Journal of Hazardous Materials 360 (2018) 536–543

Contents lists available at ScienceDirect

Journal of Hazardous Materials

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

Effects of long-lasting nitrogen and organic shock loadings on an engineered biofilter treating matured landfill leachate

Yidong Guan[a,b], Jun Zhou[a], Xiaoru Fu[a], Yaqian Zhao[c], Ancheng Luo[b], Jianqiang Xu[a], Jie Fu[d,*], Dongye Zhao[e,*]

[a] *Jiangsu Provincial Key Laboratory of Atmospheric Environment Monitoring and Pollution Control, Collaborative Innovation Center of Atmospheric Environment and Equipment Technology, School of Environmental Science and Engineering, Nanjing University of Information Science and Technology, Nanjing 210044, China*

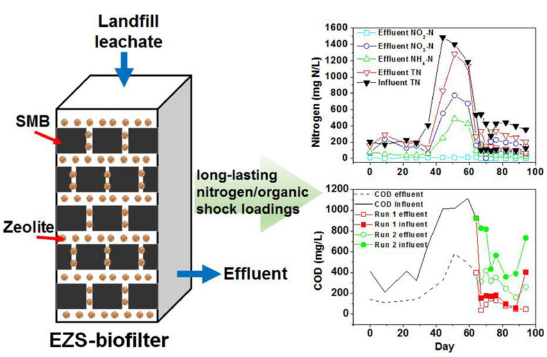
[b] *Key Laboratory of Environment Remediation and Ecological Health (Zhejiang University), Ministry of Education, College of Environmental and Resource Sciences, Zhejiang University, Hangzhou 310058, China*

[c] *Centre for Water Resources Research, School of Architecture, Landscape and Civil Engineering, University College Dublin, Belfield, Dublin 4, Ireland*

[d] *Department of Environmental Science & Engineering, Fudan University, Shanghai 200438, China*

[e] *Environmental Engineering Program, Department of Civil Engineering, Auburn University, Auburn, AL 36849, USA*

GRAPHICAL ABSTRACT



ARTICLE INFO

Keywords:
Shock loading
Ammonium shock
Nitrification
Landfill leachate
Biofilter

ABSTRACT

The decentralized bioreactor is a promising process for landfill leachate (LL) treatment, however, it is often confronted with various forms of shock loadings. To explore the robustness of bioreactors to the long-lasting substrate shocks, a long-term study of over 90 days was carried out to investigate the effects of nitrogen (mainly ammonium nitrogen, NH_4-N) and organic (in terms of chemical oxygen demand, COD) shock loading on an engineered zeolite-based biofilter with alternative soil-mixed block (SMB) (EZS-biofilter) for treating matured LL. The low-, mid-, and high-strength intensity of matured LL was theoretical defined mainly according to the content of total nitrogen (TN) and COD. The experiment proved that the EZS-biofilter could effectively absorb the substrate shocks in a range of 104, 408, and 1357 mg/L as TN and 178, 590, and 1050 mg/L as COD, corresponding to the low-, medium-, and high-strength LL, respectively. A modified sensitivity index reflected that the nitrogen shock loadings exerted much more predominant influence than COD shock due to the great variation of nitrification/denitrification. The provided information in this study are beneficial for the practical engineered operation of biofilters for treating matured LL.

* Corresponding authors.
E-mail addresses: jiefu@fudan.edu.cn (J. Fu), zhaodon@auburn.edu (D. Zhao).

https://doi.org/10.1016/j.jhazmat.2018.08.020
Received 3 March 2018; Received in revised form 21 July 2018; Accepted 6 August 2018
Available online 16 August 2018
0304-3894/

1. Introduction

Over 54% and 80% of municipal solid waste is disposed by landfilling in United States and China, respectively [1,2]. However, the percolated run-off through a landfill site can produce landfill leachate (LL), which is a highly hazardous liquid and can severely contaminate the surrounding environment, especially the groundwater and surface water [3,4]. The biological oxygen demand (BOD) of groundwater and surface water in the vicinity of a municipal landfill in India was increased to 1500–3150 mg/L and 600–5400 mg/L, respectively [5], and such water sources are unacceptable for drinking and threaten the health of residents nearby. Moreover, it is found that LL may be one of the prevailing sources of antibiotic resistance genes [5,6], which would pose a human health risk on a global scale. To mitigate the LL pollution, China has promulgated *Standard for Pollution Control on the Landfill Site of Municipal Solid Waste* (GB 16,889–2008) and required LL effluents to have < 100 mg/L of chemical oxygen demand (COD) and 40 mg/L of total nitrogen (TN).

The decentralized biological treatment process is an ideal technology for on-site treatment of LL for its advantages of cost-effectiveness, less labor demanding and environmental sustainability [7]. However, decentralized biological treatment processes would be more vulnerable to the shock loadings than the centralized counterparts due to the smaller treatment volume, which means the less balancing capacity to attenuate the fluctuation of the flow rate [8] and/or contaminant levels [9]. Although many studies have investigated LL treatment by decentralized processes, only very few reports are available on the effects of shock loadings on the biofilter used for LL treatment. Of the limited work on the shock loading effects, most was based on the short-term responses, with a measurement time no more than 4-times of the hydraulic retention time (HRT) [10–12]. However, in practical applications, the longer-lasting shock loadings is a normal rather than exception, and such persistent shocks may impede the process performance or even result in complete process failure due to substrate inhibition [9]. Consequently, it is necessary to investigate the effects of long-lasting shock loadings on the bioreactor performance.

In our previous work, an engineered zeolite-based biofilter with alternative soil-mixed block (SMB) (EZS-biofilter) has been designed to remove the organic materials (OMs): the top layer oxidizes the influent OMs absorbed, the inlaid SMB forms an anaerobic zone, where ammonium nitrogen (NH_4-N) is converted to nitrogen gas (N_2) by consuming the loaded OMs in SMBs as external carbon sources (wasted sawdust, yard waste, etc.), and the permeable layer (PL) functions as a influent passage [7,13]. EZS-biofilter can effectively treat low-strength LL (TN 74 ± 14 mg/L, NH_4-N 60 ± 22 mg/L, COD 218 ± 134 mg/L) from the domestic landfill under hydraulic load rates (HLRs) of 200–1600 L/m^2·d [7,14]. However, it is unknown whether the biofilter could adapt to a higher degree of influent substrate fluctuations (up to over 1000 mg/L of TN and COD), and for a longer-lasting (weeks to months) period of fluctuation.

It is worth mentioning that the intensity of matured LL should be classified based on the nitrogen content, rather than COD or BOD. This is because the nitrogen concentration in stabilized leachate would keep at a stable level over time [3], whilst the carbon levels would drop dramatically from the acid phase to methanogenic phase [3,9]. Thus, the concentration of nitrogen, including TN and NH_4-N, is targeted to be the most important constitution in this research. Moreover, it is a frequent misunderstanding that LL belongs to a high strength wastewater [9,15], while the LL intensity is actually decided by a group of complex factors, including the biological composition and moisture content of waste buried, waste age, stabilization degree of landfill, the landfill technology, etc. [16]. The reported values of LL intensity vary dramatically, ranging from less than 20 to over 2000 mg/L as TN [1,3,9]. Unfortunately, classification on the strength of matured LL is not addressed, which is hampering the application of sounder treatment management practices.

In this context, the present research mainly aims to (1) raise a theoretical classification of the low-, medium- and high-strength matured LL, (2) observe the long-lasting performance of EZS-biofilter for matured LL treatment in response to the lasting nitrogen and organic shock loadings, covering from ~100 to over 1000 mg/L of influent TN and COD loadings, and (3) improve the calculation of sensitivity index to better reflect the variation of bioreactor response. This research would explore the robustness of EZS-biofilter coping with the long-lasting substrate shock loadings, and could be a beneficial guidance on the practical operation of the EZS-biofilter for treating matured LL.

2. Materials and methods

2.1. Landfill leachate

The raw LL (BOD/TN ~0.08) in the experiments was taken from a matured municipal landfill in Zhejiang Province, China, which had been operated for more than ten years. The leachate was diluted with tap water to obtain the desired concentrations of nitrogen (NH_4-N, nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N)) and COD for the following studies.

2.2. Classification methodology on matured landfill leachate

2.2.1. Intensity of matured low-strength landfill leachate

There is no classification for the matured low-strength LL currently. A matured LL in Finland is represented with an NH_4-N of 60–170 mg/L and a COD level of 230–510 mg/L according to the report by Jokela et al. [17]. Based on our prior work [7], EZS-biofilter can effectively treat the matured low-strength LL with TN (74 ± 14 mg/L), NH_4-N (60 ± 22 mg/L), and COD (218 ± 134 mg/L), and these values are within the range of LL intensity reported by Jokela et al. [17] as well. The influent TN was chosen to represent leachate intensity due to its less fluctuation relative to NH_4-N. Based on the nitrogen contents reported by Jokela et al. [17] and Guan et al. [7], the TN level of low-strength LL is set as the value of the mean (74 mg/L) plus 1-time the standard deviation (14 mg/L), the NH_4-N level is set to 90% of the TN, and COD value is set at 3-times of the TN. Then the corresponding TN, NH_4-N, and COD values were calculated to be 88, 79, and 264 mg/L, respectively, which are defined to be the average levels of the matured low-strength LL.

2.2.2. Intensity of matured mid-strength landfill leachate

Information has been scarce on the definition of the matured medium-strength LL. Robinson et al. [18] reported a young medium-strength LL with pH 6.0, NH_4-N 76 mg/L, COD 4805 mg/L, and BOD/COD 0.6. Evidently, this classification as well as that from the report by Kettunen et al [19] does not apply to matured LL. In this study, the intensity of stabilized medium-strength LL is operationally set as 4-times of that for the matured low-strength LL, with mean TN, NH_4-N and COD values of 352, 316, and 1056 mg/L, respectively. This defined intensity approximates to a reported level of leachate from a matured landfill in China with an NH_4-N content of 300 mg/L [15].

2.2.3. Intensity of matured high-strength landfill leachate

Table 1 shows typical characteristics of matured high-strength LL from four countries [20–23]. It is noteworthy that the average NH_4-N concentration in the four countries is as high as 873 ± 303 mg/L. In this work, the average TN, NH_4-N and COD values of matured high-strength LL are set as 10-times of those for the low-strength LL, namely 880, 792, and 2640 mg/L, respectively.

2.3. Experiment of shock loadings

2.3.1. Experimental setup

Two vertical-flow EZS-biofilters (BF-1 and BF-2) were employed in