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Short communication

Particle circulation in irrigation reservoirs: The role of filter backwash reject on filter clogging

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ABSTRACT

The improvement of the quality of treated wastewater allowed increased zooplankton populations in reservoirs that store water for irrigation, causing severe clogging problems in irrigation systems. To cope with the clogging problem we started a research program on the relationships between filter clogging and particle distribution in irrigation reservoirs. The present study targets the water and particles circulation between the reservoir and its bank filters, in order to evaluate potential management procedures to avoid filter clogging. Two reservoirs with different management were selected, in one water for irrigation is removed from under the surface and in the other from over the reservoir bottom. Profiles of temperature, oxygen, time to clog filters of different pore and amount of suspended solids retained by each such filter were measured. Conclusions: (1) Returning backwash reject into the reservoir recovers important amounts of water but also re-introduces clogging-size particles. (2) In a thermally stratified reservoir where water for irrigation is removed from the epilimnion, a daily short-circuit of 10% of the large particles (>150 μm) present in the deep epilimnion occurred between reservoir, irrigation filters and backwash reject. (3) In a thermally stratified reservoir where water for irrigation is removed from the hypolimnion particle concentration in removed water was notably lower and the daily short-circuit did not occur. (4) Removing particles of the backwash before returning the water into the reservoir would avoid short-circuiting of particles and re-introducing live copepods that may reproduce in the reservoir. (5) Removing particles through sedimentation requires a retaining time of at least half an hour before returning the water into the reservoir, and a way to transport away from the reservoir and dispose the sedimented material. (6) Returning water into the hypolimnion is a management option to recover water while avoiding/reducing the backwash reject negative effect on filter clogging.

1. Introduction

In arid and semi-arid regions water availability is limited and wastewater turns into an important water resource. In Israel over 75% of the municipal wastewater is reused, most of it for agricultural irrigation (The Water Agency – Israel, 2014). During the years different regulations requested improved quality of the treated effluents, the major ones being the requirement for secondary treatment (BOD < 20 mg/l) in 1995 and for tertiary treatment (nutrient removal) in 2005 (Juanicó, 2008), the latter still being gradually implemented. The improvement of the quality of treated wastewater allowed increased zooplankton populations in reservoirs that store water for irrigation, mainly copepods (length about 200–1000 μm) and cladocerans (length about 300–3000 μm). These particles may cause severe clogging problems in irrigation systems, especially in the drip irrigation ones, which are the systems used in over half of the irrigated area of the country (OECD, 2011). At present some reservoirs deliver their water directly to the irrigation systems, which at their head have filters of 130–200 μm pore. But in most reservoirs another 130–200 μm pore filter battery was added at the banks of the reservoirs and the filtered water is only then sent to irrigation. This avoids/reduces clogging in the irrigation systems transferring the problem to the storage reservoirs, which must overcome it to deliver the required amounts and quality of water.

To cope with the increased clogging problem we started a research program on the relationships between filter clogging and particle distribution in irrigation reservoirs that receive secondarily treated wastewater. As a first step we studied relationships between clogging and particle size distribution in a range of reservoirs with different characteristics and water management, to

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examine the possibility of removing large zooplanktonic organisms in order to avoid clogging of irrigation filters (Milstein and Feldlite, 2014). Then we made a more detailed study of particle distribution in relation to thermal stratification development in one such reservoir, to learn about changes through the irrigation season that would affect the convenience of removing water from one depth or another in order to avoid clogging of irrigation filters (Milstein and Feldlite, 2015). The present study targets the water and particles circulation between the reservoir and its bank filters, in order to evaluate other potential management procedures to avoid filter clogging. Based on our previous studies two reservoirs with different management were selected, in one water for irrigation is removed from under the surface and in the other from over the reservoir bottom.

2. Materials and methods

2.1. The reservoirs

The work was carried out during July 2011 in two reservoirs that store secondarily treated wastewater for irrigation. Both reservoirs are deep enough to develop seasonal stratification, have plastic covered bottoms, wastewater enters into the upper reservoir water layers, and removed water passes through a battery of 130 μm pore discs filters installed on the bank before it is sent to the 130 μm pore filters at the head of the irrigation system. Each reservoir was sampled on one day representative of the conditions developed during the peak irrigation season. That includes sunny days, high temperature, and daily western breeze that moves surface water eastward inducing a westward undercurrent over the thermocline.

Galon is a 6.4 ha surface, 7.5 m depth and 480,000 m^3 reservoir when full (at sampling time water depth was only 5.5 m due to water removal for irrigation). Most of its reclaimed wastewater enters all the year round in its SE side, and few amounts from an oxidation pond enter in its E side. The outlet, located in the W side of the reservoir, is made of a pipe suspended from a raft that allows pumping water out from under the surface, its opening generally being set at the beginning of the irrigation season at 2–3 m depth. The backwash reject of the irrigation filters at the bank is returned into the reservoir in its SE side, near the main wastewater input pipe. Each filter backwash event returns 9 m^3 of water to the reservoir. Backwash cleaning is generally set to be performed when a fixed difference of pressure of 0.6 atmosphere is reached. The time it takes to reach to this difference of pressure depends on the amount of particles present in the water. By sampling time the cleaning episodes occurred each 30′. Seven clogging episodes due to zooplankton that required chemical treatment occurred during the 2011 season.

Mezer is an 8.3 ha surface, 11 m depth and 550,000 m^3 reservoir when full (at sampling time water depth was only 7 m due to water removal for irrigation). Reclaimed wastewater enters in its W side. The outlet is also located in the W side, pumping water out from over the reservoir bottom. The backwash reject of the irrigation filters is returned into the reservoir in its NE side, far from the outlet and wastewater input pipe. Each filter backwash event returns 8 m^3 of water to the reservoir. Backwash cleaning is generally set to be performed when a fixed difference of pressure of 0.6 atmosphere is reached. Three clogging episodes due to zooplankton that required chemical treatment occurred during the 2011 season. During the second half of July 2011 an aerator worked continually over the output area to mix the water column and increase its oxygen content, which also re-suspended mud from the bottom. Then, backwash cleaning frequency was increased and set to be performed each 10′. After 2 weeks the aerator was stopped because it re-suspended too much mud. Our field work was performed by the end of the mixing period.

2.2. Field work

Sampling was carried out from a boat in three stations following the west-east axis of each reservoir. In each station temperature and dissolved oxygen (DO) profiles were measured each 0.5 m from surface to bottom of the water column. In three of the six stations a Clogging Potential Meter (CPS, Sagi et al., 1996; Feldlite and Yechiely, 2011) with net filters of 150 μm, 100 μm, 60 μm and 33 μm was used to measure time to clog each net. If clogging did not occur after 5–7 min filtration was stopped. Good water quality for irrigation is considered when clogging time of the 150 μm and 100 μm nets is at least 5 min. The CPS was also used to collect the particles retained by each filter for suspended solids analysis. Besides the samples collected within the reservoirs, backwash reject of both reservoirs and input wastewater of Galon were also sampled. Farmers provided the data of the reservoirs and their water management (volume, daily amounts entering and removed, filter backwash frequency, etc.).

2.3. Laboratory work

Samples were sent to a specialized laboratory for analysis of total suspended solids (TSS) and suspended solids retained in each CPS net (SS > 150 μm, SS > 100 μm, SS > 60 μm and SS > 33 μm).

Samples of backwash reject were brought to the laboratory to measure particles sedimentation time. The backwash reject was shacked, 1 l was poured into a graduated sedimentation cone at time zero, the amount of sedimented material was measured at periodic intervals, and samples of the supernatant and sedimented material were observed under microscope.

3. Results and discussion

3.1. Reservoir Galon

Fig. 1 presents the temperature, dissolved oxygen and particle-size distribution with depth in reservoir Galon. The temperature and oxygen profiles show that the water column was stratified, with an upper 2.5 m deep warm oxygenated layer (epilimnion), a 1 m deep transition zone (thermocline) and a lower 2 m deep cold anoxic layer (hypolimnion). Particles smaller than 33 μm dominated throughout the water column. Particles larger than 100 μm, which can potentially clog the irrigation filters, were more abundant in the deep epilimnion over the thermocline. Considering the water volume and suspended solids concentration of each layer, it was estimated that there were 16 kg of particles larger than 150 μm in the 1.5 m upper epilimnion, 45 kg in the 1 m deep lower epilimnion and 18 kg in the 3 m deep hypolimnion (including transition zone).

Water for irrigation was removed from 2 m under the surface, coinciding with the particle rich layer of the deep epilimnion. Fig. 2 presents the circulation of water and particles of different size through the reservoir, estimated on a daily basis. On the sampling day 14,400 m^3 of treated wastewater containing 95 kg of TSS (6.6 g/m^3) entered the reservoir and over 6700 m^3 of water containing 65 kg of TSS (9.7 g/m^3) were removed for irrigation. After passing the reservoir's bank filter battery, 94% of that water with 32 kg of particles smaller than 130 μm were directed to the irrigation system. The remaining 430 m^3 were the backwash reject that contained 33 kg (76 g/m^3) of clogging-size particles. This means that half of the TSS removed from the west side of the reservoir were potential clogging particles that returned to the epilimnion in the east side of the reservoir, accumulated in the deep