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Reactivation of carbon exhausted sulfidogenic bioreactor by fractionated sweetmeat waste dosing: The role of neutralizing substance and nitrogen supplement

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HIGHLIGHTS

- External SMW dosing into carbon exhausted reactor regenerated sulfate reduction.
- $NaHCO_3$ maintained desired pH and provided better performance than quick lime (CaO).
- SMW combined with NH_4HCO_3 as dosing solution produced around 65% sulfate reduction.
- $COD_{consumed}/SO_4^{2-}{}_{reduced}$ and $DOC_{consumed}/SO_4^{2-}{}_{reduced}$ around 1 and 0.5 were achieved.

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ABSTRACT

The performance of passive sulfidogenic systems for the treatment of sulfate rich wastewater decreases over time due to the exhaustion of organic carbon. Bioreactors filled with spent mushroom compost (SMC) exhibited 90% sulfate removal for approximately 11 weeks in continuous operation. Performance efficiency declined sharply when dissolved organic carbon (DOC) concentration in the reactors reached below 50 mg L^{-1}. With an objective to reactivate sulfate removal in organic carbon exhausted SMC packed bioreactor, external pulse dosing of filtered sweatmeat waste (SMW) fraction was introduced. Various nitrogen compounds along with filtered SMW were tested as external dosing material. The effect of CaO and $NaHCO_3$ as neutralizing agents was also evaluated on process performance during external dosing. The mass loading ratio of chemical oxygen demand (COD) to sulfate was maintained at 1:1. Bioreactors started to reactivate within a week after SMW dosing and achieved approximately 60% sulfate reduction. SMW fraction when combined with NH_4HCO_3 as nitrogen source provided superior sulfate reduction performance compared to NH_4Cl and bacto-tryptone. Steady COD and DOC consumption to sulfate reduction mass ratios of approximately 1 and 0.5, respectively, were achieved with 70% electron flow towards sulfate reduction in this condition. Buffering with bicarbonate enhanced sulfate reduction as compared to lime. The results can be useful for reviving the performance of field treatment schemes where SMC and other similar substances are used as organic matrix.

1. Introduction

Passive remediation strategies to treat sulfate- and metal-rich wastewater are a common practice in mining and metallurgical industries for low sludge production, ease of use and low cost (Johnson and Hallberg, 2005). Sulfate reducing bacteria (SRB) play a major role in a number of passive treatment processes, such as anaerobic wetlands, anaerobic ponds, permeable reactive barriers (PRB) and successive alkalinity producing system (SAPS), by reducing sulfate to hydrogen sulfide (H_2S) with simultaneous alkalinity generation (Kaksonen and Puhakka, 2007; Bhattacharya et al., 2008). The biogenic H_2S precipitates metals as low solubility sulfides. An organic matrix is the integral

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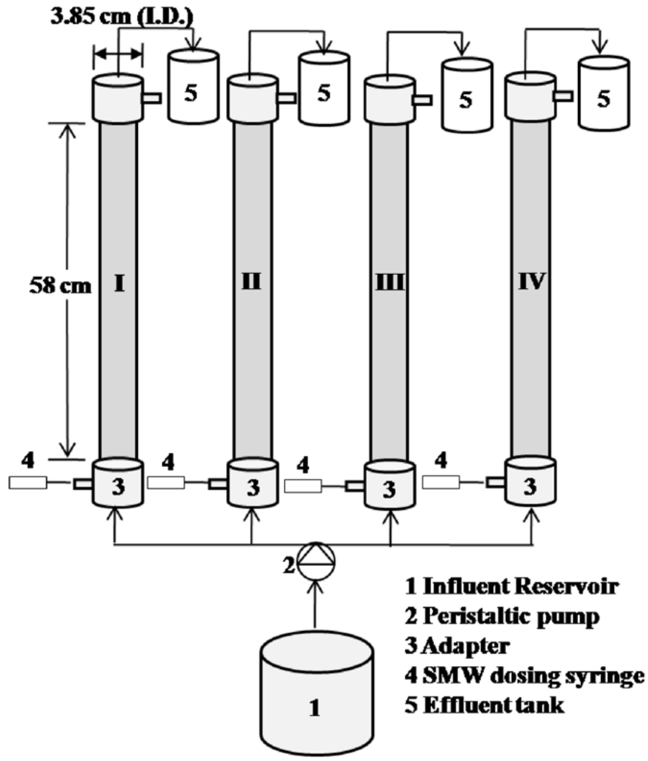

Fig. 1. Up-flow packed bed bioreactors used in the study. The bioreactors were covered with black paper to prevent light penetration.

part of these sulfidogenic treatment systems and provides substrates for SRB activity. Various organic matrices have been tested as growth substrates for SRB (Bhattacharya et al., 2008; Cheong et al., 2010).

Cellulosic and lignocellulosic solid waste materials have often been used in passive treatment systems to provide a growth matrix for biofilm formation (Coetser et al., 2006; Das et al., 2012). One of the limitations of using these plant waste based matrices is the depletion of available nutrients, especially organic carbon, over time, which leads to decreased treatment performance (Bhattacharya et al., 2008; Coetser et al., 2006; Das et al., 2012; Dann et al., 2009). SAPS or PRB treating sulfate rich wastewater often experience this problem and require periodic replacement of the matrix to maintain sufficient treatment performance (Bhattacharya et al., 2008). Replacement of exhausted organic matrix by new one delays the process restoration as SRB and other anaerobic microbes generally take long time for growth and establishment. The undegraded lignocellulosic portions in exhausted matrix along with dormant biofilm leaves an option of process rejuvenation upon external organic carbon supply (Das et al., 2012).

Selection criteria for an external organic carbon source include the biodegradability, availability and relative cost of the substance. Pure and synthetic substances, such as lactate are reported to be readily utilized by SRB (Kaksonen and Puhakka, 2007; Kaksonen et al., 2003; Das et al., 2013); however, they are not economic for passive treatment application. Recently, various food wastes have been tested as possible alternative substrates because they are readily available at low cost in some geographical locations (Das et al., 2013; Martins et al., 2011). Sweetmeat waste (SMW) is produced in high quantities in the Indian subcontinent in farms and food industries. These materials contain high sucrose content along with readily biodegradable organic acids. Das et al. (2013) reported the suitability of filtered SMW fraction as a carbon source for microbial sulfate reduction in a batch bioreactor. Its applicability as external organic carbon source to reinvigorate sulfate reduction in an exhausted reactor operating continuously has not been previously investigated.

This study aims to explore the possibility of prolonged performance of SMC packed sulfidogenic bioreactors using an external SMW fraction dosing after organic carbon exhaustion. Various nitrogenous supplements (NH_4Cl, NH_4HCO_3 and bacto-tryptone) along with filtered SMW fraction were tested for appropriate dosing material combination. Moreover, the efficacy of quick lime (CaO) and $NaHCO_3$ was tested as neutralizing agents during external dosing.

2. Materials and methods

2.1. Experimental setup

Four identical tubular up-flow packed bed bioreactors (58 cm in length and 3.85 cm in internal diameter) used in this study were made of acrylic sheet with steel adaptors at both ends (Fig. 1). The working volume in each bioreactor was 675 mL. Stainless steel mesh (1 mm pore diameter) was placed between the acrylic sheet and the steel adaptor to minimize channeling. Butyl rubber tubing was positioned over the mesh to make the bioreactor leak proof. The adaptors had two ports, one for dosing and another for sampling. Solution was pumped using a multichannel peristaltic pump and silicone tubing.

The bioreactors designated as I–IV were packed with 80 g of autoclaved spent mushroom compost (SMC), collected from a household farm after mushroom cultivation. The packed beds in bioreactors had porosities ranging from 0.63 to 0.64, and void volumes ranging from 425 to 435 cm^3. The mass density of the beds was 0.12 g cm^{-3}.