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Analysis of the contaminants released from municipal solid waste landfill site: A case study

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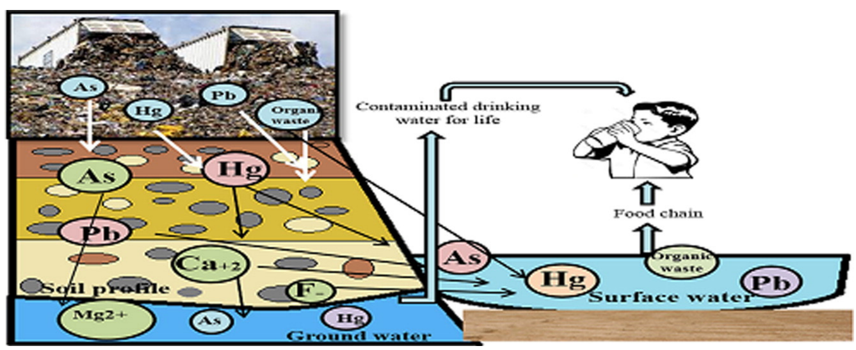
HIGHLIGHTS

- This study analyzed the contaminant released from a closed MSW landfill.
- Groundwater, surface water and soil samples were analyzed.
- Concentrations of contaminants varied across the depth of the landfill.
- Most of the parameters in groundwater exceeded the WHO drinking quality standards.
- This study will help to propose suitable measures for scientific closure of landfill.

GRAPHICAL ABSTRACT



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ABSTRACT

Release and transport of leachate from municipal solid waste landfills pose a potential hazard to both surrounding ecosystems and human populations. In the present study, soil, groundwater, and surface water samples were collected from the periphery of a municipal solid waste landfill (located at Ranital of Jabalpur, Madhya Pradesh, India) for laboratory analysis to understand the release of contaminants. The landfill does not receive any solid wastes for dumping now as the same is under a landfill closure plan. Groundwater and soil samples were collected from the bore holes of 15 m deep drilled along the periphery of the landfill and the surface water samples were collected from the existing surface water courses near the landfill. The landfill had neither any bottom liner nor any leachate collection and treatment system. Thus the leachate generated from the landfills finds paths into the groundwater and surrounding surface water courses. Concentrations of various physico-chemical parameters including some toxic metals (in collected groundwater, soil, and surface water samples) and microbiological parameters (in surface water samples) were determined. The analyzed data were integrated into ArcGIS environment and the spatial distribution of the metals and other physic- chemical parameter across the landfill was extrapolated to observe the distribution. The statistical analysis and spatial variations indicated the leaching of metals from the landfill to the groundwater aquifer system. The study will help the readers and the municipal engineers to understand the release of contaminants from landfills for better management of municipal solid wastes.

1. Introduction

The disposal of the solid waste specially the municipal solid waste (MSW) constitutes an important and emerging problem. Globally,

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landfills are the main method of solid waste disposal as it is the simplest and most cost effective practice for storing the MSW waste (Williams, 2005). Moreover, the collection, transportation and disposal of MSW are unscientific and unplanned in developing countries, such as India (Gupta et al., 1998). Landfill sites act as biological reactors, in which refuse undergoes physical, chemical and biological transformation. Landfilled putrescible waste causes gas and leachate production (Regadío et al., 2015). The leachate is an aqueous liquid stream generated from waste landfill site due to the percolation of rainwater through the waste and inherent moisture carrying the soluble (toxic and non-toxic) products of biochemical reactions occurring within the disposed waste (Renou et al., 2008). The quantity and quality of leachate is primarily influenced by the amount, waste composition and its solubility, moisture content of the solid waste, as well as by local factors such as hydrogeological conditions, climate, and height and type of landfill (Johansen and Carlson, 1976; Chu et al., 1994). The composition of leachate varies significantly across landfills mainly due to waste characteristics, composition, degradation stage and the landfilling technology. The unscientific collection, segregation, disposal practices of MSW along with the prevailing climatic condition and geology produce highly concentrated leachates (Statom et al., 2004; Tatsi and Zouboulis, 2002; Kale et al., 2008). Generally, it contains substantial amounts of dissolved organics [(biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD)], inorganic salts, ammonia, heavy metals and xenobiotic organic compounds (XOCs) that are originated from personal care products, pharmaceuticals, industrial and household chemicals.

The poorly maintained landfill sites during operation and after closure are prone to groundwater contamination through leachate percolation (Fatta et al., 1999; US EPA, 1984). This problem is more acute in the underdeveloped and developing nations, where the landfills do not have any base liners or leachate collection and treatment systems. The movement of landfill leachate in soils is not only subject to alteration in its various physical, chemical and biological processes but also the geological condition which eventually affects the concentration of pollutants in soils and groundwater. The degree of contamination in the groundwater and surface water is governed by the transport of toxic metals, organic pollutants and depository conditions at the site as the contaminants permeate through the soil media.

Advection and diffusion are the two transport processes which are believed to be responsible for contaminant mixing and movement to the groundwater (Munro et al., 1997; De Soto et al., 2012; Regadío et al., 2012). Studies of landfills on unconsolidated sand and gravel aquifers have shown that zones of leachate contaminated groundwater can extend hundreds of meters (Palmquist and Sendlein, 1975; Kimmel and Braids, 1974, 1977; Christensen et al., 1994; Williams, 1999; Butler et al., 2003). The study clearly revealed the role of hydraulic properties of aquifer material in contaminant movement to the groundwater. It has been reported that small amounts of leachate could pollute large volume of groundwater, causing them unusable for domestic and many other purposes (Bakare et al., 2005). There are insufficient information on the ill effects on exposure to landfill. Although a substantial number of studies have been conducted, but risks to health from landfill sites are difficult to quantify. However, concentration beyond permissible limits of toxic metals and metalloid (such as mercury, arsenic etc.) and other pollutants such as nitrate in groundwater and surface water due to leachate can cause the diseases like minamata, arsenicosis and blue baby syndrome. Knowing the impact of landfill leachate on the surface and groundwater, has given rise to a numerous studies across the globe including India (Benfenati et al., 2003; Olaniya et al., 1998; Kumaraswamy et al., 2000; Mor et al., 2006; Singh et al., 2008; Kanmani and Gandhimathi, 2013; Wijesekara et al., 2014). Therefore, it is necessary to monitor the landfill leachate to assure that the landfill operation does not cause harm to human health or the environment.

Generally, groundwater contamination can be assessed through either with the experimental determination of the contaminant or their estimation through mathematical modeling (Moo-Young et al., 2004; Hudak, 1998; Cuevas et al., 2012). The spatial distribution of chemical species provides some insight about the direction of groundwater movement. The spatial variation of the leachate components causing the groundwater pollution showed its significance in assessing the leaching pattern from the landfill (Regadío et al., 2013). There are limited reports on landfill leachate movement and its impact on groundwater quality in India. Most of the studies are focused on the leachate and groundwater characterization for the possible impacts. Thus the present study focuses on the measurement of several physico-chemical parameters along with the toxic metals in soil and groundwater as a function of depth around the Ranital solid waste dumping site and integration of analyzed data into geographic information system (ArcGIS) to illustrate the spatial distribution of toxic metals and other pollutants from landfill (soil) into groundwater and nearby surface water courses.

2. Materials and methods

Ranital, which was chosen as the study area, is situated in the city Jabalpur in Madhya Pradesh state of India (Fig. 1). Jabalpur is one of the largest urban agglomerations in the country with a population of about 2.46 million as per the 2011 census record of India. The climate of Jabalpur is characterized by a hot summer and general dryness except during the south west monsoon season. The normal annual mean maximum and minimum temperature is 32.1 °C and 18.3 °C respectively. The city receives an average 1386 mm of rainfall. Geologically, the area comprises of Palaeo-proterozoic rocks of Mahakoshal group to Deccan traps (Cretaceous) and alluvium (recent). Occurrence & movement of groundwater in hard rocks are mainly controlled by secondary porosity through joints and fractures. Groundwater in general occurs under unconfined, semi-confined and confined conditions. The soil strata mainly comprising of very stiff gravel to hard silty clay with gravel. The present study area is located at 23°10′31.4″N and 79°55′15.5″E. The waste collected from secondary collection points was dumped in an unorganized manner at Ranital dumpsite in Jabalpur city area. The site received around 200 tonnes of waste every day for about 10 years from the years 1999 to 2009. The site is a non-engineered and low lying open dump yard which looks like a huge heap of waste up to a height of 12–15 m. Trucks and separate vehicles from different parts of the city collected and brought the waste to this site and the waste was dumped as such without segregation, except the rag pickers who rummage through the garbage and helped in segregating it.

In an effort to study the extent of the groundwater contamination, it was designed to drill 15 bore holes for collection of both leachate and soil samples as the site was not equipped with any leachate collection system. After finalizing the bore hole locations on plan of the municipal solid waste dump yard, those were physically marked on ground and started soil exploration by drilling bore holes. The sampling locations are depicted in (Fig. 1). The sampling of soil was done using auger boring. A total of 30 soil samples from the 15 bore holes of 150 mm diameter were collected in fresh polyethylene bags from a depth of 0.10–0.20 m and 1.10–1.20 m from ground surface of the landfill respectively from each of the 15 bore holes. Similarly 15 groundwater samples from respective bore holes of depth 15 m and 4 surface water samples around the dumping yard were collected as per standard methods (APHA, 2012) in 1 L sterilized sampling bottles and preserved using 2 mL concentrated HNO_3 acid to avoid metal precipitation and brought to the laboratory for further analysis. Bottles were washed with detergent and rinsed with de-ionized water, thereafter rinsed with the water samples prior to collection. Rinsing with water sample was a precautionary measure taken to avoid any interference that may arise from using contaminated samples containers. The pH was recorded on site at the time of sampling with digital pH meter. For the analysis of biochemical oxygen demand (BOD), 300 mL capacity BOD bottles were used, and dissolved oxygen (DO) was fixed onsite using $MnSO_4$. To compare the

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