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The effect of seasonal temperature on pathogen removal efficacy of vermifilter for wastewater treatment

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ABSTRACT

The present study explored the effects of seasonal temperature on the treatment efficiency and pathogen removal efficacy from synthetic domestic wastewater, earthworm population characteristics and microbial population in the filter media of a lab-scale vermifilter (VF). The experimental phase lasted for one year and daily mean room temperature showed a difference of 2–16 °C between winter (Dec–Feb), spring (Mar–May), summer (Jun–Aug) and autumn (Sep–Nov) periods. The results showed that variation in ambient temperature had a significant effect on chemical oxygen demand (COD) and biochemical oxygen demand (BOD) reduction, indicator organisms and pathogen removal, earthworm population, bacterial and actinomycetes number, but had no effect on total suspended solids (TSS) removal and fungi number. The study showed that higher BOD and COD removal was accomplished during the spring and autumn period when the mean temperature was 25–27 °C. This temperature range is optimum for the earthworm species *Eisenia fetida* for its activity, growth and reproduction and any variation in temperature from the optimum range led to decrease in treatment efficiency and earthworm population. However, during summer, when the maximum temperature reached 38–40 °C, the indicator bacteria removal was maximum by 99.9%, *Salmonella* reduction by 96.9% and *Escherichia coli* by 99.3%. The pathogen removal efficacy of VF increases with the increase in temperature, as shown by linear regression analysis, which implied that temperature had a significant contribution to the pathogen removal efficiency of VF. Pearson coefficient of correlation (r) derived an important relationship between the seasonal temperature and treatment efficiency, pathogen removal efficacy and microbial numbers during vermifiltration.

Abbreviations: BOD, biochemical oxygen demand; CFU, colony forming unit; COD, chemical oxygen demand; DO, dissolved oxygen; HLR, hydraulic loading rate; HRT, hydraulic retention time; FC, fecal coliforms; FS, fecal streptococci; MPN, most probable number; SPC, standard plate count; TB, total bacteria; TC, total coliforms; TF, total fungi; TSS, total suspended solids; VF, vermifilter; WWTPs, wastewater treatment plants; WHO, World Health Organization.

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1. Introduction

Communities across the world are facing the problem of water scarcity due to tremendously increased societal demands, drought, depletion and contamination of existing water resources (Tyagi et al., 2011). Water reclamation, recycling and reuse address these challenges by resolving water resource issue. Recent outbreak of waterborne diseases has raised public concerns regarding the safety of water supply and in specific, water reuse (Curriero et al., 2001). In fact, one of the major barriers to water reclamation and reuse is concern regarding the health risk of exposing public to the wastewater. Out of all the contaminants in wastewater, pathogens are of major concern because of their ability to cause diseases in humans. Human pathogens are typically present in domestic sewage and their control is one of the fundamental reasons for wastewater treatment (Arias et al., 2003). Since raw wastewater contains a wide variety of fecal microorganisms and pathogens, the reduction of bacteriological pollution in wastewater is of high priority.

Wastewater treatment plants (WWTPs) are usually designed to efficiently remove organic pollutants and nutrients but seldom have been planned specifically to remove pathogenic microorganisms from wastewater. It is therefore important to find technical methods to remove pathogens from domestic wastewater, so as to prevent pollution. Fewer studies have focused on the ability of different systems to reduce pathogens from wastewater, especially indicator microorganisms like the coliform group of bacteria i.e., total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS) (Reinoso et al., 2008). One of the alternatives for rural and periurban areas is vermifilters (VFs) and use of these systems is becoming very popular in many developing countries (Sinha et al., 2008; Li et al., 2009). Vermifiltration using earthworms is a low-cost, self-enhanced, naturally acceptable and technically sustainable bio-safe technology that utilizes earthworms for domestic and industrial sewage treatment (Wang et al., 2011). VFs are engineered natural system, which are based on the symbiotic relationship between earthworms and microorganisms, in which microbes perform biochemical degradation of waste material, while earthworms degrade and homogenize the material through muscular actions of their foregut and add mucus to the ingested material, thereby increasing the surface area for microbial action (Aira et al., 2007; Rajpal et al., 2012).

Most studies on vermifiltration investigated the treatment efficacy, pollutant and nutrients removal efficiency of domestic and industrial wastewater and the stabilization effect of wastewater treatment by VFs (Sinha et al., 2008; Li et al., 2009; Xing et al., 2010, 2011; Wang et al., 2011, 2013a). These studies mostly focused on the effects of filter media (Arora et al., 2014c), hydraulic loading rate (Kumar et al., 2014), organic loading rate and stocking density of earthworms (Wang et al., 2103b), but rarely for the effect of seasonal temperature on the treatment performance of VFs. In a previous study on the effect of filter bed temperature on organics and nutrient removal, the results showed the optimal temperature range of 16–25 °C for earthworm survival (Yin et al., 2011). Li et al. (2009) also studied the effect of seasonal variations on treatment efficiency of vermifiltration for domestic wastewater but the study was limited for only two seasons (Li et al., 2009).

Temperature is an important factor for the growth and metabolic activity of microorganisms and diversity of microbial community changes with the variation of temperature (Nedwell, 1999). Earthworm is a poikilotherm, the body temperature of which is significantly associated to outside temperature, and they could die under higher or lower temperature other than optimal temperature range (Edwards, 2004). In vermifiltration, the organic matter and pathogen removal from the wastewater is due to the oxidation and decomposition process of microorganisms and earthworms; therefore, the process will inevitably be affected by temperature (Arora et al., 2014b). In context to India, the study becomes more important as the weather conditions here are variable throughout the year. India experiences variations of temperature to as low as 4–8 °C during winter to as high as 45–48 °C during summer. The studies on how temperature affects pathogen removal, earthworm growth characteristics and microbial population are limited. In addition, little is known about the effects of seasonal temperature on the treatment efficiency (BOD, COD, TSS removal), pathogen removal efficacy, bacteria, fungi and actinomycetes population and earthworm growth and reproduction pattern.

Therefore the present study aims to 1) investigate the effect of seasonal temperature on vermifiltration treatment efficiency (BOD, COD, TSS removal), 2) to determine the effect of temperature on the removal of indicator organisms (TC, FC, and FS), pathogens (*Salmonella*, *Escherichia coli*), earthworm population and microbial numbers (total bacteria (TB), total fungi (TF) and actinomycetes) and 3) to evaluate the relationship and examine the correlation between temperature and water quality parameters, pathogen removal and microbial numbers in VF for synthetic domestic wastewater treatment. The scope of our study is limited to only indicator organisms and fewer pathogens, for evaluating the pathogen removal performance.

2. Materials and methods

2.1. *Experimental design*

The study was performed in Environmental Engineering laboratory, Department of Civil Engineering at Indian Institute of Technology Roorkee (IITR), India. A polyvinyl chloride vermifilter (VF) having dimensions 25 cm × 20 cm × 30 cm was set up as shown in Fig. 1. The VF consisted of filter bed, wastewater storage tank, mixer for constant mixing, peristaltic pimp, wastewater distribution system and effluent collection system.

A pipe with small holes (1.5 mm in diameter) drilled in its underside was installed to distribute wastewater uniformly. An empty space or free board of around 5 cm is kept at the top for aeration purpose. The filter bed is filled with 4 layers (from bottom to top). The fourth supporting layer of 5 cm consisted of gravels of size 10–12 mm. The third layer comprised of gravels of size of 4–6 mm of depth 5 cm. The second layer consisted of sand particles of size 1–2 mm and the first layer