Journal of Environmental Management 177 (2016) 271–277

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Feasibility study for the treatment of municipal wastewater by using a hybrid bio-solar process

Anjali Barwal, Rubina Chaudhary*

School of Energy and Environmental Studies, Faculty of Engineering Sciences, Devi Ahilya University, Takshashila Campus, Khandwa Road, Indore, Madhya Pradesh 452001, India

A R T I C L E I N F O

Article history:
Received 14 January 2016
Received in revised form
30 March 2016
Accepted 8 April 2016
Available online 22 April 2016

Keywords:
Moving bed biofilm reactor
Municipal wastewater
Photocatalysis
Solar disinfection
Solar parabolic trough
Titanium dioxide

A B S T R A C T

A moving bed biofilm reactor (MBBR) coupled with solar parabolic structured system has been designed and developed to get the maximum organic load removal and microbial disinfection from the wastewater. The effluent was first subjected to organic degradation in MBBR (with optimized carrier filling rate of 30%) followed by the bacterial degradation using solar energy in parabolic trough and the changes in values of parameters like pH, turbidity, chemical oxygen demand (COD), bio-chemical oxygen demand (BOD) and microbial count were monitored. The titanium dioxide (TiO_2) was used as a photocatalyst for the removal of organic load from the wastewater but in optimized conditions. At optimum dose of 1.0 g/L of TiO_2 and pH value of 7.6, maximum COD removal of 69% and 13% was achieved at sunny days (solar irradiation 400–700 W m^{-2}) and cloudy days (solar irradiation 170–250 W m^{-2}) respectively within 5–6 h solar irradiation time. The results obtained showed that it is possible to decrease in six logarithms (log) the concentration of TC and FC within only 240 min of solar exposure. Moreover, this process can offer economically reasonable, chemical free and practical solution to the processing of municipal wastewater where solar intensity is readily available and can be used for making zero liquid discharge (ZLD) an effective reality.

1. Introduction

Water reuse and recycling is one of the key strategies for the sustainable management of water resources as it is most economically viable and environment friendly solution to continuing water crisis globally (Rasul et al., 2006). Conventional water and wastewater treatment processes have been long established in removing many organic/inorganic chemical and microbial contaminants of concern to the environment and public health. However, the efficiency and effectiveness of these processes has been increasingly challenged with the identification of more contaminants, rapid growth of population, various industrial activities and diminishing availability of fresh water resources (Kositzi et al., 2004; Singh et al., 2011).

Reuse of treated wastewater can deliver positive benefits to the irrigation, industrial sector, recharge of ground water and for municipal supply. With careful planning various industrial and agricultural demands may be met by purified sewage water thereby freeing fresh water only for domestic use (Hussain et al., 2002).

Conventional technologies used for disinfection of non potable water include ozonation, chlorination, artificial UV radiation, filtration and solar pasteurization. These technologies are capital intensive, require sophisticated equipment, and demand skilled operators (Caslake et al., 2004; Dejung et al., 2007). Therefore, the need for a low-cost, low-operation and maintenance, and effective disinfection system for the improvement of water quality is high. In the current scenario, renewable energies are rapidly increasing their contribution to the global mix, solar energy being the one with higher potential. The use of solar irradiation for treatment of chemically and biologically contaminated water is not a new phenomenon (Malik et al., 1982; Davies-Colley et al., 1994; Conroy et al., 1996; Safapour and Metcalf, 1999; Sinton et al., 1999, 2002; Caslake et al., 2004). Solar radiation removes a wide range of organic chemicals and pathogenic organisms by direct exposure, is relatively inexpensive, and avoids generation of harmful byproducts of chemically driven technologies (Calkins et al., 1976). The rate of photo mineralization of an organic compound depends on the nature of the photocatalyst, catalyst loading, reactor configuration,

* Corresponding author.
E-mail addresses: anjali.barwal@gmail.com (A. Barwal), rubina_chaudhary@yahoo.com (R. Chaudhary).

http://dx.doi.org/10.1016/j.jenvman.2016.04.022
0301-4797/

concentration of the compound, wavelength, radiant flux and pH (Singh et al., 2011).

The authors have made an attempt to design an efficient advanced coupled (secondary and tertiary) treatment technology to treat municipal wastewater. This study was focused on performance evaluation of hybrid bio-solar process (during sunny and cloudy conditions) for treating the high concentrations of complex organics to achieve very low COD/BOD value and potability of municipal wastewater in an economical manner.

2. Material and methodology

2.1. Wastewater

A synthetic wastewater was used to stimulate the municipal wastewater. The synthetic wastewater contains urea, ammonium chloride, sodium acetate, peptone, magnesium hydrogen orthophosphate trihydrate ($MgHPO_4 \cdot 3H_2O$), potassium dihydrogen orthophosphate (KH_2PO_4), ferrous sulphate ($FeSO_4 \cdot 7H_2O$), starch, glucose, yeast and trace nutrients, which has chemical oxygen demand (COD) of 440 $\pm$ 10 mg L^{-1}, biochemical oxygen demand (BOD) of 370 $\pm$ 20 mg L^{-1}, turbidity 65 $\pm$ 5 NTU pH of 7.2 $\pm$ 0.7, 22 $\times$ 10^6 MPN per 100 mL of Total Coliform (TC) and 4 $\times$ 10^6 MPN per 100 mL of Fecal Coliform (FC).

2.2. Designing and configuration

A lab scale hybrid bio-solar reactor was designed and fabricated (located at 22°43′0″N, 75°50′50″E at an altitude of 553 m above sea level) for the treatment of municipal wastewater to achieve very less COD and no fecal Coliform presence. The schematic of the experimental set-up is shown in Fig. 1.

2.2.1. For biological reactor

A rectangular reactor (length 60 cm; width 35.5 cm and height 14 cm) with a volume of 30 L made up of acrylic sheet was used in this study. The effective working volume was 20 L. The reactor was filled with commercially available biofilm carriers (Brand name: CoolFloat, Model No. CD-BF22), which are made of polypropylene and have shapes of rings with cross inside (density < 0.97 g cm^{-3}, diameter 22 mm, height 20 mm, specific gravity 0.90–0.95 g cm^{-3} and specific surface area 450 m^2 m^{-3}). The reactor was continuously fed with synthetic municipal wastewater. An aeration pump was used for air supply and for keeping the sludge in suspension.

2.2.2. For parabolic trough reactor

In continuation with biological reactor, a parabolic trough reactor (PTR) was designed and modified in the shape of a parabolic cylinder (aperture length 172 cm; aperture width 57.75 cm) which reflects and concentrates sun radiations towards a receiver tube located at the focus line of the parabolic cylinder. The length of the receiver tube was almost doubled (length of photoreactor tube 1.9 $\times$ 2 = 3.8 m; internal diameter 38 mm). The reflector was polished by aluminium material. The collector has a tilted N-S axis with manual tracking of sun. The receiver absorbs the incoming radiations and latter being transported and collected by a fluid medium circulating within the receiver tube. In the design of solar photocatalytic collector, the fluid is exposed to ultraviolet (UV) solar radiation and therefore, the absorber transmits UV sunlight efficiently with minimal pressure drop (Bahnemann, 2004).

2.3. Operating conditions

2.3.1. For biological reactor

To initiate biological growth and development of the biofilm, the reactor was inoculated with mixed culture of biomass having mixed liquor suspended solids (MLSS) concentration of 2300 mg L^{-1}, mixed liquor volatile suspended solids (MLVSS) concentration of 1914 mg L^{-1}, MLVSS/MLSS ratio of 0.83 and sludge volume index (SVI) of 76.2 mL g^{-1}. Wastewater feeding was done with the help of peristaltic pump. The dissolved oxygen concentration was >4 mg L^{-1} throughout the experiment. Whole study was performed under ambient conditions. Initially, the experimental work was carried out with 10, 20, 30, 40 and 50% carrier filling rate to optimize the filling ratio. The duration for each experimental run was 15-days with 10-days microbial acclimatization time. The hydraulic retention time was kept higher (20 h) as the biocarriers took long time for acclimatization.

2.3.2. For parabolic trough reactor

The treated water from biological reactor goes to the PTR with the help of peristaltic pump. A PTR concentrates the direct radiations of the photocatalytically active UV part of the solar spectrum

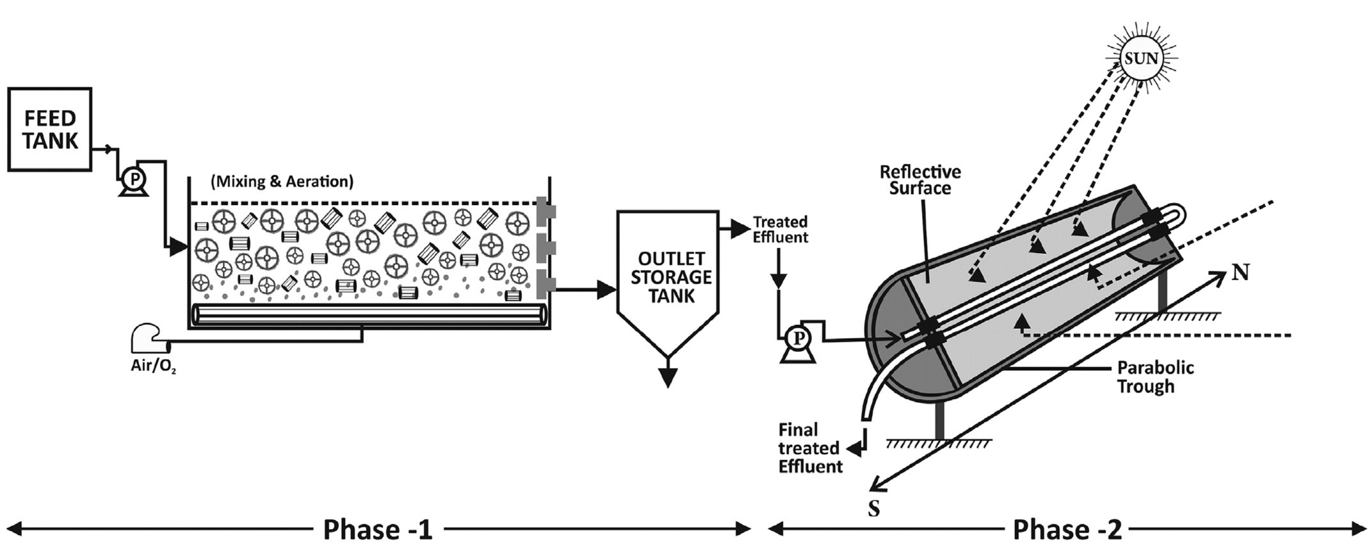

Fig. 1. Schematic of the experimental set-up of biological reactor coupled with solar parabolic trough.