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Review

The use of microbial-earthworm ecofilters for wastewater treatment with special attention to influencing factors in performance: A review

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HIGHLIGHTS

- The application of MEEs for treatment of various wastewater has been reviewed.
- The environment-economic analysis of MEEs was given.
- The influencing factors of pollutants removal in MEEs have been provided and summarized.
- Future research was given on enhancing performance and sustainability of MEEs.

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ABSTRACT

With the unique advantages of lower operational and maintenance cost, the use of microbial-earthworm ecofilters (MEEs) for the wastewater treatment has been increasing rapidly in the recent years. This paper provided an overview of the research activities on the use of MEEs for removing pollutants from various wastewater throughout the world. However, the long-term effective treatment performance and sustainable operation of this system still remain a challenge since the treatment performance would be affected by design parameters, operational conditions, and environmental factors. In order to promote the treatment performance, therefore, this paper also provided and summarized the influencing factors of pollutants removal in MEEs. The design parameters and operational conditions of MEEs include earthworm species and load, filter media type, hydraulic loading rate, nutrient load, packing bed height, chemical factors and temperature. Lastly, this review highlighted the further research on these issues to improve performance and sustainability of MEEs.

1. Introduction

In industrial society one of the burning issues is the high consumption of water and high demand for cleaning water (Schröder et al., 2007). The wastewater treatment and its reclamation have become a hard nut to crack especially in the developing countries due to the combined effects of worsening environmentally-unfriendly activity and increasing population (Singh et al., 2015). In fact, numerous technologies for wastewater purification have been widely investigated. Many traditional treatment technologies such as activated sludge treatment, membrane bioreactor and biofilm process have been implied successfully for water pollution control in a lot of countries (Li et al., 2014). However, these wastewater treatment technologies are limited to widespread use, as developing countries cannot afford for the high costs of construction, operation and maintenance (Muga and Mihelcic, 2008). Thus, it is especially necessary to select economically affordable and efficient alternative technologies for wastewater treatment.

Abbreviations: MEEs, microbial-earthworm ecofilters; WWTPs, wastewater treatment plants; TSS, total suspended solids; TDS, total dissolved solids; BOD_5, 5 day biochemical oxygen demand; COD, chemical oxygen demand; TN, total nitrogen; TP, total phosphorus; AOB, ammonia-oxidizing bacteria; HRT, hydraulic retention time; TS, total dissolved and suspended solids; HLR, hydraulic loading rate; LC_{50}, lethal concentration 50.

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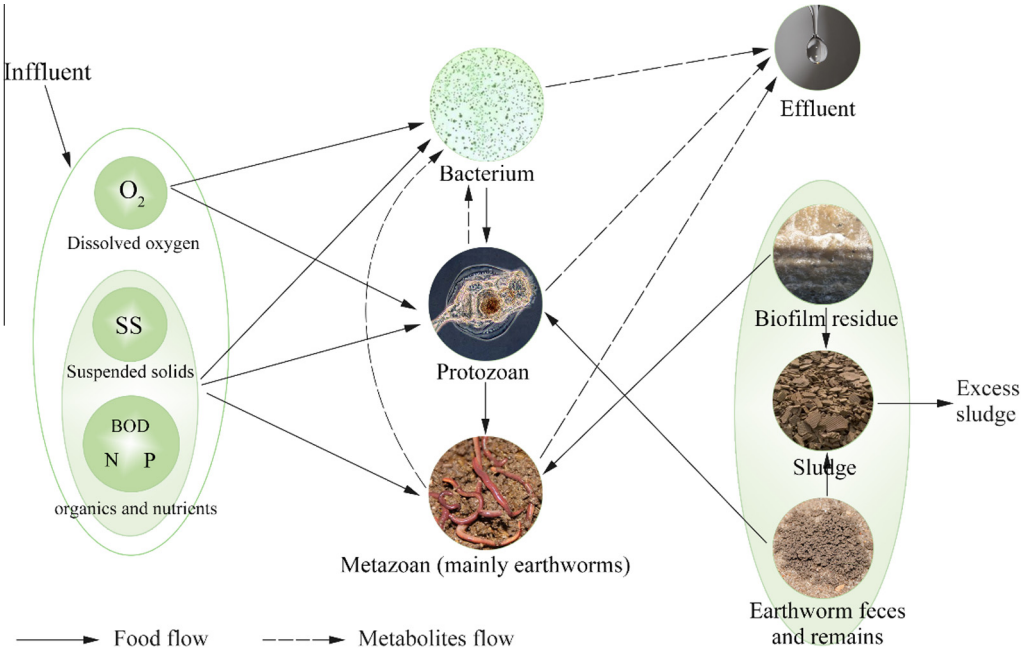

Fig. 1. The diagram for the working mechanisms in MEEs.

One of the alternatives for wastewater treatment in developing countries is microbial-earthworm ecofilters (MEEs) which is a promising economical process for treating point and diffuse sources of wastewater (Tomar and Suthar, 2011). MEEs, a natural engineered system which is based on the symbiotic relationship between earthworms and microorganisms, was first developed by Professor Jose Toha in 1992 at the University of Chile (Aguilera, 2003). The central concept behind MEEs wastewater treatment is that microorganisms perform biochemical degradation of waste material, while earthworms regulate microbial biomass and activity by directly or/and indirectly grazing on microorganisms. These processes are the essential mechanisms for pollutants removal in MEEs (Liu et al., 2012).

The effectiveness of MEEs for wastewater treatment has been demonstrated by a variety of wastewaters, such as domestic sewage, industry wastewater, urban runoff, and livestock wastewater, and at a range of scales (such as small scale, pilot-scale and full-scale) in the recent years (Ghatnekar et al., 2010; Robin et al., 2011; Tomar and Suthar, 2011). MEEs has been shown to provide more improved and consistent wastewater treatment performance than conventional biofilter without earthworm (Sinha et al., 2008). It was also reported that MEEs could be efficient for removing organic matter, nutrients, pathogens, etc. from wastewater and the nitrogen and phosphorus removal rates could reach up to 60.2% and 98.4%, respectively (Arora et al., 2014a; Wang et al., 2011a). In addition to the enhanced wastewater treatment, MEEs has an additional benefit of low excess sludge production (Sinha et al., 2008).

However, as the treatment performance of MEEs can be affected by design parameters, operational conditions, and environmental factors, the long-term effective treatment performance and the sustainable operation still remain a challenge. Thus, the feasibility of MEEs to sustainably eliminate pollutants in wastewater is requiring comprehensive understanding on the influencing factors. Firstly, earthworm species and filter media types are crucial influencing factors for the removal efficiency of MEEs because they are considered as the main biological components of MEEs and can change directly or indirectly the main removal processes of contaminants over time (Sinha et al., 2010). Secondly, the treatment performance of MEEs is highly dependent on the optimal operating parameters, such as hydraulic loading rate, nutrient load, packing bed height and design of setup, which would lead to variations in removal efficiency of pollutants among different researches (Kumar et al., 2014; Wang et al., 2014; Zhao et al., 2012). Additionally, a variety of pollutant removal processes, such as sedimentation, adsorption, filtration, volatilization, precipitation, earthworm and microbe uptake, are usually directly and/or indirectly influenced by the various internal and external environment factors such as temperatures, pH, ammonia and sodium (Hughes et al., 2009; Yang et al., 2009a,b).

Therefore, the fundamental to the success of long-term effective treatment performance and sustainable operation is the acquaintance of influencing factors and the optimization of design and operational parameters. Meanwhile, the deeply knowledge published in international books and journals on optimizing the treatment efficacy has increased significantly in recent years. Thus, it should be a step in reviewing and discussing the advancement and knowledge on the influencing factors and optimization of MEEs treatment process. The objective of this paper is to provide an overall review on the applications of MEEs for various wastewater treatments and also focus on the development of MEEs considering worm and filter media selecting, operation and design parameters optimizing for the enhancement of wastewater treatment performance. Besides, this paper highlighted the future research considerations for improving the treatment performance of MEEs.

2. Microbial-earthworm ecofilters

2.1. Mechanisms and features

Microbial-earthworm ecofilters is a natural engineered system which is inoculated traditional vermicomposting system into a passive wastewater treatment process by using potentials of earthworms (Athanasopoulos, 1993). In MEEs, microorganisms are responsible for the bio-chemical degradation of waste materials in wastewater, whereas earthworms degrade and homogenize