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Contamination of Soils Around Garbage Dump case study: the pantang garbage dump

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Abstract: The concentration of heavy metals was studied in the soil samples collected around the Pantang municipal solid waste (MSW) open dumpsite. This study sought to determine the chemical effects of un-engineered landfills on surrounding soils. Soil samples were collected on the site, uphill and downhill relative to the garbage dump for laboratory testing and analysis.

The results particularly showed high level of heavy metals such as Fe, Zn, Pb, Mn, Cu and Ni. The concentrations of these heavy metals were above the permissible limit of values for typical range in soils standards from Soil test Farm Consultants Inc. Other compounds such as SO_4^{2-}, NH_4^+, % carbon, % Organic matter and Cl^- were also above the permissible limit of values for typical range in soils.

The presence of heavy metals in soil sample indicates that there is appreciable contamination of the soil by leachate migration from an open dumping site. However, these pollutant species will continuously migrate and eventually attenuate through the soil strata and have contaminated the groundwater system (Anum 2012).

Keywords: contamination, leachate, heavy, metals, anions, waste.

Introduction

The rapid increase in volumes of unsorted or unmanaged solid wastes with the associated risk to human health is a source of concern. There is also a steady increase in the cost and logistical difficulties of municipal solid waste management. This has put increasing pressures on the infrastructure and authorities responsible for the management of solid waste. Landfill or dump spaces are diminishing and there is difficulty in finding suitable locations and getting public approval. Large investments are required for constructing the new landfill facilities. It is therefore prudent to look for and implement long-term integrated waste management strategies that ensure a sustainable approach for waste management services.

Generally, waste could be liquid or solid waste. Both of which could be hazardous. Liquid and solid waste types may also be grouped into organic, re-usable and recyclable waste.

The goals of an engineered landfill are the;

1. Protection of groundwater quality by minimizing discharge/leakage of leachates from landfill.
2. Protection of air quality and conservation of energy by installing a landfill gas recovery system
3. Minimizing the impact on adjacent wetlands by controlling and diverting or impounding surface runoff

To accomplish these goals, the "ideal" landfill site should be defined in terms of its geologic and hydrogeologic conditions such as deep soils with low hydraulic conductivity and deep occurrence of groundwater. Sometimes nontechnical considerations such as "not in my backyard" but any site located in someone else's town rules (Cameron, 1989)

The Pantang-Abokobi garbage dump operated by Zoomlion LLC; a waste management company, has been operational since 1992 and receives sufficient rainfalls with high infiltration rate due to numerous fractures present in the weathered rocks posing great danger hence this study has been carried out to assess the soil contamination around the local dump area where the municipal solid wastes have been disposed for about 22 years.

Objectives and Scope

The aim of this work was to determine the chemical effects of unengineered landfills on surrounding soils.

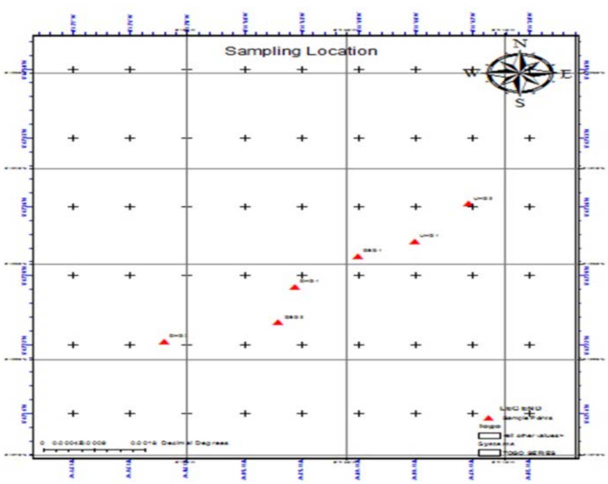
I. Determination of the concentration of some chemical species in the surrounding soil.
II. Determination of whether or not the surrounding soils were contaminated and to what extent.
III. Comparison the concentration of these chemical species to Soiltest farm Consultants Inc. normal concentration range in soils.

To accomplish these objectives, soil sample were taken uphill, downhill and on site at the landfill and were tested in the laboratory.

Study Area

Pantang is a town located in the south-eastern part of Ghana, near the capital Accra. It is about 32 km away from the capital Accra. It lies within Latitude 5.68° and Longitude -0.17°. Second class roads are found within Pantang, making accessibility in the area fairly good. The study area falls within the Ga East district, one of the ten districts of Greater Accra region (www.ghana district.com).

The location of the Pantang garbage dump is shown in the topographical map below (Fig. 1).



Geology of the Site

Pantang falls within the Togo structural unit of the Pan African Mobile Belt. Rocks in the Togo consist of strongly tectonised phyllites, quartzites, and serpentinites trending northeast. (Kesse, 1985). The area

The following objectives were necessary to achieve this,

was covered by laterites which may be as a result of weathering of the exposed rocks of the Togo.

Hydrogeology

Due to the highly consolidated nature of the rocks of the Togo series, groundwater occurrence is limited to areas where fractures and deep seated weathering have occurred which provide ingresses for recharge and groundwater storage. Groundwater occurrence is therefore dependent on the occurrence and pervasiveness of these secondary permeabilities. The success rate of drilling boreholes through the Togo formation is generally high. This is especially so in areas where the weathered zone is sufficiently thick to hold substantial quantities of water. (Yidana et al, 2011).

Methodology

Site Selection

The Pantang garbage dump (Fig. 2) with a surface area of about 2063m² was selected as a case study since it is the principal garbage dump in the Greater Accra Region managed by Zoomlion Ghana Limited.

Leachate typically changes in composition as the material degrades, therefore the age of the garbage dump is an important consideration in determination of the toxicity of leachate at the garbage dump. The selected site has been in place long enough (since 1992) to have possibly affected groundwater and soil beneath and around the garbage dump. The site was chosen due to the fact that it experiences quite considerable amount of rainfall and infiltration rates were sufficient to produce an abundance of leachate which may be present in the surrounding soil.

Sampling Procedure

For purposes of comparison between samples taken uphill, onsite and downhill, six holes to drilled on and around the garbage dump (two drill holes at each location) to give representative experimental data.

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All sampling was done in a straight line at a 50m interval at a depth of 30cm with a hand-held adjustable auger with a hollow base to collect soft sediment from the ground.

The samples were collected in labelled sample bags. These samples were labelled as UH01 and UH02 for uphill samples, OS1 and OS2 for onsite samples whiles the samples from downhill were labelled DH01 and DH02.

Testing of Physical Parameters

The physical parameters such as acidity(pH) (Fig. 3), electrical conductivity (EC) (Fig. 4) and mechanical shaker for 3hrs for testing at the Ecolab and Soil Science Laboratory of the University of Ghana using an AAS. The chemical parameters measured included heavy metals such as Fe, ZN, Pb, Mn, Ni and Cu. Other chemical species tested for included SO_4^{2-}, NH_4^+, % carbon, % Organic matter and Cl^- levels of the soil samples.

temperature of the soil samples were taken and the results are tabulated in Table 1. The pH meter, conductivity meter (Hanna meter) and a digital thermometer were the instruments used for the readings respectively.

Testing of Chemical Species

Properly stored samples for chemical analyses were filtered, the digests and distilled water extracts were then prepared by weighing 10g of soil and mixed with 100 ml of distilled water (10:1 liquid to solid ratio) which was shaked in a

Instruments used for the chemical analyses were Standard turbidimetric method, DR2011 model spectrometer, Flame photometer and Atomic absorption spectrometer (model Perlin Eimer Analyst 400). The results of the chemical analyses are tabulated in tables 3-5.

Results

Table 1. Showing soil condition and results of physical parameters of Soil samples.

	UH02	UH01	OS01	DH01	OS02	DH02
Longitude	-0.195056	-0.196	-0.197	-0.198111	-0.198389	-0.200389
Latitude	5.710083	5.709083	5.708556	5.707667	5.706639	5.706083
Sampling depth (cm)	30	30	30	30	30	30
Soil type	sandy loam	sandy loam	loamy clay	sandy loam	sand	clay
Colour	reddish brown	dark brown	dark brown	yellowish brown	cream	dark brown
Texture	medium grain	medium grain	sticky & medium grain	medium grain	medium grained	very fined grained

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Sample condition	moist	moist	moist	moist	moist	wet
Land use	commercial	residential	garbage dump	residential	garbage dump	residential
pH	5.61	5.7	7.63	3.62	5.41	2.11
EC (uScm^{-1} at 1000)	100	150	290	70	360	390
Temperature (°c)	25.8	25.8	26.1	26.1	25.9	25.9

Table 2. Showing Typical range of concentration in soil (Soiltest farm Consultants Inc.)

PARAMETER	UNITS	TYPICAL RANGE IN SIOL
Nitrate	ppm-N (mg/kg)	2 to 75
Ammonium	ppm-N (mg/kg)	1 to 20
Sulphate	ppm-S (mg/kg)	15 to 150
Organic matter	%	0.1 to 12
Zinc	ppm-Zn (mg/kg)	0.1 to 20
Manganese	ppm-Mn (mg/kg)	0.1 to 40
Copper	ppm-Cu (mg/kg)	0.1 to 10
Iron	ppm-Fe (mg/kg)	0.1 to 100
pH	s.u	5 to 9
Electrical Conductivity	µScm^{-1}	136
Chloride	ppm-Cl (mg/kg)	NA
Nickel	ppm-Ni (mg/kg)	0.000037
Lead	ppm-Pb (mg/kg)	0.000045

NA = Not Applicable

Table 3. Showing AAS readings for Heavy Metals

SAMPLE ID	Iron (Fe)	Zinc (Zn)	Manganese (Mn)	Lead (Pb)	Copper (Cu)	Nickel (Ni)
UH02	1.66	0.576	0.923	0.103	0.061	0.19
UH01	1.649	0.264	0.115	ND	0.186	0.192
OS01	1.662	7.234	3.475	0.162	0.493	0.248
DH01	1.653	0.448	0.185	0.068	0.073	0.178
OS02	1.655	0.577	0.435	0.202	0.113	0.166

DH02	1.654	0.332	0.266	0.005	0.037	0.172

ND = Not Detected

Table 4. Showing mass of Heavy Metals

			MASS OF HEAVY METAL (mg/kg)			
SAMPLE ID	**Iron (Fe)**	**Zinc (Zn)**	**Manganese (Mn)**	**Lead (Pb)**	**Copper (Cu)**	**Nickel (Ni)**
UH02	166	57.6	92.3	10.3	6.1	19
UH01	164.9	26.4	11.5	ND	18.6	19.2
OS01	166.2	723.4	347.5	16.2	49.3	24.8
DH01	165.3	44.8	18.5	6.8	7.3	17.8
OS02	165.5	57.7	43.5	20.2	11.3	16.6
DH02	165.4	33.2	26.6	0.5	3.7	17.2

ND = Not Detected

Table 5. Showing results for Other Chemical compounds

SAMPLE ID	**Carbon**	**% Carbon**	**% Organic Matter**	**Chloride (mg/kg)**	**Ammonium (mg/kg)**	**Nitrate (mg/kg)**
UH02	49	0.3270204	0.56378317	5.99814	727.2	482.4
UH01	47.7	0.53429292	0.921120994	3.99876	633.6	475.2
OS01	35.4	2.49540984	4.302086564	11.99648	583.2	288
DH01	48.2	0.45457272	0.783683369	5.99814	640.8	345.6
OS02	45	0.964782	1.663284168	13.99566	640.8	216
DH02	48.2	0.45457272	0.783683369	15.99504	799.2	266.4

Fig. 3 Variation of pH in soil samples

Standard = 5-9

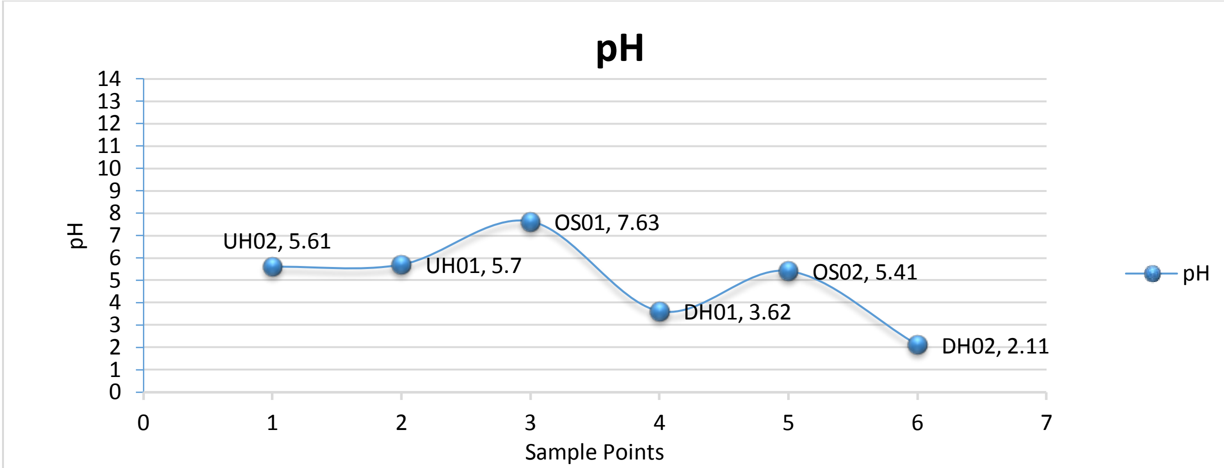

Fig. 4 Variation of EC in soil samples

Standard = 136

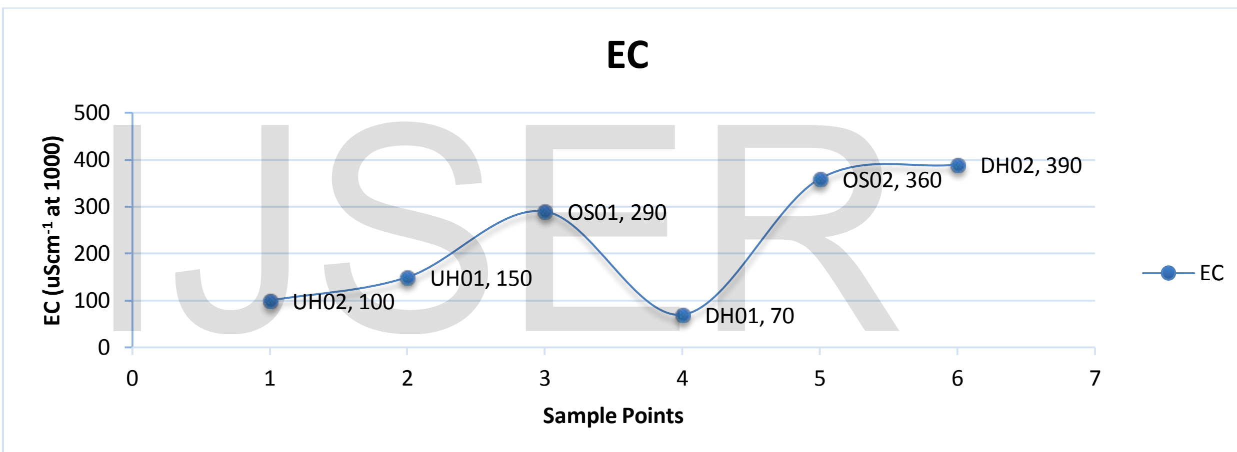

Fig. 5 Variation of Copper concentration in soil samples

Standard = 0.1-10

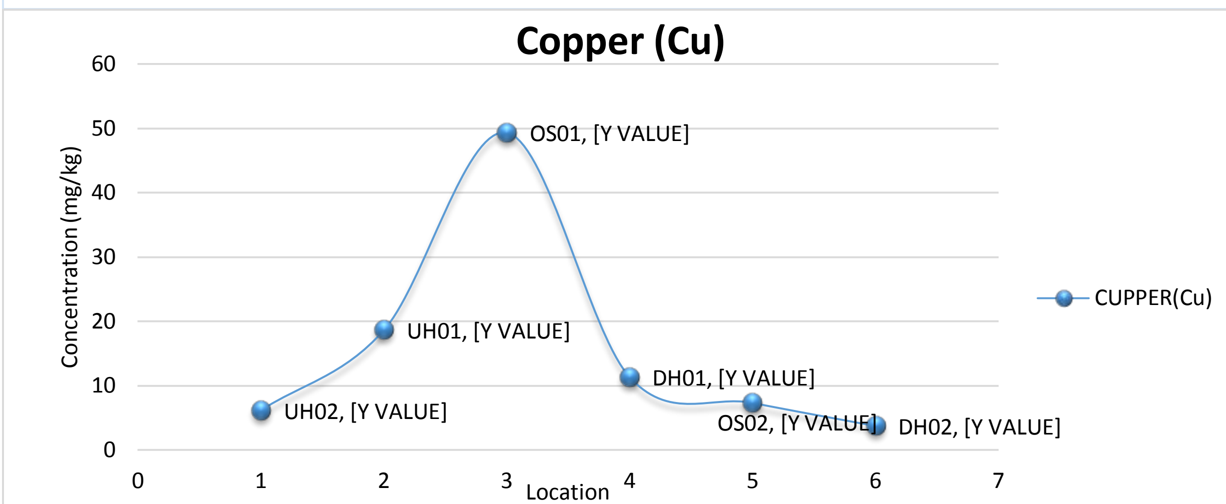

Fig. 6 Variation of Iron concentration in soil samples

Standard = 0.1-100

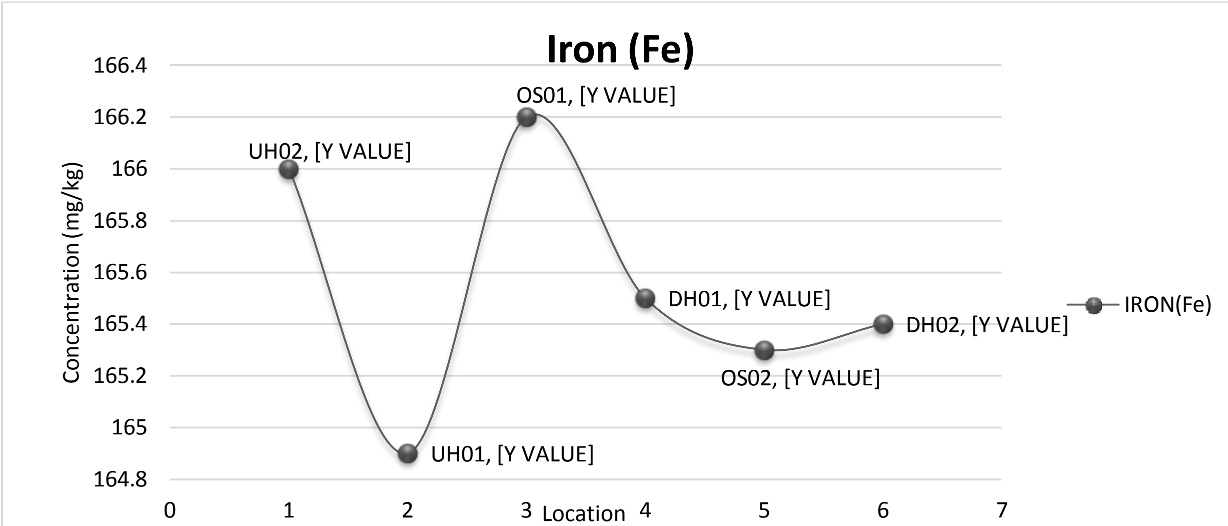

Fig. 7 Variation of Lead concentration in soil samples

Standard = 0.000045

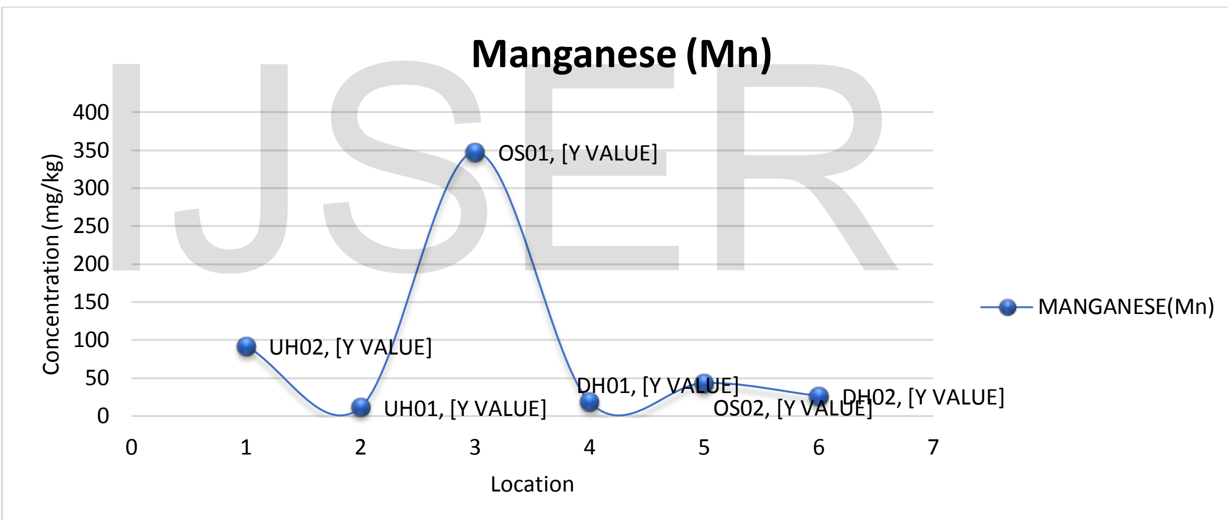

Fig. 8 Variation of Manganese concentration in soil samples

Standard = 0.1-40

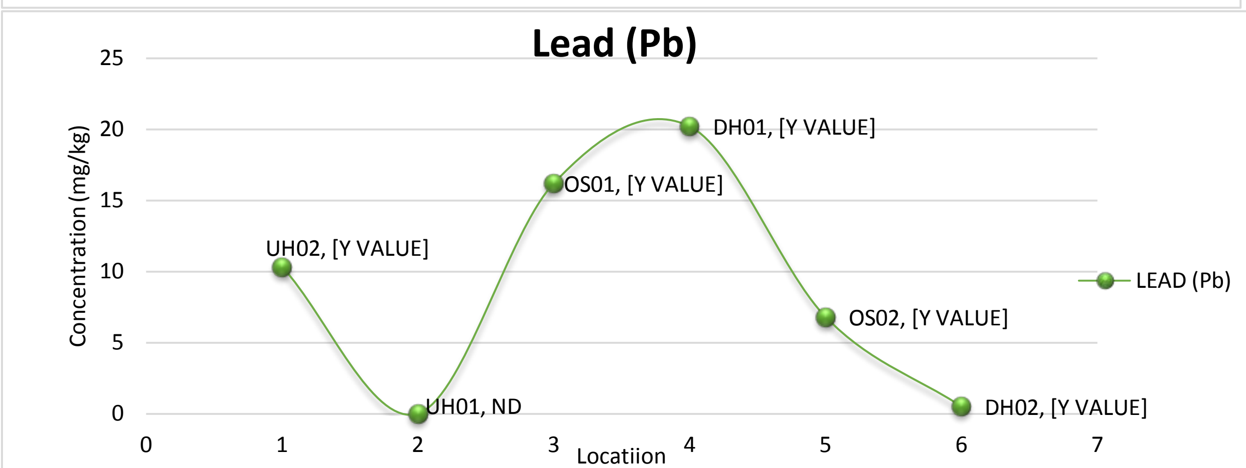

Fig. 9 Variation of Nickel concentration in soil samples

Standard = 0.000037

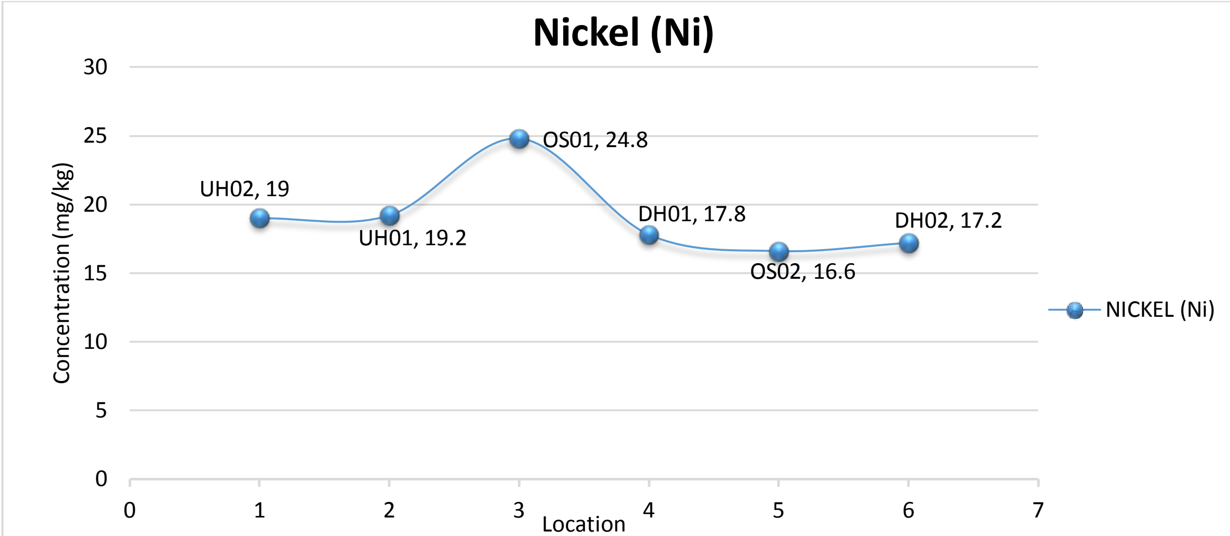

Fig. 10 Variation of Zinc concentration in soil samples

Standard = 0.1-20

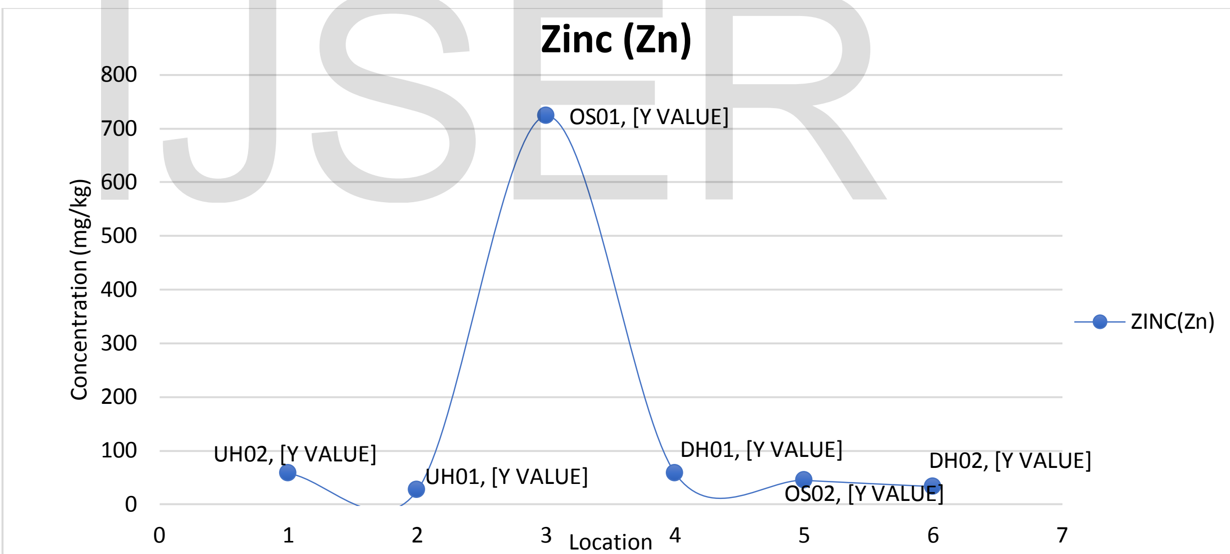

Fig. 11 Variation of Ammonium and Nitrate concentration in soil samples

NH_4^+ Standard = 1-20

NO_3^- Standard = 2-75

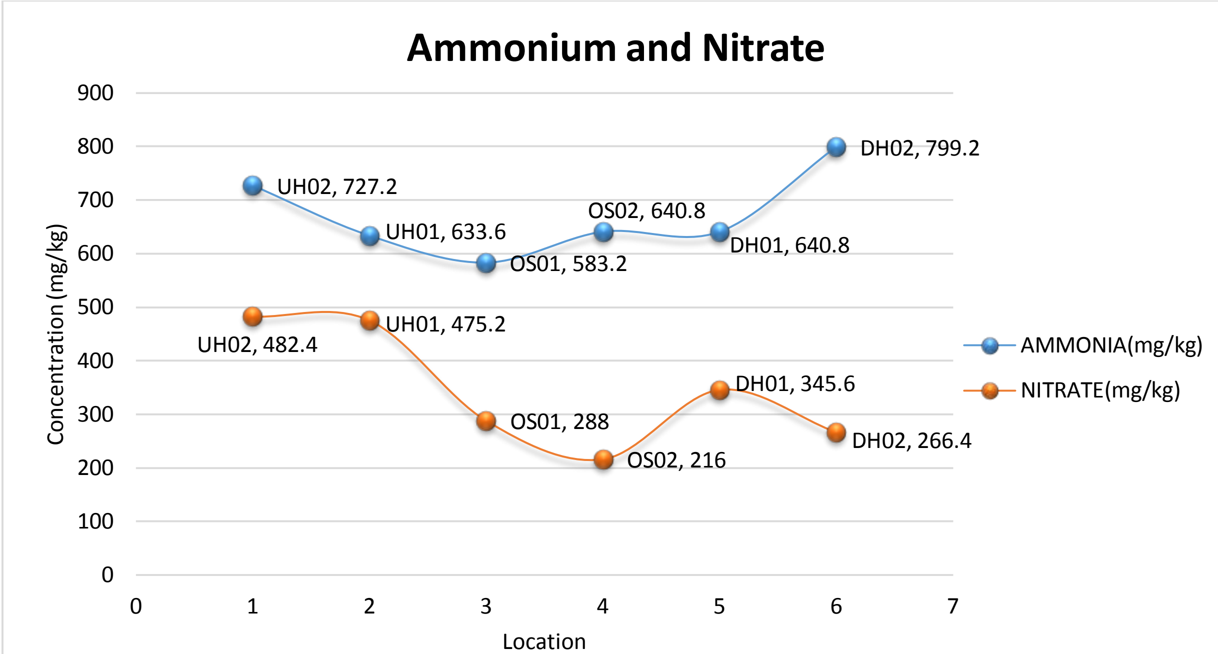

Fig. 12 Variation of Chloride concentration in soil samples

Standard = NA

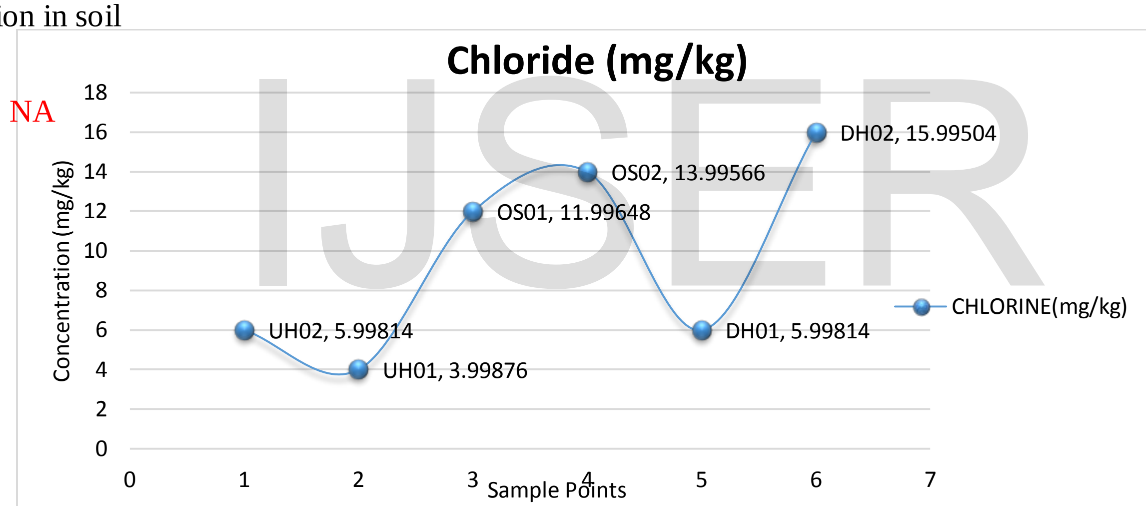

Fig. 13 Variation of percent carbon in soil samples

Standard = 0.1-12

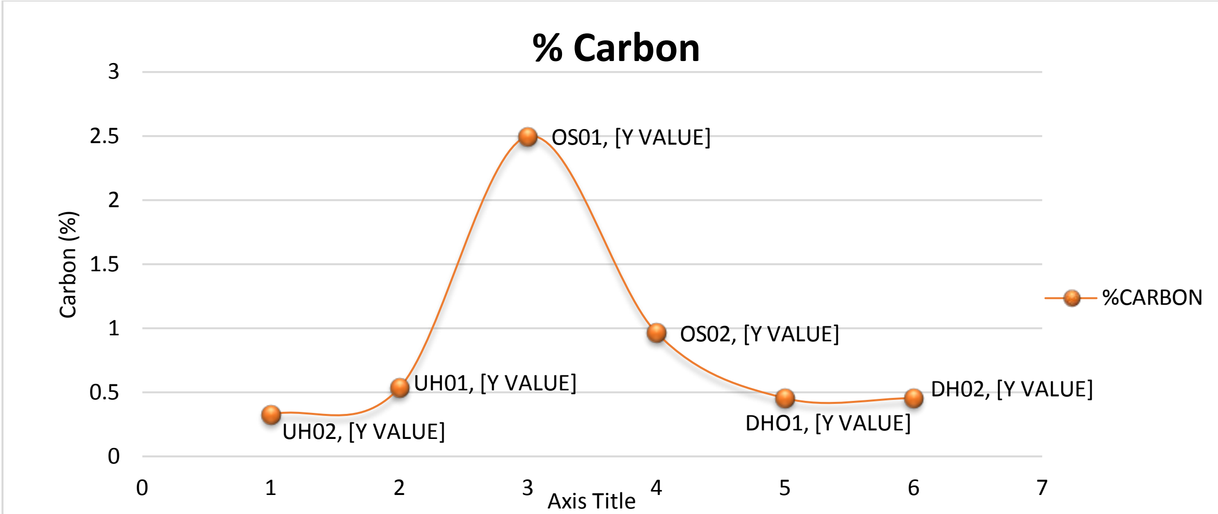

Fig 14. Distribution of Cu in study area

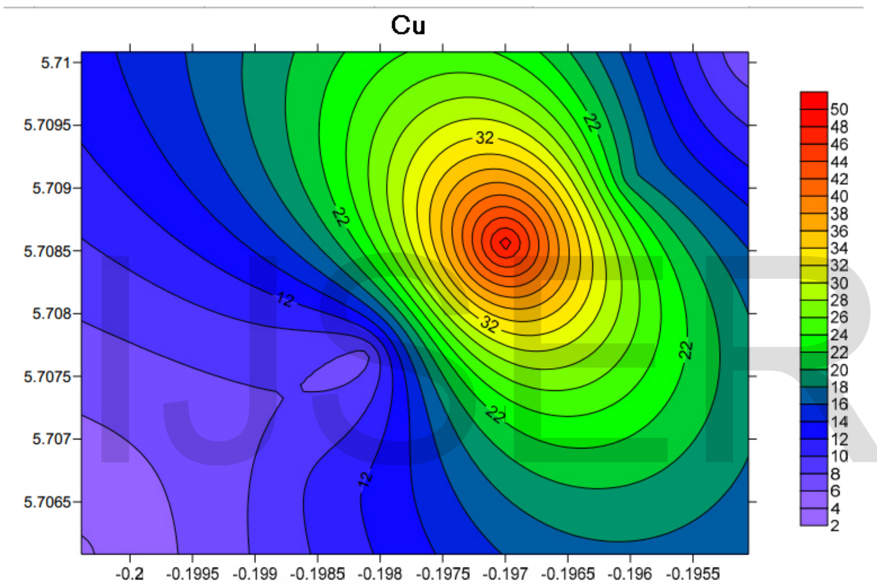

Fig 15. Distribution of Ni in study area

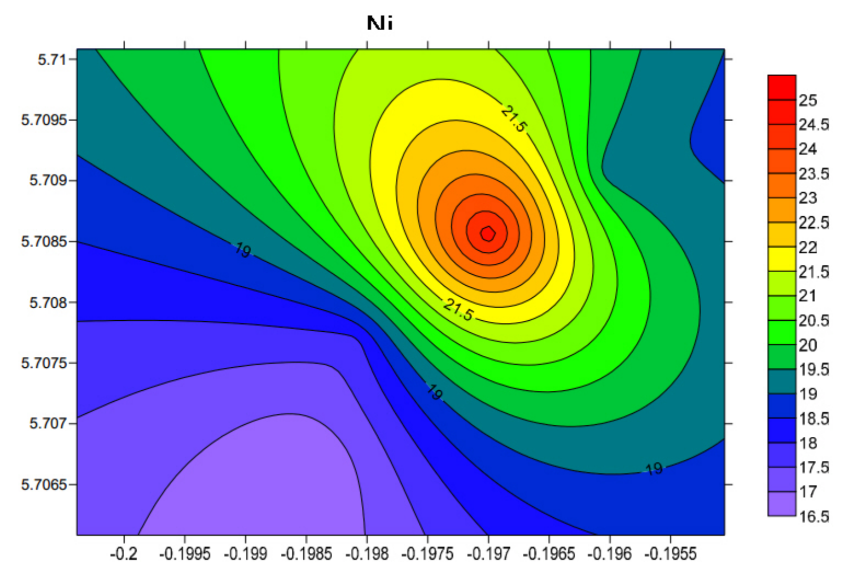

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Fig 16. Distribution of Mn in study area

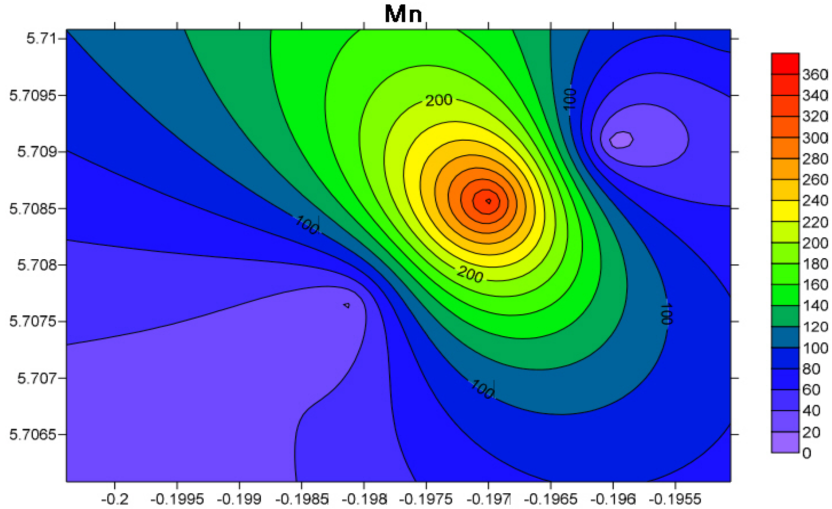


Fig 17. Distribution of Zn in study area

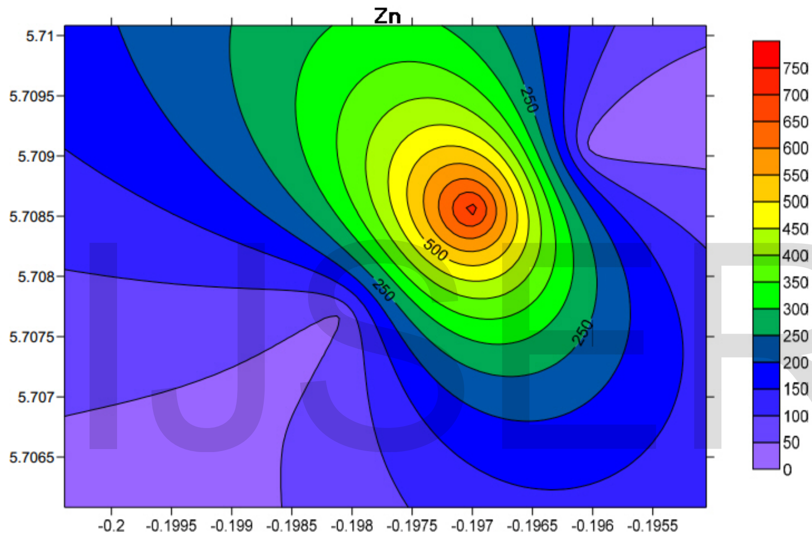


Fig 18. Distribution of Pb in study area

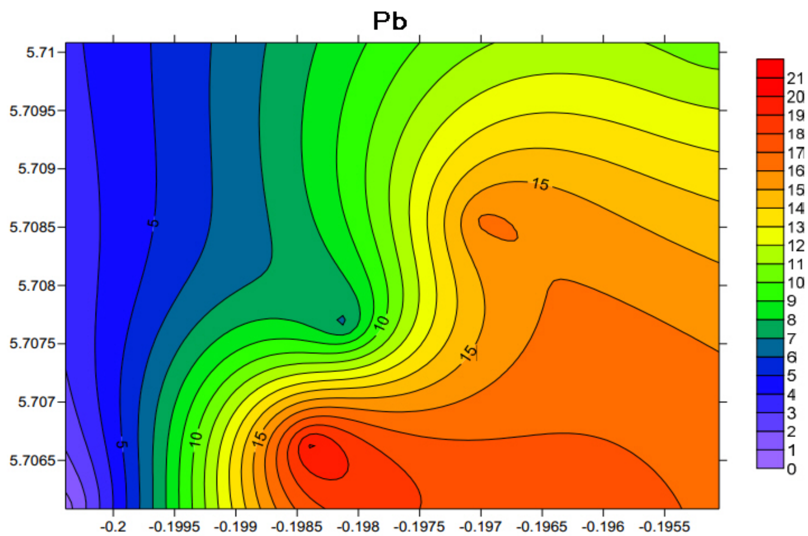
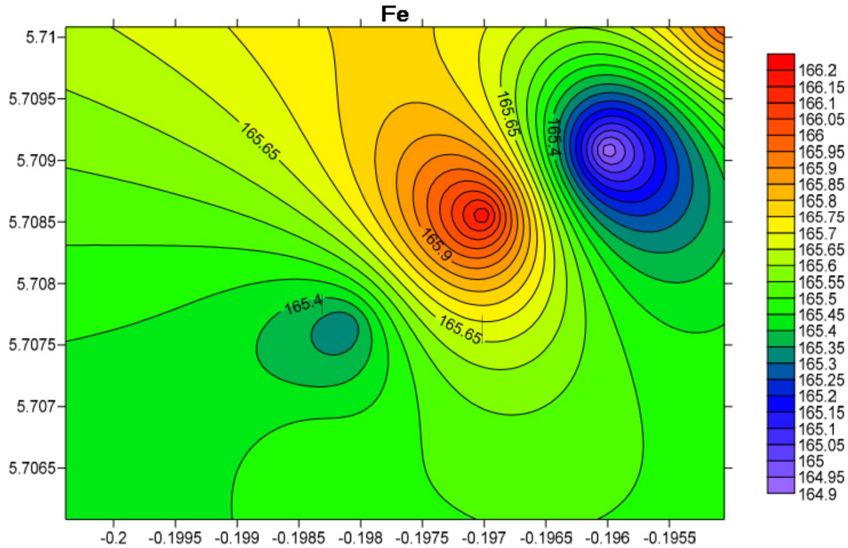


Fig 19. Distribution of Fe in study area



Discussion

Contamination of heavy metals in the environment is of major concern because of their toxicity is a threat to human life and the environment (Purves 1985). Quite an amount of research on heavy metal contamination in soils have concluded that the sources of these are from various anthropogenic sources such as industrial and municipal wastes (Gibson and Farmer 1983; Olajire and Ayodele 1998. In this study, the concentrations of heavy metal present in the collected soil samples were reported in Table 2.

pH Variance

pH is a measure of [H+] and [OH-] in a solution. Thus, acidic soils have the potential to contaminate groundwater making it unsafe.

The soil samples downhill were more acidic probably due to the downhill movement of leachate in the soil through secondary permeability via fractures. Other extraneous factors which could have affected the pH include dissolved CO_2 in rainwater seeping into the ground. The difference in pH of the downhill samples compared to the uphill samples could be as a result of the highly alkaline leachate contaminating surrounding soils by flowing from the landfill to the downhill points.

EC Variance.

Electrical conductivity is proportionally dependent on the amount of mobile cations present in solution. From table 1 and figs. 3 and 4, it is observed that pH and EC have a somewhat inverse relation, in that, the most acidic samples recorded corresponding high values for EC. This could be attributed to the high concentration of metallic ions in the samples due to the downhill movement of leachate in the soil. EC readings increased downhill in the order of magnitude DH01>UH02>UH01>OS01>OS02>DH02. However, the low EC reading at DH01 could be as a result as high lateritic clay soil at the location which did not allow for the seepage of leachate into the subsoil as effectively as the other locations.

Heavy Metals

Heavy metals are typically released by acidic pH. Usually these heavy metals are found at moderate concentration levels in municipal landfill soils (Jensen et al. 1999). The heavy metals detected in distilled water digests were Cu, Fe, Zn, Pb, Mn and Ni.

Uphill Location (UH01 & UH02)

Samples obtained from uphill location showed high concentration levels outside the range expected in typical soils with the exception of Mn (in UH01) and Cu (in UH02). UH02 generally had higher concentration levels that UH01, the low Cu read in the UH02 and Mn read in UH02 could be an indication that the soil at those locations have not been contaminated with regards to these two heavy metals.

Comparatively, the uphill samples had lower concentrations with regards to the other sampling locations within the project.

Onsite Location (OS01 & OS02)

Chemical analysis revealed that both samples were contaminated with values very far above the admissible range for typical soils. Heavy metals readings are consistent with location, due to the presence of garbage dumps on OS01 and OS02. OS02, which was an old garbage dump had lower values compared to the samples from OS01, this could be because, the old sire no longer generates leachate which may contaminate the soil and the leachate produced during its operational lifespan may have possibly leached downward beyond the sampling depth. High values in OS01 are also consistent with the presence of an active and operational garbage dump with no leachate trap

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hence the seepage of leachate into the subsurface.

Downhill Location (DH01 & DH02)

Results for DH01 and DH02 showed values far outside the permissible range of values for heavy metals in soils with the exception of Mn and Cu at both locations which could have been filtered out during leachate movement within the soil. Cu was however high but within the range but too to ignore. These high values in the downhill further suggest that the movement of the leachate contaminating the soil is primarily due to gravity in a downhill motion.

Ni at Study area

The presence of Ni in the study area is of grave concern since it is usually associated with sedimentary rocks. The geology of the study area is one of a metamorphosed terrain. Ni naturally has a strong affinity for Fe which it substitutes for and sometimes occurs as oxides and silicates within lateritic clay soils as a result of prolonged weathering of parent rocks in tropical climates.

Other Compounds

SO_4^{2-}, NO_3^-, NH_4^+, Cl^- and % Organic matter were tested for in the sample collected. SO_4^{2-} and NO^3 are of major concern since construction works are ongoing very close (as close as 5m) to the garbage dump because of their reaction with concrete and cement in construction which turns to weaken structures. Most of these species are found in fertilizers, but their excess in the soil can cause problems.

The concentration of SO_4^{2-}, NO_3^-, NH_4^+ and Cl^- high in the uphill samples. The higher levels in UH01 compared to UH02 could be attributed the presence of a farm close to the sampling point which might have already contaminated the soil with excessive use of fertilizers on the soil. However, OS02 recorded higher values for these chemical species than OS01 as did DH02 than DH01. The concentration of these species are in increasing magnitude of OS01>UH02>DH01>UH01>OS02>DH02. High consistent values for OS02 and DH02 could be associated to their location down gradient to the garbage site and as such the concentration of the species at these locations through gravity movement of leachate.

Percent organic matter levels in all the soil samples were within the typical range in soil.

Conclusion

The indiscriminate disposal of MSW without covering is considered a dangerous practice in integrated waste management at the global level.

The presence of heavy metals (Cu, Fe, Zn, Pb, Mn and Ni) in soil sample indicates that there is appreciable contamination of the soil by leachate migration. This is indicated that the migration and distribution of the contaminants species which may still localized and not diffused with a wide area. Soils immediately around the garbage dump further showed high concentration levels of SO_4^{2-}, NO^{3-} and NH_4^+ than the typical range in soils.

As water infiltrates/percolates downwards into the soil it carries along soluble element dissolved in it. Thus, it could be said that soils below the sampling depth (30cm) might have higher concentration levels of these chemical species due to leaching provided the secondary permeabilities responsible for leachate transport are persistent. This is based on the fact that top soils are prone to leaching. However, there is also a possibility that the concentration of these chemical species may gradually attenuate as they travel deeper into the subsurface as a result of filtration through the soil strata.

Recommendation

From the heavy metal concentration present in the soil samples, it is believed that Pantang open dumping site is going to cause environmental problems in both short and long term and this site should be renewed. Hence, the active dumping site should be closed down immediately and an alternate engineered landfill be constructed.

It is therefore recommended that a capped dumping site (engineered landfill) which makes provision for a leachate collection system and gas monitoring system (Allen 2001) be constructed. The provision of liner in the landfill protects the surrounding environment including soil, groundwater and surface water by containing leachate generated within the landfill, controlling ingress of groundwater and assisting in the control of the migration of landfill gas (Koerner and Soong 2000). Hence, the leachate migration through soil and the obnoxious odor can be avoided. The integrated solid waste management system for open dumping has to be time-honored and new sanitary landfill sites have to be constructed (Banar et al. 2007, 2009).

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