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Earthworm–microorganism interactions: A strategy to stabilize domestic wastewater sludge

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ABSTRACT

The performance of a conventional biofilter (BF) and a vermifilter containing the earthworm, *Eisenia foetida*, (VF) for the treatment of domestic wastewater sludge were compared with the earthworm–microorganism interaction mechanisms involved in sludge stabilization. The results revealed that the presence of earthworms in the VF led to significant stabilization of the sludge by enhancing the reduction in volatile suspended solids (VSS) by 25.1%. Digestion by earthworms and the earthworm–microorganism interactions were responsible for 54% and 46% of this increase, respectively. Specifically, earthworms in the VF were capable of transforming insoluble organic materials to a soluble form and then selectively digesting the sludge particles of 10–200 μm to finer particles of 0–2 μm, which led to the further degradation of organic materials by the microorganisms in the reactor. Additionally, denaturing gradient gel electrophoresis (DGGE) profiles showed that there was an intensified bacterial diversity in the vermifilter due to the presence of earthworms, especially in response to the nutrients in their casts.

1. Introduction

Urbanization has resulted in the production of a large amount of wastewater and sludge worldwide (Suthar, 2009). Accordingly, excess sludge produced by municipal wastewater treatment plants (WWTPs) has been subjected to increasingly stringent limitations on discharge during the last few decades, and it is expected that this trend will continue. As a result, sludge management accounts for up to 60% of the total operating cost of WWTPs (Wei et al., 2003). Most WWTPs in developing nations cannot afford to construct and maintain conventional sludge treatment processes. This is particularly true for small WWTPs, which have costs for sludge disposal that are higher than large WWTPs because the sludge must be transported to a central sludge treatment facility (Hendrickx et al., 2009). For these reasons, sewage sludge management poses environmental, economic and political challenges for WWTPs and municipalities worldwide (Murray et al., 2008).

Several mechanical, physical and chemical methods are available for improving sludge reduction and stabilization, including ultrasonic, thermal and ozone pre-treatment (Wei et al., 2003). However, most of these methods suffer from drawbacks such as the need for greater amounts of capital and higher operational costs (Hendrickx et al., 2009). Accordingly, there is a need for low-cost and ecologically sound techniques for the treatment of excess sludge.

The use of earthworms to manage sludge was first suggested over ten years ago (Elvira et al., 1998). According to Kwon et al. (2009), earthworms have the ability to breakdown a wide range of organic materials, including sewage sludge,

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provided that the materials are presented in an acceptable form. The principle of using earthworms to stabilize excess sludge comes from the fact that there will be a net loss of biomass and energy when the food chain is extended.

The use of earthworms in filtration systems, which has been termed vermifiltration (VF), was first described by Tohá (Nguyen, 2008). Since then, several studies have been conducted to evaluate the use of vermifilters in domestic wastewater treatment (Taylor et al., 2003; Sinha et al., 2008), municipal wastewater treatment (Yang et al., 2008; Yang and Zhao, 2008), and swine wastewater treatment (Li et al., 2008) processes, as well as in simultaneous sludge reduction processes (Godefroid and Yang, 2005). However, less attention has been given to the use of vermifilters to dispose of excess sludge directly. Moreover, most studies conducted to evaluate VFs have only focused on the contamination purification efficiencies, but the interactions between earthworms and microorganisms, which are very important for understanding the sludge stabilization mechanisms involved in VFs, have not been fully investigated.

Therefore, this study was conducted to explore the feasibility of using a VF to stabilize sewage sludge while focusing on elucidating the earthworm–microorganism interactions responsible for the decomposition of organic matter in the vermifilter. Additionally, this investigation sought to identify the primary mechanism by which sewage sludge stabilization in the vermifilter occurs based on the chemical and spectroscopic properties of the treated sludge, the microbial community in the biofilm, and the earthworm–microorganism interactions in the vermifilter reactor. The results of this study provide useful information regarding the use of a vermifilter for the optimal sewage sludge treatment.

2. Materials and methods

2.1. *Vermifilter setup*

A cylinder shaped vermifilter (30 cm in diameter and 60 cm in depth) that was naturally ventilated was equipped with a 0.5-inch polypropylene pipe with holes to ensure uniform distribution of the influent (Fig. 1). The vermifilter contained a 0.5 m filter bed of ceramic pellets (6–9 mm in diameter). A layer of plastic fiber was placed on the top of the filter bed to avoid direct hydraulic impact on the earthworms and to ensure an even influent distribution. The influent sludge was introduced to the vermifilter via a peristaltic pump. After passing through the filter bed, the treated sludge entered into a sedimentation tank below the vermifilter and the supernatant in the sedimentation tank was recycled.

2.2. *Experimental design*

Two sets of reactors packed with the ceramic pellets were setup so the experiments could be conducted in parallel (Fig. 1). One reactor was a conventional biofilter (BF, without earthworms), while the other (vermifilter, VF) was inoculated with *Eisenia foetida* at an initial earthworm density of 32 g/L (fresh weight basis). *E. foetida* was chosen because it has been shown to process organic wastes with the greatest efficiency (Edwards and Bater, 1992) and it is widely used in vermifiltration (Taylor et al., 2003). The hydraulic loads of these filters were kept at 3 m/d during the experimental period. The initial sludge was taken from the aeration tank of a domestic WWTP (Quyang WWTP, Shanghai) and diluted to a constant organic load of approximately 1.5 kg VSS/$m^3 \cdot d$ using tap water, after which it was introduced to the BF and VF. So, the sludge from the WWTP was continuously supplied and diluted with the continuously returning supernatant in a sludge-containing tank (Fig. 1). The ratio of VSS to suspended solids (SS) and the pH in the initial sludge was 68.2 ± 3.9% and 7.6 ± 0.2, respectively. After acclimation for approximately 40 days, the VF and BF were operated continuously for 200 days.

2.3. *Chemical analysis and scanning electron microscopy (SEM)*

Sludge characteristics such as the SS, VSS and sludge volume index (SVI) were assessed according to Chinese Standard Methods (SEPA, 2002a). Total chemical oxygen demand

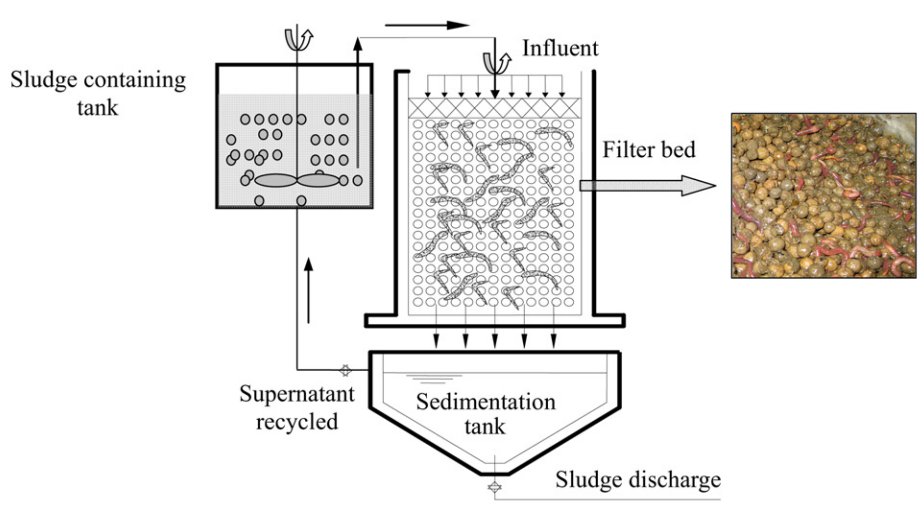

Fig. 1 – Schematic diagram of the vermifilter (with earthworms in the filter bed).