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Assessment of Soil Contamination around Municipal Solid Waste Dumpsite

K. Parameswari[1*], T. K. Padmini[1] and B. V. Mudgal[2]

[1]Sathyabama University, Rajiv Gandhi Road, Jeppiaar Nagar, Chennai - 600 119, Tamil Nadu, India; param.rm@gmail.com, padminitk@gmail.com
[2]Anna University, Chennai - 600 025, Tamil Nadu, India; bvmudgal@gmail.com

Abstract

Physicochemical and heavy metals characteristics of the municipal solid waste dumpsite, Perungudi, India were investigated. The concentration of heavy metals were analyzed at different depths and distances. The concentration is found to be higher in the top soil upto a depth of 5.5 m as the top soil is a sandy clay layer. Fe, Zn and Cu continue the trend upto a depth of 5.5 m and a change was observed at 6.5 m and the concentrations follow similar values upto 13 m. The concentration decreases with increasing soil depth, which is an indication of their low mobility. It is evident that the variation in the concentration of the heavy metals at various depths in the soils shows that the influence of the dumping activities plays a major role when compared to the geology of the area.

Keywords: Dumpsite, Heavy Metals, Soil Classification, Soil Contamination, Soil Texture

1. Introduction

The soil analysis of different stratigraphic units around Municipal Solid Waste (MSW) dumpsite within the aquifer system will aid, among other things, in understanding the level of contamination. It also helps in the selection of proper reclamation methods to reduce the contamination due to the leachate. The soil serves as a sink and recycling factory for both liquid and solid wastes. The soil is one of the repositories for anthropogenic wastes. Biochemical processes can mobilize the chemical substances contained in the soil to pollute the water supplies and impact the food chains. Perhaps of great and long term impact are the substances deposited on the soil that adversely impact the flora and fauna.

The concentrations of micronutrients, toxic heavy metals, exchangeable ions (sodium and potassium) and essential non metals (phosphorus and nitrogen) were observed to be higher in soils at the dumpsite, compared to those obtained in soils farther away from the dumpsite. This implies that the dumpsites have a significant impact on the environment. First, at the dumpsite, the concentrations of the essential elements were increased suggesting that the dumpsite possibly increased the concentrations of the essential element nutrients in the soil. On the other hand, the dumpsite also contained increased concentrations of toxic heavy metals, which may reach toxic levels through the food[1]. Heavy metal concentrations in the soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities, such as agricultural practices, industrial activities and waste disposal methods[2-7].

MSW has been found to contain an appreciable quantity of heavy metals, which may eventually end up in the soil and leach down the profile[8]. This makes municipal solid waste one of the principal sources of heavy metals in the environment. A dumpsite contains different kinds and concentrations of heavy metals, depending on the age, contents and locations[6,9-10]. In recent times, it has been reported that heavy metals from waste dumpsites can accumulate and persist in soils, at environmentally hazardous levels[6,8,11]. Although metals are essential, at higher concentrations they become toxic and cause problems to soil micro organisms.

*Author for correspondence

2. Study Area

Chennai city, capital of Tamil Nadu has a population of about 4.68 million (Census 2011). Due to urbanization, increase in population and consumption pattern, the problem of solid waste management in Chennai has been rapidly increasing. Chennai generates more than 3200 metric tones of garbage every day. The garbage generated consists primarily of organic waste, different kinds of plastics, packaging waste, paper, metal, glass, construction debris, bio-medical waste and slaughter house waste. According to Central Pollution Control Board estimates, an average person in a class I city (urban areas of population of 100000 and above), produces about 0.4 kg of garbage a day. The present study is to assess the study soil contamination due to unscientific solid waste disposal in Perungudi dumpsite.

The vertisol is identified as the most predominant soil type along the marshy area which has high content of expanding clay minerals; transmit water very slowly though it tends to be fairly high in natural fertility. Also analysis of soil samples around the dumpsite showed that the soil texture falls in clay loam category (clay - 32%, silt - 10%, sand - 58%) with pH 7.11-8.66 and conductivity 0.58 ms/cm.

3. Soil Sample Analysis

Four boreholes (B2, B3, B4 and B5) were drilled along the south eastern direction of the dumpsite. The soil samples were collected at various depths of 2.5, 3.5 m from B2, 4.5, 5.5 m from B3 3, 4.5 and 6.5 m from B4, 8.5, 11.5 and 13.5m from B5. A total of 10 soil samples are collected from four boreholes. The sample collection and analysis were done for the month of February 2010. The samples collected are as per standard methods and the sampling was done using the hand auger. The samples are taken from the auger and packed in a suitable labelled container. The collected samples are protected from sunlight to minimize any potential reaction. Then, they are properly stored in the laboratory at the end of the day for analysis. The soil samples are oven-dried, ground to fairly uniform size and sieved with a 2 mm sieve. The samples are digested with nitric acid to desorb and extract the metal contents adsorbed to the soil particles. After the acid digestion, the solutions are centrifuged at 2000 rpm for 10 min to separate the clear solution from the residue. Thereafter, the clear solutions are filtered through Whatman No. 1 filter papers and used as test samples for analysis.

Textural studies of sand, silt, and clay were carried out following the procedure of Ingram (1970). The pH, exchangeable metallic cations and non-metals like calcium, magnesium, sodium, potassium, phosphorous, nitrate and sulphur have been analyzed. Metals like copper, manganese, iron and zinc have also been analyzed. The pH is measured using the pH meter and the EC is measured using the conductivity meter. Sulphate is measured using the spectrophotometer. The calcium, magnesium, sodium, potassium is measured using the atomic absorption spectrometer. The available phosphorus is estimated using Bray's reagent. Organic matter is determined by the wet oxidation method of Walkley and Black. Copper (Cu), zinc (Zn), iron (Fe) and manganese (Mn) are measured using the atomic absorption spectrometer.

4. Texture Classification

The samples collected in the boreholes at 3.5 m in BH2, 5.4 m in BH3, 8.3 m in BH4 and 9.5 m in BH5 have been analyzed. The estimated sand, silt and clay content are presented in Table 1. The results reveals that samples collected from 3.9 m falls under the clay sand category, 5.4 m and 8.3 m falls in the field of sandy clay and 9.5 m is classified as clay based on Trefethen's soil classification (Figure 1)[12].

5. Soil Sampling Analysis

Table 2 shows the soil analysis at various depths. It indicates that the pH of the soil varies from slightly neutral to highly alkaline. The soil pH differs significantly from 6.7 to 8.3 which are below the standard value specified by the MoEF (Table 3.) but the values show that the soils are alkaline in reaction. The soil pH is an important parameter that

Table 1. Textural character of the samples of the boreholes at different depth

Sl. No.	Borehole	Depth (m)	Sand (%)	Silt (%)	Clay (%)	Sediment Type
1	BH2	3.5	70.35	14.15	15.50	Clay sand
2	BH3	5.4	43.20	10.80	46.0	Sandy clay
3	BH4	8.3	42.35	15.65	42.0	Sandy clay
4	BH5	9.5	21.0	6.0	73.0	Clay

directly influences sorption/desorption, precipitation/dissolution, complex formation and oxidation reduction reactions. The maximum retention of cationic metals occurs at pH > 7 while an anionic metal occurs at pH < 7. The solubility of metals in the soil and groundwater is predominantly controlled by the pH, the amount of metal and the Cation Exchange Capacity (CEC).

The EC values show a substantial increase from 669 to 807 in the BH2 and BH3 for a depth of 2.5 to 5.5 m. Since the top soil is of sandy or clay sand, it shows lesser EC concentrations. But in BH4 and BH5 it ranged between 5910 μS/cm at a depth of 3 m to 7560 μS/cm at a 8.5m depth. The major reason for the high EC concentrations is the composition of the subsoil of sandy clay or clayey soil. Most likely, the soil EC gives valuable information about the soil differences and similarities. Layers that have consistent EC readings are those that have similar soil properties and can be grouped together for further analysis. If the soil EC is too high, it can be an indication of a high level of exchangeable sodium. Soils with an accumulation of exchangeable sodium are often characterized as low permeable soils. The soil EC is also related to the specific soil properties that affect the pH, salt concentrations and water holding capacity. It is difficult to say the ideal EC levels, there are so many variables affecting the EC level. As a general guideline however, a good soil EC level will be somewhere between 200 μS/cm and 1200 μS/cm. Soils having EC levels below 200 μS/cm are sterile soil with little microbial activity. An EC above 1200 μS/cm may indicate a salinity problem due to lack of drainage.

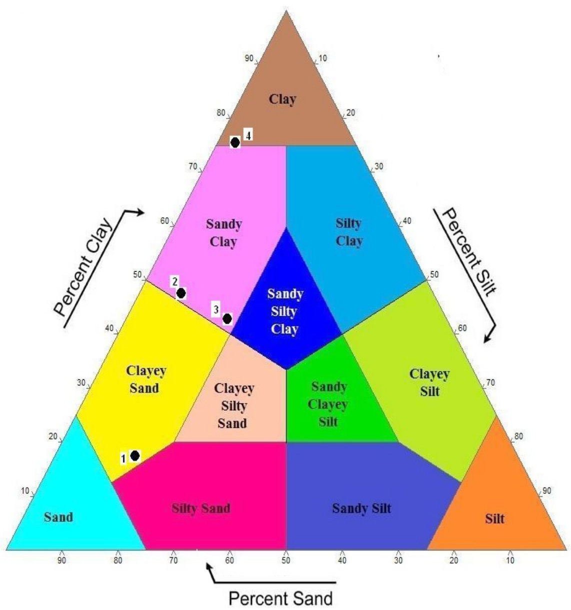

Figure 1. Trefethen's (1950) Trilinear diagram.

The organic content of the soil ranged from 0.1 to 0.62 %. As the organic content is low it allows the contaminant from the solid waste to enter the groundwater. If the organic matter content of the subsoil is high it prevents the pollutants from reaching the ground water sources as it plays an important role in the adsorption reaction in the soil.

The CEC of the soils examined showed a range of 8.58-30 meq/100g. The CEC plays an important role in the soil fertility. It is also directly related to the capacity

Table 2. Soil sample characterization at various depths

	Depth (m)	pH	EC (μS/cm)	Organic matter (%)	CEC (meq/ 100g)	Nitrate (mg/kg)	Phosphorous (mg/kg)	Na (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	Sulphur (mg/kg)
BH2	2.5	7.96	789	0.62	17.79	29.1	38.6	555	1123	1697	481	88.4
	3.5	6.72	695	0.10	8.58	8.2	1.5	858	384	297	286	175.5
BH3	4.5	8.02	669	0.10	10.26	4.9	0.9	946	196	292	502	127.4
	5.5	7.75	807	0.14	9.07	6.8	1.2	779	188	263	466	184.6
	3	7.78	5910	0.24	25.48	1.4	4.3	2203	275	1924	669	736
BH4	4.5	8.15	6540	0.10	18.39	1.1	9.6	2444	204	412	622	657
	6.5	8.37	6850	0.15	18.06	0.5	3.2	2346	213	483	588	538
	8.5	8.34	7560	0.39	28.02	0.6	2.1	2583	423	2075	640	626
BH5	11.5	8.32	7470	0.58	30.62	0.5	10.9	2714	247	2498	683	577
	13.5	7.96	6590	0.30	20.65	0.5	7.5	2601	225	787	579	493

Table 3. Compost standards by various agencies

Parameters	India	US EPA	England
pH	5.5 – 8.5		
Zinc	1000	2800	280
Manganese	–	–	–
Iron	–	–	–
Copper	300	1500	140

All parameters are in mg/kg except pH
Source: MSW Management and Handling Rules, 2000, Compost - Consulting development, 2004 and Soil quality standard from England.

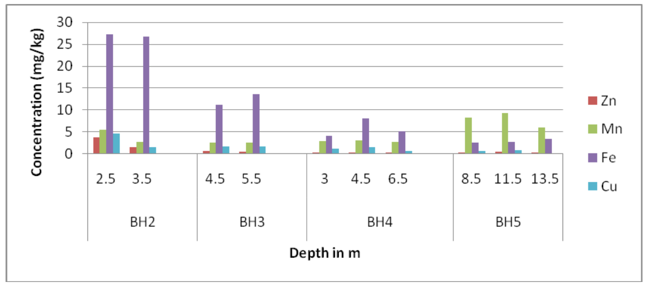

Figure 2. Heavy metal concentration of the soil samples at various depths

of adsorbing heavy metals since the adsorption behaviour depends on a combination of the soil properties and the specific characteristics of the element.

The content of water-soluble salts and exchangeable sodium and potassium also increased enormously in the soil profile at different depths. The exchangeable sodium increases as the depth increases and it varies from 555 mg/kg at 2.5m depth to 2700 mg/kg at 11.5m depth. Sodium is one of the most reactive metals and is mostly found in the combined state with other elements. Most sodium salts are liable to high temperatures and tend to decompose when exposed to very high temperature. The heat generated during the decomposition of wastes is usually high and the low concentration of sodium in the top soils at the dumpsite may probably be attributed to the loss of sodium during the decaying process.

The concentration of exchangeable potassium in the soils varying from 188-423 mg/kg shows decreased values as the depth increases. The observed concentration of potassium in the soil might have been due to the degradation of wastes. The composting of biodegradable waste introduces traces of metallic ions including potassium into soils.

Though calcium and magnesium are at an elevated range in the soil, they have not been considered as major pollutants in the environment compared to other elements. However, the higher levels in the soil indicate the leaching of these constituents into the water.

6. Heavy Metal Analysis

Figure 2 shows the heavy metal concentration in the soil at various depths. Though the sample shows a lower concentration than the permissible limits (Table 3.), the leaching of the heavy metals in the water even at a lower concentration imposes serious health risks to humans. Zinc varies from 3.78 mg/kg to 0.59 mg/kg in BH2 and BH3 at a depth of 2.5 to 5.5 m whereas the vertical distribution of zinc in BH4 and BH5 ranged from 0.27 to 0.48 mg/kg at a depth of 3 to 13.5 m. A similar trend is observed for iron and copper. The concentration is more in the top soil upto a depth of 5.5m as the top soil is a sandy clay layer. Also the iron, zinc and copper continue the trend upto a depth of 5.5m and a change was observed at 6.5m and the concentrations follow similar values upto 13m. In this study however, the concentrations of Cu, Zn and Fe decreased with increasing soil depth, which is an indication of their low mobility. It is evident that the variation in the concentration of the heavy metals at various depths in the soils shows that the influence of the dumping activities plays a major role when compared to the geology of the area. Though the dumpsite contributes to the heavy metal the concentration at different layers varies with respect to the mobile nature of the heavy metals in the soil. It depends on the soil pH, the properties of metals, redox conditions, soil chemistry, organic matter content, clay content, cation exchange capacity and the soluble ligands in the surrounding fluid.

7. Conclusion

Predominantly the soil is of sandy clay or clay soil around the dumpsite. EC values are above 1200 µS/cm for a depth greater than 3 m shows the salinity issues around the dumpsite. Though the dumpsite contributes to the heavy metal, the concentration at different layers varies with respect to the mobile nature of the heavy metals in the soil. The concentrations of heavy metal in the samples indicate that the dumpsite leachate plays a major role. Immediately the dumping has to be stopped as the heavy metals be leached out from the soil and enters the underlying aquifer, which affects the livelihood of the surrounding community.

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