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Short communication

Investigation on the performance of sugarcane bagasse as a new carbon source in two hydraulic dimensions of denitrification beds

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ABSTRACT

Hydraulic modeling of denitrification beds is very useful for improving the performance of substrates. In this work, a column study was conducted for 98 days on two types of substrates using two different column lengths and at varying loading rates to determine the best hydraulic dimensions of the substrates. One substrate consisted of soil alone and the other substrate consisted of the same soil along with sugarcane bagasse (acting as an additional carbon source). The substrate with 0.7 h actual hydraulic retention time and 5.84 cm h^{-1} hydraulic loading rate was chosen as the best model for simulation of denitrification substrate with an optimum nitrate removal efficiency (85%) and a maximum removal rate (50 mg L^{-1} h^{-1}). The Fourier Transform Infrared analysis confirmed the degradation of sugarcane bagasse during the denitrification process.

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1. Introduction

Nitrate is one of the most common groundwater contaminants (Schipper and McGill, 2008). Available technologies for reducing nitrate leaching include plant or crop harvesting (Cameron, 1997); nitrate immobilization into the organic matter (Degens et al., 2000) and denitrification (Ghane et al., 2015). Denitrification is the process by which nitrate is reduced to N_2 gas by microbes, completing the nitrogen cycle (Schipper and McGill, 2008). This technology has been developed to remove/reduce the nitrate concentrations from the aquatic environment (Xiao et al., 2013). Denitrification walls can consist of 100% woodchips or sawdust mixed with soil or sand (Robertson and Cherry, 1995). The performance of four carbon sources (wood, barley straw, rice husks, and date palm leaf) as denitrification substrates has been previously studied (Hashemi et al., 2011). Hydraulic loading rate has been reported as an important factor influencing the performance of a soil remediation system (Li et al., 2011). Recently, different types of bed reactors using heterotrophic microorganisms and solar energy-powered floating media have been examined for the removal of nitrate-nitrogen (Chang et al., 2016; Mohanty et al., 2016).

To date, a variety of solid carbon sources (e.g., fresh chips, kinloch, karaka, dargaville, maize cobs, wood chips, hardwood, green waste, wheat straw, softwood, barley straw and palm leaf) have been investigated for nitrate removal in denitrification beds (Cameron and Schipper, 2011; Robertson, 2010; Schipper et al., 2010). Nevertheless, it is still necessary to find a cost-effective and more economical carbon source. Sugarcane industries produce different types of solid and liquid wastes which cause serious environmental pollution due to the lack of sustainable solutions for their waste management (Bhatnagar et al., 2016). Sugarcane bagasse is one of the by-products generated in sugar industries. Many developing countries produce enormous quantities of sugarcane bagasse and destroy or burn them inadequately causing pollution of the environment. However, many studies have shown the beneficial uses of sugarcane bagasse for different purposes (Makul and Sua-iam, 2016; Renouf et al., 2013). Therefore, the main objectives of this study were to evaluate the performance of two substrates (i) soil alone and (ii) mixture of soil and sugarcane bagasse (as a new denitrification substrate) in the denitrification process and to determine the optimal hydraulic parameters to

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Table 1
Important properties of the biofilters used in this study.

Characteristics	Type of substrate or biofilter	
	Soil	Soil + sugarcane bagasse
Organic material (%)	1.4	2
Organic carbon (%)	0.82	1.17
Total nitrogen (%)	0.075	0.096
C:N	10.93	12.19
ρ (g cm^{-3})	(1.55[a], 1.63[b])	(1.29[a], 1.37[b])
Total porosity (%)	(41.5[a], 38.5[b])	(51[a], 48[b])
Effective porosity (%)	(12[a], 11[b])	(8[a], 12[b])
Clay (%)	12	12
Sand (%)	44.6	44.6
Silt (%)	43.4	43.4
Soil texture	Loam	Loam

[a] biofilter with length of 35 cm.
[b] biofilter with length of 65 cm.

improve the performance of substrates containing sugarcane bagasse.

2. Materials and methods

2.1. Preparation of substrates and laboratory model

The soil was collected from a depth of 40–50 cm in an agricultural field placed in the research station of Shahid Chamran University, Ahvaz, Iran. Some of the important properties of substrates or biofilters are listed in Table 1. In each column, 70% of its volume consisted of soil and 30% consisted of sugarcane bagasse (Saccharum hybrid cultivar, CP69-1062). Fig. 1 shows the schematic representation of experimental columns set-up and simulation of hydraulic loading rates. Columns with lengths of 35 and 65 cm consisted of a mixture of soil and sugarcane bagasse and were named CT_1SB and CT_2SB, respectively. Columns with lengths of 35 and 65 cm consisted of only soil were named CT_1S and CT_2S, respectively. In order to properly simulate the denitrification process with saturated conditions, an upward flow was used. The input nitrate concentration of 45 mg L^{-1} was prepared with potassium nitrate (KNO_3). The approximate temperature of the study was 35 ± 5 °C.

2.2. Monitoring process

After the preparation of the columns and before the beginning of sampling, leaching of the columns was performed with urban treated water for one month. After determining the approximate outflow rate, drainage water with a known concentration of nitrate was injected into the columns. An upward flow was used to ensure that entire pore volumes of the columns were filled. During the experiments, flow was continuous, and the average influent nitrate concentration was 45 mg L^{-1}. The daily amount of drainage water was simulated in a large reservoir. The influents were supplied from

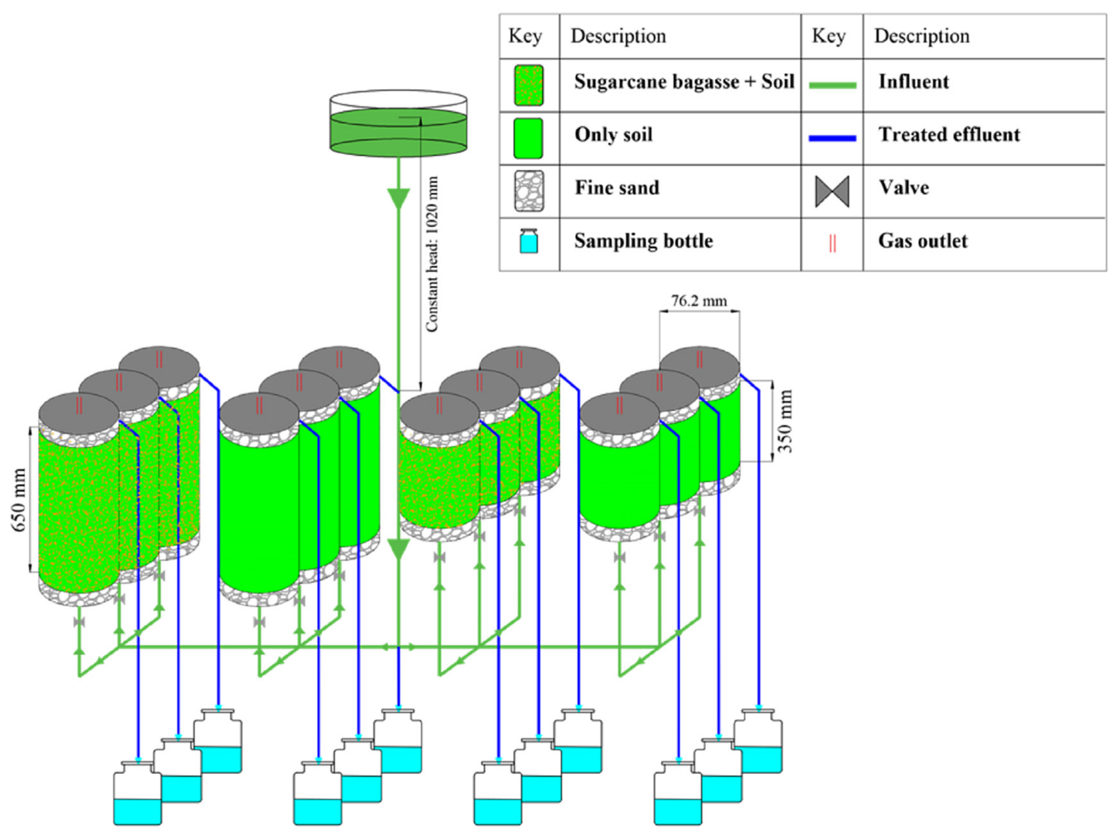

Fig. 1. Schematic representation of the laboratory columns used for the simulation of two different hydraulic loading rates.

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