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A new recycling technique for the waste tires reuse

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ABSTRACT

In this series of laboratory experiments, the feasibility of using fixed bed biofilm carriers (FBBC) manufactured from existing reclaimed waste tires (RWTs) for wastewater treatment was evaluated. To assess polyamide yarn waste tires as a media, the fixed bed sequence batch reactor (FBSBR) was evaluated under different organic loading rate (OLRs). An experimental model was used to study the kinetics of substrate consumption in biofilm. Removal efficiency of soluble chemical oxygen demand (SCOD) ranged by 76–98% for the FBSBR compared to 71–96% in a sequencing batch reactor (SBR). Removal efficiency of FBBC was significantly increased by inoculating these RWTs carriers. The results revealed that the sludge production yield (Y_{obs}) was significantly less in the FBSBR compared to the SBR ($p < 0.01$). It also produced less sludge and recorded a lower stabilization ratio (VSS/TSS). The findings show that the Stover-Kincannon model was the best fit ($R^2 > 99\%$) in a FBSBR. Results from this study suggest that RWTs to support biological activity for a variety of wastewater treatment applications as a biofilm carrier have high potential that better performance as COD and TSS removal and sludge settling properties and effluent quality supported these findings.

1. Introduction

Scrap tires are a major environmental problem worldwide. The current scrap tire recycling market is too small compared to the annual number of waste tires generated globally (17 million T) (Herrera-Sosa et al., 2015; Mehdiabadi et al., 2013). Waste tires are nearly non-degradable and take up large landfill space. If not properly disposed of, they can hold water that provides a breeding ground for mosquitos and facilitate the spread of mosquito-borne disease. It is essential to develop new markets for waste tires (Lin et al., 2008; Selbes et al., 2015).

An improper management of waste tires, as the combustion, unfortunately still a common phenomenon and it produces serious air, water, and soil pollution issues (Sciacca and Conti, 2009; Derakhshan et al., 2017; Oliveri Conti et al., 2017a; Dehghani et al., 2017; Oliveri Conti et al., 2017b); however, waste tire has a high heat value and is used as supplemental fuel in cement kilns and paper mills (Chyan et al., 2013; Naz et al., 2014). Waste tires can also be recycled as: roadway pavement material, refuse-derived fuel, or reproduced as tires, but also to produce rubber mats, roadway guard rails, protective cushions or bumpers, and building materials (Gupta et al., 2014). In marine applications, they are used as a wave breaking material, ship/dock protective bumpers, and to construct artificial reefs in the offshore fish farming industry (Lin et al., 2008). Nevertheless, these markets are small compared to the number of tires generated each year. It is of great interest to explore new applications/markets for the scrap tire industry (Herrera-Sosa et al., 2015; Lin et al., 2008).

Among the biological technologies, the sequencing batch reactor (SBR) is unique for its flexible operation, compact structure and simple

Abbreviations: BOD_5, Biochemical Oxygen Demand; COD, Chemical Oxygen Demand; DO, Dissolved Oxygen; FBBC, Fixed Bed Biofilm Carriers; FBSBR, Fixed-Bed Sequence Batch Reactor; HRT, Hydraulic Retention Time; MLSS, Mixed Liquor Suspended Solids; OLRs, Organic Loading Rates;; RWTs, Reclaim Waste Tires; SEM, Scanning Electron Microscopy; SBR, Sequencing Batch Reactor; SRT, Solids Retention Time; SCOD, Soluble Chemical Oxygen Demand; TSS, Total Suspended Solids; VSS, Volatile Suspended Solids; VOL, Volumetric Organic Loads; VOR, Volumetric Organic Removal

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construction (Kulkarni, 2013; Mahvi et al., 2011; Takdastan et al., 2009). But also, the hybrid system combining suspended and biofilm process to realize the compact structure and flexible operation with high efficiency is well accepted in current literature (Mahvi, 2008; Maranon et al., 2008; Rodríguez et al., 2011; Santos and Boaventura, 2015).

Among the hybrid process, FBSBR method is an effective method for the wastewater treatment for its high efficiency in organic material's deletion by wastewater and it is able to quickly reduction the biodegradable organic materials. A highest use of this system is justified by more stringent provisions to the higher quality for output wastewater finalized to protect and preserve the resources water. Several studies have proven that FBSBR possesses attractive properties such as high biomass, high chemical oxygen demand (COD) loading, strong tolerance of loading, and no sludge bulking problem (Santos and Boaventura, 2015). The FBSBR can maximize sludge retention time (SRT) in the biofilm and has the potential for operating a suspended activated sludge system with a relatively short hydraulic retention time (HRT). Moreover, in FBSBR, microorganisms with different SRTs can be developed in a single reactor (Chen et al., 2015; Moghaddam and Sargolzaei, 2015; Santos and Boaventura, 2015).

Several materials have been tested as carriers (media) in sequencing batch biofilm reactors. Soltani et al. (2013) investigated the effects of peach pits as media on the efficiency of a fixed-bed sequencing batch reactor (FSBR). Their study showed that when organic loading was 12 kg_{COD}/m^3.d, organic matter removal in the FSBR and SBR reactors was 71.84% and 56.57%, respectively, and SRT decreased from 40 to 19.8 d (Soltani et al., 2013). Dutta et al. (2014) studied the effects of granular activated carbon and natural zeolite as attached carriers in anaerobic sequencing batch biofilm reactors and showed that the addition of carriers improved both the COD removal efficiency and biogas production. A summary of researches on the sequencing batch biofilm reactors is presented in Table 1.

The main objective of present study was to explore the feasibility of using reclaim waste tires (RWTs) as a suitable media for biological growth and biofilm development in wastewater treatment system. More specifically, the study focused on using RWTs as a biofilm carrier in FBSBRs. In addition, the possibility of an alternative form of recycling of RWTs was also evaluated.

2. Materials and methods

Two reactors (SBR and FBSBR) were powered in parallel, under the same conditions, to determine the effectiveness of RWTs as a media for biological removal of organic carbon, to improve sludge quality, and reduce sludge production yield.

2.1. Preparation of media

The RWTs were obtained from Yazd Tire Company. The RWTs were measured using a ruler to determine the approximate average size. Physicochemical characterization studies were performed to verify the chemical resistance of the novel biofilm carrier by placing it in glass beakers containing tap water, acidic (pH = 4.9), and basic (pH = 9.2) solutions for 30 days. The media were then removed from the solution, rinsed repeatedly with distilled water, dried in an oven at 60 °C for 24 h, cooled in a desiccator, and then reweighed (Natarajan et al., 2015). Weight loss of 1.8% and 2.5% were recorded for samples placed in acidic and basic solutions, respectively.

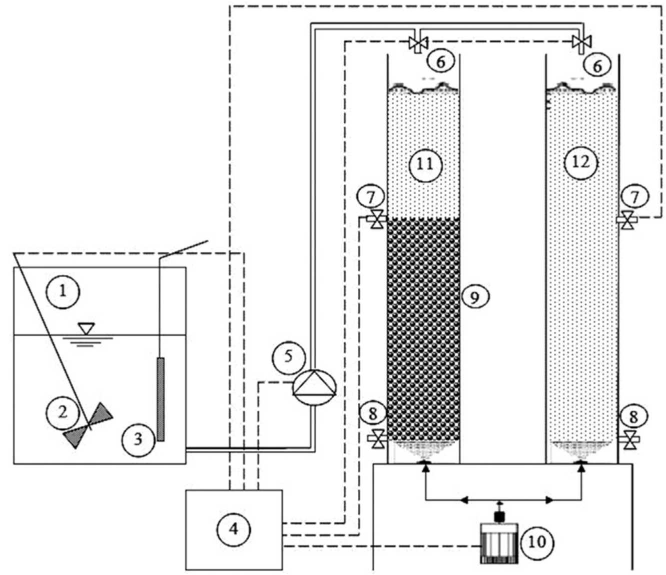

Fig. 1. Schematics of SBR and FBSBR. 1- Feed Tank, 2- Mixer, 3- Heater, 4- Control Unit, 5- Peristaltic Pump, 6- Feed Control Valve. 7- Decanter(Sampling) Valve, 8- Discharge Sludge Port, 9- Novel Packing Media, 10-Air compressor, 11- FBSBR Reactor, 12- SBR Reactor.

2.2. Experimental set-up and operating conditions

The experiment was carried out in the SBR and FBSBR at a total volume of 4.7 l, a diameter of 0.1 m, and a height of 0.6 m (Fig. 1). In the FBSBR, RWTs with a porosity of 90%, specific surface area of ~370 m^2 m^3 and a total volume of 2 l (40%) were fixed to the bottom of the reactor.

2.3. Pilot start-up

Activated sludge from the Yazd wastewater treatment plant was used to seed the pilot start-up at a volume of ~3.5 l per reactor and a COD of 500 ± 7.54 mg/l. The floc was established over 3 wk. of aeration and reaction. At this stage, food was added each day. The COD, dissolved oxygen (DO), pH, and temperature of the wastewater were recorded and compared with the results of samples collected at 3 wk. after pilot start-up. The effluent's COD values were similar to each other, which indicates the end of the start-up period. Biofilm had also formed on the media in the FBSBR.

The exchangeable volume of each reactor was 2 l. The reactors were maintained at a fixed temperature of 30 ± 2.4 °C (average temperature of Yazd from January through June is 30 °C) using a thermostaticheater. The reactors were operated in cycles of 10, 8, 6 and 4 h. The system was controlled using the timer switches (Theben; Germany).

Each cycle comprised 4 phases.

Table 1
Estimated Efficiency of some researches on fixed-bed sequencing batch reactors.

Type of reactor	Media	Environment	Efficiency (%)	Reference
Anaerobic/aerobic fixed-bed sequencing batch biofilm reactor	Volcanic pumice stone	Synthetic wastewater	92–94	(Hosseini Koupaie et al., 2013)
	Plastic media (polyethylene)		95–96	
FBSBR	Plastic media (polyethylene)	Synthetic wastewater	90–96	(Rahimi et al., 2011)
SBBR	Fibrous carrier	Synthetic wastewater	90–95	(Zhang et al., 2009)
Sequencing batch reactor biofilm	Polypropylene carriers	Wastewater	95	(Yin et al., 2015)