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Municipal solid waste dumping and its impact on soil quality in Karachi

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Abstract
In this study, the surface soil samples (n=12) were randomly collected from both the waste dump and the non dumpsites (control). The characterization of Municipal Solid Waste (MSW) at dumpsites indicated a significant higher proportion of biodegradable waste (71%). Hence, the analysis of soil samples showed a high pH, TDS, EC, volatile solids and organic carbon in comparison to control sites. Similarly, the increased con-centration of heavy metals was observed. Overall, the mean metal concentrations at dumpsites soil were in the following descending order: Zn>Cr>Pb>Cu>Ni>Cd. Ex-cept for lead, the analyzed metals concentration was found below the permissible lim-its. However, on comparison with control sites, the trend indicated the likely increase in pollutant concentration. The study therefore concluded that MSW dumping has not only altered the soil color and texture, but also has changed the physico-chemical constituents. These findings might help in proper management of municipal solid waste in Karachi.

Keywords
Municipal Solid Waste, biodegradable waste, dumpsites, soil, heavy metals

Introduction

Karachi, a mega city of Pakistan, with population >20 million is generating about 12,000 tons per day of municipal solid waste (MSW). The collection efficiencies of MSW range from 0 percent in low-income rural areas to 90 percent in high income areas (Pak EPA, 2005). However, the rate of collection and transportation of the respective municipality to the landfill site ranges from 35% to 45% of the total waste generated. The uncollected waste, i.e., 55 % to 65% remains on street, open spaces and vacant plots, which poses serious threat to soil and groundwater resources. Moreover, the dumpsites wastes are commonly set to fire, hence adding to air pollution (Rehan et al., 1998). It was noted that MSW in Karachi contains a significant high proportion of biodegradable waste such as food waste (Jilani, 2007). Dumping such waste produce leachate, that causes soil and ground water contamination (Isidori et al., 2003; Pelegrini et al., 2007; Ande and Onajobi 2009, Chukwudi et al., 2017). Further, the biodegradable wastes provided breeding sites for mosquitoes, house flies, rats, cockroaches, birds as well as stray animals and therefore acts as passive vectors in the transmission of diseases.

Presently, it has been realized that unscientific waste disposal practices are also contributing to global warming.

Generally, the MSW contained a considerable proportion of plastic, paper, metal rubbish and batteries. These were considered to be the known sources of heavy metals contamination. In fact, most heavy metals pollution in soil was associated with the massive dumping of solid wastes (Amusan and Ojo, 2005). It has been reported that human exposure to toxic metals via the food chain caused blood and bone disorders, kidney damage and decreased mental capacity and neurological damages (Hughes, 1996; NIEHS, 2004; Alissa and Ferns, 2011). Besides heavy metals contamination, other constituents such as organic matter and pH

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of the waste were also controlling the heavy metals availability (Nyamangara and Mzezewa, 1999). It is therefore necessary to evaluate the relationship among these parameters as these plays a significant role in the accumulation of heavy metal in soil.

It is worth mentioning here that the move from landfill-based to resource-based waste management systems would require an adequate knowledge about composition of municipal solid waste (Burnley, 2007). Therefore, characterization of MSW is important as it will improve the prevailing waste management systems. This would also help in taking the better financial, regulatory and institutional decisions (Chandrappa and Das, 2012). The present research study was conducted with the aim to provide the baseline information regarding municipal solid waste composition and its impact in dumping soil. The study findings would help in the development of sustainable solid waste management system in Karachi City.

Materials and Methods

Study area and samples collection

For this study, the informal MSW dumping sites located in five major residential areas of Karachi metropolis (New Karachi, Landhi, Defence, Kemari and Gulshan) were selected. The city geographic coordinates are 24° 51'36" N and 67° 0' 36" E. However, the study area map and geographic co-ordinates of the location are shown in Figure 1 and Table 1.

Sample Location	Latitude	Longitude
New Karachi	24°59'55.65" N	67°3' 16.23" E
Landhi	24°50'12.30" N	67°11' 25.77"E
Defence	24°49'18.20" N	67°2' 43.08" E
Kemari	24°49'22.36" N	66°58' 39.35"E
Gulshan	24°54'37.29" N	67°5' 13.24"E

Table 1. GPS coordinates of MSW dumping sites

Figure 1. Map showing the study area

At these locations, besides open waste dumping, the heavy influxes of traffic, waste from commercial shops, and other roadside activities were observed. To collect data, a two-month survey during Sept.– Oct. 2017 was carried out. All soil samples were randomly collected at a depth of 0-3 cm using a hand auger. In order to compare the impact of MSW dumping, the control soil samples not treated with MSW were also obtained. The investigation of each site was carried out repeatedly. A total of twelve soil samples, two from each site, within the residential areas of Karachi City were collected and analyzed using the standard method.

Waste composition analysis

Manual sorting and weighing of individual component in a municipal solid waste stream was conducted using standard methods (ASTM, 2003). In this method, the sorted sample of 100 kg weight, was prepared properly (mixed and quartered) at each MSW dumpsite.

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Soil analysis

For physicochemical estimation, all soil samples were homogenized, air-dried, ground and sieved using a 2mm mesh and stored in polythene bags. The treated soil samples were analyzed for pH, electrical conductivity, total dissolved solids, salinity, volatile organic matter and organic carbon content using standard procedures described elsewhere (Rayment & Higginson 1992; Vesilind *et al*., 2003; Jilani 2007).

Sample digestion for heavy metal analysis

In the laboratory, the soil acid digestion was carried out in a closed vessel using microwave digester by providing the electrical power of 1200 Watts (US-EPA 1996). This method requires 0.5 g of the soil sample in 9 ml of nitric acid and 3 ml of hydrofluoric acid with 60 min digestion. After cooling, 5 ml of 1% HNO_3 was added to the digestion mixture, filtered through a 0.45 mμ pore size filter membrane and marked up to 25 ml with de-ionized water. The metal concentrations in the final solution were then measured using an Atomic Absorption Spectrophotometer (Perkin Elmer Model Analyst 400).

To calculate metal concentration in the sample, calibration curve for each metal (Pb, Cd, Cr, Ni, Cu, Zn) was prepared. Moreover, to verify the testing method, reagent blank was used in which no detectable amount of metal was found. However, the level of accuracy in the determination of metal concentration was obtained by the measurement of Certified Reference solution, determination of spike recovery for selected heavy metals and by measurements of duplicate for each sample.

Results and Discussion

Composition of municipal solid waste

The average composition of MSW at five dumpsites in the residential areas of Karachi is shown in Figure 2.

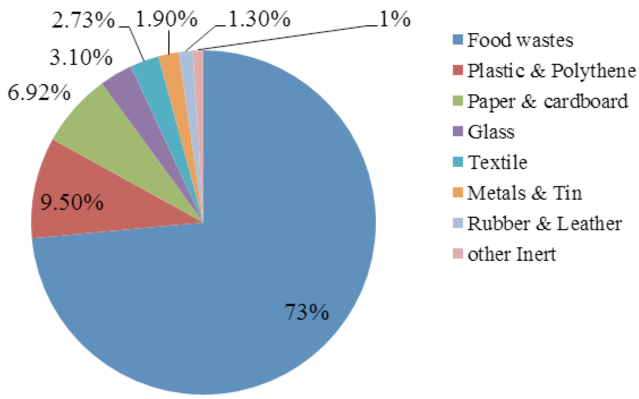

Figure 2. Average composition of municipal solid waste in the dumping sites

The results clearly indicate that municipal solid waste contains a significant higher proportion of biodegradable waste (73%). Other waste includes the plastics (9.5%), paper & cardboard (6.92%), glass (3.1%), textile (2.73%), metals (1.9%), rubber & leather (1.3%) and other inert substances (1.0%). During analysis, it was noted that the mixed type of biodegradable waste generally contains the leftover food residue, vegetable and fruit waste. It was noted by many researchers that more the biodegradable organic fraction in the wastes, the higher the pH and Biochemical Oxygen Demand (BOD) of the leachate (Zainol 2012; Tatsi and Zouboulis 2002). The increase pH values plays a major role in metal bioavailability, toxicity and leaching of contaminants in the surrounding areas (Chimuka et al., 2005). The heavy metals contamination in general causes an insidious effect on human health, animals and soil productivity (Smith et al., 1996; El-Fadel et al., 1997; Isidori et al., 2003; Okoronkwo et al., 2006; Pelegrini et al., 2007).

Comparative assessment of soil characteristics at waste dump and non-dump sites.

The physico-chemical properties of soils are presented in Table 1. The mean pH values at both the control (pH 7.6) and dumpsites (pH 7.95) were found towards the alkaline side. However, a significant difference in the mean values of Electrical Conductivity (EC) and Total Dissolved Solids (TDS) was observed. It was found low at control sites while significantly different and higher value at waste disposal sites. The EC and TDS at control sites were 590μS/cm and 387 mg/L while at disposal sites, these were 4526 μS/cm and 2681 mg/L respectively. The high TDS increases the soil salt concentration and decreases the water availability, thus result in stunted plant growth. Moreover, the high salt

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concentration in soil decreases the ground water *recharge* capability (Pluhowski and Spinello, 1978).
The values in Table 2, describe that as compare to control, the soil at disposal sites contained a high percentage of moisture organic matter and organic carbon content.

Soil Parameters	Waste Disposal Sites				Non-dump site (Control)
	Min	Max	Mean	*S.D	
pH	7.60	8.40	7.95	0.230	7.60±0.36
Electrical Conductivity (μS/cm)	995	8950	4526	2260	590±267
Salinity (%)	0.45	4.80	2.45	1.410	0.28±0.14
Total Dissolved Solids (mg/l)	657	5862	2681	1401	387±17
Moisture content (%)	3.57	25.50	4.48	3.971	1.04±0.33
Volatile Organic Matter (%)	4.38	24.50	9.0	5.385	3.4±0.4
Carbon content (%)	1.80	13.50	3.55	6.71	1.75±0.38

*Standard Deviation (n=8 for waste disposal sites; n=2 for control)

Table 2 . Physico-chemical properties of soil samples at waste dump and non-dump sites.

The high moisture content would cause a leachate contamination. Further, the organic carbon has a strong affinity for heavy metal. Therefore, it might increase the metal concentration in dumpsites soil.

Comparative assessment of heavy metals at waste dump and non-dump sites.

The results presented in Table 3 and shown in Figure 3, indicated varying concentrations of heavy metals in the soil samples of both the sites. This might be due to ongoing human activities in the area, such as municipal solid wastes dumping, the heavy influxes of traffic, commercial shops wastes dumping and other activities. The analysis of samples indicated that the mean metal concentration (mg/kg) in the dumpsites soil followed the descending pattern: Pb>Cd>Cr>Zn>Cu>Ni. Whereas, the metal concentrations in the study area followed the decreasing trend like: New Karachi > Landhi > Defence > Kemari > Gulshan. Among the six heavy metals, the highest concentration of Pb (116 mg/Kg) and Cr (75.42 mg/Kg) was observed in the New Karachi and the lowest concentration of Pb (20 mg/Kg) and Cr (41.16 mg/Kg) was reported in Gulshan area. However, the mean values of Pb and Cr at waste disposal sites were 51.27 mg/Kg and 65.71 mg/Kg, whereas at control site it was 13.2 mg/Kg and 25.5 mg/Kg respectively.

Heavy Metals (mg/Kg)	Waste Disposal Sites				Non-dump site (Control)	*Permissible Limit
	Min	Max	Mean	*S.D		
Lead (Pb)	20.3	116	51.3	37.3	13.2±5	50
Chromium (Cr)	41.2	75.4	65.7	14.1	5.5±22	75
Copper (Cu)	29.4	81.4	45.1	20.7	8.8±11	100
Zinc (Zn)	142.8	201.4	168.9	27.9	45.6±37	300
Nickel (Ni)	34.8	49.5	40.4	6.01	29.3±17	100
Cadmium (Cd)	3.12	3.92	3.30	0.35	2.7±0.3	3

Standard Deviation (n=10 for waste disposal sites; n=2 for control sites)
*Source: FAO/WHO, 200; Fagbote and Olanipekun 2010; Nartey *et al.* 2012

Table 3. Average heavy metals concentrations (mg/Kg, dry weight) in the soil samples sites.

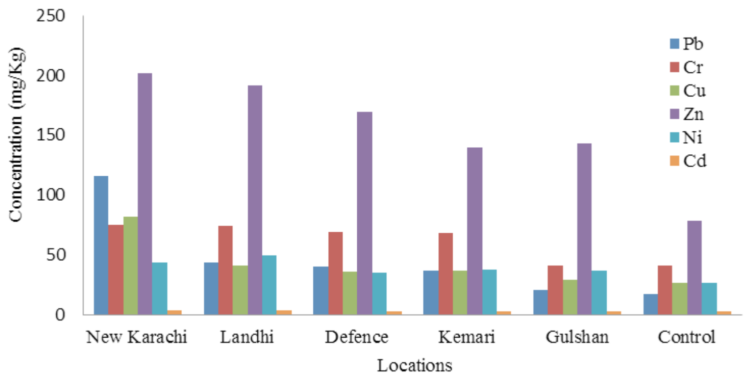

Figure 3. Heavy metal concentration in the soil of waste dump and nondump sites.

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Moreover, a noteworthy difference in the mean values of other heavy metals was observed. It was found high at dumpsites, whereas low at control sites. Overall, the mean concentration in dumpsites soil was found below the permissible limits (FAO/WHO 2001; Nartey et al., 2012), except in New Karachi. At this site a significant high value of Lead and Chromium was noted, which could be linked to heavy movement of traffic and other commercial activities in the area besides the dumping of MSW. Moreover, the variation in the concentration of heavy metals at each site might be due to changes in soil pH and organic matter content. It was observed that soil with alkaline pH and more organic matter content significantly accumulated the high concentrations of heavy metals (Syeda et al., 2014), as also observed in this study.
It is worth mentioning here that the high values of Cu and Zn in the dumpsite soils could be traced to a number of sources, like atmospheric pollution from vehicle emissions and disposal of all kinds of solid waste. The corrosion of brass and other copper containing metals could be the major source of Copper contamination. Whereas, the high values of Zinc might be due to dump of Zinc-coated sheets, generally used as a roofing material in the country. Further, the large amount of galvanized scraps also finds its way into the dumps, thereby increasing Zinc concentration in the soils beyond the levels found in the control areas.

Conclusion

The results of the investigation showed that Municipal Solid Waste (MSW) in the residential area of Karachi contained a significant higher proportion of biodegradable organic waste, dominated by food waste (70%). Dumping such waste had increased the soil moisture, pH, EC, TDS, volatile solids, organic carbon and heavy metals concentrations. It may be mentioned here that the huge quantity of biodegradable waste which is generated in the city could be effectively managed by using these material for energy or compost (biofertilizer) production. Such approach of waste management would minimize the hazard caused by dumping waste. Further, the MSW composting and the use of compost would provide multiple benefits like waste recycling, pollution minimization, environmental and public health protection.

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