Environmental Pollution 220 (2017) 1–12

Contents lists available at ScienceDirect

Environmental Pollution

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

Physico-chemical and biological characterization of urban municipal landfill leachate☆

B.P. Naveen [a], Durga Madhab Mahapatra [b, c, *], T.G. Sitharam [a], P.V. Sivapullaiah [a], T.V. Ramachandra [b, c]

[a] Department of Civil Engineering, Indian Institute of Science, Bangalore, India
[b] Centre for Sustainable Technologies (CST), Indian Institute of Science, Bangalore, India
[c] Energy and Wetlands Research Group (EWRG), Center for Ecological Sciences (CES), Indian Institute of Science, Bangalore, India

A R T I C L E I N F O

Article history:
Received 5 April 2016
Received in revised form
20 August 2016
Accepted 2 September 2016
Available online 8 September 2016

Keywords:
Leachate characterization
Microbial analysis
Heavy metals
Landfill
LPI

A B S T R A C T

Unscientific management and ad-hoc approaches in municipal solid waste management have led to a generation of voluminous leachate in urban conglomerates. Quantification, quality assessment, following treatment and management of leachate has become a serious problem worldwide. In this context, the present study investigates the physico-chemical and biological characterization of landfill leachate and nearby water sources and attempts to identify relationships between the key parameters together with understanding the various processes for chemical transformations. The analysis shows an intermediate leachate age (5–10 years) with higher nutrient levels of 10,000–12,000 mg/l and ~2000–3000 mg/l of carbon (COD) and nitrogen (TKN) respectively. Elemental analysis and underlying mechanisms reveal chemical precipitation and co-precipitation as the vital processes in leachate pond systems resulting in accumulation of trace metals. Based on the above criteria the samples were clustered into major groups that showed a clear distinction between leachate and water bodies. The microbial analysis showed bacterial communities correlating with specific factors relevant to redox environments indicating a gradient in nature and abundance of biotic diversity with a change in leachate environment. Finally, the quality and the contamination potential of the samples were evaluated with the help of leachate pollution index (LPI) and water quality index (WQI) analysis. The study helps in understanding the contamination potential of landfill leachate and establishes linkages between microbial communities and physico-chemical parameters for effective management of landfill leachate.

1. Introduction

With rapid urbanisation and population growth municipal solid waste (MSW) generation in urban localities has increased many folds. Leachate, a liquid manifestation from MSW, has been considered as a serious pollutant affecting natural resources as surface and ground waters, human health and hygiene. It is a tainted liquid emanating from the bottom of the solid waste disposal facilities such as landfills that contains both soluble organic and inorganic compounds as well as suspended particles. The composition of landfill leachate depends upon the nature of solid waste buried, chemical and biochemical processes responsible for the decomposition of waste materials and total water content in waste (Fatta et al., 1999). A highly concentrated leachate is generated due to unscientific collection, segregation, and disposal practices of MSW. Dispersal of leachate poses a potential threat to soil and ground water quality (Jorstad et al., 2004; Chian and Dewalle, 1976). In developing nations like India especially the contamination problem is more serious, where the landfills do not have any leachate containment i.e. collection and treatment systems. Therefore, it is essential to adopt appropriate treatment/remedial measures to avoid contamination of the underlying soils and groundwater aquifers from the leachate generated from the landfills.

In India older landfills do not have a barrier system/liner and leachate collection system to restrict the migration of leachate into ground water. These landfills are often observed over permeable

☆ This paper has been recommended for acceptance by Dr. Chen Da.
* Corresponding author. Energy and Wetlands Research Group (EWRG), Center for Ecological Sciences (CES), Indian Institute of Science, Bangalore, India.
E-mail addresses: durgamadhab@ces.iisc.ernet.in, durgamadhab.mahapatra@gmail.com (D.M. Mahapatra).

http://dx.doi.org/10.1016/j.envpol.2016.09.002
0269-7491/

soils with shallow water tables beneath, enhancing the potential of the leachate to contaminate ground water. Presently there are no scientific leachate collection systems in India and other developing countries (Kumar and Alappat, 2005). Although the municipal solid waste (management and handling) rules 2000, Schedule III – Gazette 22(b) for specifications for landfill base clearly suggests leachate collection and treatment, leachate containment through 1.5 mm HDPE liner and provisions for storm water runoff gutters (MSW, 2000). In developed countries like Canada there are even stringent norms and regulations for leachate collection, containment, treatment and disposal that also emphasize regular monitoring of the surface and ground water in the vicinity of the landfill location (https://dr6j45jk9xcmk.cloudfront.net/documents/1110/66-landfill-standards-en.pdf).

In landfill leachate, numerous hazardous compounds as aromatics, halogenated compounds, phenols, pesticides, heavy metals and ammonium have been identified (Devare and Bahadir, 1994). This presses grave concerns about safety and health of human beings together with other aquatic life forms, impacting its ecology and food chains. Moreover, landfill leachate also imposes significant influence on the mobilization and attenuation through complexation of organic ligands and colloidal matters (Achankeng, 2004) in soil. Hence, it becomes imperative to assess the quality of leachate from MSW landfill. The physico-chemical environment and microbial communities play vital role in transformations of organic and inorganic compounds that helps in leachate decomposition and mineralization. This leads to the treatment of leachate. The presence of trace metals indicates toxicity in landfill leachate and its negative impacts on the growth of beneficial microflora that would have otherwise helped in leachate degradation and treatment. Morphological analysis of the microbial community is essential for identification and further characterization to determine the suitability of the microflora in the degradation of landfill leachate. Advanced tools as scanning electron microscopy (SEM) can be potentially used for rapid identification of the leachate microflora and enumeration (Mahapatra et al., 2014). Understanding various groups of bacterial and other microbial community aids in identifying dominant communities and potential to degrade leachate. These hosts of different bacterial microflora can be potentially used for the treatment of the leachate in-situ. Due to a heterogeneous mixture of municipal solid waste, various types of non-biodegradable organics are also present in landfill leachate. Thus pollution indices are essential for rapid assessment, monitoring and comparison of leachate quality (Kumar and Alappat, 2005). Presently the landfill leachate is gaining a serious attention in the developing countries and to a lesser extent in the developed world with relevance to its toxicity and harmful environmental externalities.

This research paper attempts to characterize landfill leachate through physico-chemical, and biological analysis. A leachate pollution index has been developed for urban landfill localities that can be used as a tool for determining its quality and evaluates its contamination potential. This study also aims to serve as a guideline for the implementation of an appropriate leachate treatment technique for reducing adverse effects on the environment.

2. Materials and methods

2.1. Study area

The Mavallipura landfill site is located north of Bangalore, India at Latitude 13°50′ North, Longitude 77°36′ East in the state of Karnataka. This landfill site has been used as a processing site for the municipal solid waste generated from Bangalore city. The average annual rainfall is 978 mm. Rainy seasons are from June to September and the secondary rainy season is from November to December. Mavallipura village is located about 20 Kilometer away from Bangalore. About 100 acres of land in and around the village are used for dumping Bangalore's MSW by the Bruhat Bengaluru Mahanagara Palike (BBMP–Greater Bangalore Municipal Corporation) that began accepting waste from 2005. Mavallipura landfill site is about 40.48 ha located in Mavallipura village, of which approximately 35 acres is used for landfill. The landfill was maintained at M/s Ramky Environmental Engineers commissioned in 2007 which had the capacity to sustain about 600 tonnes of waste. However, the BBMP has been sending almost 1000 tonnes of garbage from Bangalore city every day. Citizens around Mavalipura village demand that the landfill site must be stopped immediately as it is illegal and unscientifically managed and thus it is now closed for land filling. A little soil cover (0.3 m thickness) has been applied on a daily basis, and MSW is dumped in an unscientific manner that has resulted in steep, unstable slopes, leachate accumulation within the MSW mass, and leachate runoff into nearby water bodies such as pond and opened well.

2.2. Sampling and physico-chemical analysis

Fig. 1 gives the view of (a) sampling locations points on google earth and also shows (b–f) the location of sample points in Mavallipura landfill site. In order to observe the spatiotemporal variations of the geochemistry of leachate and ground waters, three undiluted representative leachate samples (L1 leachate collected directly from landfill, L2 leachate collected from landfill sump, L3 leachate collected from landfill pond) and another two samples of water from the nearby pond (P4) and open well (G5) were collected from downstream of Mavallipura landfill site in the month of April 2012. Three replicates of each of the sample were analyzed for every location. After the sample collections, these landfill sites were abandoned and were restricted to any further treatment and disposal due to agitation in the nearby local communities. Therefore further sampling was not possible, and the analysis was carried out for only one season. The samples were collected in labeled clean bottles that were rinsed thrice before sample collection. The pH and electrical conductivity (EC) were recorded on site at the time of sampling with digital pH meter and digital EC meter, respectively. For the analysis of biological oxygen demand (BOD), 300 ml capacity BOD bottles were used for the collection of samples. For heavy metal analyses, samples were separately collected in prewashed polyethylene containers of 100 ml capacity and acidified (few drops of concentrated nitric acid were added to the leachate sample) onsite to avoid precipitation of metals. The samples were then transported in cooler boxes at a temperature below 5 °C immediately to the laboratory. Leachate samples was stored in a refrigerator at 4 °C before proceeding with the laboratory analysis. Physico-chemical parameters, ionic parameters, trace elements analysis was carried out according to standard methods for the examination of water and wastewater unless otherwise stated (APHA, 1998).

2.3. Statistical analysis

Univariate analysis was performed to know the nature of the sample and extent of spread across mean. Correlation coefficient (r) is computed to explore significant relationships between changes in physico-chemical variables against biological variables (bacterial and algal communities). Multivariate analysis - Detrended Correspondence Analysis (CCA) was performed to understand transitions in biological communities with the varying physico-chemical variables to know relationships among them and identifying the most impacting drivers. Cluster Analysis (CA) was performed in order to