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ScienceDirect
Chemosphere 71 (2008) 975–981
CHEMOSPHERE
www.elsevier.com/locate/chemosphere

Technical Note

Municipal wastewater treatment using novel constructed soil filter system

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Received 4 July 2007; received in revised form 16 November 2007; accepted 19 November 2007
Available online 22 January 2008

Abstract

The study gives a new approach for contaminant removal from municipal wastewater using constructed soil filter (CSF) and presents performance of two CSF units located in Mumbai, India. In this system, natural weathered rock is formulated which combines sedimentation, infiltration and biochemical processes to remove suspended solids and oxidisable organics and inorganics of the wastewater. Results show elevated dissolved oxygen (DO) levels, removal of COD (136–205 to 38–40 mg l^{-1}) and BOD (80–125 to less than 12 mg l^{-1}) suspended solids from 135–203 to 13–18 mg l^{-1} and turbidity from 84–124 to 8–11 NTU, bacterial removal of 2.4–3.1 log order for Total coliform and Fecal coliform from site I which is almost 8 years old facility, and site II which is 3 years old. Estimated hydraulic retention time of 0.5–1.0 h, hydraulic loading of 0.036–0.047 $m^3\ m^{-2}\ h^{-1}$, no pretreatment, high DO levels in the effluent, no bio-sludge production, no mechanical aeration, low energy requirement (0.04 kW h m^{-3}) and green aesthetic ambience are its unique features.

Keywords: Constructed soil filter (CSF); Soil biotechnology; SBT; Wastewater purification; Pathogen removal

1. Introduction

Water resources on earth are diminishing rapidly and human activities continue to affect detrimentally the quality and quantity of existing fresh water resources. Perks et al. (2004) has projected a water demand of 18 000 million litres per day (MLD) and wastewater generation of 14 400 MLD for the Mumbai city by 2025. So there is urgent need for fresh water conservation and wastewater renovation (Kivaisi, 2001).

There are conventional and non conventional approaches for wastewater treatment. For waters already treated to primary and secondary levels, land treatment is a promising tertiary treatment technology. There are many types of land treatment system namely slow-rate irrigation system (Ou et al., 1997), overland flow system (Smith and Schroeder, 1985), rapid infiltration systems (Bouwer, 1985), sand filters (Bahgat et al., 1999), soil infiltration systems (Jenssen and Siegrist, 1990) and intermittent buried sand filters (Schudel and Boller, 1990). Operation cost, mismatch of operating requirements with local skills and space constraint has limited their applications (Bahgat et al., 1999).

2. Constructed soil filter (CSF) system

CSF is a new process wherein formulated media comprising local weathered rock of suitable mineral constitution and culture containing native microflora and bio-indicator plants is used to bring about treatment. In CSF system, geophagus worm – *Pheretima elongata* (*k* selected organism) is cultured to maintain required soil microbial ecology. US patent covers details (Shankar et al., 2005). Experimental studies with lab scale CSF show oxygen transfer coefficient in the range of 10^{-2}–$10^{-3}\ s^{-1}$ (Kadam, 2007) and reduction potentials of more than

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0045-6535/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.chemosphere.2007.11.048

600 mV for organic loading of less than 0.15 kg m^{-2} d^{-1} for hydraulic loading of 0.35 m^3 m^{-2} d^{-1} (Pattanaik, 2000).

In this work we present results for wastewater purification in two CSF facilities monitored over a period of 9–10 months. We show that CSF with natural oxygen supply and microbial ecology in place brings about primary, secondary and tertiary level wastewater purification in one pass.

3. Study site

3.1. Plant description

The facilities are located in Mumbai, India. Mumbai being a port city shows very little variation in temperature ranging from 24 to 32 °C with heavy rainfall of 2500 mm during June–October. Both the plants receive raw sewage from municipality mixed with septic tank effluent and the treated water is used for irrigation of golf complex.

These systems are housed in reinforced cement concrete (site I), stone-masonry or soil embankment (site II) and consist of an impervious containment typically below ground, 0.7 m deep. At the bottom, a 0.3 m of underdrain layer of stone or rubble, above which there is a 0.4 m layer of media housing culture and bioindicator plants. Soil medium used here is completely weathered Deccan Trap Basalt soil found in and around Mumbai. The design has suitable provision for manual removal of suspended solids from the biofilter surface. Fig. 1 shows layout of the media. Distribution of wastewater over the media is achieved via pumping, piping and distribution arrangements.

3.2. Process description and operation

The process can be operated on batch or continuous mode. However, at these sites the system operates in a batch mode in which wastewater is pumped and applied onto the top surface of the system as shown in Fig. 1. Typical hydraulic loading is in the range of 0.036–0.047 m^3 m^{-2} h^{-1}. A batch volume of 30 m^3 or 300 m^3 is pumped into the trenches of the respective sites. Water first percolates through the trenches and gets collected into the collection tank. It is then distributed over the media through distribution system in order to achieve high solid liquid contact. The treated water is collected in the collection tank. Recirculation is done if necessary. Details of the sites and the operating conditions are given in Table 1.

Table 1
Constructed soil filter plant details of the two sites

Site	I	II
Wastewater	Domestic + septic tank	Domestic + septic tank
Batch volume (m^3 d^{-1})	30	300
Design capacity (m^3 d^{-1})	120	1000
Pretreatment	No	No
BED		
Bed dimensions (m)	20 × 12 × 0.7	50 × 30 × 0.7
Bed surface area (m^2)	240	1500
Upper media (m^3)	72	317
Lower media (m^3)	96	450
Hydraulics		
Flow	Vertical	Vertical
Mean hydraulic load (m h^{-1})	0.027	0.018
Raw flow (m^3 h^{-1})	14.4	39.6
Recycle flow (m^3 h^{-1})	10.8	54.0
Batch time: h	4.67 (2.40 + 2.0)	11 (5.30 + 5.30)
Plant age	1995 onwards	2003 onwards

I: site located at Bombay Presidency Golf club, Chembur, Mumbai, India; II: site located at Bombay Presidency Golf club, Chembur, Mumbai, India.

4. Materials and methods

4.1. Physicochemical and microbial analysis

Samples of raw water and treated water were collected from the respective sites once in a week and analyzed during the period from October 2003 to July 2004. Samples were collected in sterile 2 l plastic cans, brought to the laboratory and stored at 4 °C before analysis. Water samples were filtered through Millipore membrane filters (0.45 μm) for all physicochemical analysis except for solids.

Water temperature, conductivity and total dissolved solids (TDS) were measured immediately using WTW (Germany) Inolab1 conductivity meter; pH and dissolved oxygen (DO) using WTW (Germany) Inolab1 pH/Oxi meter; turbidity using WTW (Germany) Turb 550. Chemical analysis viz. BOD (5-d BOD test), COD (close reflux),

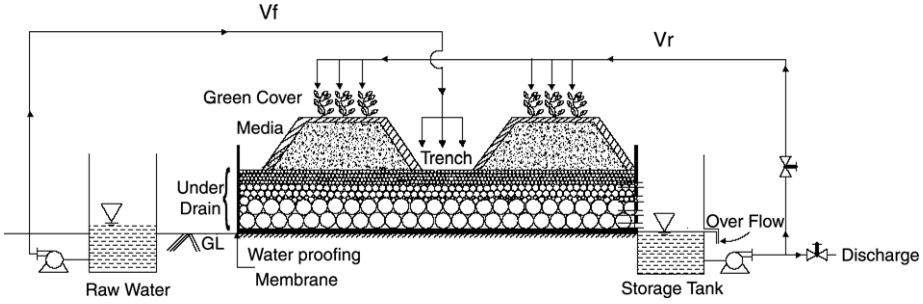

Fig. 1. Upper and Lower media showing layout for processing water.