge, C_3). However, the time integrated samples could not be collected in some months, and hence grab samples were taken.

TSS in water samples were determined by the filtration method using glass fiber filters according to standard methods (APHA *et al*., 1998). In order to distinguish FSS from catchment-derived suspended solids, FSS concentrations (C_{farm}) were calculated by difference between outlet and inlet concentrations (Equation 1). Relative FSS (R_{farm}) represented relative contribution of aquaculture activities to outlet TSS concentrations (Equation 2). Relative treatment efficiency of RDFs for TSS (R_{TSS}) were calculated by differences between outlet and discharge concentrations (Equation 3). Relative treatment efficiency of RDFs for FSS (R_{FSS}) was also calculated by an additional difference of inlet TSS (Equation 4).

$$C_{farm} = C_2 - C_1 \quad (1)$$

$$R_{farm}\,(\%) = [C_{farm}/C_2] \times 100 \quad (2)$$

$$R_{TSS}\,(\%) = [(C_2 - C_3) / C_2] \times 100 \quad (3)$$

$$R_{FSS}\,(\%) = [((C_{farm}) - (C_3 - C_1)) / (C_{farm})] \times 100 \quad (4)$$

One-way analysis of variance (ANOVA) was used to determine differences among the farms. The Tukey's honestly significant difference (HSD) test was used to discriminate significant differences among the farms. Linear regression analysis was also used to determine a relationship among the two variables. JMP 8 (SAS Institute Inc., Cary, NC, USA) was used for statistical analysis.

Results

Average TSS concentrations in the farm inlet waters were between 0.8 and 2.2 mg/L. The average concentrations in outlet waters of the farms increased up to as much as 6.0 mg/L, with a maximum of 15 mg/L (Figure 2). FSS concentrations changed between 0.3 and 10.9 mg/L with the average concentrations between 1.1 and 3.4 mg/L. Indeed, aquaculture activities caused an average increase between 47 and 71% of suspended solids in the outlet waters (Figure 3). Using micro-screen RDFs with a mesh size of 200 µm, FSS were removed at higher rates in an average efficiency range of 28 and 53% compared to TSS with average treatment efficiencies between 18 and 32% (Figure 4).

The results revealed that there was a significant linear regression relationship (r^2 = 0.90, P<0.001, n = 75) between FSS and outlet TSS concentrations, indicating major contribution of flow-through aquaculture activities to TSS concentrations in discharges of fish farms rather than catchment-based suspended solids (r^2 = 0.52, P<0.0001, n = 75).

On the other hand, TSS treatment efficiency of RDFs did not related linearly to FSS (r^2 = 0.01, P = 0.94, n = 67) and inlet TSS (r^2 = 0.02, P = 0.26, n = 68) and outlet TSS (r^2 = 0.01, P = 0.58, n = 72) concentrations. This result suggested that low TSS concentrations caused by high flow rates in flow-through trout farms may lead to relatively low treatment efficiency of RDFs in farm outlets. ANOVA supported that treatment efficiency of RDFs in Farm 1 which had the highest average outlet TSS concentration was significantly higher for both TSS ($F_{(7,66)}$ = 2.47, P<0.05) and FSS ($F_{(7,66)}$ = 2.01, P<0.05) than the other farms, indicating increased removal efficiency by high concentrations.

Discussions

The results on outlet TSS and FSS concentrations and contribution to TSS concentrations of fish farming for 8 rainbow trout farms were largely consistent with the results of a previous study in the same site (Koçer *et al*., 2013) as well as those reported in the literature (Stewart *et al*., 2006; Sindilariu *et al*., 2009a; Tello *et al*., 2010; Aubin *et al*., 2011).

Average TSS treatment efficiencies of RDFs in the studied farms (18 to 32%) were close to lower margin of literature data ranging from 10 to 90% for micro-screens with a mesh size between 30 and 350 µm (Cripps, 1994, 1995; Bergheim and Brinker, 2003; Sindilariu *et al*., 2009b). However, treatment efficiencies of RDFs are highly variable depending on many factors. These factors can be related to structures and operations of the farms such as used feed quality and composition, stocked fish size, raceway characteristics, particle characteristics, in-farm waterfalls and flow rate and duration to treatment unit from raceway outflows (Cripps, 1995; Kelly *et al*., 1997; Maillard *et al*., 2005; Dolan *et al*., 2013). Although we could not specifically test most of these factors in the farms, the results indicated that farm characteristics and practices were highly significant on treatment efficiencies of RDFs.

A lower TSS concentration in farm outlets may have influenced the filter efficiency, in consider to high efficiencies were obtained with high TSS loading (Brinker and Rösch, 2005), as in recirculated farms (Ali, 2013). It's clear that a filter cake build-up increases treatment efficiency by restricting the passage of particles smaller than the nominal pore diameter (Wakeman, 2007; Dolan *et al*., 2013). However, effluent treatment in flow-through farms is a new issue for Turkey, and RDFs already could not

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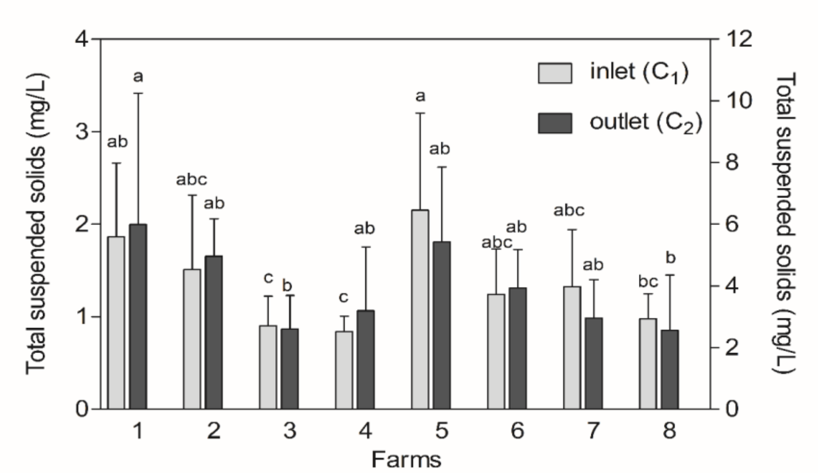

Figure 2. Average concentrations with standard deviations of total suspended solids in inlet and outlet of the 8 flow-through trout farms in the study site (left-y axis represents inlet concentrations, right-y axis represents outlet concentrations; values not sharing a common letter were significantly different as a result of Tukey's HSD test).

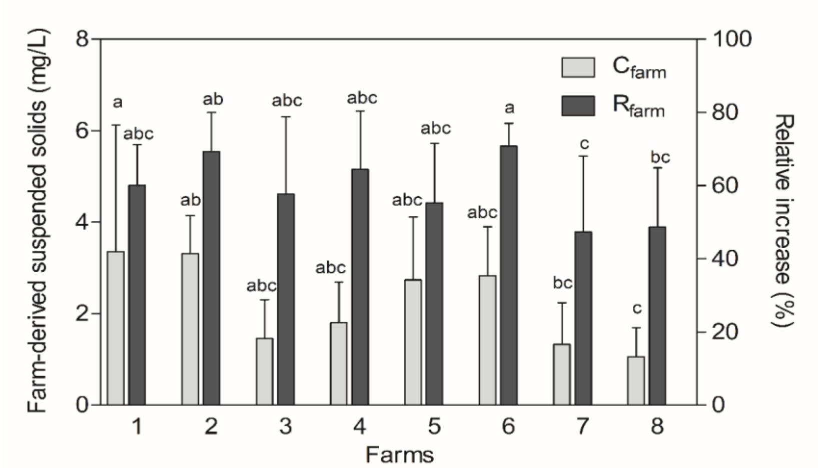

Figure 3. Average concentrations with standard deviations of farm-derived suspended solids of the 8 flow-through trout farms and their relative contribution to suspended solids increase in the study site (left-y axis represents concentrations, right-y axis represents relative increase; values not sharing a common letter were significantly different as a result of Tukey's HSD test).

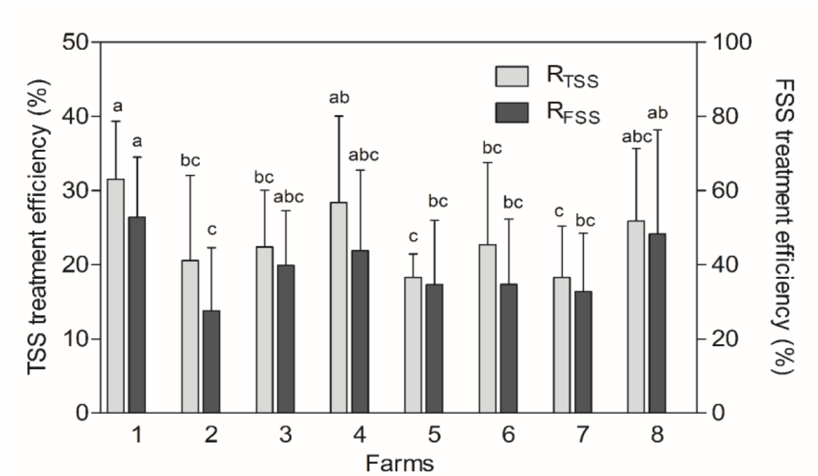

Figure 4. Average treatment efficiency with standard deviations of total and farm-derived suspended solids in the 8 flow-through trout farms in the study site (left-y axis represents R_{TSS}, right-y axis represents R_{FSS}; values not sharing a common letter were significantly different as a result of Tukey's HSD test).

operate regularly depending on some technical, infrastructure and logistic problems during the first year of experience in the study site (personal observations). Therefore, a cake in micro-screens of many farms may not have built. When RDFs were regularly operated together with high concentrations in outlet, treatment efficiency for FSS could be increased up to an average of 32% as in Farm 1.

Since the majority of particles in aquaculture-derived sludge may occur as > 250 µm (Maillard *et al*., 2005), it is important for a treatment process to avoid degradation and to remove these large particles (Cripps, 1995). As expected, the results showed that TSS originating from river catchment had a significant effect on treatment efficiencies. However, these TSS loads in the inlets were not related to aquaculture activities in a farm determined. The results indicate that the mass of aquaculture-derived suspended solids in farm outlets was probably in the form of large particles. It is, therefore, catchment-derived suspended load in the inlets that should be eliminated for calculations, and FSS treatment efficiencies rather than TSS should be considered for an assessment when studying fish farm discharges. Indeed, FSS treatment efficiencies with an average of 40% by RDFs were higher than for TSS, and this result can be considered as satisfactory for high inflow rates at the sites studied.

The results of this study will provide information about treatment efficiencies for suspended solids of RDFs operated in flow-through trout farms. Even in the farms with very intensive and high inflow rates, FSS treatment efficiencies of RDFs with micro-screens of 200 µm mesh size were relatively high. The monitoring data on farm-specific practices in the future researches will a better understanding the factors on efficiencies of RDFs. Regardless of the factors, effluent treatment of flow-through trout farms using by RDFs in the studied site certainly provided a significant reduction of waste loading into receiving river.

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