ARTICLE IN PRESS

Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

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

Assessment on the leakage hazard of landfill leachate using three-dimensional excitation-emission fluorescence and parallel factor analysis method

Hongwei Pan, Hongjun Lei *, Xin Liu, Huaibin Wei, Shufang Liu

ARTICLE INFO

Article history:
Received 10 August 2016
Revised 23 May 2017
Accepted 25 May 2017
Available online xxxx

Keywords:
Municipal solid waste
Landfill leachate
Leakage hazard
Dissolved organic matter
3D-EEMF
PARAFAC

ABSTRACT

A large number of simple and informal landfills exist in developing countries, which pose as tremendous soil and groundwater pollution threats. Early warning and monitoring of landfill leachate pollution status is of great importance. However, there is a shortage of affordable and effective tools and methods. In this study, a soil column experiment was performed to simulate the pollution status of leachate using three-dimensional excitation-emission fluorescence (3D-EEMF) and parallel factor analysis (PARAFAC) models. Sum of squared residuals (SSR) and principal component analysis (PCA) were used to determine the optimal components for PARAFAC. A one-way analysis of variance showed that the component scores of the soil column leachate were significant influenced by landfill leachate ($p < 0.05$). Therefore, the ratio of the component scores of the soil under the landfill to that of natural soil could be used to evaluate the leakage status of landfill leachate. Furthermore, a hazard index (*HI*) and a hazard evaluation standard were established. A case study of Kaifeng landfill indicated a low hazard (level 5) by the use of *HI*. In summation, *HI* is presented as a tool to evaluate landfill pollution status and for the guidance of municipal solid waste management.

1. Introduction

With rapid urbanization and increasing product consumption, millions of tons of municipal solid wastes are produced in metropolises every year (Dyson and Chang, 2005; Henry et al., 2006; Fu et al., 2015). One of the toughest problems faced by the government is effective urban solid waste treatment (Vergara and Tchobanoglous, 2012; Zhang et al., 2010). Landfills are a popular choice for municipal solid waste disposal, and can be used in the treatment of toxic and hazardous substances by bioreactor composting (Rowe, 2011).

Under strictly controlled measures, environmental landfill hazards caused can be reduced to a minimum. However, the municipal solid landfill waste landfill is often improperly treated and disposed of (Vergara and Tchobanoglous, 2012; Zhang et al., 2010). Landfills frequently have minimal impervious treatments or just simple layer treatments. The impermeable membrane can be damaged during the transportation or operation processes, decomposed over time, or broken due to unforeseen circumstances such as earthquakes. All these factors increase the risk of soil and groundwater pollution through landfill leakage (Mor et al., 2006; Gutiérrez et al., 2015; Xi et al., 2015). This is especially the case in developing countries, where many municipalities do not properly treat their solid waste, and have no seepage control measures (Sharholy et al., 2008; Mukherjee et al., 2015; Xi et al., 2016).

As a result of precipitation, moisture content in municipal solid wastes builds, landfill leachate accumulates, and large amounts of waste water are produced in the long run (El-Fadel et al., 2002). In humid environments, a series of biochemical reactions within the solid waste occur (Stroot et al., 2001; Eleazer et al., 1997), and large quantities of pollutants are produced, including heavy metals, inorganic salt, gases, and organic matter (Isidori et al., 2003; He et al., 1992, 1995; Liu et al., 2015). These pollutants cause secondary pollution to the water, air, and soil (Wang et al., 2015). Except for gas emission, most landfill pollutants penetrate the soil and flow with the leachate. Landfill leachate contains numerous components, among which, dissolved organic matter (DOM) is one of the most important (Clarke et al., 2015). This pollutant accounts for over 85% of the total organic leachate. Organic acids in DOM act as complexing agents to accelerate the migration of toxic heavy metals, such as Pb, and Cd. The leaching of fluoranthene and polycyclic aromatic hydrocarbons (PAH) can increase from DOM adsorption, further contributing to heavy metal and other organic pollutant migration. Therefore, special attention should be paid to the harmfulness of DOM in landfill leachate,

* Corresponding author.
E-mail address: hj_lei2002@163.com (H. Lei).

http://dx.doi.org/10.1016/j.wasman.2017.05.041
0956-053X/© 2017 Elsevier Ltd. All rights reserved.

and by effectively monitoring it, the wetting front and pollution extent of landfill leachate could be identified, and then the pollution status evaluated.

Presently, most studies focus on urban solid waste treatment technology, such as fast stabilization of biological compost (Xi et al., 2015) and the optimization of management of municipal solid waste management (Eriksson et al., 2005; Laner et al., 2012). As the final product of municipal solid waste, landfill leachate is exposed to the environment. Leachate monitoring is easily overlooked, and thus it is of great significance to set up an easy, efficient, and rapid diagnosis system for landfill leakage hazard assessment.

Due to the complex composition of pollutants in leachate, conventional chemical monitoring to these pollutants is very expensive. Daily monitoring is infeasible for landfill management. As a rapid and non-destructive chemical analysis method, three-dimensional excitation emission fluorescence (3D-EEMF) technology is sensitive to the recognition of organic matter, inexpensive to operate, and can be used to analyze the behavior of organic matter in landfills (He et al., 2011a, 2011b, 2013, 2016; Wei et al., 2014a, 2014b; Clarke et al., 2015). The objective of this study was to establish a leakage hazard assessment method on landfill leachate using three-dimensional fluorescence spectrum technology. The soil spectroscopy was analyzed to identify on the component characteristics using the three-dimensional fluorescence spectrum technology and parallel factor analysis (PARAFAC) model to determine leakage hazards, and provide technical support for landfill management. It's worth pointing outAnd t that the aim of choosing DOM as the research objectfocus was not to establish an accurate assessment method of landfill leachate to the underlying soil because it's not a non-reactive component; instead, we tried to study the effect of leachate on the bottom soil pollution from a new perspective by using three -dimensional fluorescence spectrum.

2. Materials and methods

2.1. Sampling procedure

A municipal solid waste landfill (34°44′11″N, 114°19′14″E) located at Kaifeng City in China was chosen as the leachate sampling site. The service life of the landfill site is 20 years, and was still operational during the collection campaign. The stacking quantity of the landfill site is 4–5 million tons. The lithology of the vadose zone is fine sand, which is distributed evenly throughout the study area at a thickness of 5 m. A synthetic double liner was placed at the bottom of the landfill as a seepage control measure. Due to the long service life, the seepage layer may be damaged, resulting in leachate leakage. 30 L of landfill leachate was collected from the leachate collecting system, and samples were preserved at 4 °C in sampling boxes with two ice packs beneath the bottom of sampling box. A soil sample was collected within the first 10 cm of the soil layer in the southwest of the landfill edge under the landfill bottom using a drill.

Four types of land use soil samples were collected around the landfill site at the same time: wheat-corn field (NS1), vineyard (NS2), vegetable field (NS3), and grassland (NS4). The properties of the soils were shown in Table 1. All four agricultural soils revealed low DOM content, and were used as the background value. The purpose of selecting more than one kind of soil was to illustrate the effects that landfill leachate has on different kinds of land use types of soil. For each agricultural land use type, a volume of 40 × 40 × 30 cm soil block was collected by digging a soil profile with a spade. Each of the soil profiles were divided into four groups of 0–10 cm, 10–20 cm, 20–30 cm, and 30–40 cm, ventilated to air dry in a shaded environment in a laboratory, and finally grinded and sieved.

Table 1
Physical and chemical properties of soil samples.

pH	8.05	8.12	8.14	7.66
ρ_b (g cm^{-3})	1.42	1.44	1.40	1.43
D > 0.002 mm (%)	55	48	43	41
0.002 mm < D ≤ 0.002 mm (%)	32	26	38	26
D ≤ 0.002 mm (%)	13	26	19	33
n (%)	48	47	43	39

Note: ρ_b denotes the soil bulk density; D represents the diameter of the soil particles; n means the soil porosity.

2.2. Experiment design of soil column

The aim of the soil column experiment in this study was to prove whether the soil DOM fluorescence spectra changed significantly after the leachate pass through 10 cm, 20 cm, 30 cm, and 40 cm of soil when compared with the agriculture soil unpolluted by landfill leachate. If the DOM fluorescence spectrua of all the leachate polluted soil layers are significantly different from the natural soil, the natural soil can be used for the analysis of landfill leachate pollution influence on the landfill's bottom soil layer of landfill bottom. Accordingly, in this study, more attention was paid to the results of leachate on the soil DOM fluorescence spectra after contact with the leaked leachate, rather than the infiltration effect that the leachate process had on the soil DOM fluorescence spectra by a infiltration effect. Therefore, the physicochemical properties of the soil at the bottom of the landfill were not the focus.

The device for the soil column experiment was comprised of a vacuum pump, a simulation column (organic glass material), a drench filtrate collection device, and two connecting hoses (Fig. 1). The simulation soil column was an open-end organic glass cylinder with diameter of 20 cm and height of 75 cm. A 500-mL conical flask was used to collect the leachate. The bottom of the column was filled with 20 cm of sand, and then filled with four layers of NS1 soil sample (followed by the sieved soil samples from the profile depth of 30–40 cm, 20–30 cm, 10–20 cm, and 0–10 cm) from the bottom to top layer.

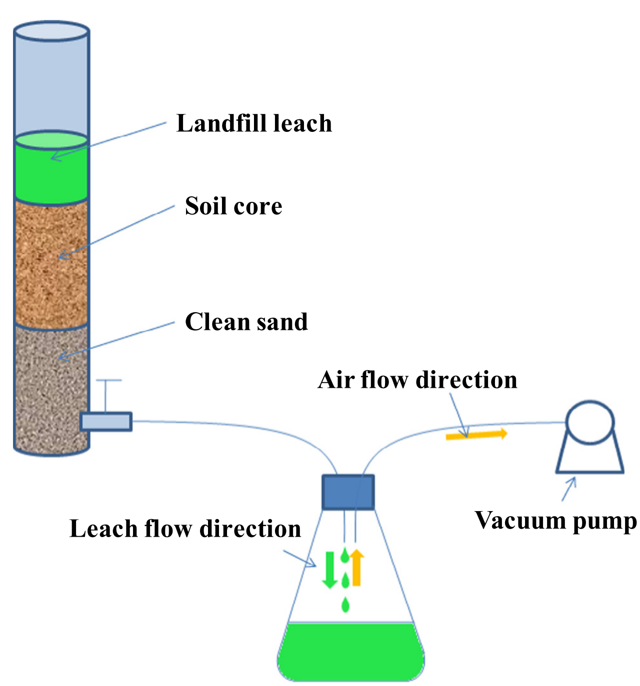

Fig. 1. The schematic of simulation experimental device.

Please cite this article in press as: Pan, H., et al. Assessment on the leakage hazard of landfill leachate using three-dimensional excitation-emission fluorescence and parallel factor analysis method. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.05.041