JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

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JOURNAL OF ENVIRONMENTAL SCIENCES
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Effects of the support material addition on the hydrodynamic behavior of an anaerobic expanded granular sludge bed reactor

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ARTICLE INFO

Article history:
Received 6 November 2015
Revised 18 February 2016
Accepted 19 February 2016
Available online xxxx

Keywords:
Anaerobic digestion
Axial dispersion degree
EGSB reactor
Hydrodynamics
Upflow velocity
Zeolite

ABSTRACT

As a support material, zeolite can be used to promote the granulation process due to its high settable property and the ability to retain biomass on its surface. The present paper reports on the influence of zeolite addition on the hydrodynamic behavior of an expanded granular sludge bed reactor (EGSB). Different models were applied to fit the flow pattern and to compare EGSB hydrodynamic performance with and without the addition of zeolite. The experimental data fit the tanks in a series model for zeolite bed height of 5 cm and upflow velocity of 6 m/hr. Higher axial dispersion degree (D/uL) was obtained at lower heights of zeolite. The real hydraulic retention time (HRTr) was increased with both increased zeolite bed height and increased upflow velocity. The short-circuit results for 5 cm of zeolite bed and 6, 8 and 10 m/hr upflow velocity were 0.3, 0.24 and 0.19 respectively, demonstrating the feasibility of using zeolite for a proper hydrodynamic environment to operate the EGSB reactor. The presence of zeolite resulted in the higher percentage values of dead zones, ranging from 12% to 24%. Zeolite addition exerted a positive effect on the hydrodynamics pattern for this technology being advantageous for the anaerobic process because of its possible contribution to better biofilm agglomeration, granule formation and substrate-microorganism contact.

Introduction

The expanded granular sludge bed (EGSB) reactor is a modified version of the Upflow Anaerobic Sludge Blanket (UASB) reactor operated at high superficial upflow velocities, which can be achieved by applying both a higher height/diameter ratio for the reactor and effluent recirculation (O'Reilly and Colleran, 2005). The EGSB was developed to improve sludge/wastewater contact and to reduce the existence of dead zones, preferential flow, and short-circuits (Kato et al., 1994; Seghezzo et al., 1998; Nicolella et al., 2000; Fuentes et al., 2011). EGSB reactors are gaining more attention than UASB applications due to EGSB's higher loading rates, which are favored by the hydrodynamics (Puñal et al., 2003). UASB and EGSB systems have been applied

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http://dx.doi.org/10.1016/j.jes.2016.02.011
1001-0742 © 2016 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

to a wide range of wastewater strengths. Both EGSB and UASB reactors are based on the ability of microorganisms to form dense aggregates by autoimmobilization.

Because of its complex nature, the local hydrodynamic behavior of EGSB reactors is not well-documented. From the hydrodynamic point of view, the model to describe EGSB reactors is based on completely mixed reactors. By incorporating a hydraulic short-circuit assumption, no significant improvement is obtained; therefore, the ideal mixing model is considered the appropriate representation of the flow conditions in the EGSB reactor (Rodríguez et al., 1983; Arvin and Harremöes, 1990). When simple kinetic models are used, the deviations of the completely mixed performance are not considered (López and Borzacconi, 2010). In general, a high interstitial velocity tends to increase the plug-flow characteristics, but recirculation increases back mixing, and this effect predominates in the EGSB (Brito and Melo, 1997; Ojha and Singh, 2002; Chowdhury and Mehrotra, 2004; Batstone et al., 2006; Chou et al., 2011; Fang et al., 2011; Fuentes et al., 2011; López and Borzacconi, 2011).

The hydrodynamics of upflow reactors are regulated so that bacteria coalesce to form granules with high settling velocities. However, due to the upflow velocity of the liquid and gas bubbles, the sludge bed is expanded and partially fluidized (Bhattacharyya et al., 2009). Many theories regarding the conditions in which bacterial adhesion is responsible for a proper granulation process are well-documented. However, these theories are based on the notion of increased growth resulting in heavier sludge agglomeration. Consequently, the presence of inert particles with remarkable settable properties serving as surfaces on which bacteria can adhere is beneficial (Rough et al., 2005).

In this respect, several clay minerals and other materials have been reported due to their influence on the microbial and enzymatic transformations of a wide variety of substances (Borja et al., 1996; Milán et al., 2003; Pereda et al., 2006). Zeolite, because of its structure and physical properties, is ideal in biological purification wastewater processes (Wong and Yeung, 2007; Carretero and Pozo, 2009; Marty et al., 2010; Park et al., 2010). Its use as a porous support in fluidized and fixed-bed configurations enables anaerobic reactors to retain high biomass concentrations and thereby to operate with significantly reduced hydraulic retention times (Milán et al., 2010). Consequently, the use of natural zeolite in different wastewater biological treatment processes has increased in recent years (Apollo et al., 2014; Zheng et al., 2015; Ziganshina et al., 2015).

As demonstrated, hydrodynamic behavior affects biological processes (Brito and Melo, 1997; Karim et al., 2005). Furthermore, zeolite, due to its high settable property and capability to retain biomass on its surface, can be used as a promotor of the granulation process. Combining the EGSB configuration with zeolite in wastewater treatment could be very advantageous. Therefore, this paper aimed to evaluate the effects of zeolite addition on the hydrodynamics of an anaerobic EGSB to guarantee a more successful biological process.

1. Materials and methods

1.1. Experimental set up

The lab experiment was conducted in an acrylic EGSB reactor with a tube and separator with diameters of 0.05 and 0.11 m, respectively. The heights of the tube and separator, respectively, were 0.96 and 0.11 m (Fig. 1). The effective volume was 3.04 L. Small crystal balls were used at the bottom of the reactor to guarantee a homogeneous distribution of the water upflow.

The tests were performed for different upflow velocities (6, 8 and 10 m/hr) using three amounts of zeolite in beds with heights of 1, 3 and 5 cm (without fluidization), with mean particle diameters of 0.151, 0.174 and 0.196 mm. The amounts of zeolite corresponded to 0.6%, 1.9% and 3.2% of the effective volume of the EGSB reactor. Trials without the addition of zeolite were performed with these same velocities. The theoretical hydraulic retention time (HRTt) was 12 hr (obtained with a feeding flow of approximately 4 mL/min), and recirculation flows (Q_r) of 195, 260 and 320 mL/min were used to obtain the desired upflow velocities.

1.2. Zeolite

The zeolite used in the study was naturally purified and was from the Tasajeras deposit in Villa Clara Province, Cuba. The zeolite is characterized by a mixture of 70% clinoptilolite–heulandite, 5% mordenite, 15% anorthite and 10% quartz. The zeolite was sieved to different granulometries. The mean diameter of the particles in the sample was calculated using the equation described by Kunni and Levenspiel (1991).

1.3. Tracer study

The hydraulic characteristics of the EGSB reactor were measured through mixing studies using a solution of Dextran Blue as tracer at a concentration of 10 g/L to obtain a residence time distribution (RTD) curve or exit age distribution curve (E-curve for pulse input).The reactor was fed with water from the public supply system, and the hydrodynamic tests were

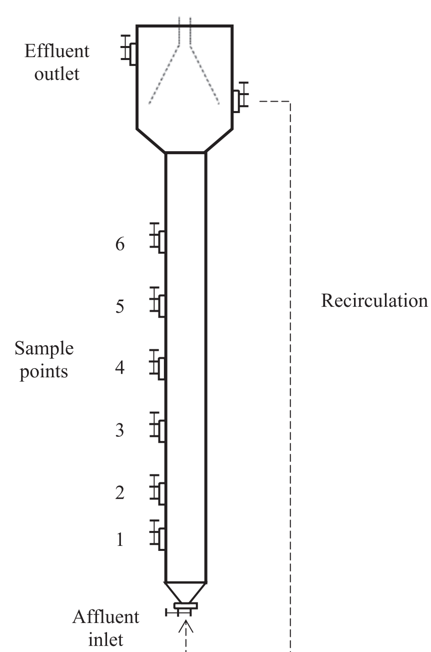

Fig. 1 – Expanded Granular Sludge Bed reactor used in the trials.