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A PRELIMINARY APPRAISAL OF THE IMPACT OF DUMPING MUNICIPAL SOLID WASTE ON THE SOIL QUALITY IN THE DISTRICT KORANGI, KARACHI CITY

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ABSTRACT

In Karachi, the generation, collection, and disposal of untreated municipal solid waste (MSW) is a matter of great concern as it tends to deteriorate the soil quality of the waste dumping sites, and leachate pollution may contaminate the underground water quality, which is a freshwater resource for citizens. The aim of this study was to evaluate the impact of the dumping of MSW on the physico-chemical characteristics of soil collected from 44 open dumpsites covering the 4 towns of District Korangi, namely Shah Faisal Town, Korangi Town, Landhi Town, and Model Colony. The soil samples were analyzed for physico-chemical and heavy metal parameters. pH, moisture content, organic matter, total organic carbon (TOC), water holding capacity (WHC), SO_4, NO_3, PO_4, Ca, Mg, Na and K were analyzed. High pH values, indicating slightly alkaline pH along with higher concentrations of Na and K in these soil samples showed the level of deterioration of soil quality in response to MSW dumping. Heavy metals of interest include As, Pb, Ni, Cr, Fe and Zn, but their concentrations were below the guideline values. The mean concentrations of heavy metals examined in this study follows the descending pattern: Zn > Fe > Ni > Pb > Cr > As. Although, these heavy metals do not pose any ecological hazard to the soil quality of dumping areas. According to the principal component analysis (PCA) analysis, organic matter, nitrate, Ni, and TOC all play major roles in the first component; the second component is primarily governed by Mg, Ca, Fe, and K; and the third component is influenced by Cr, As, Mg, and Na. The cluster analysis (CA) made two major cluster groups of 44 sampling sites. The sample sites in Group 1 had higher organic matter, TOC, and Ca while the sample sites in Group 2 had greater Na, K, and Cr. This study concluded that the physical and chemical properties of soil are altered due to the dumping of untreated MSW. In addition, heavy metals also accumulate in the soil and leached along with rainwater, thus entering the groundwater aquifers. Proper MSW management and disposal system should be implemented so that the quantity of waste might be reduced, which will also control the possible spread of pollutants in soil and water aquifers.

KEY WORDS: Solid waste, Korangi, heavy metals, soil pollution, waste disposal site

INTRODUCTION

The explosion of the human population, technological advancement, and economic development are the key factors behind the enormous amounts of air pollutants and solid waste generated in developing countries (Raza *et al.*, 2022). When solid waste is dumped on open disposal sites and roadways, the situation deteriorates through contamination of soil, air, water, and land, causing environmental pollution (Raza *et al.,* 2023). Instead, solid waste is one of the major pollutants that is responsible for the deterioration of all the spheres of the earth. In Pakistan, the Municipal Solid Waste (MSW) that comprises daily household, commercial, and institutional wastes that are discarded by people, hence called garbage, is the major reason for environmental pollution (Singh *et al*., 2011). Almost in every city of Pakistan, one can observe heaps of garbage along the roads, streets, highways, near water resources and even in water bodies, especially concerning the freshwater bodies that are the main backbone of Pakistan. Rapidly increasing solid waste generation and its inadequate disposal are responsible for nuisance and ruining our country's aesthetically pleasing tourism spots. Not only the MSW which is non-hazardous but the hospital waste that is hazardous or maybe infectious are mixed when dumped on the same disposal sites. In this manner, the whole of the solid waste becomes hazardous and poses threats to the environment, human health, animal life and plant diversity (Pattnaik and Reddy, 2009). The low literacy rate and lack of finance are responsible for all of this. Solid waste should not be considered as a waste instead it is a potential economic asset.

Karachi is the metropolitan city and the amount of solid waste generation is higher in the areas with people having high incomes as compared to people having middle and low incomes. Open dumping of solid waste is a common practice and due to the financial issues and lack of trained manpower. Soil and underground water resources are threatened by this act of the dwellers of the urban areas (Ali *et al*., 2014). Smith *et al*., (1996) stated that the productivity of soil, human health and animals are adversely affected by the soil that is contaminated with heavy metals. Voutsa *et al*. (1996) discovered that various metals are carried by solid waste and therefore transferred to plants in different ways. The soil contaminants have the tendency to either reach the water that is held by soil or leached to the underground water aquifers. Some heavy metals alter the soil chemistry and affect the plants and living organisms that are inhabited on that soil (Shaylor *et al*., 2009). The soil characteristics are in direct relation to the vegetation diversity (Ali *et al*., 2014). According to Papageorgiou (2006), the physico-chemical characteristics of soil are altered by the pollutants present in the solid waste hence resulting in insufficient production of vegetation. Initially pollutants inhibit the normal metabolism of plants and consequently growth retardation can be observed (Ahmed *et al*., 1986). During the rainfall season, the rainwater comes in contact with the solid waste. As a result, leachate is formed which may contain large amount of heavy metals, inorganic salts and organic matter that percolates to the soil strata and underground water aquifers (Renou *et al*., 2008; Aziz *et al*., 2010; Aziz and Maulood, 2015; Mojiri *et al*., 2016).

Khan *et al*., (2018) found that Karachi produces 14,712 tonnes per day of MSW. The city is facing a serious problem of solid waste disposal, and the point sources of soil and underground aquifer pollution are undesigned solid waste disposal sites and landfill sites (Sharma *et al*., 2018). The aim of the study is to assess the impact of open dumping of municipal solid waste (MSW) on the physico-chemical characteristics of soil collected from different open dumpsites. The study will provide the information to municipal authorities to develop immediate mitigation measures at open dumping sites in order to control the possible spread of pollutants in soil and water aquifers.

STUDY METHODOLOGY

Study Area

The District Korangi is one of the seven administrative districts of Karachi, comprising four towns: Korangi Town, Shah Faisal Town, Landhi Town, and Model Colony, with a population of 2,577,556 at the time of the 2017 census. One of Karachi's primary industrial areas, Korangi Industrial Area (KIA), is situated in this district and spans more than 10,000 acres. It is home to over 5,000 commercial, industrial, and service industries, including the nation's two largest oil refineries. Every day, KIA contributes roughly Rs. 600 million to the national coffers. Approximately 1.5 million workers, both skilled and unskilled, travel to this industrial sector every day from various sections of the city.

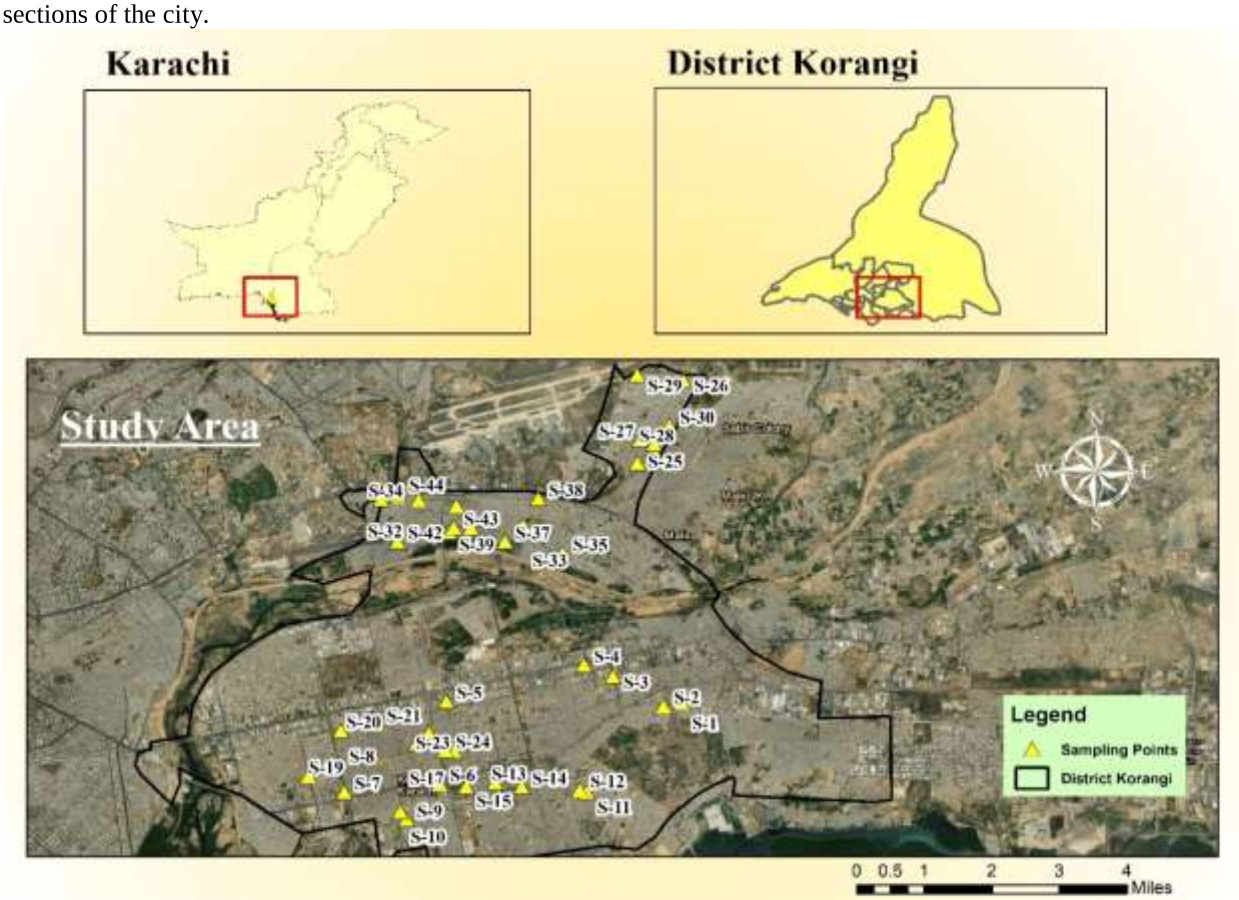

Fig 1. Map of sampling sites.

Soil Sampling and Analysis

A total of 44 open MSW disposal sites (Fig. 1) situated in these four towns were selected, and 44 random soil samples were taken from 0 to 3 cm in depth for physical, chemical, and heavy metal analysis. The soil samples were homogenised, air dried, powdered and sieved with a 2mm mesh before being stored in polythene bags for physicochemical evaluation. The treated soil samples were subjected to conventional methods previously described (Rayment and Higginson 1992; Jilani 2007) for the analysis.

Physico-chemical Analysis

Sample pH was determined using HANNA portable pH meter Model # HI98107. Moisture content, Organic matter and Water Holding capacity (WHC) of the soil samples were determined gravimetrically APHA (2005). Walkely and Black, (1934) was used to estimate TOC of the samples. Sulphate, nitrate and phosphate in the soil samples were estimated by using Merck Kits with Spectroquant NOVA-60.

Metal Analysis

A microwave digester with 1200 Watts of electrical power was used in the lab to perform soil acid digestion in a closed vessel (US-EPA 1996). For this method, 0.5 g of soil sample must be digested in 60 minutes in 9 ml of nitric acid and 3 ml of hydrofluoric acid. When the digestion mixture had cooled, 5 ml of 1% HNO was added, filtered through a membrane with a pore size of 0.45 µm and marked up to 25 ml with deionized water. The metals (As, Pb, Ca, Mg, Na, K, Ni, Cr, Fe and Zn) in the soil samples were detected using Merck Spectroquant NOVA-60.

Statistical Analysis

A statistical programme (STATISTICA version 10, Tulsa, Oklahoma) was used for data analysis collected by physico-chemical and metal analysis in order to determine descriptive statistics for each variable. The software stated above was used to carry out principal component analysis (PCA) and cluster analysis. Cluster analysis made use of Ward's approach.

RESULTS AND DISCUSSION

Soil Analysis

Table 1 illustrate the comparative study of the physical, chemical properties and heavy metals in the MSW soils of the present study with previous studies conducted in the other regions. Soil samples collected from 44 different MSW open dumpsites showed high pH value of 8.1 with a range of 6.4-9.9, indicating the slightly alkaline nature of soil as it exceeds the guideline value of 6.0-7.5 (FAO. 2021). According to Goswami and Sarma (2008), the increase in soil pH is due to the alkaline nature of the waste materials and the presence of K, Na, CO_3, HCO_3 and some alkaline materials in the debris which are the key factors for increased alkalinity. The samples have a mean value of moisture content (M.C) equal to 18.411% with a minimum of 8.371% to a maximum of 40.826%. The leaching capability of soil is enhanced if the moisture content is high (Jilani and Rashid, 2020). The soil samples collected from the open dumping sites consisted of 7.317% organic matter within a range of 3.954%-12.796%. The organic matter content in the waste soil accounts for the degradation and composting process of the organic waste as well as the dead plants and animals (Dangi *et al*., 2013). Mineralization of organic matter release exchangeable cations hence, contributing to an increase in organic matter and pH of the soil (Woomer *et al*., 1994; Anikwe and Nwobodo, 2002). By analyzing the Total Organic Carbon (TOC), the mean value is calculated to be 8.200% having the minimum of 3.109% to maximum of 12.347%. The soil samples have a mean Water Holding Capacity (WHC) of 13.331% ranging between 6.033%-24.862%. The mean concentration of SO_4 in the soils of open disposal sites of District Korangi is examined to be 264.089 ppm within a span of 182.996 ppm to 356.000 ppm. The mean NO_3 and PO_4 concentrations are evaluated as 9.402 ppm (range: 3.314 ppm-15.950 ppm) and 6.279 ppm (range: 1.979 ppm-8.916 ppm) respectively. The analyzed soil nutrients are Ca, Mg, Na and K with mean concentrations of 23.555 ppm, 15.772 ppm, 37.794 ppm and 13.493 ppm respectively. According to USDA (2007), the Na levels in the soil should be in between 0.3-0.7 mg/Kg. In this study, the Na levels fall within a radius of 23.934 ppm to 55.981 ppm which failed to meet the guidelines. FAO (2004) set the permissible limit of K in soils to be 0-2 mg/L but the range analyzed in this research study is between 8.865 ppm to 19.536 ppm thus, crossing the guideline value hence, representing the deteriorated soil quality proving that the municipal solid waste (MSW) dumping on open disposal sites have an exacerbating impact on the physical and chemical properties of soil. Goswami and Sarma (2008) observed that soils treated with MSW have increased K and Na contents as these elements leached from the waste because they are readily solubilized during the decomposition of solid waste.

Table 1. Comparative Study of the Physical, Chemical Properties and Heavy Metals in the MSW Soils of Present Study with Previous Studies.

	District Korangi, Karachi, Pakistan	Guwahati, India	Islamabad, Pakistan	Karachi, Pakistan	Chennai, India	Ain-El-Hammam, Algeria	Pilsen, Czech Republic	Ahfir-Saidia, Morocco	Malagrotta, Italy
pH	6.371-9.801	8.3-9.4	8.3-9.1	7.60-8.40	6.30-7.00	7.4	-	-	-
M.C (%)	8.371-40.826	-	0.70-11.48	3.57-25.50	8.42-9.64	-	-	-	-
Organic matter (%)	3.954-12.796	-	0.91-2.09	Volatile Organic Matter (%) 4.38-24.50	-	1.7	-	-	-
TOC (%)	3.109-12.347	Organic carbon (g/Kg) 13.8-18.5	-	Carbon content (%) 1.80-13.50	-	-	-	-	-
WHC (%)	6.033-24.862	-	-	-	-	-	-	-	-
SO_4 (ppm)	182.996-356.000	-	-	-	-	-	-	-	-
NO_3 (ppm)	3.314-15.950	-	-	-	-	-	-	-	-
PO_4 (ppm)	1.979-8.916	-	-	-	-	-	-	-	-
Ca (ppm)	10.957-38.576	-	758.45–41738.36 µg/g	-	-	-	-	-	-
Mg (ppm)	9.043-29.687	-	3565.8–77680.1µg/g	-	-	-	-	-	-
Na (ppm)	23.934-55.981	Water soluble 64-91	178.97–368.3 µg/g	-	-	-	-	-	-
K (ppm)	8.865-19.536	Water soluble 57-83	4156.6–28253.4 µg/g	-	-	-	-	-	-
As (ppm)	0.336-1.442	-	-	-	-	-	-	-	-
Pb (ppm)	3.525-37.108	-	38.65–236 µg/g	20.3-116	7.43-51.52	7.3	5.4	61.8	53.6
Ni (ppm)	3.796-42.237	-	10.37–223.12 µg/g	34.8-49.5	4.68-9.52	20.0	44.1	47.2	10.3
Cr (ppm)	0.447-4.229	-	0–7.97 µg/g	41.2-75.4	6.50-44.28	76.0	86.7	51.5	16.8
Fe (ppm)	6.379-37.919	-	-	-	-	-	-	-	-
Zn (ppm)	7.897-36.713	-	93.91–1607.34 µg/g	142.8-201.4	-	43.0	42.0	68.1	25.6
Reference	Present Study	Goswami and Sarma (2008)	Ali *et al.*, 2014	Jilani and Rashid, 2020	Raman and Narayanan (2008)	Mouhoun-Chouaki *et al.*, 2019	Adamcova *et al.*, 2016	Ogbonna, *et al.*, (2009)	Barbieri *et al.*, 2014

As, Pb, Ni, Cr, Fe and Zn are the heavy metals of interest which are analyzed and their mean, minimum and maximum concentration values lie under the WHO/FAO (2001) guidelines clearly proving that the solid waste dumping, pose no impact on the soil quality of the dumping sites in terms of heavy metals. Udom *et al*., (2003) reported lead (Pb) is a phytotoxic heavy metal. Heavy metals, if exceeding the guideline values become the reason of soil pollution and thus create serious environmental hazards (Seignez *et al*., 2008). The pH of soil contributes in the bioavailability, leaching capability and toxicity of the heavy metals (Obiyo *et al*., 2005). The dumping of solid waste on open disposal sites, results in the contamination of groundwater as the leachate flow through the soil horizons carrying all the pollutants therefore, threatening the public health and all life forms (Usman *et al*., 2017). The mean concentrations (ppm) of heavy metals analyzed in this research follows the descending pattern: Zn>Fe>Ni>Pb>Cr>As. Glaub and Golueke (1989) reported municipal solid waste provide several advantages including reduced soil erosion, fertilizer requirements, increasing water retention and soil fertility. According to Hortenstine and Rothwell (1969) applications of municipal compost increase the water holding capacity, conductivity, soluble salts, Ca, Mg, K and P in the soil.

Possible sources of contamination

According to Goswami and Sarma (2008), soil pH may decrease as a result of mechanical composition of waste, nature of soil and the leaching of solid waste. Biodegradable waste contains organic matter which is sourced from garden waste, food waste, browns (fallen leaves) and cow dung. On the other hand, potassium levels in the waste dumped soils fluctuate because of the inorganic and organic materials in the solid waste which include components of vegetable, ash, metal, rubber etc. The sodium levels in the waste are a mutual contribution of inorganic salts and organic matter along with ash particles.

Jilani and Rashid (2020) reported the reason behind the presence of heavy metals in the waste dumped soil. According to them, the anthropogenic activities such as heavy traffic near waste dumping sites and the disposal of commercial, institutional and municipal solid waste are in direct proportion to the high concentrations of chromium and lead in such soils. Whereas, emissions from vehicles and discarding all types of solid waste especially roofing material such as zinc-coated sheets and galvanized remnants accounts for zinc and copper in the soil samples of disposal sites.

Ali *et al*. (2014) stated that the pH, organic matter content, conductivity and the heavy metals availability in the soils of open waste dumpsites depend upon the quantity of solid waste dumped. They observed that high organic matter and alkaline pH in the soil tends to accumulate higher concentrations of heavy metals. High Fe concentrations in a soil, could be partly due to the geomorphology of that area, iron-rich rocks' weathering and leaching (Afolagboye *et al*., 2020).

Statistical Analysis

PCA

Using normalized data, PCA was used to investigate the effect of physico-chemical and metal parameters on the soil quality in the district Korangi. The first three fundamental components are shown in Table 2 together with their eigenvalues, variances, and cumulative percentages. The Fig. 2 also provides a three-dimensional (3D) ordination for PCA analysis of physico-chemical and metals characteristics in the MSW soil samples and separating out the sites having common characteristics.

Table 2. Results of PCA of physico-chemical and metal analysis of MSW soil samples collected from District Korangi, Karachi.

Component	Eigenvalue	Percentage variance	Cumulative percentage variance	First 4 eigenvector coefficients	Associated variables
1	5.174	28.745	28.745	0.871630	OM
				0.795540	Nitrate
				-0.765520	Ni
				0.753129	TOC
2	2.061	11.453	40.198	0.632873	Mg
				0.536069	Ca
				-0.524186	Fe
				-0.464325	K
3	1.639	9.11	49.306	-0.680885	Cr
				-0.533562	As
				-0.522157	Mg
				-0.401602	Na

According to Table 2, the first, second, and third main components together accounted for 49.306 % of the total variance and explained 28.745, 11.453, and 9.11 % of it. Organic matter, Nitrate, Ni and TOC all play major roles in the first component while the second component is primarily governed by Mg, Ca, Fe and K. The third component is mostly influenced Cr, As, Mg and Na.

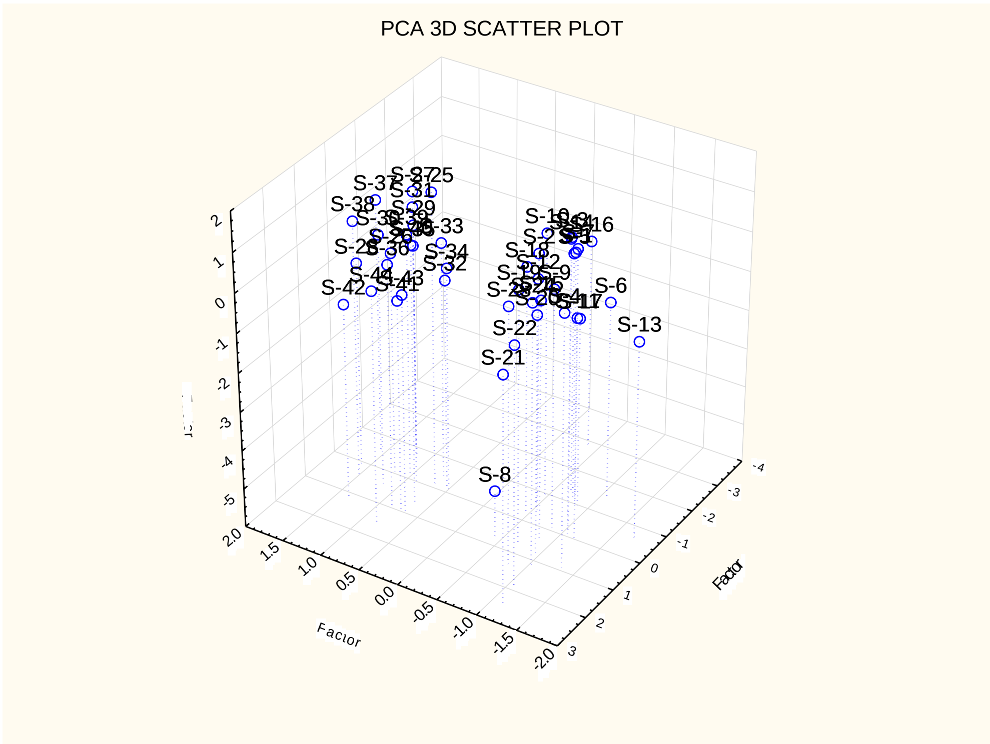

Fig. 2. Three-dimensional (3D) ordination for PCA analysis of physico-chemical and metals characteristics of soil samples of MSW dumping sites of District Korangi, Karachi.

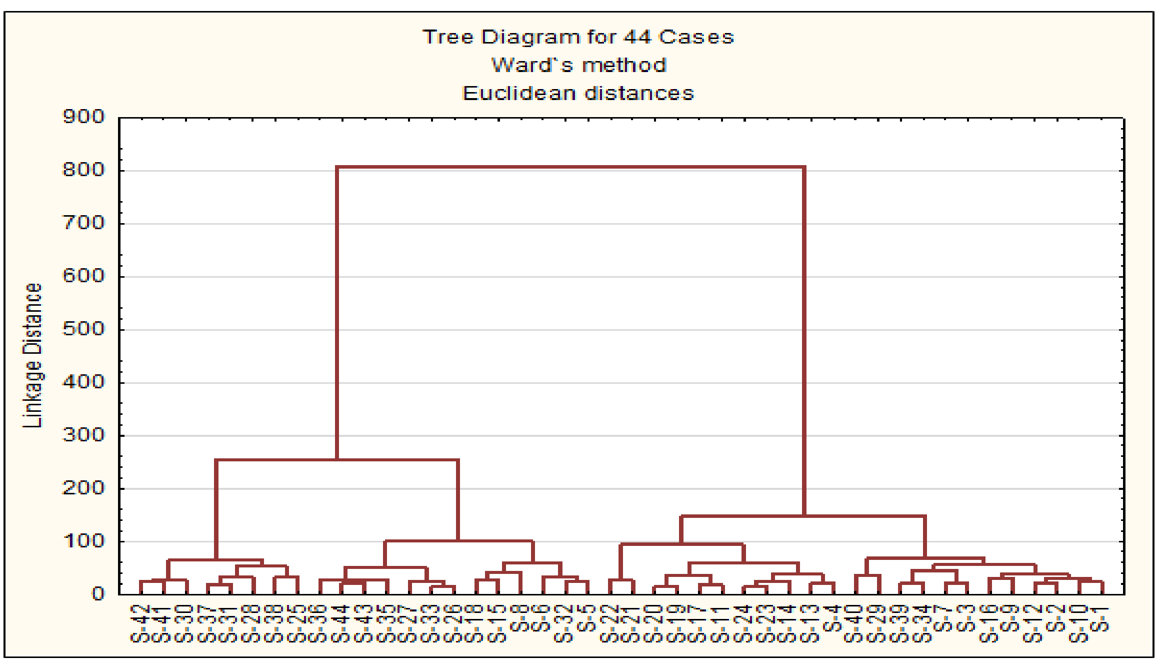

Fig. 3. Dendrogram grouping sampling sites on the basis of physicochemical and heavy metal data analysis.

Cluster Analysis

Cluster analysis and the Ward's technique-created dendrogram revealed that the sampling locations could be split into two major groups (Fig. 3) using physicochemical and metal data. 21 samples from Group 1 demonstrate that all sampling sites have similar features. Group 1 members are characterized by medium to high O.M, TOC, Ca, As but low to medium pH, SO4, NO3, Ni and Cr with moderate Pb and Zn. In contrast, Group 2 consists of 23 samples and further divided into two multiple sub-groups (2a and 2b). Group 2a consists of 11 samples while Group 2b consist of 12 samples. Group 2a sites are characterized by low to medium OM, TOC, As, Pb, Ni and Cr while pH and WHC were medium to high. Moreover, SO4, NO3, PO4, Ca, Mg, Na and K were relatively high in Group 2a. Group 2b sites possess high Na, K, Cr and Zn but low to medium M.C, SO4, and Fe while medium to high pH, O.M, TOC, WHC, NO3, PO4, Ca, Mg, As, Pb and Ni.

CONCLUSIONS

The results showed that the informal waste dumping sites of the residential areas of Karachi city have a significant change in the physical and chemical nature of soil. pH, Na and K values of the soil samples were visibly high as compared to the threshold values. The study concludes that the physical and chemical properties of soil are altered due to the dumping of untreated MSW. In addition to it, the heavy metals also accumulate in the soil and leached along with rainwater thus, entering the groundwater aquifers. This calls for more future research on the physico-chemical characteristics of the groundwater in the vicinity of these disposal sites. In order to enable the development of prompt mitigation, this will give the local authorities a comprehensive profile of the contaminants leaking from the MSW. To further limit the amount of garbage, management of MSW collection, treatment, and disposal should be strongly encouraged. It is imperative that individuals practice the practices of reusing, recycling, and recovering garbage in addition to the division of biodegradable and non-biodegradable waste.

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