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Effect of Open Dump on Geotechnical Properties and Heavy Metal Concentrations of Soil in North of Hilla City, Babylon Governorate, Iraq

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ABSTRACT

Random and unscientific disposal of municipal waste is an important factor affecting the geotechnical characteristics and concentrations of heavy metals in the soil. Unconfined compressive strength, Atterberg limit, and maximum dry density tests were included. These tests were designed to determine the effects of open waste dumps on geotechnical properties and the concentration of heavy metals in the underlying open dump soil. Soil samples collected from the landfill at Al-Sayyahia Village, Babylon Governorate, showed changes in the rates of geotechnical properties evaluation, as the value of the confined compressive strength decreased by high rates from 54 to 22 kN/m^2. As well, when comparing the maximum values of dry density of samples from the control site, neighboring the landfill, the average value decreased from 1.91 to 1.74 gm/cm^3. Chemical tests revealed that the pH and organic matter percentages in the open dump soil samples were significantly higher than in the control site. These percentages ranged from 9.67% and 2.542% to 7.4% and 0.215%, respectively. In addition, the average value of electrical conductivity was 5.6 mS/cm in the open dump soil, whereas in the control site was 3.6 mS/cm. Iron, lead, Copper, Nickel, Chrome, Zinc, Cadmium, and Arsenic have average concentrations of 4.64%, 14.02, 44.86, 236.36, 278.36, 95.26, 2.034, and 13.84 ppm, respectively. They are higher at open landfill sites than in control site samples.

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INTRODUCTION

The significant increase in the world population associated with industrial activities and urbanization has generated large amounts of domestic, municipal, and industrial waste (Lagerkvist and Dahlen, 2019). The open landfill is an old and unsatisfactory method of solid waste disposal. It is still widely used in many countries around the world, particularly in developing countries, because it requires little effort and costs little. Open dumps are generally ugly, unhygienic, and smelly some toxic gases are emitted from landfills (Montgomery, 2011). Besides, they attract mice, insects, and other pests, as well as being a fire hazard. As surface water seeps through the garbage can, it dissolves or leaches harmful chemicals that are carried off-site by runoff or percolation into the groundwater. Groundwater properties change in these areas, and the concentration of polluting elements increases as a result of human use and mismanagement of waste, which will be harmful to human health and the environment in the future (Nasrabadi and Maedeh, 2014; Fazeli et al., 2019). The pollution of ground and surface waters by heavy metals such as arsenic signifies a crucial environmental problem owing to its lethal impacts, non-biodegradability, and accumulation in the food chain (Saravanakumar et al., 2020). Because the dissolved heavy metal ions do not naturally disintegrate, they have a

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greater tendency to bioaccumulate and create harmful health conditions (Oladipo et al., 2019). In addition, the decomposition of organic waste by microorganisms and the climate (Kebede et al., 2018). The problem is that water leaches from the surface and accumulates in the landfill, and leachate may eventually leak and pollute the surrounding environment (Figure 1).

Solid waste soils may be rich in organic matter, but a substantial increase in some elements (Fe, Zn, Cu, Ni, As, Cd, and Mn) present in the waste is likely over time. If these elements are higher than the required quantity needed in the soil, they may be poisonous to the ecosystem. So, the potential negative impacts of solid waste on soil must be considered (Dominguez et al., 2019). This requires a specific management technique, otherwise; it would result in long-term degradation of the environment. Therefore, the evaluation of heavy metal contamination is an imperative component of risk assessment at waste dump sites (Pattnaik and Reddy, 2010).

Among the literature reviews that contributed to supporting this research was Ali et al. (2014), who observed an obvious change in the soil characteristics of some open landfill sites. These soil characteristics contained high values of total dissolved solids, pH, and electrical conductivity (Ec) compared with those surrounding open dump sites. Breza-Boruta et al. (2016) pointed out that the accumulated waste in the landfill leads to the depletion of organic matter in the soil, which inhibits the growth of microorganisms. Chabuk et al. (2017) investigated the most suitable design of landfills for municipal solid waste. Information from the Geographic Information System (GIS) and soil investigations concluded that the most suitable designs for the landfill dump in the Babylon Governorate are those above the surface of the earth due to the nature of the soil in the governorate. Indorial et al. (2017) found that the nature and quality of soil structure are greatly influenced by the quantity and quality of organic matter in the soil.

The study was conducted within the open dump site near Hilla City, located in Al-Sayyahia Village, Babylon Governorate, which is located 100 km south of Baghdad. The open landfill area is approximately 25 acres. The dump is surrounded by drainage rivers on three sides. Generally, the climate of Babylon Governorate is characterized by different seasons: hot, dry

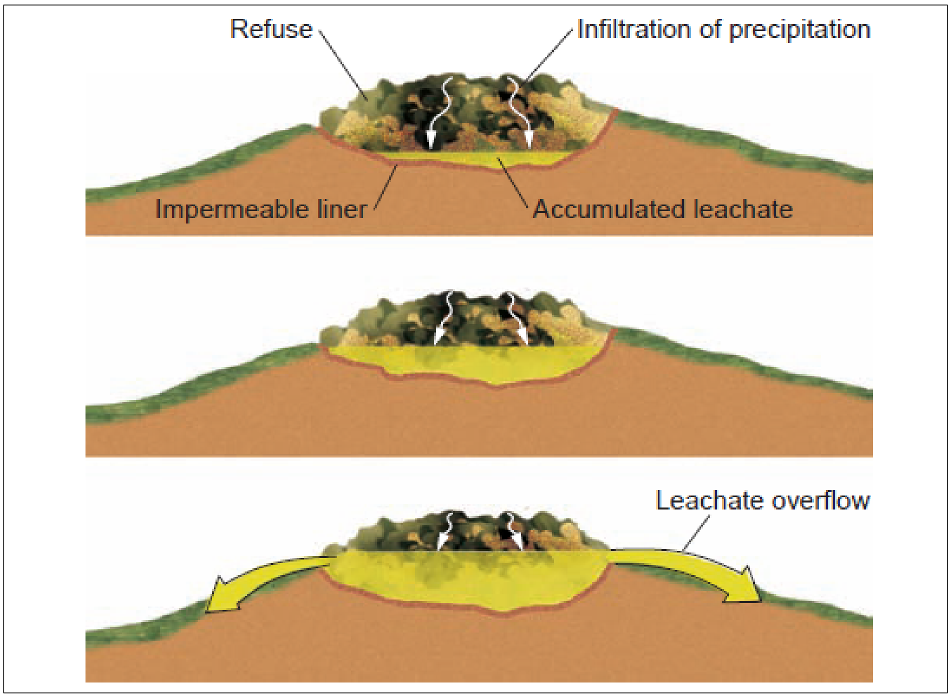

Fig. 1. Accumulation of infiltrated leachate above impermeable liner in an unmonitored landfill. Overflow may not occur for months or years (Montgomery, 2011)

summers and cold, rainy winters, and the water table level is mostly close to the surface of the ground. Hilla soil is characterized by an alluvial sandy loam. This means high filtration of liquids from the surface of the ground. This helps to make the soil of the open landfill site more affected and polluted than the soil surrounding the open dump site. The most dangerous bioavailable contaminants might be cadmium, in addition to arsenic and lead, which were also mentioned. Damps act like ticking time bombs and can be seen as sources of pollution (Karbassi et al., 2016; Jonasi et al., 2017).

The study area is part of the Mesopotamian plain from a geological point of view, located in the unstable shelf according to the tectonic division of Iraq (Jassim and Goff, 2006). The study area geologically, consists of modern deposits from the Pleistocene and Holocene. Depression-filled sediment accumulates as a result of floods and generally consists of thin layers of fine sand and silty clay through which the river passes (Al-Rubaiee and Al-Owaidi, 2022). The swampy sediments of the Tigris and Euphrates rivers filled the Mesopotamian plain, including the study area (Al-Rubaiee and Al-Owaidi, 2022) (Figure 2).

The purpose is to study the effect of the open dump near Hilla City on the geotechnical and chemical properties and heavy metal concentrations in the subsurface soil of open landfill.

MATERIAL AND METHODS

The study started during the major dry and hot season (July 2022) at Al-Sayyahia municipal waste dump (Figure 2). Five sampling sites were located and selected radially from the landfill and perimeter, and their coordinates were identified by GIS (Table 1; Figure 2). The garbage was removed by hydraulic excavators at each site to reach the landfill soil floor (Figure 3). The excavation borehole was drilled to a depth of 50 cm beneath the ground's surface.

Then, four kilograms of soil samples were collected from each drill hole. Before further analysis, these samples were stored in polyethylene plastic bags that were numbered and tightly sealed. As for the control sample (sixth sample), it was taken by hand using an auger at a distance of 100 m from the perimeter of the dump and a depth of 50 cm beneath the surface of the earth.

The moisture content (MC) was examined according to the methods approved by the American Society for Testing and Materials (ASTM D-2216, 2005). The process includes taking a specific wet weight of soil, placing it in a container of known weight, then putting it in an oven at a temperature of 110± 5 °C for 24 hours, then weighing the sample. Dry with the container after extracting it from the oven (with a sensitive scale) and the moisture content is calculated by equation.

$$MC\% = \frac{W2 - W3}{W3 - W1}$$

Where: W1 = Weight of tin (g), W2 = Weight of moist soil + tin (g), W3 = Weight of dried soil + tin (g)

Atterberg limits (liquid limit, plastic limit, and plasticity index) were determined according to the methods approved by the American Society for Testing and Materials ASTM D-854, 2010. It is placed in the Gasagrandi device, repeated several times, the moisture content is calculated for several tries, and 25 strokes are applied to the flow curve to extract the value of the liquidity limit of the soil. As for the plasticity limit, it is calculated by rotating a thread of clay with a diameter of 3.25 mm until cracks appear, and the water content is calculated for it. As for the plasticity index, it is calculated from the difference between the liquidity limit and the plasticity limit using the following equation:

$$Plasticity\ Index\ P.I = Liquid\ Limit\ L.L - Plastic\ Limit\ P.L$$

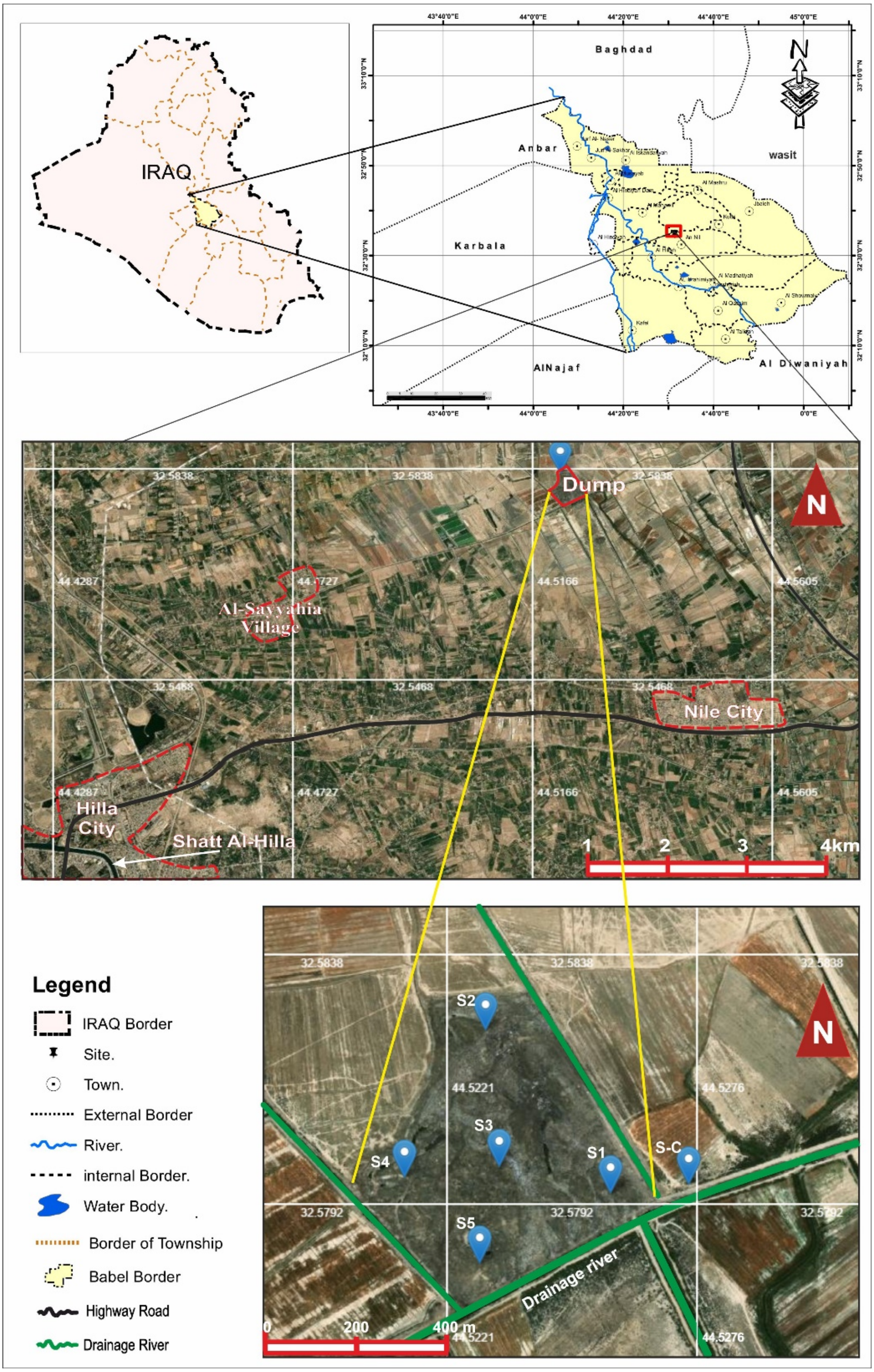

Fig. 2. The map of study area in Babylon Governorate

Table 1. Coordinates of sampling site

Sample No.	Latitude	Longitude
S-control	32.5796	44.5273
S-1	32.5793	44.5257
S-2	32.5825	44.5233
S-3	32.5796	44.5212
S-4	32.5779	44.5228
S-5	32.5802	44.5233

Fig. 3. Open dump sites and the method of taking samples

This test was carried out for natural soils using the method followed in the American Society for Testing and Materials (ASTM D-854, 2010) standard. The test was carried out using a glass bottle called the Pycnometer, by taking the weight of dry soil not exceeding 100 gm and placing it in the Pycnometer, and continue with the work steps until we calculate the specific gravity (Gs).

The maximum dry density and optimum moisture content for all samples used in the research were examined using the method adopted by the American Society for Testing and Materials. (ASTM D-698, 2012) by using the cylinder (102×117 mm) with the modified compaction energy to obtain the compaction curve. The tests shall be conducted on cylindrical samples with a diameter of not less than 33 mm and the length of the sample ranging from one and a half to three times the diameter of the sample, then it is placed in the unconfined compressive strength testing device, and the examination is carried out according to the standard specification numbered (ASTM D2166-82, 1986). Record the average of three samples used for each value of the unconfined compressive strength, use the unconfined compressive strength test device with a load rate of = 1mm/min for all samples.

The geotechnical tests were performed in the laboratories of the Department of Applied Geology/ College of Science/ Babylon University, as well as the laboratories of the National Centre of Construction Laboratories, in Babylon. The analysis of heavy metal concentrations was carried out by XRF testing using the following method: Six soil samples were prepared by grinding and pressing each sample into a disc shape. The samples were then analyzed by using the SPECTRO-XPOS instrument in the XRF laboratory of the Department of Geology/ University of Baghdad. The results of the laboratory tests are presented in Table 2.

Table 2. Experimenter tests and specifications carried out on open dump site samples

	Type of Test		Tested Samples	Specifications
Geotechnical tests	Moisture content		6	ASTM D-2216, 2005
	Atterberg limits		6	ASTM D-854, 2010
	Specific gravity		6	ASTM D-854, 2010
	Grain size analysis		6	ASTM D-422, 2007
	Classification of soils		6	ASTM D-2487, 2011
	Unconfined compressive strength		6	ASTM D2166-82, 1986
	Maximum dry density and optimum moisture content		6	ASTM D-698, 2012
Chemical tests	pH Tests		6	BS 1377:1975
	Organic matter	%	6	
	Gypsum		6	
	Sulphate		6	
	Ec		6	
Heavy metal testing	Fe, Pb, Cu, Ni, Cr, Zn, Cd, As. Concentration tests		6	Taylor and McLennan (1985)

Table 3. Physical and engineering properties of the soil samples

Geotechnical properties			Soil samples						
			S-1	S-2	S-3	S-4	S-5	AV.	S-control
Moisture content		%	30	25	23	26	25	25.8	19
Atterberg limits	Liquid limits		46	45	40	47	44	44	32
	Plastic limits		22	20	18	23	18	20	15
	Plasticity index		24	25	22	24	26	24	17
Specific gravity			2.71	2.7	2.67	2.67	2.7	2.69	2.75
Grain size	Clay	%	62	58	39	40	59	52	48
	Silt		29	26	38	42	27	32	28
	Sand		9	16	23	18	14	16	24
Classification of soils			CL	CL	CL	CL	CL	CL	CL
Unconfined compressive strength		kN/m^2	21	18	20	30	19	22	54
Maximum dry density		gm/cm^3	1.72	1.74	1.77	1.76	1.74	1.74	1.91
Optimum moisture content		%	21	20	15	16	21	19	14

RESULTS AND DISCUSSION

The average values of soil physical and engineering properties of soil at the six location sites in and near the waste dump are presented in Table 3.

Dumpsite soil had the highest moisture content, ranging from 23 to 30%, while control site soil had a moisture content of 19%. significant increase in the liquid limit and the plasticity index within the Atterberg limits (Figure 4).

This is due to the increase in the proportions of clay and organic matter in the selected sites, or the excess spots in the PI of the samples may have been caused by the decrease in the effective porosity due to the shading effect of pore areas resulting from the increasing size and amount of microorganisms in the leachate. As to the specific gravity of the soil, a decrease was

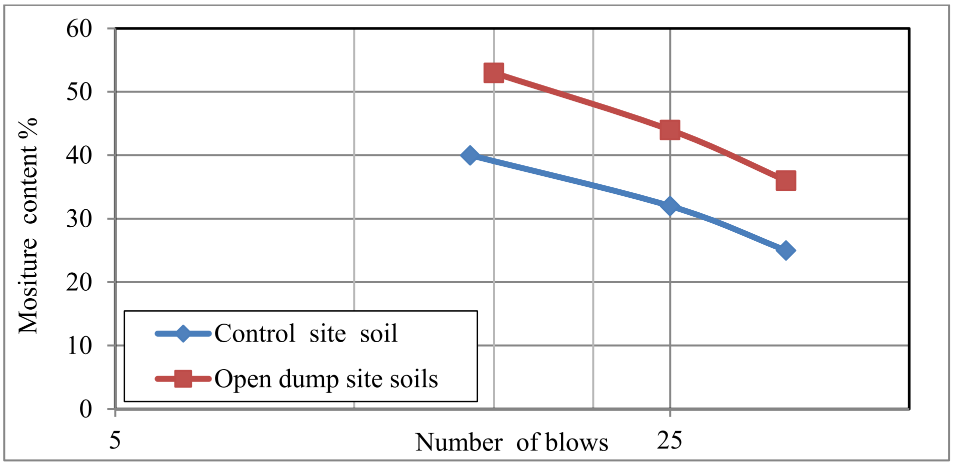

Fig. 4. Liquid limit gained from open dump site soils and control site soil

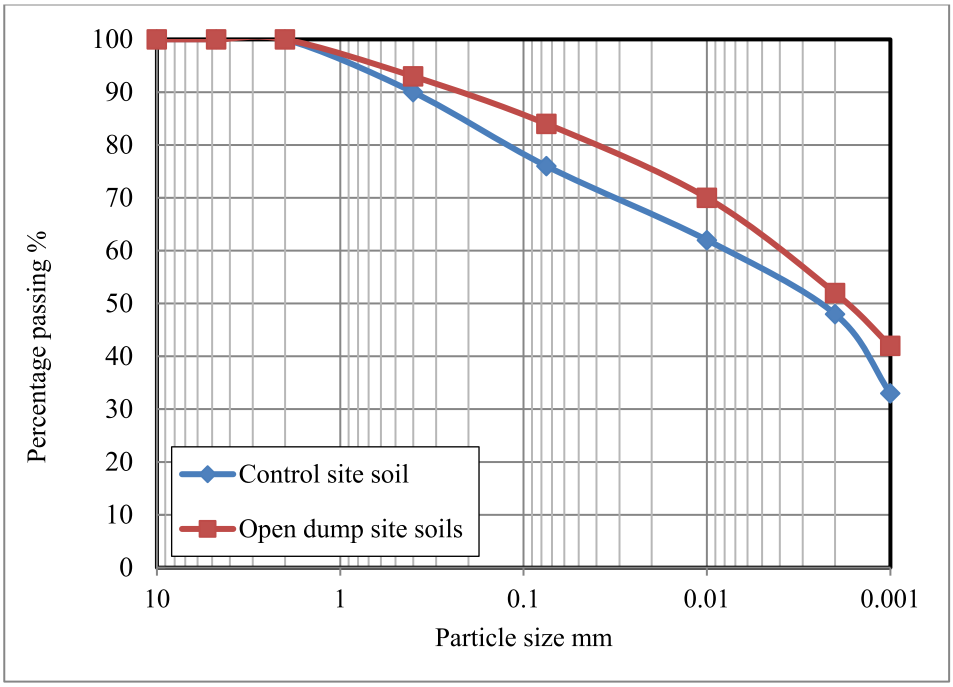

Fig. 5. Grain size distribution gained from open dump site soils and control site soil

noted in the value of the specific gravity of the open landfill soil compared to the control site. As a result, the density of open landfill soil has decreased.

Based on the grain size analysis, clay had the highest proportion value, ranging from 39 to 62%. In contrast, silt had values between 26 and 42%, whereas sand had the lowest value, ranging from 9 to 24%. There were no significant differences in the percentages of clay, silt, and sand among the six locations (Figure 5). This indicates that waste did not affect soil classification. However, it may affect the structure of the soil through its stiffness due to the appearance of organic matter from the precipitation of waste (Indorial et al., 2017).

Soil samples from the dump site were generally sandy silty clay, and they were classified (CL) under the unified soil classification system. The dump soils had the highest dry density values of 1.72 to 1.76 g/cm^3, followed by the controlled site soils at 1.91 g/cm^3. The average

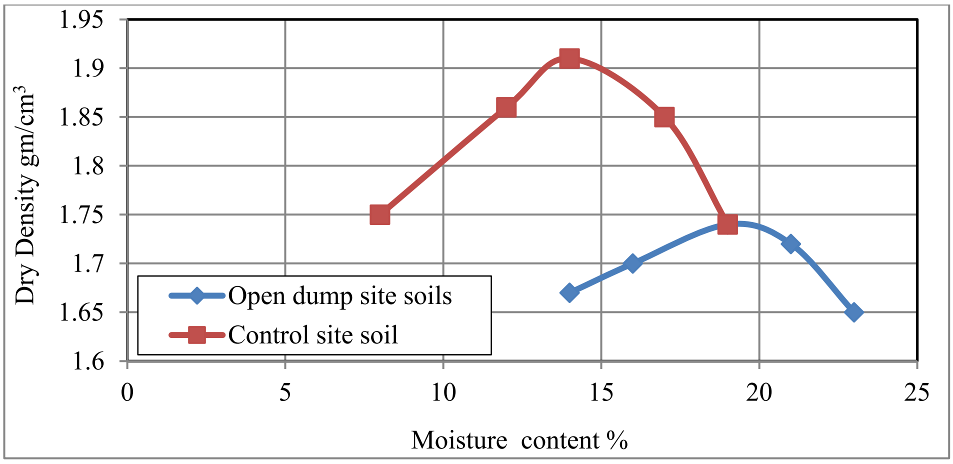

Fig. 6. Density –moisture relationships gained from open dump site soils and control site soil

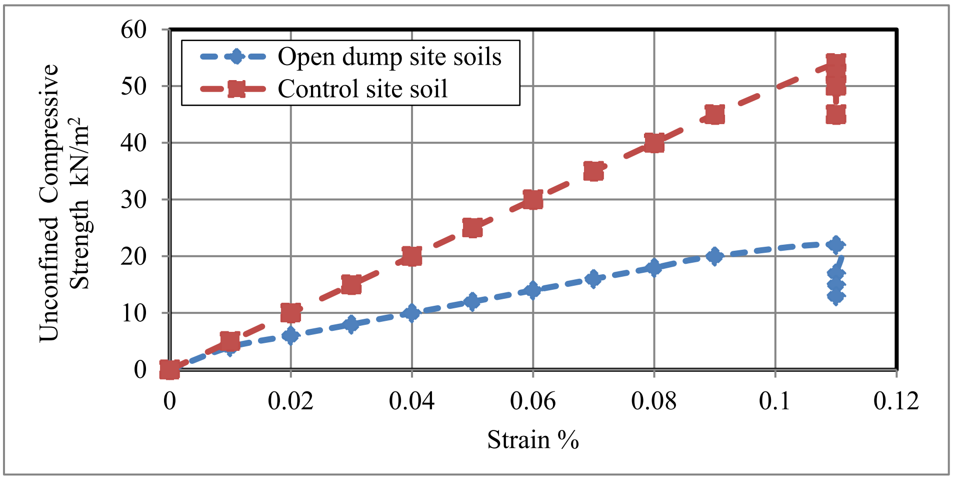

Fig. 7. Unconfined compressive strength obtained from open dump soils and control site soil

optimum moisture content value in the dumpsite soils was 19%. It was observed that the maximum dry density of the soil decreased at the dump site while increasing around the dump site (S-controlled) (Figure 6).

As for the optimum moisture content, it increased in the open landfill soil due to the increase in the concentration of alkalis. The unconfined compressive strength values of the soils from the dumpsite had the lowest values, ranging from 18 to 30 kN/m^2. However, the unconfined compressive strength values were high at the site outside the open landfill, the control point, equal to 54 kN/m^2 (Figure 7).

Significant differences were observed among the sampling locations related to moisture content, maximum dry density, and unconfined compressive strength. These can be related to differences in soil organic matter content that increase the pore area and cause the soil to pile together (Brevik, 2014).

The effect of open dump on geochemical properties must be studied. Analysis of geochemical properties such as sulfate, gypsum, pH, organic matter content, and Ec was performed on the collected soil samples. The average values of sulfate and gypsum salts were relatively low (0.792 and 1.934%) compared to their values at the control site (2.455 and 5.301%). The reason was the leaching and dissolving that occur due to the presence of groundwater in the open dump soil.

Table 4. Values of chemical properties

Chemical properties		Soil samples						
		S-1	S-2	S-3	S-4	S-5	AV.	S-control
Sulphate	%	1.03	1.05	0.264	0.54	1.087	0.792	2.455
Gypsum	%	2.216	2.55	0.578	1.99	2.340	1.934	5.301
Organic Matter	%	1.96	2.93	2.85	3.10	1.87	2.542	0.215
PH		9.68	9.29	10.03	9.13	10.22	9.67	7.4
Ec	mS/cm	5.5	6.2	5.4	6.7	4.500	5.6	3.6

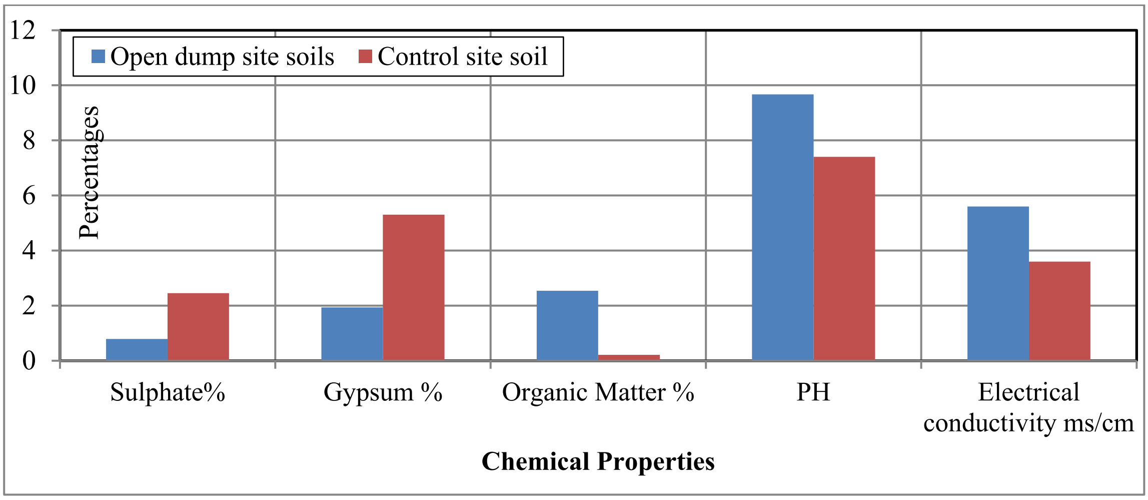

Fig. 8. Bar shape of chemical properties obtained from open dump soils and control soil

The open dump soil from the five studied samples had an average organic matter content of 2.542%. There was an elevated average value of organic matter content in open dump soils when compared to control soil values of 0.215%. This is due to the decay of organic waste by soil microbial activities that have led to an increase in soil organic matter content. The high organic matter content of waste open dump soils will have an extensive influence on soil properties, including maximum dry density, liquid limit, unconfined compressive strength values, and moisture content. The dump's soil was alkaline, with a pH ranging between 9.29 and 10.22, while the soil control site was neutral (7.4) (Table 4). The higher pH values recorded in the dump soils could contribute to the appearance of a high quantity of liming material and biological activities (soil microorganisms) on solid waste.

The Ec average of the open dump soils was 5.6 mS/cm, while the Ec value at the control site was 3.6 mS/cm (Table 4; Figure 8). In general, Ec values depend on several factors, including the age of the open dump, the type of waste, and the size of the landfill. From the results, it was found that the average Ec values increased in the landfill soil models compared to the soil around the control site. This is due to the presence of more cations and anions in the dumpsite as a result of the presence of ionized materials (Mekonnen et al., 2020).

The average concentrations of heavy metals in the soils showed that Fe had the highest concentrations in the studied soil samples (Table 3). Iron (Fe) showed a significantly higher concentration in the soil of the open dump (4.64%). The concentrations of Cu, Cr, Ni, Zn, and As in the soils from open dumps were 44.86, 236.36, 278.36, 95.26, and 13.84 ppm, respectively. But there were lower concentrations of Pb (14.02 ppm) and Cd (2.034 ppm) (Table 5). The concentrations of micronutrients in the soil samples were in the order of Fe > Cu > Cr > Ni > Zn and As. Lower concentrations of heavy metals were observed in the soil at the control site compared to the site inside the open landfill. The comparatively higher iron concentrations in

Table 5. Concentrations of heavy elements in soil samples

Ione	Unit	S-1	S-2	S-3	S-4	S-5	Av.	S-Control	UCC*
Fe	%	4.9	4.7	4.3	4.10	5.2	4.64	3.00	3.5
Pb		17.0	14.1	13.6	10.6	14.6	14.02	6.52	17
Cu		52.8	47.6	40.6	38.3	45.0	44.86	32.85	25
Ni		235.9	226.0	210.7	264.40	244.8	236.36	183.81	44
Cr	ppm	275.52	268.79	310.72	264.40	272.37	278.36	238.56	83
Zn		121.5	94.2	82.7	79.1	98.8	95.26	57.74	71
Cd		1.99	1.99	2.09	2.12	1.98	2.034	1.46	22.7
As		12.1	18.2	15.0	9.9	14.0	13.84	7.26	1.5

* Taylor and McLennan (1985)

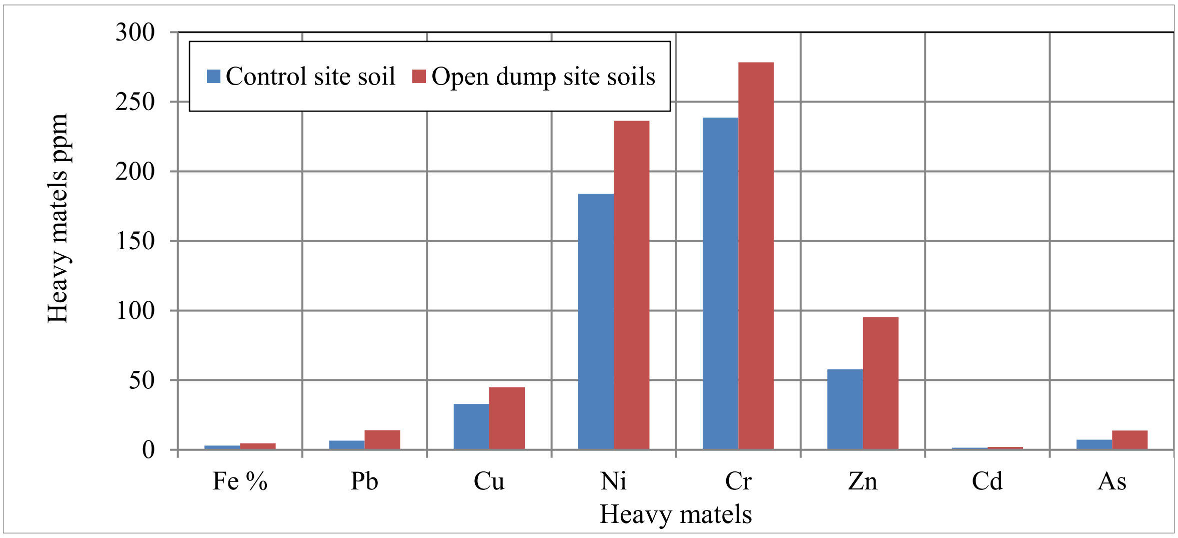

Fig. 9. Bar shape pf heavy metals concentrations obtained from open dump soils and control soil

the investigated soils are due to the abundance of iron in the earth's crust and iron-rich residues, as well as the mineral composition of the base rocks in the respective study area. Plants usually need iron (Fe) for growth and nutrition (Agbeshie et al., 2020).

The highest concentrations of iron, copper, chromium, nickel, and zinc in the open dump (Figure 9), can be attributed to the deposition of heavy metal-rich materials such as used automobile batteries, electronic materials, and some parts of electrical appliances, etc. As a micronutrient for plant growth, such as zinc, it plays an imperative role in enzyme reaction activities in the soil. Therefore, its relative presence in the soil may lower the level of cadmium uptake by plants (Sozubek et al., 2015).

The heavy-polluting elements in the study area are iron, copper, chromium, nickel, zinc, and arsenic. Human waste at open dump sites may be a natural source of these contaminants. High interchangeable bases on the soil of the studied landfills are an indicator of increased nutrient availability and soil microbial activities, so the soil will be appropriate for the care, cultivation, and management of agricultural plants (Okonkwo et al., 2013). This confirms why farmers choose to plant in such locations.

CONCLUSIONS

The physical and chemical properties of the soil in and around the dump site were evaluated in this study. According to the study, the deposition and decomposition of waste affect soil sulfate, gypsum, organic matter, pH, Ec, maximum dry density, moisture content, and heavy metals (Fe, Cu, Cr, Ni, Zn, and As). Among the significant conclusions that were obtained from the results of the examination are:

No noticeable impact was noticed on the texture of the soils, where the classification and soil type are unchanged (CL). Fine grains (clay and silt) were dominant on the site. The rate of the liquid limit increased in the open landfill soil relative to the control site soil. This is due to the increase in the percentage of organic matter and the rising pH in open-dump soil.

The higher pH values and organic matter content of the dumpsite soils improved the soil's nutrient content due to a higher exchangeable base and micronutrient content. This has increased soil microbial activity, fertility, and productivity, leading to maximum plant growth.

A rise in heavy metal concentrations in dumpsite soils, however, requires continual assessment and monitoring. Therefore, sorting, reuse, and recycling should be encouraged to reduce metal loads over time. It was also shown from the results of the research that some of the geotechnical characteristics are compatible with many researchers, such as Ajibade et al., (2021) and Essienubong et al., (2019).

Hence, a liner is recommended for each open dump or open dump system designed to mitigate the challenges associated with an open dump system in the environment. If not planned, harmful materials released, such as concentrated contamination liquids, could enter the food chain. Thus, it is highly recommended that suitable methods be taken to enable the safe disposal of municipal solid waste, such as waste management and treatment. In addition, regular environmental impact studies will undoubtedly limit the entry of harmful microbes into groundwater or surface water bodies. This can pose a potential threat to the environment and public health.

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CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication &/ or falsification, double publication &/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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