Agricultural Water Management 153 (2015) 63–70

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Relationships between thermal stratification in a secondarily treated wastewater reservoir that stores water for irrigation and filter clogging in the irrigation system☆

Ana Milstein[a,*], Mordehai Feldlite[b]

[a] Agricultural Research Organization (ARO), Fish and Aquaculture Research Station Dor, M.P. Hof HaCarmel, 30820 Israel
[b] Israel Water Workers Association, Eyal, mid-Sharon 45480, Israel

ARTICLE INFO

Article history:
Received 11 November 2014
Accepted 9 February 2015
Available online 27 February 2015

Keywords:
Clogging
Irrigation reservoir
Thermal stratification
Wastewater reservoir
Water management

ABSTRACT

We studied particle distribution in relation to thermal stratification development in a secondarily treated wastewater reservoir, to learn about changes through the irrigation season that would affect the efficiency of removing water from different depths to avoid filter clogging. During an irrigation season a datalogger continually recorded temperature at 12 depths of the water column and manual measurements of the water clogging potential were carried out at relevant depths. The datalogger allowed following the development of thermal stratification, which was established during April with a 4–4.5 m deep epilimnion. The epilimnion depth did not change during the irrigation season. Particles accumulated at the bottom of the epilimnion.

Conclusions: (1) In reservoirs that remove water from subsurface layers a manual temperature profile measured at the beginning of the irrigation season allow determining epilimnion depth, hence efficient water removal depth during most of the irrigation season. (2) Removing water for irrigation from the bottom of the epilimnion is not efficient. (3) Either if water is removed from subsurface or over-bottom layers, clogging will occur when only the particle rich epilimnion remains. (4) Removing water for irrigation from the near bottom starting before much organic matter accumulates in the hypolimnion would avoid sulfide accumulation and development of zooplanktonic organisms that could clog irrigation filters. (5) In reservoirs that remove water from subsurface layers a proper management of pumping depth should be performed to remove water from the hypolimnion to avoid clogging due to zooplankton, and from the epilimnion when required to eliminate anaerobic bacteria.

1. Introduction

In Israel reservoirs for irrigation are artificial deep water bodies of different size (5 ha to 40 ha and 5 m to 23 m maximum depth) that store waters of a wide range of qualities, from drinking water quality to different degrees of treated wastewater. Over 75% of the municipal wastewater of the country is reused, most of it for agricultural irrigation (The Water Agency—Israel, 2014). In all reservoirs rain water is collected during the rainy winter, while in wastewater reservoirs treated wastewater may enter all the year round. Before the outset of the irrigation season reservoirs are generally full. During spring thermal stratification develops, leading to strong vertical gradients of environmental conditions: a warm, oxygen rich, upper 3–5 m deep layer where photosynthesis prevails (epilimnion), a 1–2 m deep transition layer where temperature steeply decrease (thermocline), and a cold, oxygen depleted, deeper layer where decomposition processes prevail (hypolimnion) (e.g. Juanico, 1994; Krambeck et al., 1994; Milstein et al., 1992; Shisha and Sagi, 1997). Water depth decreases as water is removed for irrigation. In some reservoirs water is pumped out from near the reservoir bottom, while in most reservoirs the water outlet is made of a pipe suspended from a raft that allows choosing the pumping depth from the subsurface water layer (from 1 m to 4–6 m depth).

In lentic water bodies the water column hosts particles of a wide variety of types and sizes. In reservoirs that store water for irrigation those particles may cause severe clogging problems in irrigation systems, especially in the drip irrigation ones. This constitutes a major problem in Israel, where over half of the irrigated

☆ Article number 700/15 of the Animal Science Institute, Agricultural Research Organization, Israel.

* Corresponding author. Tel.: +972 4 6390651x108; fax: +972 4 6390652.
E-mail addresses: anamilstein@agri.gov.il (A. Milstein), motif@gan.org.il (M. Feldlite).

http://dx.doi.org/10.1016/j.agwat.2015.02.007
0378-3774/

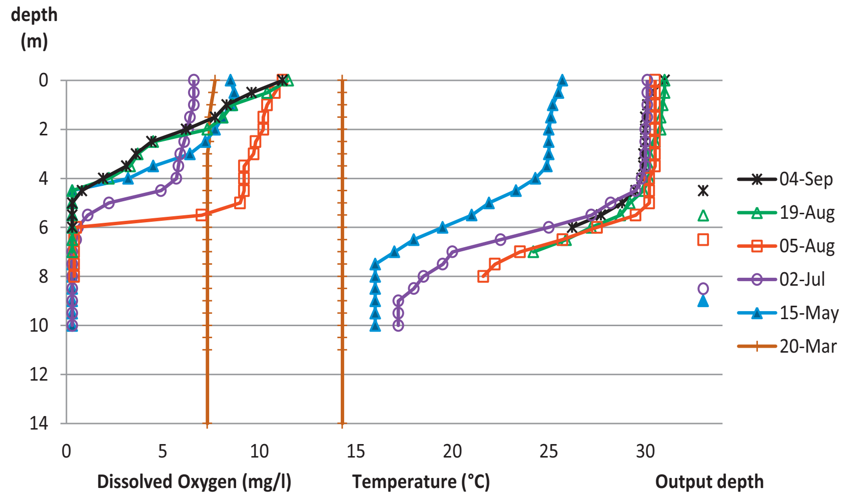

Fig. 1. Temperature and oxygen profiles and depth of water output for irrigation, before (March) and after (May–September) stratification. Manual sampling, 2012.

area of the country is under drip irrigation (OECD, 2011). Clogging of filters, pipes and drippers produce inequality of water supply and shortage of water to the crops. Clogging depends on the interaction between the presence of clogging agents, reservoir design and hydrology, and water management, which when combined often produce more serious clogging events (Juanico et al., 1995). Clogging agents may be rather large planktonic organisms, their decomposing rests, detritus and inorganic materials like sand or clay. In Israel some reservoirs deliver their water directly to the irrigation systems, where they pass through 130–200 μm pore filters before reaching the crops. But to avoid/decrease clogging problems in the irrigation system proper, in most reservoirs water is further filtered at the reservoirs banks through another 130–200 μm pore filter before being sent to irrigation. In both cases the clogging problem worsened with the improvement of the quality of treated wastewater, which allowed increased zooplankton populations in the reservoirs, mainly copepods (length about 200–1000 μm) and cladocerans (length about 500–3000 μm).

To cope with the clogging problem, solutions at long-term to avoid clogging and at short-term to solve already happening clogging events are required. As a first step towards the long-term approach we studied relationships between clogging and particle size distribution in a range of reservoirs with different characteristics and water management (Milstein and Feldlite, 2014). This article presents a more detailed study of particle distribution in relation to thermal stratification development in one such reservoir, to learn about changes though the irrigation season that would affect the convenience of removing water from one depth or another in order to avoid clogging of irrigation filters.

2. Materials and methods

Field work was carried out in the irrigation reservoir Haviva, which is 23 ha, 17 m maximum depth when full, has earthen bottom, and receives wastewater after secondary treatment. Reclaimed wastewater enters into the upper water layers in the reservoir's SW bank, and is removed for crop irrigation from its NW side. Up to 2011 and in 2014 water was removed from the epilimnion, while in 2012 and 2013 the outlet pipe laid on the reservoir bottom. Before water is sent to the irrigation system it passes through 130 μm pore filters. The rejected backwash of the filters is returned to the SW corner of the reservoir near the input wastewater area.

A temperature data logger was assembled and installed in the reservoir at about 30 m from the water outlet. The logger continually recorded temperature at 12 depths of the water column during the 2012 irrigation season. The data was recorded once per hour in an Excel file and transmitted to the computer each few days. From 20-Mar to 24-May-2012 temperature was measured from 0.5 m to 6 m from the surface, at 0.5 m intervals. From 24-May-2012 to 20-Sep-2012 temperature was measured at the surface and from 1.5 m to 6.5 m depth at 0.5 m intervals.

Several times during the 2011 and 2012 irrigation seasons temperature and dissolved oxygen profiles and measurements of the water clogging potential were performed from a boat in the water outlet area (near the logger in 2012) during the mid and late morning hours. The water clogging potential was measured with the clogging potential meter (CPM) developed by the Israel Water Works Association (IWWA), which measured the time it takes to partially clog a filter when the examined irrigation water flowed at a constant rate (10 l per min) with a differential pressure of 3 m across a small screen filter. The earlier version of the instrument was described by Sagi et al. (1996) and the more advanced version by Feldlite and Yechiely (2011). Temperature and dissolved oxygen were manually measured each 0.5 m from surface to bottom of the water column. The potential of the water to clog net filters of 150 μm, 100 μm, 60 μm and 33 μm was measured according to those profiles, at least at surface and hypolimnion and if relevant also above the transition zone (deep epilimnion over the thermocline). If clogging did not occur after 5 min filtration was stopped. Good water quality for irrigation was considered when clogging time of the two larger pore nets was at least 4 min. The CPM was also used to collect the particles retained by each filter for suspended solids analysis and for microscopic examination of plankton.

3. Results

3.1. Temperature and dissolved oxygen

Temperature and oxygen profiles obtained by manual sampling in 2012 are presented in Fig. 1. During the winter the water was cold and mixed, with the same temperature and oxygen concentration throughout the water column. As the season advanced, temperature increased at different rates according to the depth, leading to stratification. In the lack of vertical water mixing, oxygen produced in the epilimnion by phytoplankton or diffusing from the atmosphere does not reach the hypolimnion, so that its vertical distribution follows the same pattern of temperature. Fig. 2 shows the temperature change in the upper 6–6.5 m of the water column recorded by the data-logger from mid-March to mid-September