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Leachate Characterization and Assessment of Soil Pollution Near Some Municipal Solid Waste Transfer Stations in Baghdad City

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ABSTRACT

This study is conducted to determine the extent to which transfer stations in the Karkh neighborhood of Baghdad, Iraq, contribute to physicochemical and heavy-metal contamination of the soils in the immediate area. The concentrations of physicochemical primary indicators (pH, OC, OM, Ca^{+2}, Mg^{+2}, Na^{+1}, NO_3^{-1}, Cl^{-1}, SO_4^{-2}) and heavy metals (Pb, Cd, and Cu) were measured during July 2022 at four investigation sites that were located at distances of 5 m (Site 1), 10 m (Site 2), 15 m (Site 3), and 20 m (Site 4) from the edges of the mentioned transfer stations (Al-Rasheed, Al-Mansour, Al-Shula, and Al-Dora). The concentrations of the physico-chemicals and heavy metals were compared to the standards of the Food and Agriculture Organization (FAO) and the Consensus-Based Sediment Quality Guidelines (CBSQG). Based on the data collected, it was determined that Site 1 had the greatest physico-chemical and heavy metal concentrations, whereas Site 4 had the lowest. The metals tested were found to accumulate in the following order: Cu > Pb > Cd. Additionally, it was noticed that all the measured concentrations of metals were higher than the limitations of the CBSQG. The presence of Ca^{+2}, Mg^{+2}, Na^{+1}, Pb, Cd, and Cu in soil suggests that leachate percolation is having a major impact on the soil.

INTRODUCTION

The most environmentally friendly method of solid waste disposal is still a problem in virtually all industrialized nations due to many political, environmental, economic, and social restrictions (Adani et al. 2000, Glewa & Al-Alwani 2013). Numerous studies in recent years have looked at how solid waste leachate affects soil (Eyankware et al. 2016, Okeke et al. 2019, Ruth et al. 2021, Hussieny et al. 2022, Rysul et al. 2022). Assessing soil and groundwater pollution has been done in a variety of ways. It may be evaluated either by experimental detection of contaminants or through computational simulations of their concentrations (Saarela 2003, Moo-Young et al. 2004, Mirbagheri et al. 2009, Bilgili 2011, Siddique et al.2021, Liu & Wang 2022).

After Cairo, Baghdad is the biggest city in the Arab world and the capital of Iraq. The population was counted at 8,780,422. Located in a mostly agricultural zone, the Tigris River provides considerable irrigation for a diverse variety of crops. Unfortunately, most soil quality is harmed by leachate that enters the soil via seepage and infiltration. The city of Baghdad has a widespread problem with open dumping. The contamination of soil and groundwater systems by leachate from these sites is a major threat to the local ecosystem.

Water percolates into a landfill, interacting with refuse and absorbing Calcium, magnesium, potassium, nitrogen, and ammonia are common elements found in leachate, as are trace metals like iron, copper, manganese, chromium, nickel, and lead, and organic compounds like phenols, polyaromatic hydrocarbons, acetone, benzene, toluene, chloroform, and so on (Freeze & Cherry1979). Both leachate and water contain varying concentrations of these substances, which are affected by the wastes' makeup (Alker et al. 1995). During a leachate's travel through the soil, some of the contaminants may be adsorbed onto the medium. In essence, the trace elements and contaminants are particularly adsorbed onto the fine soil and sediment particles with more surface area (Varkouhi 2009).

Municipal solid waste (MSW) has become a big challenge for environmental authorities since it not only pollutes subsurface waterways and surface water bodies with a diverse variety of organic and inorganic pollutants (Idowu et al. 2019, Ding et al. 2021, Xu et al.2022) but also significantly pollutes the surrounding soils. In addition, landfills emit greenhouse gases that contribute to global warming, resulting in environmental disasters and increased water consumption (Zubaidi et al. 2018, Liu et al. 2021, Nhien & Giao 2022). In Iraq, the published literature indicates that the generation of the MSW has also rapidly increased during the last 15 years and, unfortunately, it still follows an increasing trend (Chabuk et al. 2015, Abdulredha et al. 2017, Zubaidi et al. 2019, Abdulredha et al. 2020). Therefore, this study aims to evaluate the impacts of solid waste leachate on soil.

MATERIALS AND METHODS

Leachate

Due to the lack of a leachate collector on-site, four independent samples of leachate were taken from waste compactor trucks destined for each transfer station (Al-Rasheed, Al-Mansour, Al-Shula, and Al-Dora). They mixed all samples before being subjected to analysis for various elements (APHA 2005).

Soil

Sixteen drill holes were brought from four transfer stations to measure soil pollution. In July 2022, soil samples were collected from four different locations (1, 2, 3, and 4) at 5, 10, 15, and 20 meters from each transfer station. These samples were taken using a soil drill at a depth of 50 centimeters. As soon as soil samples were obtained, they were sealed in plastic bags, labeled, and sent to the lab to prevent the spread of any microorganisms. The obtained samples were treated and prepared according to the method of soil analysis (Page et al. 1982, Khan et al. 2008). All powdered samples were sieved through a 2 mm screen to get rid of any larger stones or pebbles.

Physical Properties

With the use of a pH meter, we were able to figure out what the pH level of the saturation paste extract was obtained according to (APHA 2005). Analyzing the soil's main particle size by sieving as well as its particle-size distribution after air-drying soil samples are both possible. The dried samples are soaked in water on a tray and then combined with either 1 gram of sodium hydroxide or 1 gram of sodium carbonate per litter of water as a dispersing agent before being transferred to a 1000-ml jar for hydrometer measurement (Das 1989).

Chemical Properties

The soil was chemically analyzed using the Standard Method of Soil Analysis (Page et al. 1982). Soil's chemical was analyzed after being extracted from its solid (the soil) form into a liquid (the solvent). Different elements need different extraction techniques. However, the saturation extract may be used to quantify several components, such as Ca^{+2}, Mg^{+2}, Na^{+1}, NO_3^{-1}, Cl^{-1}, SO_4^{-2}, Pb, Cd, and Cu.

(EDS, SEM)

Energy Dispersive X-ray Spectroscopy (EDS or EDX) is an analytical technique used to identify and characterize the elemental composition of four samples of soil taken from transfer stations. Using a scanning electron microscope (SEM) equipped with an X-ray detector, atoms within soil samples are excited by an electron beam.

Study Area

The Municipality of Baghdad has been responsible for the civil works within its implementation of the project to establish nine transfer stations in Baghdad City, four of which are on the Karkh side (Al-Rasheed, Al-Mansour, Al-Shula, and Al-Dora) and five on the Rusafa side (Al-Sadr, Al-Shaab, Al-Rusafa Center, Al-Ghadir, and Al-Karrada). All the municipal departments transport municipal waste from the transfer stations to only one landfill site in the Al-Nabai area, outside the borders of the Baghdad governorate and near the district of Tarmiyah, which is a random site and does not have environmental approval.

The purpose of this type of station is to collect and compress waste into closed containers and then transfer it by specialized mechanisms to sanitary landfill sites in a way that helps reduce the volume of waste by an average of one-third. The design capacity of one station is 500 "tonnes" per day, and in exceptional cases, it reaches 1000 "tonnes" per day. The transfer stations are intermediate places for solid waste collection. They contain scales to weigh the collected waste and compress it by pistons to be then unloaded into tankers (trailers) of large sizes designated for this purpose to be transported to sanitary landfill sites. Domestic garbage such as food scraps, paper, plastic, glass, cardboard, and clothing are all accepted in these dumps. Sand, bricks, and concrete blocks from demolition and construction projects are also discarded.

The lands adjacent to the transfer stations (Al-Rasheed, Al-Mansour, Al-Shula, and Al-Dora) are virgin (untouched, not plowed), not lands of agricultural use. There are no major industrial sites or other objects that might have an impact on soil quality close to the transfer stations.

RESULTS AND DISCUSSION

Leachate Characterization

Characterization of leachate has been done, and the results are shown in Table 1 to help us comprehend the effect leachate quality has on the soil.

The composition of the solid waste and the amount of water in the trash as a whole are the two most important

Table 1: Characterization of leachate quality.

No.	Parameter	Value
1	pH	7.33
2	EC [$dS.m^{-1}$]	17.4
3	TSS [$g.L^{-1}$]	14.48
4	TDS [$mg.L^{-1}$]	10561
5	Hardness	8.04
6	HCO_3 [$meq.L^{-1}$]	7.65
7	Na^{+1} [$meq.L^{-1}$]	16.59
8	Ca^{+2} [$meq.L^{-1}$]	87.05
9	Mg^{+2} [$meq.L^{-1}$]	59.31
10	K [$meq.L^{-1}$]	5.03
11	SAR	1.54
12	Cl^{-1} [$meq.L^{-1}$]	145.01
13	Cu [ppm]	35.2
14	Zn [ppm]	65.2
15	Pb [ppm]	44.29
16	Fe [ppm]	102.45
17	Cd [ppm]	0.00124

factors influencing the leachate's physical and chemical properties. After testing, it was determined that the pH of the obtained sample was 7.33. Both the EC (17.4 $dS.m^{-1}$) and TDS (10,561 $mg.L^{-1}$) are quite high, suggesting the presence of inorganic matter in the samples. Because of the high concentration of Fe (102.45 ppm) in the leachate sample, it is possible that steel scrap and other ferrous metals were also deposited at the site. The dark brown color of the leachate is mostly due to ferrous oxidation to ferric and the subsequent formation of ferric hydroxide colloids and complexes with fulvic/humic material (Chu et al. 1994). A Zn reading of 65.2 ppm in leachate suggests that the landfill has been polluted by waste from batteries and CFLs. The presence of lead (44.29 ppm) in the leachate samples indicates that lead-acid batteries, lead-based paints, and lead-based pipes were discarded in the landfill (Moturi et al. 2004, Mor et al. 2006). The lead levels are between the threshold effect levels (TEL) and the probable effect level (PEL), indicating that adverse effects on biota are predicted to occur occasionally (Varkouhi 2009). Cu (35.2 ppm) and Cd (0.00124 ppm) values were also detected in leachate samples. The very low concentrations of Cd are consistent with significantly reduced effects of mining land-use practices in urban areas (Varkouhi 2007).

Soil Characterization

Soil physicochemical characteristics at the location of the transfer stations are listed in Table 2. According to Table 2, this kind of soil is called loamy sand. A grain size study showed that sand ranged from 752 to 872 milligrams per kilogram of soil, silt from 100 to 200 milligrams per kilogram of soil, and clay from 28 to 68 milligrams per kilogram of soil. Higher levels of moisture in the garbage and landfill are correlated with more microbial activity and more organic material (Akinbile 2012).

Energy Dispersive Spectroscopy (EDS) of Soil Samples

Acidity levels in soil samples ranged from 7.42 to 7.41 and 7.09 to 6.99, indicating the soil's exceptional buffering ability. The soils were categorized as loamy sand soils based on particle-size distributional analysis. Fig. 1 shows the energy dispersive x-ray spectroscopy (EDS) curve for soils, which shows that Si, Ca, K, S, Cl, Mg, Al, Na, Mg, Sb, and Fe are present in relatively high amounts.

Scanning Electron Microscopy (SEM) of Soil Samples

The soil at transfer stations was characterized using scanning electron microscopy (SEM) images of soil particles and pore architecture. Soil from Al-Mansour, Al-Rasheed, Al-Shula, and Al-Dora was enlarged to 20 m using scanning electron microscopy (SEM) near transfer stations. Fig. 2 displays the soil samples' morphological properties according to (Wang et al. 2017). The white coating on the soil's surface in Fig. 2 (a, b, c, and d) is owing to the pollution residues that have saturated the soil's particles. As a result of this decreased sorption, no more contaminants will be taken up by the soil (Rashid & Faisal 2018, Safia et al. 2021).

Soil Analysis

Soil samples were taken from four locations, five to twenty meters from the edge of each of the transfer stations under study, as described above. From what can be seen

Table 2: Physical properties of soil class in the transfer Stations Baghdad city (%).

Locations	Moisture content [%]	Porosity [%]	Grain size analysis [$g.kg^{-1}.soil^{-1}$]			
			Sand	Clay	Silt	Tissue class
Al-Mansour	3.3	0.42	772	48	180	Loamy Sand
Al-Rasheed	1.7	0.41	792	68	140	Loamy Sand
Al-Shula	2.9	0.46	752	48	200	Loamy Sand
Al-Dora	4.3	0.48	872	28	100	Loamy Sand

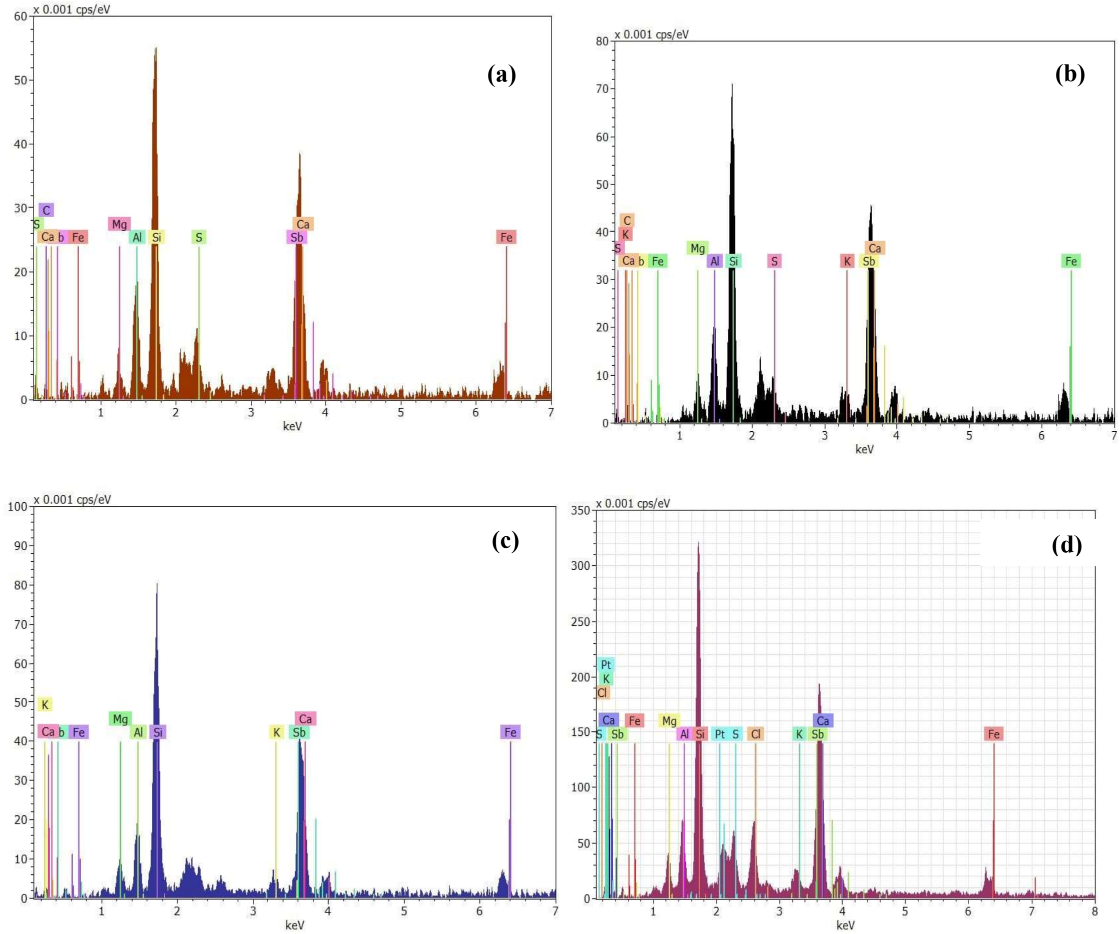

Fig. 1: EDS for the composition of the soil sample:
(a) Al-Mansour soil, (b) Al-Rasheed soil, (c) Al-Shula soil, (d) Al-Dora soil.

in Figs. 3-14, it seems that when distance is put between a certain location and the transfer stations, concentrations of the various physicochemical and heavy metals under study diminish. There may be many causes for the correlation between distance and physiochemical and metal concentrations.

The first is a condition known as "seepage," in which the pollutants are concentrated in a small area around the transfer station locations because the leached water from the collected MSW is insufficient to spread over great distances.

Secondly, recent years have seen less rainfall and more dryness, which has reduced the amount of surface runoff that may leak into the landfill and wash contaminants into the soil and water sources nearby.

Third, the concentrations of the studied physicochemical (Ca^{+2}, Mg^{+2}, Na^{+1}) and heavy metals (Pb, Cu, and Cd)

Were higher than the stated limits by the (FAO 2012, CBSQG 2003), the limit values for Ca^{+2} (0.5988 meql), Mg^{+2} (0.0822 meql), and Na^{+1}(0.0260 meql), and Pb (0.036 ppm), Cu (0.032 ppm), and Cd (0.001 ppm).

Finally, Cu was found to have the concentration that exceeded the limit values the most, followed by Pb and Cd, the one that exceeded the least. It is possible that the chemical composition of the dumped MSW and the makeup of the soil under study are to blame for the observed fluctuation in the content of the heavy metals under study (Jawad et al. 2021). Soil fertility, as well as the capacity to farm it, may be negatively impacted by metal pollution (Hill 2005). Crops grown in polluted soil may provide a significant health risk due to heavy metals and other toxins being absorbed by the plant (Sidra 2009).

The findings emphasized the pressing need for more study into the fluctuation of heavy metals in the examined

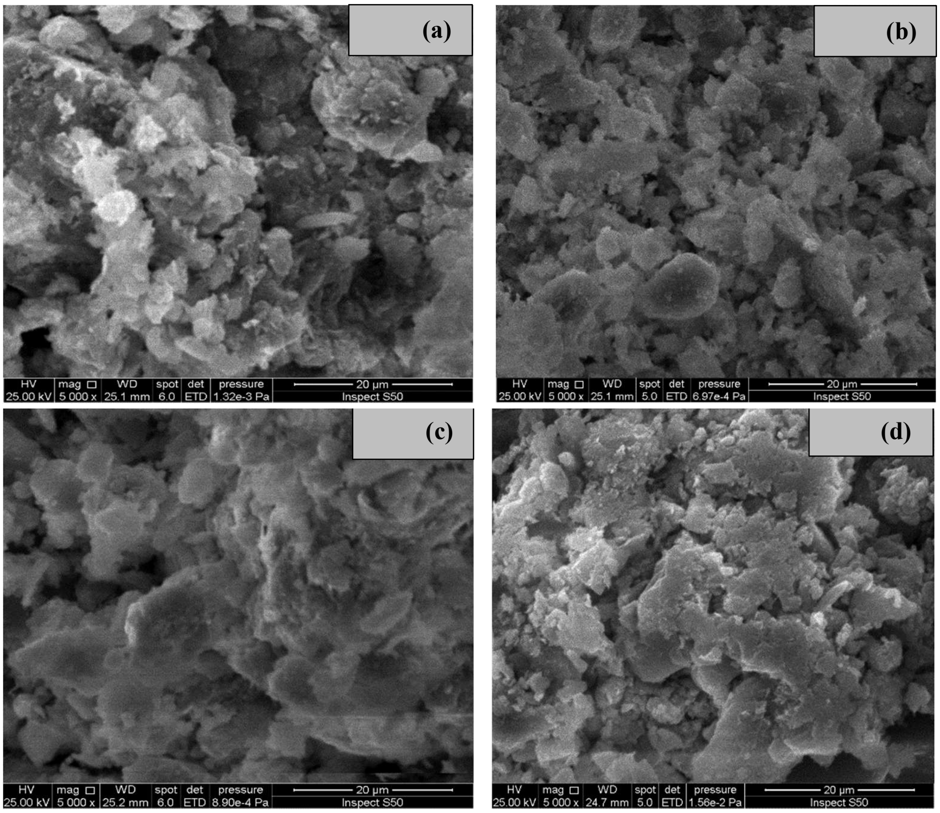

Fig. 2: SEM images for the samples:
Al-Mansour soil, (b) Al-Rasheed soil, (c) Al-Shula soil, (d) Al-Dora soil.

soil and the methods by which heavy metals are transported from transfer stations to the neighboring soils. Several studies should be undertaken throughout the rainy season to track how heavy metals are distributed around the landfill and how their concentration changes as surface runoff increases (Gkantou et al. 2019, Teng et al. 2019).

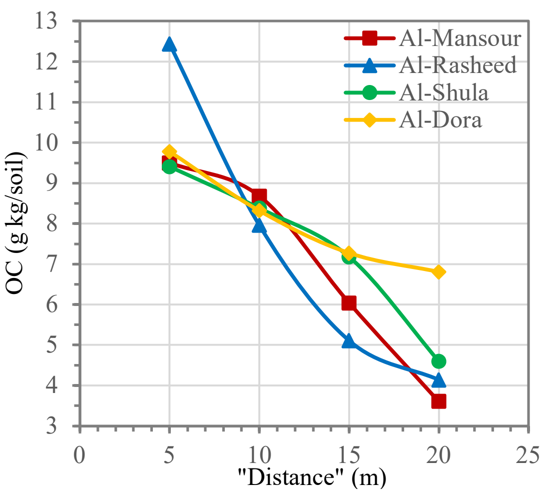

Fig. 3: Concentration of “OC” at various soil distances.

CONCLUSIONS

The current study sought to assess the physiochemical and heavy metal concentration effects of municipal transfer stations on the soils surrounding them. It was shown that the concentration of all pollutants investigated decreased with

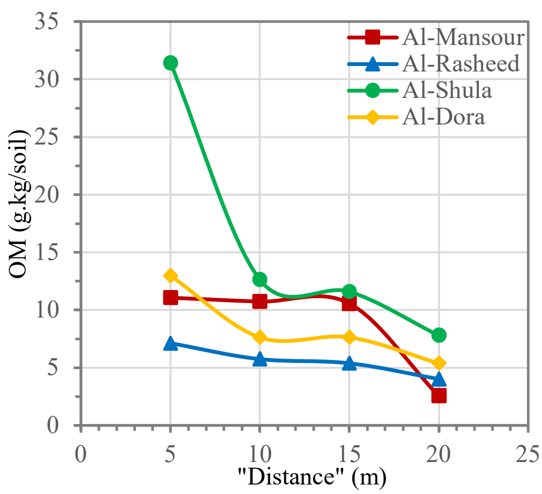

Fig. 4: Concentration of “OM” at various soil distances.

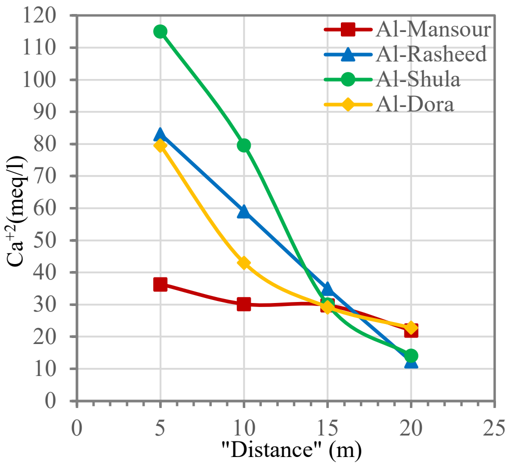

Fig. 5: Concentration of "Ca^{+2}" at various soil distances.

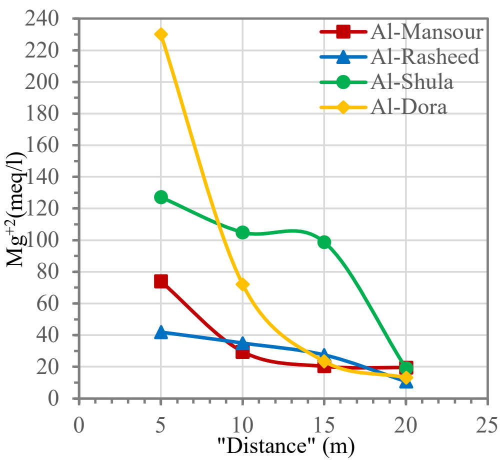

Fig. 6: Concentration of "Mg^{+2}" at various soil distances.

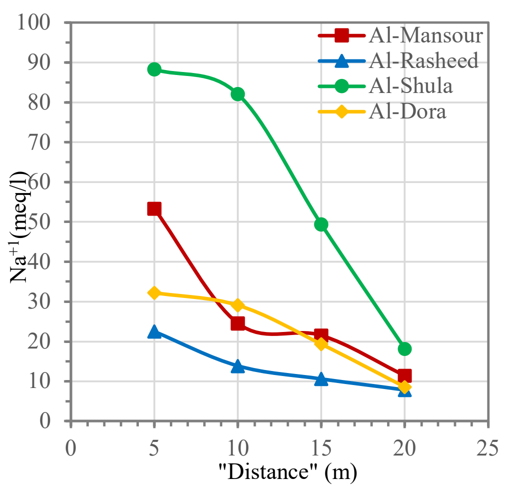

Fig. 7: Concentration of " Na^{+1}" at various soil distances.

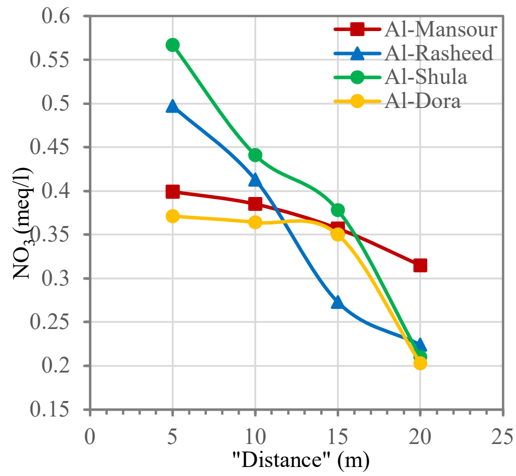

Fig. 8: Concentration of "NO_3" at various soil distances.

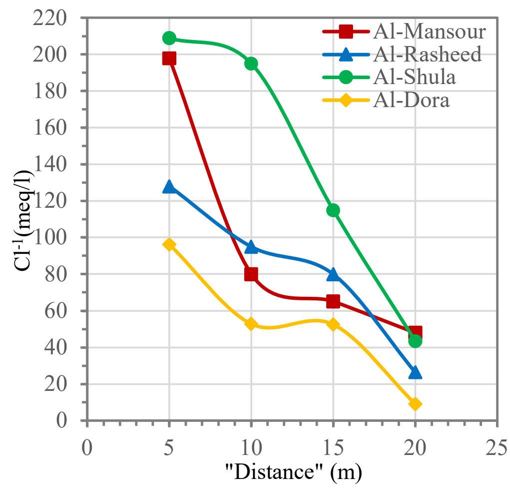

Fig. 9: Concentration of "Cl^{-1}" at various soil distances.

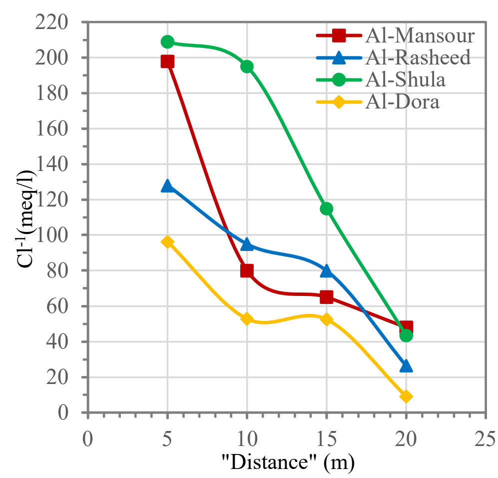

Fig. 10: Concentration of "SO_4" at various soil distances.

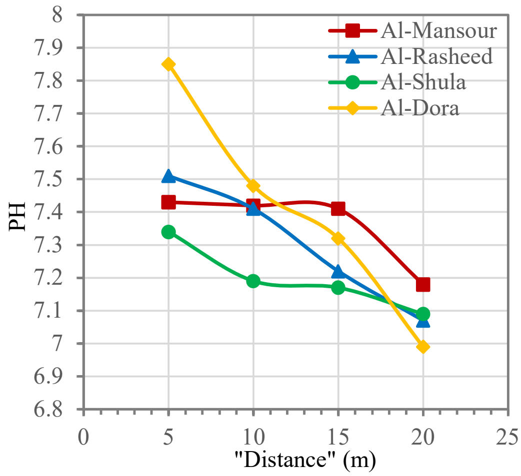

Fig. 11: Concentration of “PH” at various soil distances.

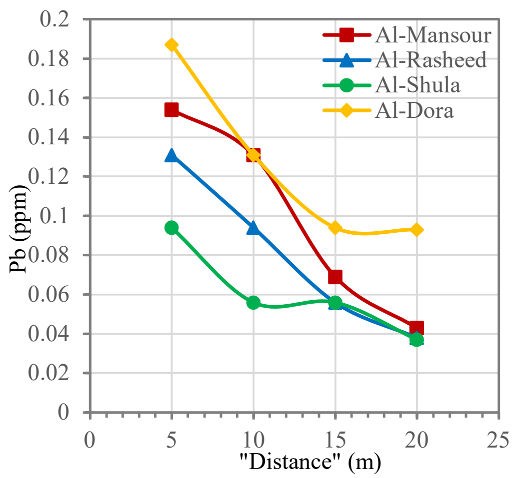

Fig. 12: Concentration of “Pb” at various soil distances.

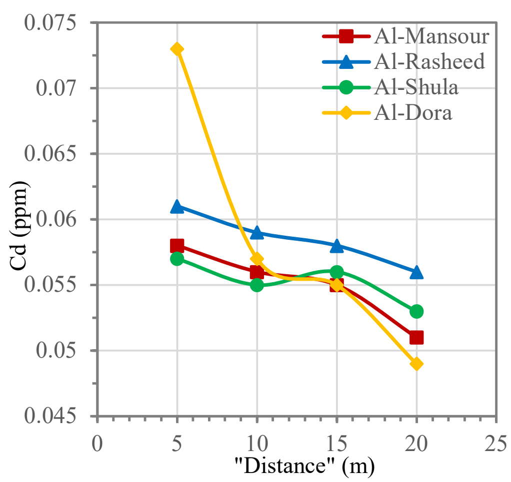

Fig. 13: Concentration of “Cd” at various soil distances.

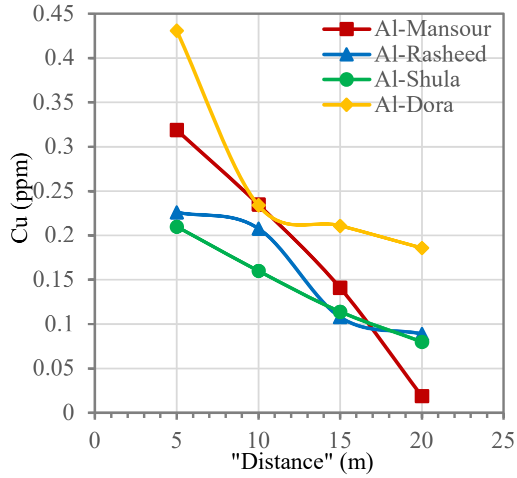

Fig. 14: Concentration of “Cu” at various soil distances.

increasing distance from the transfer stations. Furthermore, the observed concentrations of the studied iones (Ca^{+2}, Mg^{+2}, Na^{+1}) and heavy metals (exceeded the FAO and CBSQG recommended limits. In the areas we looked at, copper was by far the most prevalent heavy metal, whereas cadmium was by far the least. Multiple studies are needed to understand the geological and meteorological effects of heavy metal distribution in the landfill area, including an investigation of the effects of wet weather on pollutant leaching and an analysis of the chemical composition of both the disposed MSW and the landfill’s natural soil.

ABBREVIATIONS

MSW	Municipal Solid Waste
APHA	American Public Health Association
FAO	Food and Agriculture Organization
CBSQG	Consensus-Based Sediment Quality Guidelines
SAR	Sodium Adsorption Ratio
SEM	Scanning Electron Microscope
EDS	Energy Dispersive Spectroscopy
OC	Organic Content
OM	Organic Matter

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