Journal of Environmental Management 197 (2017) 656–672

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

A mechanistic review on vermifiltration of wastewater: Design, operation and performance

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A R T I C L E I N F O

Article history:
Received 20 February 2017
Received in revised form
12 April 2017
Accepted 13 April 2017
Available online 20 April 2017

Keywords:
Vermifiltration
Wastewater
Pollution
Aquatic ecosystem
Earthworms

A B S T R A C T

With global population explosion, the available water resources are slowly being polluted due to the excessive human interference. To encounter this, it is the need of this hour to find out sustainable pollution remediating technologies to meet the stringent discharge standards for domestic as well as industrial wastewaters. In addition, those techniques should have the capabilities for effective implementation even in developing countries. Based on the available literatures, one such technique, named vermifilter, has been identified which takes care of almost all the sustainable and economical criteria for its effective implementation even in developing countries. The aim of this meta-analysis is to provide a comprehensive review on assessment mechanisms involved, factors affecting the process and performance of vermifiltration under different scenarios. The present review envisages the current state of the knowledge regarding physical, chemical and biological aspects related to the treatment mechanisms and effective functioning of earthworms. This review has also proposed several suggestive plans on its application at any proposed site.

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http://dx.doi.org/10.1016/j.jenvman.2017.04.042
0301-4797/

1. Introduction

In the present age of rapid urbanization and industrialization, population explosion and modern lifestyle have led to severe depletion of natural resources (Verma et al., 2012). Communities located in rural as well as urban areas are facing severe shortage of clean water available for their domestic chores, agricultural irrigation and other purposes. One of the major reasons behind this shortage is the poor management of wastewater. Application of efficient wastewater collection and treatment system like traditional sewage treatment plant (STPs) might provide a significant solution to overcome this water crisis but they generate huge amount of sludge as their end product. Apart from the operation and maintenance cost, sludge produced from the STPs also fails to meet the increasing stringent norms of disposal and discharge, applied over the last few years (Mburu et al., 2013; Volkman, 2003; Zhao et al., 2010). The other novel technologies considered for this herculean task also required higher capital investment and skilled labor for its operation. Such technologies, requiring higher energy and resources ultimately end up adding unwanted elements in our ecosystem and leaving a larger footprint. Eventually, these unwanted products from wastewater treatment might also become a cause of concern for the authorities, if not taken care of properly. In order to conserve the water and nutrient resources in developing countries, an economical, ecologically safe and easy to manage wastewater treatment approach is often required and deserves to be explored.

Based upon literatures, numerous physical, chemical and biological methods can be applied for wastewater treatment. Amongst these, the physical and chemical methods of wastewater treatment were either too expensive or proved inefficient in removing the targeted pollutants from the effluents. Methods based on biological treatment proved themselves as somewhat effective in treating wastewater with a higher efficiency compared to the other widely practiced methods. Amongst biological treatment methods, anaerobic treatment usually generates obnoxious odor and results in less efficiency with respect to dissolved organics and turbidity removal for low organic strength wastewater such as domestic sewage (Simate et al., 2011). In addition, the treated effluents from anaerobic processes are normally devoid of dissolved oxygen (DO) and it becomes a limitation to the system, because effluent devoid of oxygen should not be disposed off directly to any water bodies. Another limitation of the anaerobic system is its incompetence in handling wastewater streams of fluctuating temperature, pH and organic's presence (Metcalf and Eddy, 1991). Whereas, the biological aerobic systems have been reported to be relatively better than the anaerobic systems in terms of easy adoption of imbalances in pH, temperature and organic loading rates (Degrémont, 1989). Comparatively, aerobic systems have displayed higher efficiency of treatment in case of low organic strength wastewaters and produce no or minimal odor. Despite all these benefits, systems based on aerobic wastewater treatment mechanism, displayed drawbacks such as excess sludge generation and high energy drawing system due to their demand for external aeration (Feng et al., 2008). In addition to this, aerobic systems are robust in nature occupying a high surface area for better aeration prospects (Metcalf and Eddy, 1991).

To treat wastewater by aerobic systems, one needs to take care of the system limitations mentioned in the above lines. From the extensive review of literatures, it has been observed that among all the existing options, vermifiltration is the only choice, which functions like an aerobic filter that generates no sludge and requires no energy. It can be appreciated by the fact that earthworms eat all the suspended particles screened on the filter bed and in the process of ingestion; it passively aerates the system by burrowing action. It favors the same approach by adapting the traditional vermi-technology to a passive wastewater treatment (Athanasopoulos, 1993; Kumar et al., 2016; Li et al., 2009).

Vermifiltration may be a competitive method for wastewater treatment in Indian context due to its cost saving and ecological characteristics. Even though till date, vermifilter has been largely applied in municipal and domestic sewage mostly, but recently several researchers have started treating industrial wastewater by vermifiltration (Bharambe, 2006; Sinha et al., 2008a, b). In addition to this, it has also been tested for digestion of sludge and resulting in high settling characteristics. However, surprisingly only very little information is available about the application of vermifiltration, and adoption of vermifiltration technology for the treatment of wastewater. To the best of our knowledge, so far, only one research review article has been published on vermifiltration. The present meta-analysis summarizes a deep understanding on vermifiltration. The distinctive features of this review are in-depth description of mechanism of vermifiltration, performance analysis, properties of vermicompost and the growth of earthworms within the vermibed. The objective of this manuscript is to thoroughly review the current state of practice, applications, and recent researches explaining the mechanism and performance of vermifiltration in the removal of various contaminants from wastewater. The understanding of the minutes of the vermifilter may prove helpful for achieving even higher removal efficiency and thus ensuring protection of aquatic ecosystem. Apart from identifying critical gaps and potential areas of future exploration, the impacts of different design considerations and effects of variables on the performance of vermifilter have also been summarized and highlighted.

2. Vermifilter

2.1. Definition and general information

In vermifilter, earthworms are incorporated for offering a favorable ecosystem to stimulate and accelerate microbial degradation of wastewater organics inside the vermi-bedding (Sinha et al., 2008a). Effluent obtained from vermifiltration is highly nutritive in nature and can be applied to agricultural crops, gardening and other reuse purposes. Despite being an aerobic system of treatment, no sludge is produced from vermifiltration while in conventional aerobic treatment, huge quantity of sludge is generated (Krishnasamy et al., 2013; Kumar et al., 2014). Additionally, vermifiltration has been reported to produce little or no foul odor (Xing et al., 2010). Vermifiltration also possesses the ability to stimulate and enhance bacterial flora to reduce the pathogens enormously present in the system (Li et al., 2008; Sinha et al., 2008a). Vermifiltration offers an effective reduction efficiency