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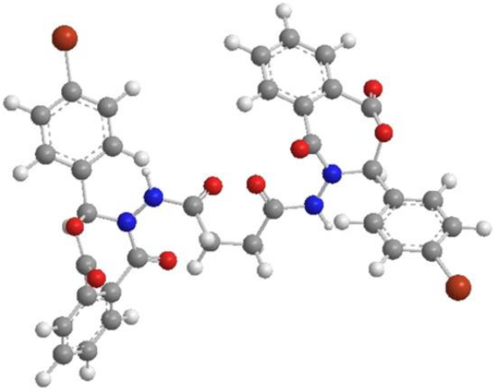

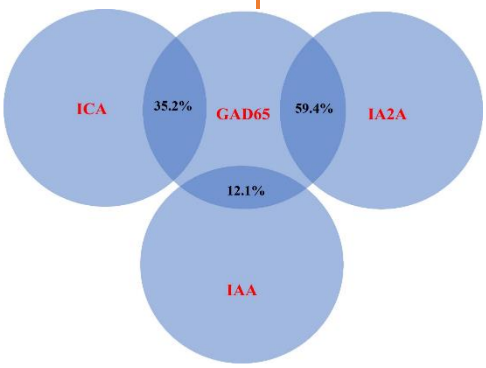

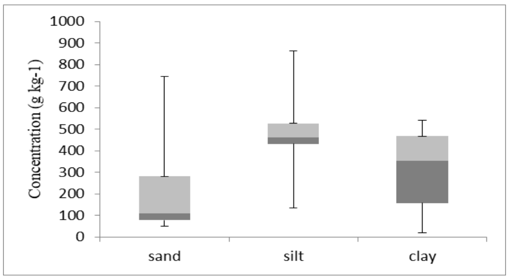

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Assessment of Fe, Ni, Zn, Cu, Cr, and Cd Migration in Soil Profiles Affected by Open Dump Leachate in Tanjero area

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Abstract

The properties of an open dump area are important to the application of the elements to the soils and their migrations through soil depth; therefore this study was investigated to evaluate the migration of elements in an open dump area. Soil samples were taken from three soil profiles, one of them was at an open dump site, and the second and third profiles were taken at different distances from the open dump site. In total eighteen soil sample were collected. Some soil physical and chemical properties were determined for each horizon. Total concentrations of Fe, Ni, Zn, Cu, Cr, and Cd were determined in each soil sample. The results indicated that the Fe had the highest value and the Cd had the lowest values in all soil samples. The orders of profiles for the total heavy (Ni, Cd, and Cr) metals were as follows: Profile1 > profile3 > profile 2. The order of profiles for the total heavy (Zn and Cu) metals was as follows: Profile 1 > profile 2 > profile 3. The mean value of total Ni ranged between 9.17 and 11.13, Cd between 0.29 and 0.37, Cr between 2.67 and 3.36, Zn between 6.90 and 17.23, and Cu between 4.90 and 12.52. The highest amount of total Ni, Cd, Cr, Zn, and Cu were observed in open dump area (profile 1) with the mean value (11.13, 0.37, 3.36, 17.23, and 12.52) respectively, compared to the profile 2 and 3. In general, the heavy metals did not show a specific pattern of distribution with depth in the three soil profiles, because there are many factors affecting migration of heavy metals in soil depth. In both profile 2 and 3, some of the heavy metals migrated in soil depth.

Introduction

The open dump area is the place for the accumulation of solid waste dumping, which has resulted in environmental pollution (1). Leachate migration in open dumping places is a dominant source of heavy metals from the soil surface to groundwater (2). Some heavy metals have a serious problem when they are found in toxic concentrations; they include cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) (3 and 4). One of the important sources of heavy metals that enters the soil and environment is solid waste disposal, open dumps, and landfills (5 and 6). Some soil properties that affect the rate of migration leachate from an open dump area to the soil depth are, soil texture, pH, soil organic matter, cation exchange capacity, and the mineralogical composition of the soil (7). Chemical properties of the soil have a great effect on the leachate migration in the soil, which include, soil pH, ion exchange, and adsorption of heavy metals on the clay particles (8). Also there are some physical properties affecting the solute transfer during soil depth, which include the horizon layering sequence, depth, structure, texture, bulk density, permeability, saturated hydraulic conductivity, volumetric water content, and field capacity (9). Regarding environmental problems in the area, it is a new subject; there are a few works about migration of heavy metals through the soil profile. The aims of the study were (i) to determine the total contents of Fe, Ni, Zn, Cu, Cr and Cd in soil profiles around dump leachate site in Tanjaro region; (ii) to look into the impact of the physical and chemical parameters (Texture, pH, EC, and OM) on the migration of the total amount of Fe, Ni, Zn, Cu, and Cr, and Cd contents at soil profiles within depth; (iii) to compare the migration of total heavy metals in soil depth between the open dump area and another two locations far from open dump area.

Materials and Methods

Field work

This study conducted on the Tanjaro area, first location represent soil sites in open dump area which affected by leachate, second location include soil site far from open dump area, and the third location site include soil site close to the road street were chosen; in total three profile were dug, profile No.1 located in (N 35° 29′ 14″; E 45° 26′ 14.39″), Profile No.2 (N 35° 29′ 16.33″; E 45° 26′ 9.7″) and Profile No.3 (N 35° 29′ 16.6″; E 45° 25′ 51.96″). Eighteen soil samples were collected depending on the morphological properties of the soil according to (10), soil colors of the soil profiles were determined under dry and moist condition using the Munsell soil colour chart, and other morphological characteristics were studied such as; depth of each horizon, texture, structure, consistency for each soil horizons depending on (Table 1) according to (11). Soil samples were collected, air dried, grinded and sieved using sieve (<2 mm) for physical and chemical analyses.

Table 1: Morphological descriptions for studied soil profiles

Soil sample	Soil depth (cm)	Soil color		Soil structure			consistency			
		dry	moist	Type	Grad	Size	Dry	Most	wet	
									ST	PL
Profile 1	0-20	7.5 YR 4/3	7.5 YR 4/6	SB	2	Medium	VH	VF	VS	SP
	20-40	7.5 YR 5/4	7.5 YR 4/4	SB	1-2	Medium	S.H	Fr.	VS	NP
	40-60	7.5 YR 6/3	7.5 YR 4/4	SB	2	Coarse	VH	VF	VS	NP
	60-100	7.5 YR 6/4	7.5 YR 4/4	AB	2	Medium	VH	VF	VS	NP
	100-130	7.5 YR 5/4	7.5 YR 4/4	AB	1	Medium	S.H	Fr.	VS	SP
	130-150	7.5 YR 8/2	7.5 YR 6/4	A	1	Fine	S.H	Fr.	VS	SP
Profile 2	0-20	5 Y 6/1	5 Y 4/1	AB		Medium	Hard	VF	VS	SP
	20-40	7.5 YR 7/3	7.5 YR 4/6	A	2	Corse	VH	EF	VS	NP
	40-60	7.5 YR 6/3	7.5 YR 4/4	SB	2	Medium	VH	F	VS	SP
	60-80	7.5 YR 6/3	7.5 YR 4/4	AB	1	Medium	S.H	Fr.	VS	NP
	80-90	7.5 YR 6/2	7.5 YR 4/6	SB	2	Coarse	VH	VF	VS	NP
	90-150	5 Y 7/2	5 Y 5/3	AB	2	Coarse	EH	VF	NS	NP
Profile 3	0-20	7.5 YR 5/3	7.5 YR 4/3	A	2	Coarse	VH	VF	VS	NP
	20-40	7.5 YR 6/3	7.5 YR 3/3	SA	2	Medium	VH	EF	VS	NP
	40-80	7.5 YR 6/3	7.5 YR 4/6	SB	2	Medium 2	Hard	VFr.	VS	NP
	80-94	7.5 YR 6/3	7.5 YR 4/6	SB	2	Medium	VH	F	VS	NP
	94-121	7.5 YR 6/3	7.5 YR 4/4	AB	2	Medium	VH	Fr.	VS	NP
	121-150	7.5 YR 7/3	7.5 YR 4/6	S	2	Medium	VH	VF	VS	NP

VH→Very Hard; S.H→ Slightly Hard; EH→ Extremely Hard; F→Firm; Fr.→Friable; VFr.→Very Friable; VF→Very Firm; EF→ Extremely Firm; VS→ Very Sticky; NS→Non Sticky; SP→ Slightly Plastic; NP→Non Plastic

Physico-chemical Analysis

Some physical and chemical analyses were performed for soil samples. The particle size distribution was determined using the pipette method described by (12). Soil pH was determined with a glass electrode pH meter using soil paste extraction, and EC was determined according to (12). Soil organic matter was determined using the Walkley-Black wet digestion method (13). Total heavy metal contents of the soil samples were determined according to the following procedure: A 0.5 g of air-dry soil (<0.15 mm) was digested with 3ml of (HNO_3 69%), and the mixture was heated for 1 hour at 145°C on block digester. Then 4 ml of ($HCLO_4$ 70%) were added and putted on the block digester for the second time to digest the mixture for another 1 more hour at 240°C. The suspension was filtered through whatman No. 42 filter paper, and diluted to bring 50ml volumetric flask. Total (Fe, Zn, Ni, Cr, Cd, and Cu) contents were determined using Perkin-Elmer/Optical Emission Spectrometer Optima 2100DV, (Inductively Coupled Plasma mass spectrometer ICP) as described by (14).

Results and Discussion

Soil Properties

Table 2 shows the physical and chemical properties of studied soil samples in three profiles. And the box-and-whisker plots for sand, silt, and clay contents in the three soil profiles are shown in Figure 1. Median of sand, silt, and clay values were 351.96, 461.48, and 109.765 g kg^{-1}, respectively. Silt contents had the higher value compared to clay and sand content in soil samples, and texture classes ranged from (clay to silty clay loam).

Table 2 shows pattern distribution of sand, silt, and clay contents within soil depth in all soil profiles. The clay contents increased with soil depth then decrease in depth 100-130 cm and 40-60 cm of profile 1 and 2, respectively. In profile 3 the maximum content of clay observed in depth 121-150 cm. increasing clay particle in subsurface soil and then decreasing in deeper soil profile may be because of the effect pedogenic process (15). Silt and sand did not show specific pattern of distribution within soil depth in all studied profiles and they range from (132.87 to 864.63 g kg^{-1}) and from (50.61 to 744.75 g kg^{-1}) respectively.

Results in Table 2 indicated the value of pH was between 6.3 and 7.7. The lowest value was recorded in the open dump area (profile 1), while the highest value was recorded in (profile 2). These results of pH indicated that the reaction of three soil profiles were around slightly acidic to moderate alkali; this may be because the parent materials of these soils is calcareous parent material. The value of pH was different between soil profiles and within soil depths. Figure 2 indicated the pH value of soils around the open dump area (profile 1) was lower than the pH values in profile 2 and 3. The difference of pH values between the profile in open dump area and those profiles far from the open dump area maybe due to the effect of leachate component in the soil were make soil in dumping area slightly acidic. Seo et al., (16) who reported that there is bicarbonate in the leachate cause to change pH value to slightly acidic. Results showed there was no specific pattern for pH values with depth in all studied profiles.

Results of Electrical conductivity (EC) showed that studied soil profiles were non-saline, because soil samples have low values of EC (0.08-0.68 dS m^{-1}). The lowest value of EC was in (60-80) and (90-150) depth of profile 2, while the highest value was in (100-130) depth at (profile 1). The low soluble salt contents in all studied soil profiles attributed to desalinization process as affected by high amount of rainfall, and increasing of leaching rate through all studied profiles.

The values of EC were different between soil profiles. Figure (3) showed the EC value was higher in open dump area (profile 1) compared to the values of both (profile 3) and (profile 2). In general, the values of EC decrease within soil depth at profile 2 and 3, while in open dump area (profile 1) the values were increase with depth. Increased values of EC within soil depth in open dump area profile maybe due to the penetrating of leachate from open dump area during rain fall. This result in agreement with (17).

The amount of organic matter was reported in (Table 2 and Figure 4). Results showed the values of organic matter content in studied soil profiles ranged between 16.2 and 34.1 g kg^{-1}. The highest value is obtained at (profile 2) and the lowest value is at open dump area (profile 1). The lowest value of organic matter in open dump area may be due to the washing effect of rainfall cause washing of organic matter and moving to the part of area far from open dump site. In general, higher values of organic matter were observed in soil surface and decreased with soil depth at profile 2 and 3; this is due to the greater accumulation of organic residuals and recreation activity at the upper part of soil (18). The difference between the values of organic matter in the studied soil samples may be due to the organic matter decomposition in different rate.

The opposite result found in open dump area (profile 1) showed the low value of organic matter content in soil surface and increase within soil depths was likely to be caused by decomposition of waste materials, produce some elements and then migration through soil depths.

Table 2: Some physico-chemical properties of the studied soils profiles

Soil sample	Soil depth (cm)	Soil texture (g kg^{-1})			Soil texture	pH	Ec (ds m^{-1})	O.M. (g kg^{-1})
		Sand	Silt	Clay				
Profile 1	0-20	74.24	628.82	296.94	SiL	7.30	0.44	16.2
	20-40	50.61	513.09	436.30	SC	6.30	0.34	23.4
	40-60	61.74	433.91	504.35	SC	6.32	0.55	24.1
	60-100	55.94	402.10	541.96	SC	6.45	0.65	27.2
	100-130	168.84	430.81	400.35	SC	6.68	0.68	21.7
	130-150	381.98	531.52	86.50	SiL	6.63	0.51	25.5
Profile 2	0-20	378.95	603.51	17.54	SiL	6.90	0.42	34.1
	20-40	229.24	511.25	259.51	SiL	6.94	0.17	26.5
	40-60	117.90	864.63	17.47	S	7.7	0.12	28.6
	60-80	92.56	474.92	432.52	SC	7.25	0.08	26.5
	80-90	456.28	498.70	45.02	SL	7.23	0.09	25.8
	90-150	744.75	132.87	122.38	SL	7.34	0.08	23.8
Profile 3	0-20	298.51	438.1	263.39	L	7.20	0.30	30.0
	20-40	80.35	448.04	471.61	SC	7.20	0.31	21.7
	40-80	101.63	444.65	453.72	SC	7.24	0.27	27.2
	80-94	122.32	574.11	303.57	SCL	7.23	0.31	25.5
	94-121	94.73	422.70	482.57	SC	7.26	0.25	26.2
	121-150	77.59	381.87	540.54	C	7.27	0.16	23.1

C→Clay; S→Silty; L→Loam; SiL→Silty Loam; SC→Silty Clay; SL→Sandy Loam; SCL→Silty Clay Loam

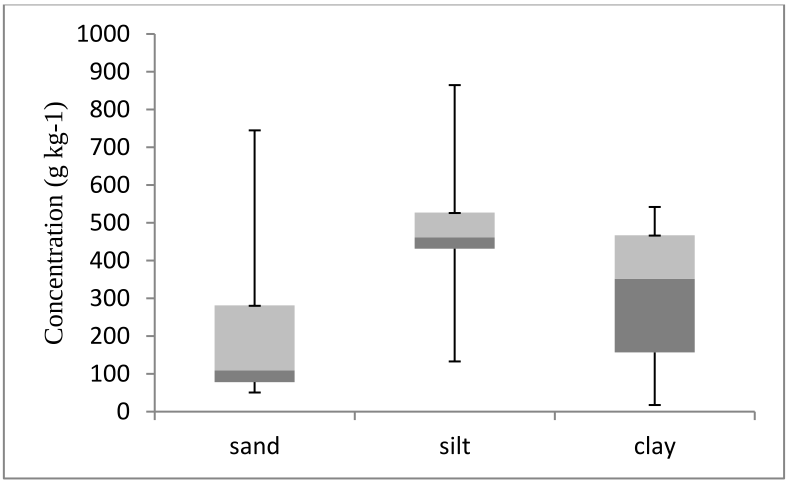


Figure 1: Box- and –whisker plots showing sand, silt, and clay contents in the studied soil profiles

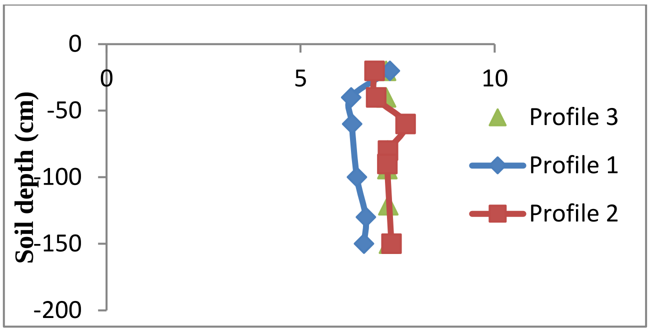


Figure 2: Distribution of soil pH values within soil depth in three profiles

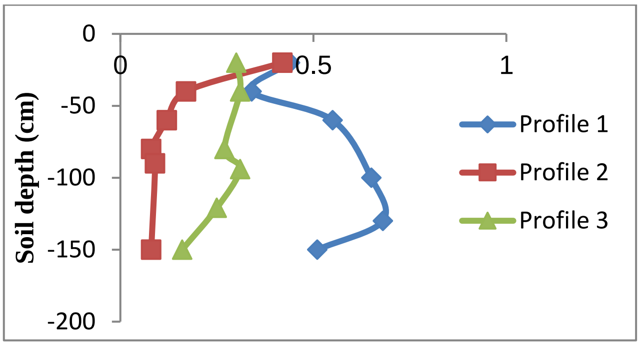


Figure 3: Distribution of soil Electrical Conductivity (Ec) within soil depth in three profiles

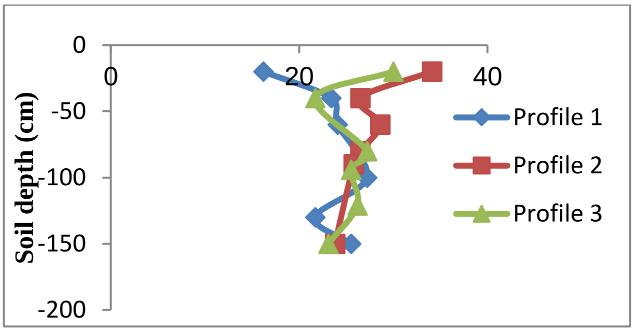
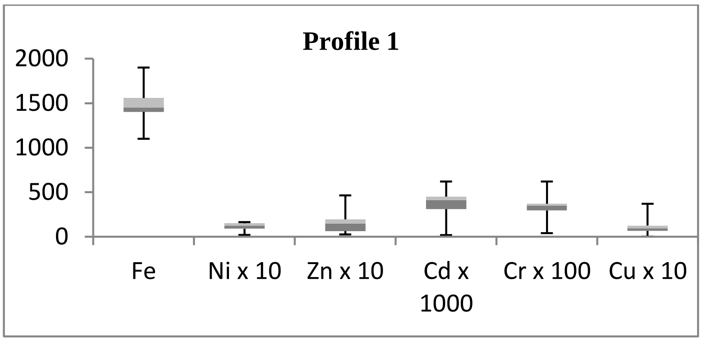


Figure 4: Distribution of soil organic matter within soil depth in three profiles

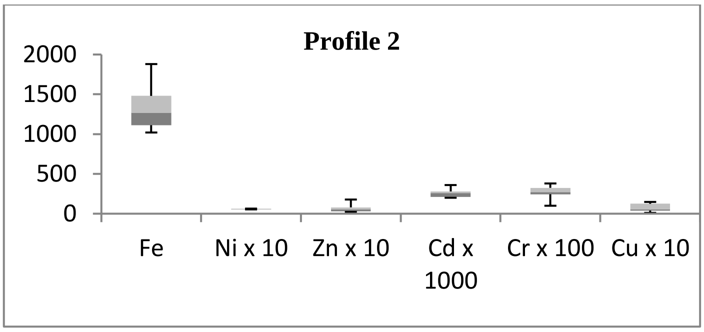
Total heavy metals contents in three soil profiles

Total heavy metals contents in the three soil profiles were shown in Figure 5. (a, b, and c). The box and whisker plots indicate there were higher values of total Fe compared to other metals contents in the soil profiles. Sheikh-Abdullah, (19) found that total value of Fe had higher values compared to total (Zn, Cu, and Mn) metals. Total Cd had the lowest values. In soil profile 1, the order for the total heavy metals were Fe > Zn > Cu > Ni > Cr > Cd. Figure 5 (b) shows the total heavy metals content within soil depth in the soil (profile 2). The dominant total heavy metals can be ordered as follows: Fe > Cu > Zn > Ni > Cr >Cd. The box and whisker plots in Figure 5 (c) had shown the total heavy metals content in (profile 3). The dominant heavy metal content in the studied soil profiles within depth follows the following order: Fe > Ni > Zn > Cu > Cr >Cd.

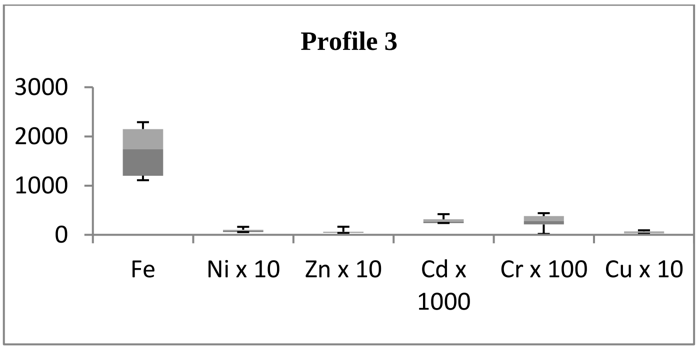
In general, the higher values of (Zn, Ni, Cu, Cr, and Cd) observed at open dump area (profile 1) compared to the profiles (2 and 3) in all soil depths. This is maybe due to the accumulation of leachate in profile 1, and leachate contain high amount of the heavy metals and then applied to the soil surface. Decomposition different forms of waste materials in open dump site produce high values of Cu concentration and apply it to the soil (17). The mean values and standard error of total heavy metals concentrations between soil profiles shown in Table 5. Total concentration of Fe in profile 3 had the higher values compared to profile 1 and then profile 2. This is maybe reflecting to the high amount of clay particles in the profile 3 and retention or bearing iron. Some soil properties had an effect on the cation retention as soil texture, organic matter, soil pH, and calcium carbonate content (20 and 21). The orders of profiles for the total heavy metals (Ni, Cd, and Cr) were as follows: Profile1 > profile3 > profile 2. Higher values of total Ni, Cd, and Cr in profile 1 compared to other profiles may be due to the increasing of EC value in profile 1. While the order of profiles for the total (Zn and Cu) metals were as follows: Profile 1 > profile 2 > profile 3. The higher amount of total Ni, Cd, Cr, Zn, and Cu were observed in open dump site (profile 1) compared to the profile (2 and 3) by different forms of solid wastes which had been dumped in location open dump area. Highest amount of heavy metals content in profile 1, due to the contaminated soil samples by ash, plastic, and industrial wastes; degradation of the materials produce high values of heavy metals and apply to the soil surface. There are high values of heavy metals in the contaminated soil with anthropogenic activity (22). The type of waste materials composition had an important effect on the rate of heavy metals supply to the soil (23).



(a)



(b)



(c)

Figure 5: Box- and –whisker plots showing total concentrations of Fe, Ni, Zn, Cd, Cr, and Cu in the studied soil profiles at: (a) profile 1, (b) profile 2, and (c) profile 3.

Table 5: The mean, and standard error of sand, silt, clay, pH, Ec, O.M., and total metals contents in soil profiles

Location	Sand	Silt	Clay	pH	Ec	OM	Fe	Ni	Zn	Cd	Cr	Cu
Profile 1	132.23	490.04	377.73	6.61	0.53	2.30	1480.00	11.13	17.23	0.37	3.36	12.52
Profile 2	336.61	514.31	149.07	7.23	0.16	2.76	1341.67	5.90	6.94	0.26	2.67	7.50
Profile 3	129.19	451.58	419.23	7.23	0.27	2.56	1698.33	9.17	6.90	0.29	2.70	4.90
SE	68.64	18.26	83.99	0.21	0.11	0.13	103.82	1.53	3.44	0.03	0.23	2.24

Migration of heavy metals within soil depth in studied soil profiles

Figure 6 shows distribution the total amount of heavy metals concentrations within soil depth in (profile 1). Total Fe value ranged from 1100 to 1900 mg kg^{-1}, the minimum value was in depth (130–150 cm) and maximum value was in depth (0–20 cm). In general, total Fe increased with increasing clay content in the soil samples. This is because of chelating total Fe by clay particle in soil (19). Total Ni, Cd, Cr, and Cu values ranged between (2-16.4), (0.018-0.62), (0.4-6.2), and (0.14-37) respectively. The highest values of the mentioned metals were observed in depth (0-20) cm. while, the lowest amount were found in depth (130-150) cm. Total content of Zn ranged between 2.56 and 46.4 mg kg^{-1}; the minimum amount was recorded in depth (100–130 cm), and the maximum amount was found in depth (0–20 cm). Total Ni, Cd, and Cu contents were higher in surface soil compared to the soil depth. This result indicates that the leachate contains heavy metals and added the heavy metals to the soil surface. This agrees with finding of (17) who found that there is high amount of Cu in leachate of the dump leachate area and they come from decomposition of the leachate source materials. In general, the distribution of heavy metals with depth didn't show specific pattern in soil profile. The values decreased within soil depth and then increased in depth (60-100 cm). These results may be due to migration of heavy metals from surface till reaching sub surface horizon but still not reaching deeper horizon. Total Ni increased in landfill through adding different waste materials, like batteries (24).

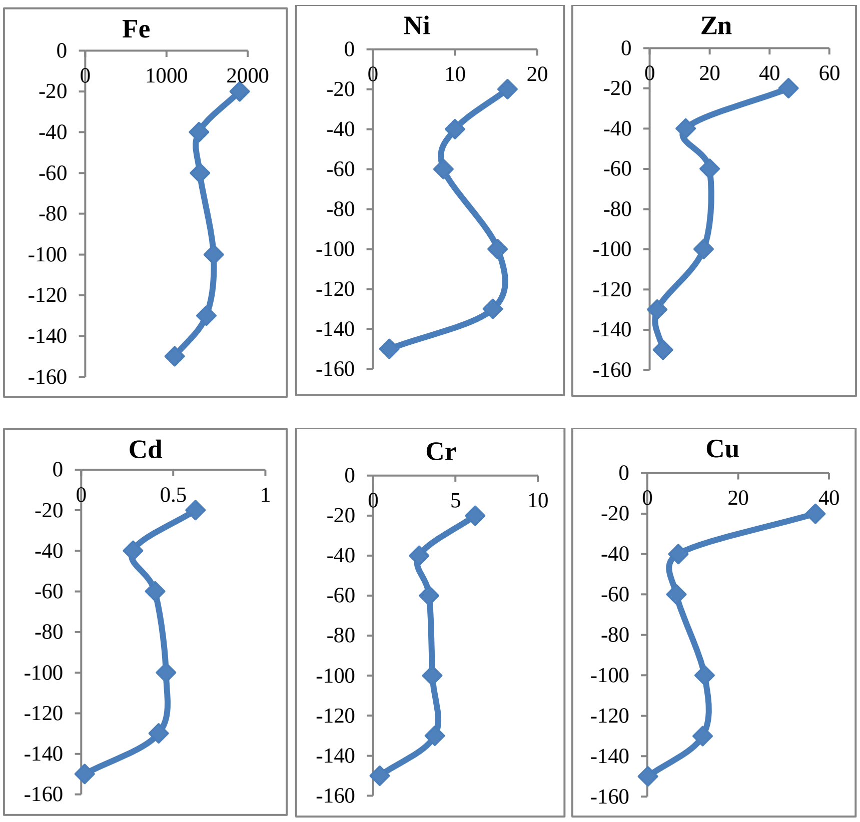


Figure 6: Distribution of total heavy metals concentrations within soil depth in profile 1

Figure 7 shows distribution of total heavy metals concentrations within soil depth in profile 2. Total Fe ranged between 1020 and 1880 mg kg^{-1} in the soil profile, the minimum value found in depth (0–20 cm) and the maximum value found in depth (20–40 cm), this may be due to migration of Fe which exist in soil profile for long period of times. Total Ni content ranged between 5.4 and 6.4 mg kg^{-1}, the minimum value recorded in depth (40–60 cm) and (90-150), while the maximum value recorded in depth (0–20 cm). Total amount of Zn ranged between 2.26 and 17.8 mg kg^{-1}; the minimum amount was recorded in depth (80–90 cm), and the maximum amount was found in depth (0–20 cm). The value of total Cd ranged from 0.2 to 0.36 mg kg^{-1}, the minimum amount was recorded in depth (0–20 cm) and (80-90), while the maximum value recorded in depth (40–60 cm). Total value of Cr was ranged from 1 to 3.8 mg kg^{-1}, the minimum value recorded in depth (60–80 cm), and the maximum value recorded in depth (90–150 cm).Total amount of Cu ranged from 1 to 14.8 mg kg^{-1}; the minimum value found in depth (60–80 cm), and the maximum value found in depth (0–20 cm). The high contents of total Ni, Zn, and Cu in depth (0-20 cm), maybe due to the high values of organic matter and EC cause to increase these values. Sheikh-Abdullah (19), mentioned that organic matter has ability to retention total Zn and Cu in the soil.

The highest contents of total Fe, Cd, and Cr was observed in the depth of soil profiles, this is maybe there are migration of the elements within soil depth. The results maybe indicated that there is migration of Fe, Cd, and Cr metals within soil depth and penetration with water into the soil depth during rainfall.

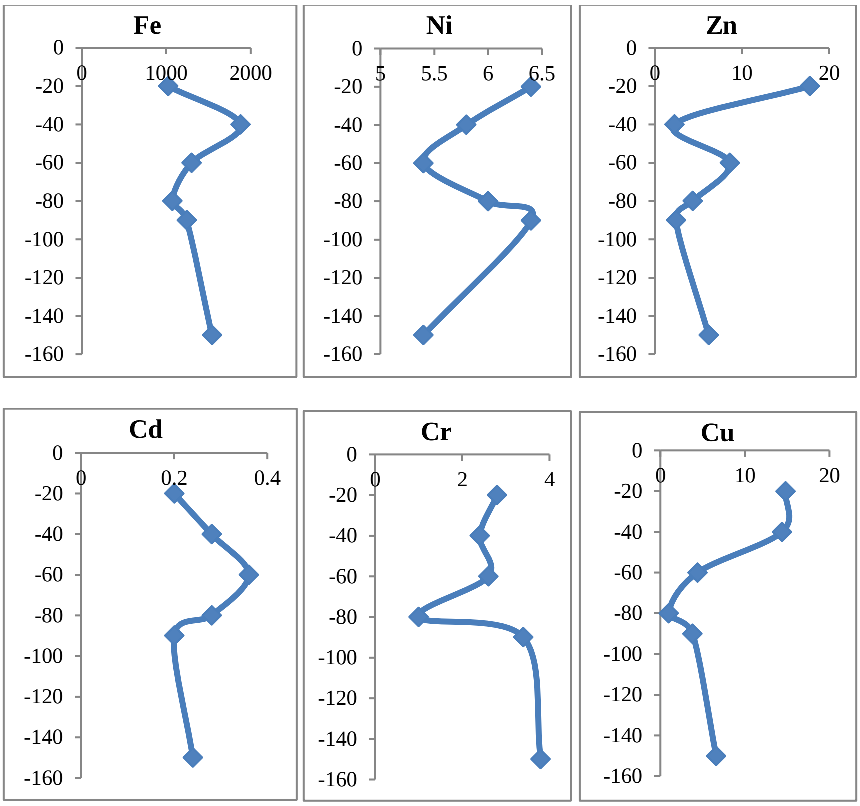


Figure 7: Distribution of total heavy metals concentrations within soil depth in profile 2

Figure 8 shows distribution of total heavy metals concentrations within soil depth in profile 3. Total Fe ranged between 1110 and 2290 mg kg^{-1} in the soil profile, the minimum value recorded in depth (94–121 cm) and the maximum value recorded in depth (40–80 cm). In general, the higher values of total Fe observed in the three-layer surface, while the lower values observed in the three-layer depth in the profile. The total Ni content ranged between 5.6 and 16.2 mg kg^{-1}, the minimum value recorded in depth (20–40 cm) and (94-121), while the maximum value recorded in depth (40–80 cm). Total (Fe, Ni, Cr, and Cu) contents were higher in soil depth (40-80) cm. This is may be due to the migration of the metals and then precipitate in the soil depth. There are many factors which affecting on the values of metals in the soil as parent material, total calcium carbonate, and organic matter content (19). The total value of Zn ranged from 3.76 to 16.4 mg kg^{-1}, with the minimum amount observed in depth (94-121), and the maximum amount observed in depth (20–40 cm). The main sources to supply total Zn to the soil are composition of parent materials (25). The total Cd amount ranged between 0.24 and 0.42 mg kg^{-1}, the minimum value recorded in depth (0–20 cm) and (40-80), while the maximum amount recorded in depth (94–121 cm). The total Cr value ranged between 0.18 and 4.4 mg kg^{-1}, the minimum value found in depth (20–40 cm), and the maximum value recorded in depth (40–80 cm). The value of total Cu was ranged from 2 to 9.2 mg kg^{-1}, the minimum amount recorded in depth (121–150 cm), and the maximum value recorded in depth (40–80 cm). There are many factors that affecting to the increase metal concentration in to the soil they are: redox reaction, adsorbed of the metals on soil particle surface, sediments composition, and properties (26).

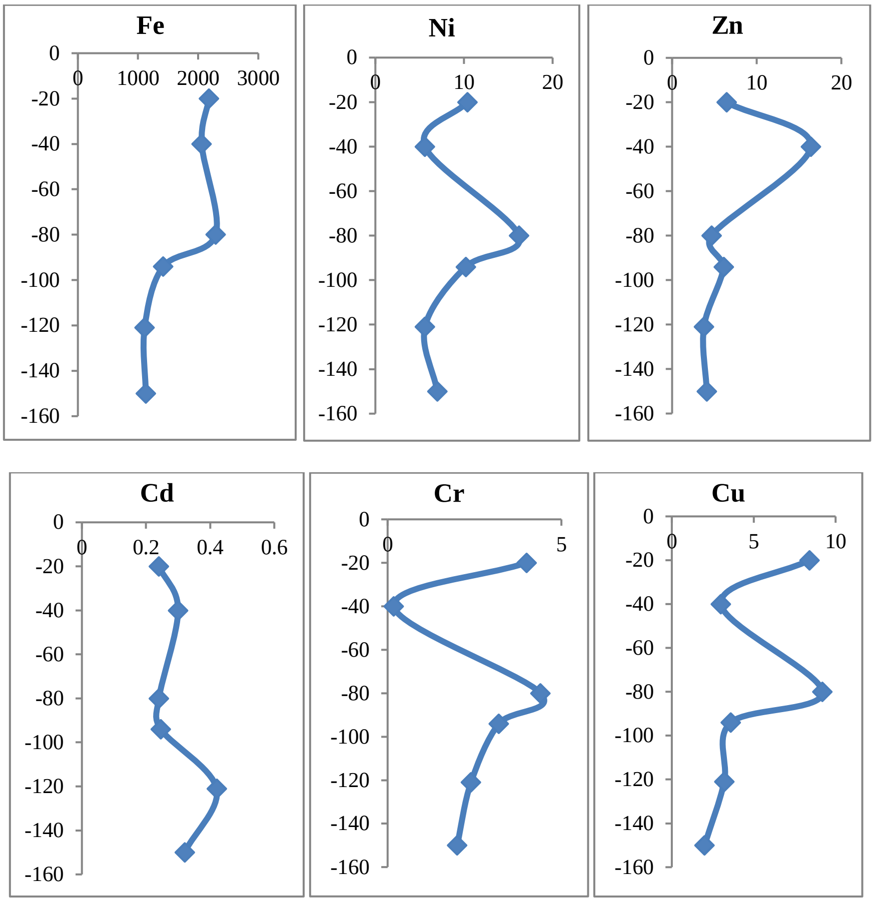


Figure 8: Distribution of total heavy metals concentrations within soil depth in profile 3

Conclusions

This study examined the migration of some heavy metals in soil profiles impacted by an open dump site in Tanjaro region. The soil samples were characterized by fine soil texture; soil pH ranged from slightly acidic in soil profiles close to open dump areas to moderately alkaline in two profiles far from open dump areas. Total Fe content had higher values compared to the Zn, Ni, Cu, Cr, and Cd metals in the studied soil profiles. Leachate cause to increase the concentrations of heavy metals in (profile 1) compared to the two profiles far from open dump area. Migration of heavy metals in soil depth was affected by some physical and chemical properties of the soil. Further studies should determine type of minerals in the area because parent materials are an important source to apply heavy metals to the soil.

Conflict of interest

The authors confirm that they are not affiliated with or involved in any organization or entity with financial interests.

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