Toxicity Analysis and Public Health Aspects of Municipal Landfill Leachate: A Case Study of Okhla Landfill, Delhi

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Abstract

Uncontrolled landfilling is predominant in developing countries like India. Leachate generated from these landfills contains variety of contaminants, which even at trace levels can cause health problems of unknown dimensions and magnitude. Unchecked release of these leachates into the environments poses a substantial risk to the origins of potable water. Toxicity analysis can be used as an important tool to assess the leachate contamination potential. In the present study, Okhla municipal landfill leachate was subjected to acute toxicity tests using fish bioassay. The toxicity varied substantially with time of sampling. The leachates were found to be highly toxic to the test organisms, indicating significant risk to public health. Results from this study, demonstrate the importance of conducting such toxicity tests to assess the potential impact of a pollutant discharge on aquatic resources and demand for the proper management of solid waste in Delhi.

Keywords

Landfill leachate; contaminants; acute toxicity; bioassay; public health

INTRODUCTION

In developing countries like India, landfilling is the most commonly practiced form of municipal solid waste (MSW) disposal due to its economic advantages. However, the leachate arising from such landfills is now being recognized as a potential health risk to both surrounding ecosystems and human populations.

Delhi, capital of India, generates approximately 7,000 metric tons of MSW daily. The monthly production of leachate has been estimated to be 81.5 m^3 (Kumar et al., 2002). At present, there are three landfill sites in Delhi - Bhalsawa, Gazipur and Okhla (Figure 1). All the three are unlined and fall under the category of uncontrolled solid waste disposal facility. The leachate generated mostly percolated down the ground surface and the excess quantity gets collected in some low lying areas and sometimes gets mixed up with sewer and drainage systems thereby polluting ground water and surface water sources. A number of incidences have been reported in the past where leachate had contaminated the surrounding soil and polluted the underlying ground water aquifer or nearby surface water (Mor et al., 2006; Zafar and Alappat, 2001).

Around 30 % of population in Delhi watershed depends upon groundwater. Due to the presence of toxic constituent in leachate, its unchecked release into the environment poses a substantial risk to local resource users. Research has shown that many leachates do contain toxic and sometimes carcinogenic compounds (Baun et al., 1999; Brown and Donnelly, 1988). Additional studies have shown that leachate from a municipal solid waste landfill can be more toxic than leachate from hazardous waste landfill (Brown and Donnelly, 1988; Clement et al., 1996; Schrab et al., 1993). Chemical analysis can identify the presence of specific compounds, but the identification is not enough to assess the potential danger (Baun et al., 1999; Clement et al., 1996; Cheung et al., 1993). In addition chemical analysis only detects a small percentage of the toxic compounds present. Bioassay toxicity tests that measure effects on organisms and can detect toxicity even when the contaminants are not identified by chemical analysis. They reflect the cumulative and synergistic effects of all the compounds (Baun et al., 1999; Lambolez et al., 1994).

Toxic compounds can have two different effects on living organisms: acute toxicity, which is possible to evaluate in the short term, and chronic toxicity, whose evaluation takes longer since, in this case sub-lethal effects must be analyzed. In this work acute toxicity was studied in the samples of Okhla municipal landfill leachate with a view to determining the degree of pollution and contamination in this wastewater. A freshwater fish *Poecilia reticulata* (Guppy) was used in the toxicity tests.

MATERIALS & METHODS

Site details

The Okhla landfill site was commissioned in 1996. The waste dumped at this site includes domestic waste, e.g. kitchen waste; paper, plastic, glass, cardboard and cloths; construction waste, and unauthorized industrial waste. A high waste density of 1200 kg/m^3 may be attributed to the high content of construction and demolition waste and inert waste.

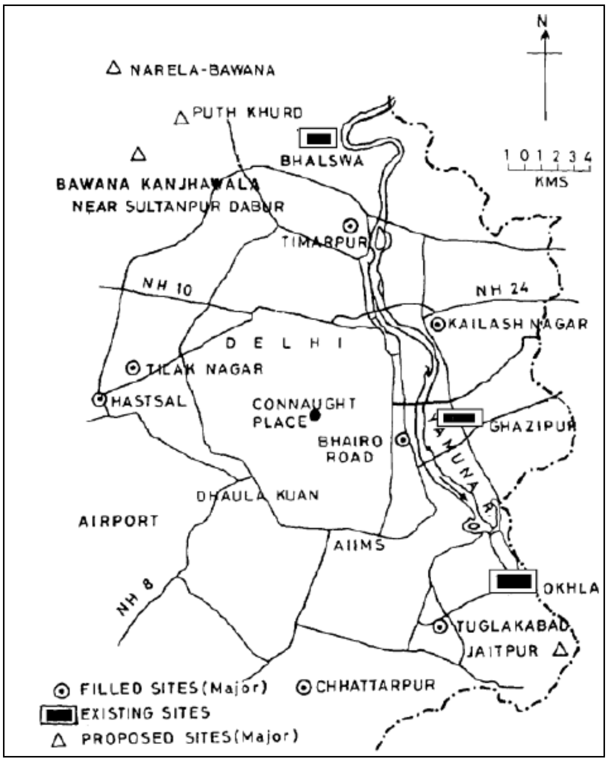

Figure 1: Location of Okhla and other landfill sites in Delhi (adopted from Zafar and Alappat, 2004)

Leachate characteristics

The leachate used in the study was collected from the Okhla landfill site, Delhi. The collected leachate was stored in the laboratory at 4^oC for further analysis. The following parameters were employed to evaluate characteristics of leachate: analyzed for Chemical Oxygen Demand (COD), hardness, chloride, ammoniacal nitrogen (NH_3-N), pH, alkalinity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS) and metals. All analysis was performed in accordance with the Standard Methods for the Examination of Water and Wastewater 20th Edition (1998).

Analysis of leachate toxicity

Leachate toxicity was determined using static 96-h fish bioassays. *Poecilia reticulata*, commonly known as guppy fish, was used as test organism. The fish were exposed to varying percentage of the leachate diluted with tap water. Fish mortality was observed at frequent time intervals for the determination of toxicity values. Dead fish were removed immediately from the test vessels. Toxicity was expressed as the leachate concentration (% v/v) that causes death for 50% of fish (LC50). For all the tests LC50 were calculated using the Spearman-Karber method (Hamilton et al., 1977).

RESULTS AND DISCUSSION

Leachate characteristics

Leachate samples were collected in the month of June and December of the year 2007. Leachate was always collected from two different places of the landfill site. The wide range of values for various parameters presented in table 1 shows, that the characteristics of leachate varied significantly with space and time.

TABLE 1: Characteristics of Okhla landfill leachates used in the fish bioassays

Parameters	Range of values[a]
pH	7.6 – 8.2
Alkalinity	12,000 – 32,000
Hardness	9,000 – 25,000
Chloride	16,000 – 23,000
COD	6,000 – 20,000
NH_3-N	1,000 – 3,000
TSS	20,000 – 35,000
TDS	2,000 – 19,000
TS	24,000 – 54,000

[a]All in mg/l except pH

Leachate toxicity

The studies were aimed to assess acute toxicity (96-h LC50) of leachate by estimating the rate of mortality in *Poecilia reticulata*. Prior to the 96-h toxicity tests, range finding tests were conducted in order to determine the appropriate dilution range for leachate. The leachate collected in the month of December was found to be more toxic with 96-h LC50 less than 3% for L1 (Figure 4) and less than 4% for L2 (Figure 5), compared to the June leachate with LC50 less than 13% for L1 (Figure 2) and less than 12 % for L2 (Figure 3).

Though, toxicological and physico-chemical analysis was done simultaneously, no correlation could be established between leachate toxicity and its physico-chemical characteristics, as reported by previous studies. (Clement and Merlin, 1995; Atwater et al., 1983; Cameron and Koch, 1980). The toxicity of the complex leachate matrix may be due to the synergetic interaction between the various pollutants. High concentration of heavy metals, organic matter and nitrogen (Table 1) are known to contribute to extreme elevation of toxicity levels in any environment. These classes of compounds are a risk to the ecosystems and public health.

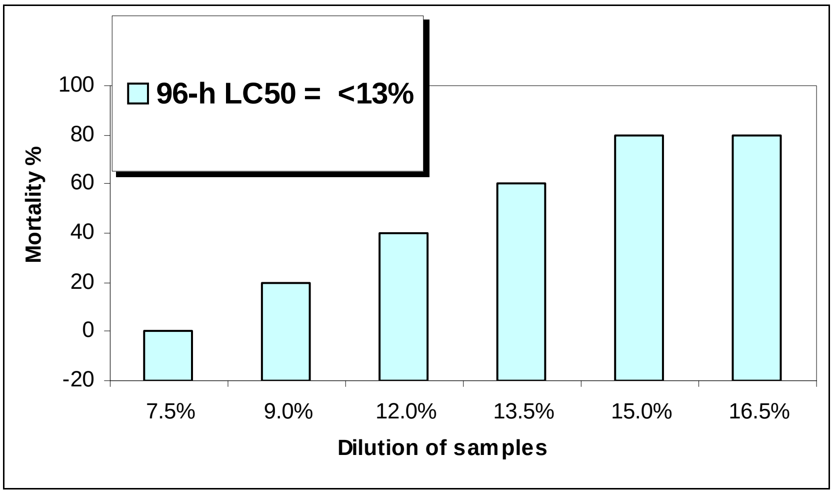

Figure 2: Toxicity assay L1 June 2007

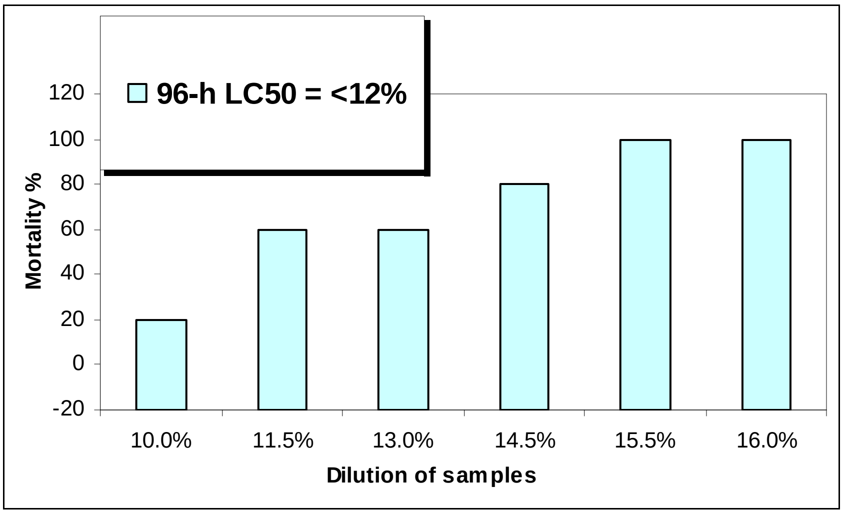

Figure 3: Toxicity assay L2 June 2007

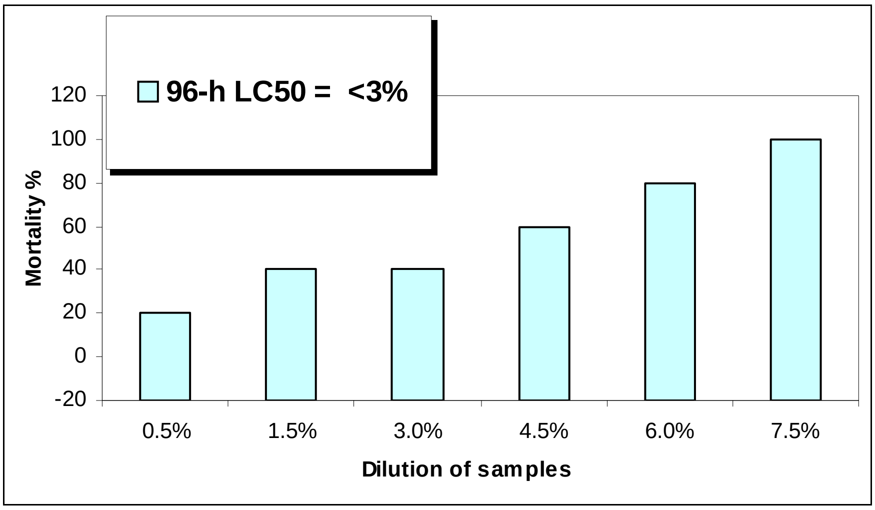

Figure 4: Toxicity assay L1 December 2007

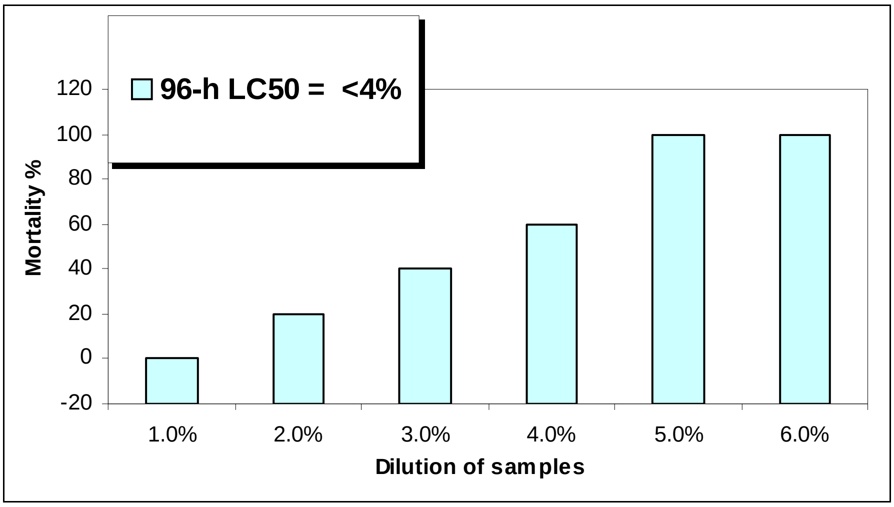

Figure 5: Toxicity assay L2 December 2007

Metals in the leachate

Mobilization of heavy metals from the landfill into leachate usually occurs both when hydrated ions are formed and by complexation with organic substrates with low molecular weight (amino acids and sugars), with polymers (fulvic and humic acids), and with colloids of high molecular weight (Zoumis et al., 2000). Significant amount of heavy metals can also bond with both inorganic and organic particulate matter. These constitute important means for leachate transportation.

In the leachate samples studied, various metals deemed as hazardous to the environment and public health were detected. Lead (Pb), Cadmium (Cd), Chromium (Cr), Nickel (Ni), and Cobalt (Co) have been implicated for various human health problems even at trace levels.

Pb is potentially carcinogenic and its toxic effects on humans can be detected via symptoms originated in the nervous system, such as muscle tremor, convulsions, paralysis, and coma (Wang et al., 2005). In the present study lead ranged between 0.9-1.5 mg/L. Cd, which was detected in the range of 0.2- 0.3 mg/L, also has been reported to cause agonistic and antagonistic effects on hormones and enzymes leading to lots of malformations like renal damage (Lewis, 1991; Donalson, 1980). These two metals have affinity for SH groups in proteins, haemoglobin, enzymes/ hormones (Manahan, 1992). Likewise, Ni and Cd are classified as carcinogens (Pekey, 2006; USEPA 1999). Other metals, investigated in this study, were Co, Cr, Zn and Cu, each of which has been reported for various health problems being non-biodegradable and with the possibility of accumulation in the food web (Langston, 1990). Fe and Mn which are commonly detected in water, were also detected in leachate and at very high concentrations. Fe and Ni showed the highest concentrations in all the four leachate samples. Fe ranged between 4-9 mg/L whereas Ni ranged between 1-5 mg/L.

TABLE 2: Heavy metals detected in the Okhla landfill leachate

Metals	Range of values[a]
Lead (Pb)	0.9 – 1.5
Cadmium (Cd)	0.2 - 0.4
Copper (Cu)	0.2 - 1.5
Manganese (Mn)	0.2 - 0.5
Zinc (Zn)	0.8 – 1.5
Chromium (Cr)	0.8 – 2.2
Iron (Fe)	4.0 – 9.5
Nickel (Ni)	1.0 – 5.0
Cobalt (Co)	0.3 – 1.0

[a]All in mg/L

Bioavailability of organic compounds and toxicity

The structure of organic compounds is a determining factor in toxicity analysis. Organonitrogenated substances for instance have a highly polluting potential, especially due to its metabolites, among which is ammonia. High concentrations of ammoniacal nitrogen were detected in leachate (Table 1). Concentrations exceeding 1,000 mg/L could be observed throughout the monitoring period. Studies have shown that municipal landfill leachates do contain high concentrations of organo-halogenated compounds, which can cause great concern since they can persist in aquatic environments and cause bioaccumulation (Araujo et al., 2006). The effects of toxicity of organic compounds on the aquatic organisms as well as humans can range from mortality to hepatoxicity, immunotoxicity, carcinogenicity, and metabolic alterations that can lead to a decrease in the rates of reproduction and other activities (Agundiran and Afolabi, 2008; Araujo et al., 2006; Dave and Nilsson, 2005).

Organonitrogenated compounds as well as heavy metals remain highly toxic, with a high potential of bioavailability, especially when they are water soluble. The pH values and the ion exchange capacity are important factors that interfere with the relation between adsorption and de-adsorption in compounds as it may render the species either more or less available. pH values of leachate were found to be slightly alkaline. These is due to the methanogenic phase of solid waste degradation at the landfill and contribute to reduce toxicity levels since these alkaline values can favor the precipitation of metals by making them less bioavailable (Table 1).

CONCLUSIONS

The toxicity assays of the leachate highlight the high pollution potential of the Okhla landfill leachate. In India there is scant information available on deleterious effects of leachate. Ecotoxicological evaluation of wastewater from such a source is fundamental for assessing the risk posed to environment and public health in municipalities where waste is not adequately treated. Consequently, it is absolutely necessary to introduce the monitoring of toxicity of leachates flowing from municipal landfills. Presence of heavy metals in the leachate supports the toxicity data. There is a clear cut case of potential environmental pollution as indicated by the toxicity of the leachate.

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