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ORIGINAL ARTICLE

Open dumping of municipal solid waste and its hazardous impacts on soil and vegetation diversity at waste dumping sites of Islamabad city

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Abstract Deteriorating soil quality and decrease in vegetation abundance are grave consequences of open waste dumping which have resulted in growing public concern. The focus of this study is to assess the contribution of open waste dumping in soil contamination and its effect on plant diversity in one of the renowned green cities of Pakistan. Surface soil samples ($n = 12 + 12$) were collected from both the open waste dumping areas allocated by Capital Development Authority (CDA) and sub- sectors of H-belt of Islamabad city (representative of control site). The diversity of vegetation was studied at both sampling sites. Significant modifications were observed in the soil properties of the dumping sites. Soils at the disposal sites showed high pH, TDS and EC regime in comparison to control sites. Various heavy metal concentrations i.e., Lead (Pb), Copper (Cu), Nickel (Ni), Chromium (Cr) and Zinc (Zn) were also found to be higher at the dumping sites except for Cadmium (Cd) which had a higher value in control site. A similar trend was observed in plant diversity. Control sites showed diversified variety of plants i.e., 44 plant species while this number reduced to only

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32 plant species at the disposal sites. This is attributed to changes in soil characteristics at disposal sites and in its vicinity areas.

1. Introduction

The menace of environmental pollution has been haunting the human world since early times and is still growing due to excessive growth in developing countries. Municipal solid waste (MSW) normally termed as "garbage" or "trash" is an inevitable byproduct of human activity. Population growth and economic development lead to enormous amounts of solid waste generation by the dwellers of the urban areas (Karishnamurti and Naidu, 2003). Urban MSW is usually generated from human settlements, small industries and commercial activities (Singh et al., 2011). An additional source of waste that finds its way to MSW is the waste from hospitals and clinics. In majority of countries most of the smaller units do not have any specific technique of managing these wastes. When these wastes are mixed with MSW, they pose a threat for health and also they may have long term effect on environment (Pattnaik and Reddy, 2009).

In developing countries open dumpsites are common, due to the low budget for waste disposal and non-availability of trained manpower. Open dumping of MSW is a common practice in Pakistan. It also poses serious threat to groundwater resources and soil. The contamination of soil by heavy metal can cause adverse effects on human health, animals and soil productivity (Smith et al., 1996). Over the last many years, heavy metals have considerably damaged the soil quality and fertility in consequence of increased environmental pollution from industrial, agricultural and municipal sources (Adriano, 1986). Metals cause physiological disorders in soils as absorption through root system consequently retards plant growth and deprives it of vigour (Moustakas et al., 1994). Waste carries different metals which are then transferred to plants by different ways (Voutsa et al., 1996). Depending on the tendency of the contaminants they end up either in water held in the soil or leached to the underground water. Contaminants like Cd, Cu, Ni, Pb and Zn can alter the soil chemistry and have an impact on the organisms and plants depending on the soil for nutrition (Shaylor et al., 2009).

Diversity of vegetation is directly influenced by soil characteristics. Many studies show evidence of seriousness of hazards caused by open waste dumping ultimately affecting the plant life on the planet leading towards an irreversible erosion trend unless the present land use pattern is checked (Phil-Eze, 2010). Solid waste pollutants serve as an external force affecting the physico-chemical characteristics of soil ultimately contributing towards the poor production of vegetation (Papageorgiou, 2006). The pollutants, in the first place, hinder the normal metabolism of plants which is an invisible injury and owing to which the visible injury appears in the aftermath (Ahmed et al., 1986). It is depriving our ecosystem of the natural balance and bear result beyond any repair. Assessment of soil pollution becomes difficult when contaminants belong to different sources and their products are variably distributed (Partha et al., 2011). Chemical properties of soil serve as main reason of vegetation changes (Neave et al., 1994). In plants accumulation of chemical elements depends not only on their absolute content in a soil but also on the level of fertility, acidic–alkaline and oxidative-reductive conditions and on the presence of organic matter (Subbiah and Asija, 1976). The disturbances of higher intensity sometimes endanger the survival of some species and yield to low richness (Hussain and Palmer, 2006). In this regard, developing countries are even deeper into the chaos as having poor financial resources to upgrade their disposal facilities and turned out to be more vulnerable to the hazards of dumping for their environment (Hazra and Goel, 2009).

Pakistan is generally faced with rapid deterioration of environmental conditions due to the conventional system of collection and dumping of solid wastes. Therefore urban waste management has become a major concern in cities. Little efforts have been made in order to improve the waste collection and disposal facilities. This has some grave consequences ranging from deterioration of soil quality to reduced plant diversity. The present study has been conducted in order to assess the prevailing condition of soil physico-chemical characteristics and its impact on vegetation.

1.1. Description of the Study Area

The dumping site is located in Sector H-10 of Islamabad city. Geographically it is situated at 33° 42' 0'' northern latitude and 73° 10' 0'' eastern longitude at 540 m above sea level (asl) (Fig 1). According to the master plan one fourth of the city's land was reserved as green area. The city is characterized by a grid pattern which divides the city into eight basic zones viz., administrative, diplomatic enclave, residential areas, educational sectors, industrial sectors, commercial areas, rural and green areas, along with protected green belts. The plan concentrated on the division of the city into equal sized sectors, each of which is subdivided into four sub-sectors separated by green belts and parks. The total area of each sector is 4 km square. Each sector is facilitated with its own shopping area and public and recreational parks (Islamabad Census Report, 1998). The Sector H-10 lies in the Capital Territory of Islamabad (ICT) and the waste dumping site is situated in an open reserved area.

Climatically the area falls in the semi-arid zone having moderate summers and winters. The mean maximum temperature of the region reaches 45 °C during the summer and the mean minimum temperature is 24 °C falling below zero occasionally in winters. Monsoon prevails from July to September. The records of the Pakistan Department of Meteorology indicate a monsoonal climate of rainy hot summers and cool dry winters, with an annual average rainfall of 60–64 mm.

Geologically Islamabad is in the South margin and leading edge of the Hazara fault zone. The terrain in the metropolitan area of Islamabad consists of plains and mountains. Geology of Islamabad is dominantly controlled by the convergence and collision of the Pakistan, India and Eurasian tectonic plates that produce complex structures (Williams et al., 1999).

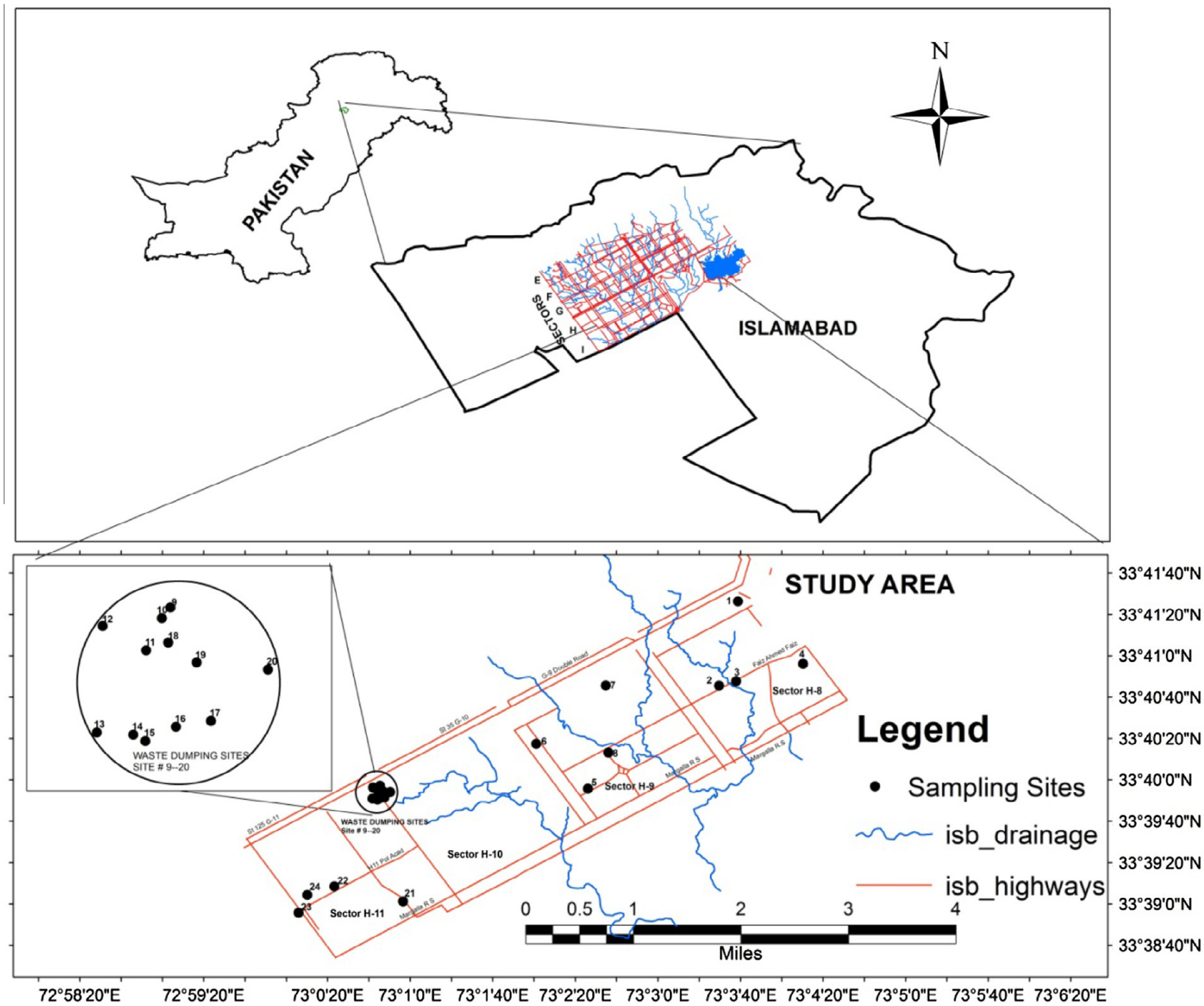

Figure 1 Map of sectors of H-belt of Islamabad including the open waste dumping area allocated by CDA.

The disposal site covers an area of about one and a half acres approx. of the total urban area which is mostly covered with large heaps of garbage dumped on open land. Almost 96% of the total waste generated from all residential, industrial and commercial sites of the city is deposited at dumping site reserved at Sector H-10. The volume of solid waste generated lies within the municipal limits. It ranges between 500–550 metric tons per day, with an average waste generated according to social and economic conditions.

2. Materials and methods

Based on the focus of this study, surface soil samples ($n = 12$) from the depth of 9 inches were collected from the waste disposal site located behind the International Islamic University (IIU), Sector H-10, Islamabad (Fig. 1). This site has been specified as an open area which is now used for waste dumping. Twelve samples from the other sub-sectors of H-Belt (H8/1, H8/2, H8/3, H9/1, H9/2) were also taken in order to compare the quality of soil from dumping sites and control sites. Soil samples were brought to the laboratory of IIUI and were prepared for further analyses. They were air dried, sieved and ground.

Several analyses were performed in order to study the parameters that evaluate soil quality. Each soil sample was estimated for pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) in a soil to water ratio of 1:5 using a combined digital meter (Milwaukee SM802). Organic matter (OM) was determined by Tyurin's method (Nikolskii, 1963). The particle size analysis was carried out by the hydrometer method and soil textural classes were determined by using the textural triangle (Robert and Frederick, 1995). The soil acid digests were prepared for the determination of total content of soil nutrients and heavy metals. These were prepared in a closed vessel microwave digester (CEM). Each soil sample was weighed (0.5 g) and placed in pre-washed Teflon vessels. All vessels were acid washed and rinsed with nitric acid and reagent water. Added to it were 9 ± 0.1 ml concentrated nitric acid and 3 ± 0.1 ml concentrated hydrochloric acid. The microwave unit was calibrated for power and temperature. Ramping of temperature was adjusted to 220 °C ± 5 °C and a power of 1200 watts was provided (USEPA Method 3051a). The contents of the vessels were then filtered using Whatman filter paper No. 42 and transferred to acid clean bottles and diluted to volume (50 ml). Nutrient concentrations [Calcium (Ca), Magnesium (Mg), Sodium (Na) and Potassium

(K)] and heavy metal concentrations (Pb, Cd, Cr, Ni, Cu, Zn) in the soil acid digests were measured using atomic absorption spectrophotometer (Varian FSS-240).

The abundance of vegetation was also recorded at each site using quadrat method (Kent and Coker, 1992) and vegetation data were analyzed through PCORD version 4.16 (McCune and Mefford, 1999). This software performs multivariate analysis of ecological data. It also offers many ordination and classification techniques. Cluster Analysis (CA) method was followed for the determination of grouping of sampling sites correlated with vegetation.

3. Results

The results obtained for physico-chemical properties of soils at both control and waste disposal sites are shown in Table 1. Clustering of different plant species is based on soil properties.

3.1. Comparative assessment of physico-chemical variables at control and waste dumping sites

Basic statistics plots showed comparison of physico-chemical properties of soils at both control and waste disposal sites (Table 1). The mean value of pH at control site was 8.65 while the mean value of pH at dumping site was 8.75 (Table 1). A significant difference in the mean values of EC and TDS was observed in the soils of both areas. It was found to be low in control sites while it was significantly different and found higher at waste disposal sites. The mean values for EC and TDS at control site were recorded as 0.092µS/cm and 64.16 ppm while at disposal site they were 0.23 µS/cm and 158.33 ppm respectively (Table 1). A variation in the soil textural composition was observed at the sampling sites. Sandy loam the main soil texture was recorded in sectors H-8, H-9 and H-11 (Control sites) and also at sampling sites 11, 12, 13, 14, 15 and 16 of disposal area except for sampling sites 9 and 10 where loamy sand was prominent. The mean value of percentage of sand and silt was lower at control site than disposal site. The mean values for sand and silt percentage were 68.24; 14.66 and 75.4; 16.04 at control and disposal site respectively (Table 1). The percentage of clay, OM and moisture content of the control site were found to be higher as compared to disposal site due to which vegetation was more abundant at control site.

A significant difference in the mean content of Ca was found in the soils of both sites. Table 1 showed that the mean value of Ca at control site was 695.45 ug g^{-1} while at disposal site it was 14196.32 ug g^{-1}. At a particular location the background concentration of metals in the soil arises due to the geological matter from which it is formed. Mean values of Mg at control and disposal site were not much different as Mg is part of parent rock material therefore found in high concentrations at both localities. The mean value of Mg at control site was 26465.63 ug g^{-1} while it was 24704.85 ug g^{-1} at disposal site (Table 1). The mean value of Na was lower at control site and variance was high while it was high at disposal sites with less variance. It is shown from the Table 1 that the mean value and variance of Na at control site were 228.20 ug g^{-1} and 21127.61 while they were 282.09 ug g^{-1} and 4302.22 at disposal site. Large amounts of *K* can be detrimental to plants and other species. Therefore, Potassium should be released to the environment in minimum quantity.

Table 1 Statistical description of soil physico-chemical properties of control sites and waste dumping sites.

	Control sites				Waste Disposal Sites				CCME (2001)
Soil parameter	Mean ± SE	Min–Max	Variance	SD	Mean ± SE	Min–Max	Variance	SD	Threshold Values
pH	8.65 ± 0.09	7.8–9.3	0.12	0.34	8.75 ± 0.07	8.3–9.1	0.06	0.25	6–8
EC	0.09 ± 0.001	0.03–0.16	0.00	0.031	0.23 ± 0.04	0.06–0.65	0.02	0.16	–
TDS (ppm)	64.16 ± 5.56	40–110	371.97	19.28	158.33 ± 33.45	40–450	13433.33	115.90	–
MC	5.48 ± 1.00	0.90–11.84	12.01	3.46	4.72 ± 0.988	0.70–11.48	11.72	3.42	–
OM (%)	1.64 + 0.14	0.78–2.29	0.23	0.48	1.54 ± 0.109	0.91–2.09	0.14	0.37	–
Sand (%)	68.24 ± 6.18	0.73–77.35	458.75	21.41	75.4 ± 2.09	68–96.5	52.73	7.26	–
Silt (%)	14.66 ± 1.52	0.14–20.5	27.79	5.27	16.04 ± 1.68	0.35–22.85	34.05	5.83	–
Clay (%)	9.87 ± 0.57	6–12.5	4.00	1.99	8.55 ± 0.73	3.15–12.05	6.11	2.47	–
Ca (ug g^{-1})	695.45 ± 74.37	392.66–1311.93	66384.11	257.65	14196.32 ± 5051.88	758.45–41738.36	3.06E + 08	17500.23	–
Mg (ug g^{-1})	26465.63 ± 5480.58	11129–70354.2	3.6E + 08	18985.28	24704.85 ± 6209.24	3565.8–77680.1	4.63E + 08	21509.47	–
Na (ug g^{-1})	228.20 ± 41.95	9.17–488.67	21127.61	145.35	282.09 ± 18.93	178.97–368.3	4302.22	65.59	–
K (ug g^{-1})	25985.91 ± 1431.53	19031.5–39593	24591576	4958.989	19229.5 ± 3186.96	4156.6–28253.4	1.22E + 08	11039.97	–
Pb (ug g^{-1})	67.06 ± 11.41	5.3–137.46	1562.71	39.53	133.23 ± 20.60	38.65–236	5094.59	20.60	70.0
Cd (ug g^{-1})	11.92 ± 2.32	2.99–26.8	64.95	8.05	6.17 ± 1.73	1.38–20.65	36.14	1.73	1.4
Cu (ug g^{-1})	9.46 ± 2.30	1.29–24.6	63.79	7.98	19.79 ± 9.38	1.62–119.73	1057.85	9.38	63.0
Ni (ug g^{-1})	27.15 ± 4.70	0–55.45	266.02	16.31	101.92 ± 16.31	10.37–223.12	56.50	16.31	50.0
Cr (ug g^{-1})	0.85 ± 0.42	0–3.7	2.19	1.48	3.45 ± 0.79	0–7.97	2.74	0.79	64.0
Zn (ug g^{-1})	196.99 ± 44.19	38.11–499.13	23434.15	153.0822	632.4892 ± 186.66	93.91–1607.34	418138.7	646.63	200.0

*Significance level was observed at 0.01 P value. All parameters showed $P < 0.01$ except Ca and Cu at Waste Disposal sites and Cr at Control site.

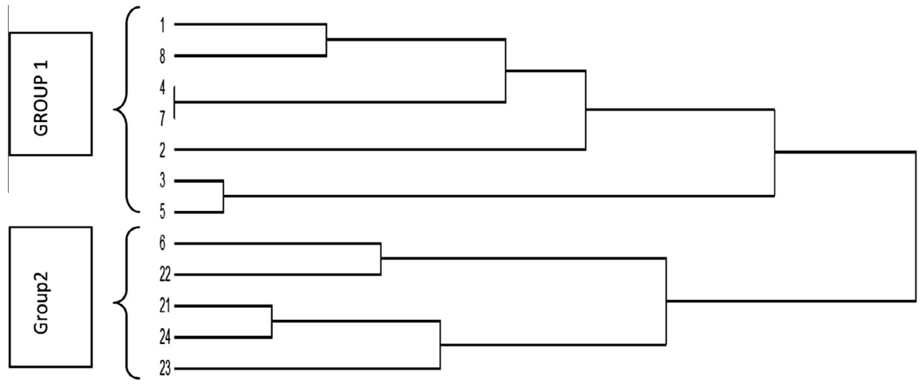

Figure 2 Cluster analysis of control sites using Ward's method (matrix: Euclidean distance).

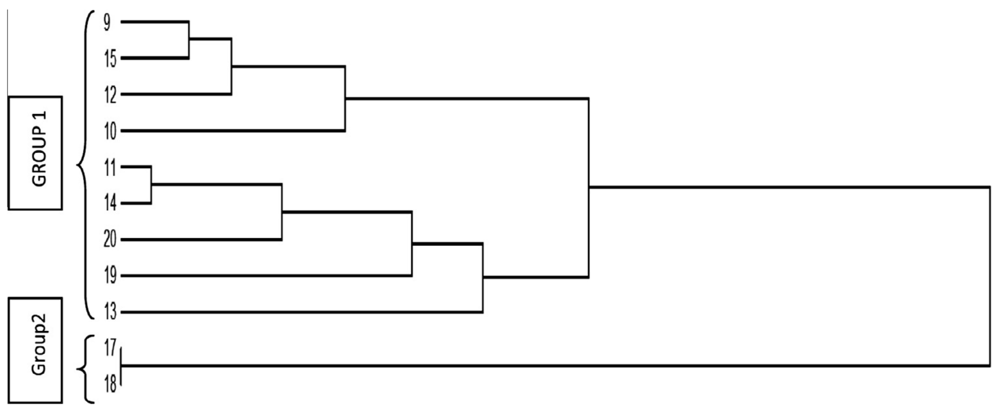

Figure 3 Cluster analysis for waste disposal sites using Ward's method (matrix: Euclidean distance).

The mean value of *K* at control site was 25985.91 ug g^{-1} while it was 4156.67 ug g^{-1} at disposal site (Table 1).

Metal content of soils at both control and waste disposal sites is also shown in Table 1. The mean value of Pb was very high at disposal site. The mean value of Pb was 67.06 ug g^{-1} at control site which was 133.23 ug g^{-1} at disposal site (Table 1). The mean value of Cd was high at control site and was low at disposal site. The mean value of Cd at control site was 11.92 ug g^{-1} while it was 6.17 ug g^{-1} at dumped site (Table 1). A significant difference was observed in the mean values of Cu, Ni, Cr and Zn at both sites. They were found to be low in control sites while they were significantly different and were found higher at waste disposal sites. The mean values of Cu, Ni, Cr and Zn were 9.46 ug g^{-1}, 27.15 ug g^{-1}, 0.85 ug g^{-1}, and 196.99 ug g^{-1} at control site while they were 19.79 ug g^{-1}, 101.92 ug g^{-1}, 3.45 ug g^{-1}, and 632.48 ug g^{-1}at disposal site.

3.2. Clustering at control sampling sites

Two major groups were formed as a result of clustering at control sites. First major group is represented by sites 1, 2, 3, 4, 5, 6, 7, 8, that were located in Sectors H-8 and H-9 (Fig. 2). These were grouped together as they support a similar kind of vegetation pattern. The major species found on these sites were *Acacia modesta, Broussonetia papyrifera, Canabis sativa, Parthenium hysterophorus, Taraxacum officinale, Verbena tenuisecta, and Ziziphus numalaria*. These species were not present in continuous manner rather had a patchy distribution. The abundance of plant species is corelated with soil properties that resulted in grouping of these plant species. Sampling sites consisted of alkaline soil from slightly basic to highly basic with pH range between 7.8 and 9.3. High pH value results in immobilization of heavy nutrients especially in the semi-arid ecosystem favouring plant growth. A similar type of vegetation was observed due to moderate soil salinity as recorded by low concentration of EC that showed the mean value of 0.092 μS/cm and TDS with mean value of 64.16 ppm that varied between 40 ppm and 110 ppm (Table 1). The second group comprised of site No. 21, 22, 23, 24 and 6. Site 20, 21, 22, and 23 were located in sector H-11 while only one site (6) was present in sector H-9/2. This site had been grouped with the rest due to their presence along drain sides which supported similar kind of habitat conditions. Patches of vegetation cover were found along the gullies formed due to rain or runoff water that ultimately ends up in the drainage system. Patchy distribution of vegetation on the slopes near water is mainly due to wind and water erosion (Brady and Niel, 1996). Major plant species that were found on these sites were *Canabis sativa, Chenopodium album, Parthenium hysterophorus, Solanum surrantense, and Taraxacum officinale*. Invasive plant species have the ability to aggressively grow and self reproduce overcoming the environmental barrier. Furthermore, their growth is enhanced in sites with greater water, though capable of occupying dry sites (Malik and Husain, 2006). This is also supported by the present study results where abundance of these plant species had been noticed that showed high concentrations of moisture (ranged between 0.907% and 11.84%) at above mentioned sites.

3.3. Clustering at waste disposal sites

Sampling sites of waste dumping area formed two distinctive groups (Fig 3). Group 1 constituted of site No. 9, 10, 11, 12, 14, 15, 19, 20 which were all located at the dumping site. Major plant species observed at these sites were *Broussonetia papyrifera*, *Delbergia sissoo and Parthenium hysterophorus*. Distinctive physio-chemical properties of polluted soil at the disposal area are one of the important reasons for grouping of these sites. Most of the species recorded in this group were invasive. *Broussonetia papyrifera* is considered as a worst plant invader in Pakistan that thrives along streams and nullahs due to high moisture content in such areas which favours its robust growth (Ali and Malik, 2010). This species also reduces herbaceous and woody species diversity in its nearby vicinity (Khatoon and Ali, 1999). We found stunted growth in most of the plant species like *Canabis sativa, Lantana camara and Parthenium hysterophorus* and they were found distributed over the uneven land in the form of small patches. This was due to open dumping of waste in these areas that has resulted in deterioration of soils of the area which does not support large number of plants. Only 32 plant species were recorded at these sampling sites.

TDS concentration observed at the disposal site was very high that varied between 40 and 450 ppm. High soluble solid concentration decreases the water availability to the plants as increase in salt concentration reduces the osmotic potential resulting in stunted plant growth. The pH value of dumping sites was relatively higher as compared to control sites. Average pH of 8.3–9.1 was observed at waste disposal sites.

The second group consisted of two sites (No. 17 and 18) located at International Islamic University, Islamabad. Although these two sites are not CDA allocated dumping sites but the reason for their grouping within the disposal sites is attributed to their close proximity to disposal area (Fig 3). Physico-chemical properties of soil were found to be similar to the disposal site properties which indicate that perhaps some kind of similar deterioration has taken place in these areas.

4. Discussion

Soil is a crucial component of urban environments and its management is the key to its quality. In the study area the waste disposal site is located near to the residential blocks allocated by the CDA in H-10 Sector. The vegetation status of both sites shows that rather than composition, diversity is suffering due to open dumping of wastes. Large number of vegetation species (44 species) was supported by soils of control sites while less number of species was recorded at dumping site (i.e., 32 species). Relatively high organic matter with an average mean value of 1.54 was found at open dump sites contributing to an increase in pH also. This is mainly due to release of exchangeable cations during mineralization of organic matter (Woomer et al., 1994; Anikwe and Nwobodo, 2002). Soil pH generally has a major contribution in metal bioavailability, toxicity and leaching capability into the surrounding areas (Chimuka et al., 2005). The organic matter content, pH, conductivity, and available heavy metals on open dump sites are greatly affected by the quantity of wastes dumped. Much more attention is needed for solid waste management to reduce the risks from heavy metal pollution.

Heavy metals also occur naturally but rarely at toxic levels (USDA, 2000). Cadmium was found to be low at control sites resulting in reduced primary Cd metal production. However, combined toxic effect of Pb and Cd was seen. The amount of Pb was found above the threshold values as described in the Canadian Council of Ministers of the Environment (CCME, 2001). Pb like the other three elements of Zn, Cu and Cd is generally the metal of great concern as well as being phytotoxic while heavy metals like Ni, Pb, Cu, Zn, and Cr were typical entropic elements (Udom et al., 2003). Usage of toxic metals had produced a significant effect on biomass production and plant growth (Iqbal et al., 2001). There are many factors which control the mobility of heavy metals in soils profile e.g., soil pH, soil texture, type of clay minerals, percentage of organic matter, cation and anion exchange capacity soil drainage and amount of rainfall. Many studies also have examined relationships among elements (major and trace) and other soil properties (clay content, cation exchange capacity, pH, soil texture, carbonates) in non-contaminated soils (Covelo et al., 2007; Long et al., 2011). Heavy metals present in soils consist of serious environmental hazards from the point of view of polluting the soils (Seignez et al., 2008). Some factors including the properties of the metals, soil texture, pH and competing cations in the soil solution that increase their mobility can result in more plant uptake or have dangerous effects on soil.

5. Conclusion

Municipal Solid waste Management services in most of the countries come as a third priority in municipal commitments, after water supply and sanitation. Soils of the study area allocated by the CDA in H-10 Sector of Islamabad city for open waste dumping are located in the residential area and are extensively investigated in terms of physico-chemical properties of soil. However they are under pressure from their own legislation to move away from the current disposal practices of open dumping to sanitary land filling. Such a change is unlikely to occur in the nearest future due to limitations on finance, shortage of technical resources and lack of institutional arrangements. The main environmental problem associated with the disposal sites is the potential risk posed to the soil. Since the waste was disposed directly onto surface of soil, a number of contaminants including heavy metals readily penetrate and eventually they contaminate the soil and affect vegetation abundance of the area.

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