Saudi Journal of Biological Sciences (2014) 21, 250–255

King Saud University

Saudi Journal of Biological Sciences

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ORIGINAL ARTICLE

Cilioprotists as biological indicators for estimating the efficiency of using Gravel Bed Hydroponics System in domestic wastewater treatment

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Received 9 September 2013; revised 6 November 2013; accepted 13 November 2013
Available online 21 November 2013

KEYWORDS
Ciliates;
Wastewater;
Sewage;
Pollution indicator;
Gravel Bed Hydroponics Systems

Abstract Interest has increased over the last several years in using different methods for treating sewage. The rapid population growth in developing countries (Egypt, for example, with a population of more than 87 millions) has created significant sewage disposal problems. There is therefore a growing need for sewage treatment solutions with low energy requirements and using indigenous materials and skills. Gravel Bed Hydroponics (GBH) as a constructed wetland system for sewage treatment has been proved effective for sewage treatment in several Egyptian villages. The system provided an excellent environment for a wide range of species of ciliates (23 species) and these organisms were potentially very useful as biological indicators for various saprobic conditions. Moreover, the ciliates provided excellent means for estimating the efficiency of the system for sewage purification. Results affirmed the ability of this system to produce high quality effluent with sufficient microbial reduction to enable the production of irrigation quality water.

1. Introduction

Water is more critical than energy, as we have alternative sources of energy, but with water there is no other choice. Thus, it is necessary to find ecologically sound ways to recycle valuable resources like wastewater and at the same time have an alternative agricultural crop production. Agricultural land

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Peer review under responsibility of King Saud University.

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http://dx.doi.org/10.1016/j.sjbs.2013.11.003

is now an alternative disposal route for wastewater. In this situation, wastewater components are used productively to supply crop growth with nutrients (Dewedar et al., 2005; Roushdi et al., 2012). The main problem with wastewater utilization for irrigation in agriculture, apart from the possibility of it containing hazardous constituents, such as trace elements and organic compounds, is the risk of polluting groundwater. Furthermore, wastewater used on farming land increases the possibilities of damaging the productivity of the soils in the long run.

The growth of non-food crops in a closed hydroponic system, using wastewater as nutrient solution, could solve in an ecologically acceptable way the domestic wastewater problem in the developing countries and in the meantime produce biofuels, or other products useful for the industry (Mavrogianopoulos et al., 2002).

Constructed wetlands are a sewage technology which is appropriate for developing countries (Butler et al., 1988; Butler and Dewedar, 1991). Such systems have low energy and maintenance requirements (Williams et al., 1999). In addition, operating skills tend to be similar to those required for agriculture and irrigation, unlike the technically demanding control and maintenance requirements of conventional sewage treatment plants, which can pose problems in many locations. In developing countries there are also concerns about the public health implications of relatively unrestricted effluent disposal and re-use. The main objective in wastewater treatment, therefore, is often the removal of potentially pathogenic microorganisms (WHO, 1989).

Gravel Bed Hydroponics (GBH) engineered ecosystems consist of sloping channels lined with an impermeable membrane and filled with gravel or an equivalent aggregate to provide a matrix in which hydrophytes are then planted (Butler et al., 1988; Dewedar et al., 2005). Feed water is introduced at the top of the bed flows through the aggregate to emerge downstream as a final effluent.

It has been proposed that pathogen removal within gravel filled wetlands occurs through a variety of mechanisms: adsorption, sedimentation, filtration predation and inactivation due to environmental stresses. Previously mentioned mechanisms are all thought to have a role in the process of removing pathogens from wastewater being treated by the Gravel Bed Hydroponics System (Gersberg et al., 1989; Williams et al., 1995; Mavrogianopoulos et al., 2002; Shalaby et al., 2008).

Ciliates are organisms that can use the predation mechanism for pathogen removal from the Gravel Bed Hydroponics System. Moreover ciliates are organisms that are used to identify the saprobic level of a water body (Madoni, 1994). This is because certain saprobic organisms/ciliates can live in certain condition (polluted and less polluted and unpolluted) water. However the lack of information concerning the role of ciliated protozoa in improving and/or estimating the saprobic condition of the domestic wastewater being treated using Gravel Bed Hydroponics System is very regrettable.

In view of the lack of detailed information on the ciliated Protozoa from GBH systems, this study was made to (1) characterize the ciliate species present in such systems used for sewage treatment, (2) describe the distributional pattern of ciliated Protozoa within GBH systems, (3) explain the importance of ciliate organisms in raising the biological efficiency of the pilot system used for sewage purification in Ismailia.

2. Material and methods

2.1. Gravel Bed Hydroponics System (GBH)

The Gravel Bed Hydroponics System is a type of system used for sewage treatment, especially for secondary or tertiary treatment of sewage effluent (Butler et al., 1988; Dewedar et al., 2005). Fig. 1 shows the details of the GBH system established at Abu-Attwa in Ismailia city which lies on the Northeastern side of Egypt along the Western bank of the Suez Canal. It consists of two series of inclined filled beds lined with an impermeable membrane. The first series comprises of 6 beds planted with the common reed. Each bed in this series is 100 m long; except the first two (50 m each); 2 m wide; 300 mm deep; except the first two (600 mm each) and with a slope of 1 in 50–1 in 100. The second series is similar in its construction to the first, except that the beds are 40 m long, 150 mm deep and with a gradient of 1 in 50. All in all these six beds of the latter series were planted with crops except bed number three which was unplanted and kept as control. Crop Beds 1 and 2 were planted with Napier Grass. Crop Beds 4, 5 and 6 were planted with summer crops (e.g. Cotton, Sunflower, Sorghum, Beans), then with winter crops: (Sugar Beat, Maize and Beans).

Field scale trials of GBH systems have been applied to the treatment of domestic wastewaters in three different villages in Egypt for some fifteen years (Abu-Attwa, El-Takadom, and Samaha). During this period an extensive database of physical and chemical treatment information has been established.

This study will focus on the field scale trail based at Abu-Attwa in Ismailia city, as a joint project between Suez Canal University and Portsmouth University. The types of system employed at Abu-Attwa have been discussed by many authors (Butler and Dewedar, 1991; Stott et al., 1997; Dewedar et al., 2005).

2.2. Sample collection and examination

Sampling was carried out from six different sites in the GBH system vise: the system inlet, and the outlets of the following beds: Read Bed 2 and, 4 and Crop Beds 2, 3 and 6. These sites were chosen to represent as wide a range of different conditions as possible. Samples were collected from each bed on the same day and in the same sequence between 9.00 h and 11.00 h. Sixty samples (10 from each site) were collected during this study through ten visits. In each visit 300 ml samples were collected from each of the previously mentioned six sites in the GBH system. The samples were taken directly to the laboratory, where a volume of 200 ml from each sample was fixed using lugol's iodine 1% final concentration. The live ciliates in sub-samples of 100 ml volume from each sample were counted in a Borgrov counting chamber within 2 h of return to the laboratory. The number of live ciliates in the chamber was counted under a stereo microscope "Krowa optical", model SDZ-PL at a magnification of 14× – 90×. Live counts were repeated 5 times per sample. The fixed ciliates were concentrated by passing them through a fine meshed plankton net of mesh size 20 um and counted using an " Biovert" Inverted Transmitted Light Microscope model "115 US DMT 7" at a magnification of 400×. The morphology of the ciliates was studied on Protargol stained specimens (Tuffrau, 1967). Many