



Soil Quality as Affected by Municipal Solid Waste Dumping

S. A. Nta^{1*}, M. J. Ayotamuno², A. H. Igoni² and R. H. Okparanma²

¹Department of Agricultural Engineering, Akwa Ibom State University, P.M.B. 1167, Ikot Akpaden, Akwa Ibom State, Nigeria.

²Department of Agricultural and Environmental Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. This work was part of author SAN thesis work. Author MJA was a major supervisor. Authors AHI and RHO were co-supervisors. Author SAN did the study design, wrote the protocol, statistical analysis, literature searches, analyses of study, supervisors read and approved the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ASRJ/2020/v3i230067

Editor(s):

(1) Alessandro Buccolieri, University of Salento, Italy.

Reviewers:

(1) Bamidele Martin Amos-Tautua, Niger Delta University, Nigeria.

(2) Dorota Porowska, University of Warsaw, Poland.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/55536>

Original Research Article

Received 14 January 2020

Accepted 21 March 2020

Published 31 March 2020

ABSTRACT

This paper presents soil quality as affected by dumped municipal solid waste. Landfill leachate was collected from a hole dug 10 m away from the waste dump site for laboratory analysis. Soil samples were also collected from four trial pits in the dumpsites at the depth of 0.3, 0.6 and 0.9 m and at a distance of 10, 20, 30 m and the control 100 m away from the dumping site. The collected soil samples were subjected to physiochemical and geotechnical analysis. This includes particle size distribution, pH, EC, total organic carbon, total organic matter, extractable micronutrients and heavy metals (Zn, Cu, Mn, Fe, Pb, Cd, Cr, Cl and Ni), Atterberg limits, specific gravity and hydraulic conductivity. The physicochemical concentration was then compared with the maximum allowable concentrations of chemical constituents in uncontaminated soil. The Laboratory analysis shows high value of pH (8.51) DO (0.17 mg/l), COD (68mg/l), BOD₅ (324 mg/l), Pb (0.31 mg/l) and Cd (0.06 mg/l) in the leachate sample. The physical properties of the soil near the dumpsite indicated that the soil belongs to sandy loam in texture. pH (6.3-8.32), Electrical conductivity (241-2018 μ s/cm), total organic carbon (0.24-2.16%) and total organic matter (0.41-3.73%) were higher near the vicinity of

*Corresponding author: E-mail: samuelnta@aksu.edu.ng;

the dumpsite and decreased with increase in the depth and distance. Extractable micro nutrient and heavy metal concentration (Zn, Cu, Mn, Fe, Pb, Cd, Cr, Cl and Ni) were also found to be high near the dumpsite and decreased along the soil depth and distance from the dumping site. The variance in the geotechnical properties of soil revealed by the test results was impacted by the dumped municipal solid waste. These effects decrease with increase in depth. These findings will help in facilitating the invention and introduction of site specific technologies.

Keywords: Physio-chemical properties of soil; geotechnical properties of soil; leachate; municipal solid waste.

1. INTRODUCTION

Large volume of leachate is generated in the process of breakdown of solid waste. Interactivity of moisture with municipal solid waste lead to the generation of leachate. The composition of municipal solid waste landfill leachate depends on the type of waste deposited at the sites. This composition differs with age, landfill sites and it holds organic matter, inorganic pollutants and unsafe substances [1,2]. Key elements like calcium, potassium, nitrogen, magnesium and ammonia, trace metals like manganese, Cadmium, iron, copper, chromium, nickel, lead and organic compounds like poly-aromatic hydrocarbons, phenols, benzene, toluene, acetone, chloroform are commonly found in leachate from a solid waste disposal site. The concentration of these in the leachate depends on the composition of waste. Leachate produced from such landfill sites present grave environmental risks to the nearby soil [3,4,5]. The chemicals contained in leachate from the landfill may undergo a range of conversion and destruction reactions as they move through the soil and into the primary formations. The efficiency of each soil to weaken leachate is different, and not all elements or compounds are equally removed or reduced in concentration. Most of the pollutants may be adsorbed on to the soil during the process of percolation of the leachate through the soil media [6]. Literature reports had indicated that the index and engineering properties of soil contaminated with landfill leachate, changes due to chemical reactions between the soil mineral particles and the contaminant [7,8,9,10]. Knowledge of the effects of dumped municipal solid waste on the physio-chemicals and geotechnical properties of soil cannot be over emphasized. Therefore, this study was carry out to understand the extent of harmful effects on soil around the municipal solid waste dumping with the aim to determine soil properties of surrounding areas of municipal solid waste dumping sites.

2. MATERIALS AND METHODS

2.1 Location and Climate of the Study Area

This study was carried out at the main refuse dumpsite located on Uyo village road Uyo local government area. The site was engulfed by main gully erosion many years ago and was adopted by the Akwa Ibom State government as erosion control measures to recover the site. The dumpsite receives solid waste from all the communities in Uyo local government area. The dumpsite is over twenty years. Uyo is the capital city of Akwa Ibom State, Nigeria. It's situated at 5.03° North latitude, 7.93° East longitude and 196 meters elevation above the sea level. The average annual temperature in Uyo is 26.4°C. The rainfall here averages 2509 mm.

2.2 Leachate Collection and Analysis

Leachate was collected from a hole dug 10 m away from the municipal solid waste dumping site and characterized for some physico-chemical and heavy metals properties. The methods of analyses for all the parameters in the leachate were in line with American Public Health Association [11] standard recommendation.

2.3 Characterization of Soil Samples

A total of four soil profile samples were collected at a specified distance (10, 20, 30 and control 100 m away) from the boundary of Municipal Solid Waste dumping site and characterized for physio-chemical and geotechnical properties of the soil.

2.3.1 Collection of soil samples

Soil samples at the depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m were collected from each soil profile at a distance of 10, 20, 30 m and the control 100 m away from the dumping site. This

was done in line with [12], which documented that analysis of the upper layers is the key in understanding soil interactions with other environmental compartments and the pathways of pollutants between them.

2.3.2 Determination of soil properties

Analytical methods used for soil samples were chosen based on the parameters of interest. The collected soil samples were air-dried. The air-dried samples were sieved using a 2 mm sieve mesh size to remove debris and stones. The air-dried and sieved samples were used to examine for various parameters. The following parameters were analyzed; particle size distribution, soil pH, EC, organic carbon, organic matter, extractable micronutrients and heavy metals (Zn, Cu, Mn, Fe, Pb, Cd, Cr, Cl and Ni). Geotechnical properties include; Atterberg limits, specific gravity and hydraulic conductivity.

To obtain the particle size distribution of the soil samples, the method suggested by ASTM [13] was used. The soil pH was determined in 1:2:5 soils: water suspensions using digital pH meter with glass electrode [14]. The electrical conductivity of soil was determined using clear extract of soil: water suspension using conductivity bridge [14]. Organic carbon measurement was carried out by the method of Jackson [14]. The organic matter content of the soil was determined using the method of British Standards Institution [15]. The organic matter of the soil was determined as the percentage loss in soil mass when the soil was combusted in a muffle oven. The method developed by Lindsay and Norvell [16] using DTPA extractant

(Diethylene triamine penta acetic acid) was followed for the estimation of Zn, Cu, Mn, Fe, Pb, Cd, Cr, Cl, and Ni. Ten grams' soil was shaken with 20 ml of DTPA extractant for 2 hours for the extraction of micronutrient cations. Atomic absorption spectrophotometer was used for measuring the concentration.

The liquid limit was determined using liquid limit apparatus of ASTM [17]. The plastic limit was carried out using the method of ASTM [17], where a thread of soil was rolled on a glass plate. The specific gravity (Gs) of the soil was determined using the standard pycnometer method [18]. The hydraulic conductivity of the soil was done as per the [19].

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Characteristics and Heavy Metal Properties of Leachate

The data on Table 1 presents the physico-chemical and heavy metal properties of leachate produced by municipal solid waste dumping site.

Table 1. Mean physico-chemical and heavy metal properties of leachate

Details	Leachate
pH	8.51
DO (mg/l)	0.17
COD (mg/l)	68
BOD ₅ (mg/l)	324
Lead (mg/l)	0.31
Cadmium (mg/l)	0.06

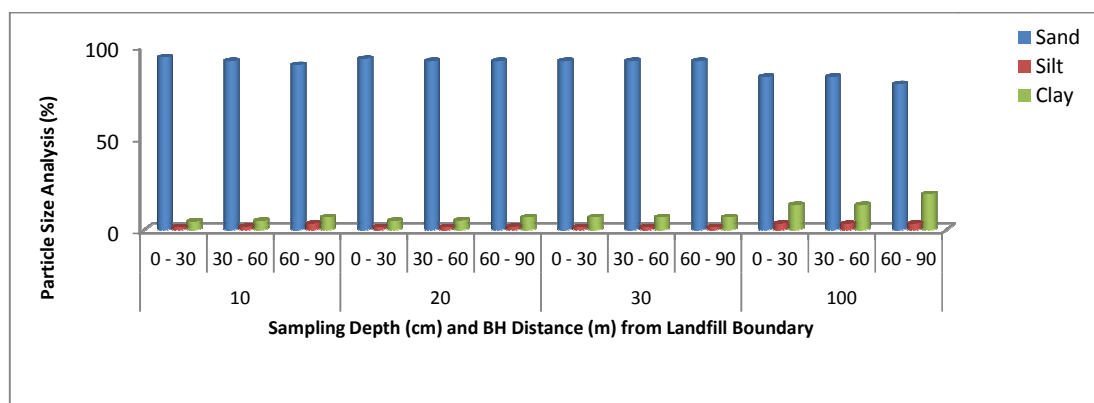


Fig. 1. Variation in particle size analysis with respect to the depth and BH distance from landfill boundary

The pH of the leachate sample determined was 8.51. This is maybe due to the fact that leachates have witnessed washing-away by rainfall or percolated over time into the soil to a large extent. This means that age and kind of waste are the most important factors which affect the composition of leachate. High pH in the leachate specifies low metal solubility where the solubility generally decreases with increasing pH due to the precipitation of metal ions as insoluble hydroxides. The value of dissolved oxygen 0.17 mg/l lower than the permissible limits 2 mg/l was an indication of oxygen depletion in leachate sample, which inferred the presence of pollutants that might have use up oxygen in water. Dissolved oxygen concentrations indicate whether aerobic or anaerobic conditions take place in groundwater, and therefore supply useful information to assess the potential for biodegradation or biotransformation of chemical of potential concern.

The COD in the leachate recorded 68 mg/l. High COD value indicates the high organic strength in the leachate of the dumping site. The BOD₅ of the leachate was 324 mg/l. The high biological oxygen demand value indicates the high organic strength in the leachate of the dumping site. The concentration of Pb in the leachate was 0.31 mg/l. The observation of high level of Pb in leachate is an indication that the unmaintained accumulation of leachates for a long period of time at the landfill base will posed a significant threat to the groundwater quality. The concentration of Cd in the leachate was 0.06 mg/l. The observation of elevated level of Cd in leachate is an indication that the unmaintained accumulation of leachates for a long period of time at the landfill base will posed a significant threat to the groundwater quality. However, the depth of water table on this site is less than 1 m.

3.2 Characterization of Soil Samples

Table 2 gives the physicochemical concentration of landfill soil and the result is compared with the maximum allowable concentrations of chemical constituents in uncontaminated soil as per [20].

3.2.1 Physical properties

The sand fractions recorded 93.8, 91.8 and 89.7% at 10 m distance (profile-1), 93.1, 91.8 and 91.8% at 20 m distance (profile-2), 91.8, 91.8 and 91.8% at 30 m distance (profile-3) and 83.2, 83.2 and 79.2% at 100 m distance

(profile-4) in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m, respectively. The sand fraction was higher at the surface (0 – 0.3 m depth) and reduced with the soil depth at 0.3 – 0.6 and 0.6 – 0.9m in all the profiles. Silt and clay fractions determined were lower in the surface samples (0 – 0.3 m) and increased with increase in the soil depth (0.3 – 0.6 and 0.6 – 0.9 m) in all the profiles. The clay and silt fractions recorded 4.5, 4.8, 6.8 and 1.4, 1.7, 3.4% at 10 m distance (profile-1), 4.8, 5.1 6.8 and 1.4, 1.4, 1.7% in the second profile sample at 20 m distance (profile-2), 6.8, 6.8, 6.8 and 1.4, 1.4, 1.4% at 30 m distance (profile-3) and 13.4, 13.4, 19.4 and 3.4, 3.4, 3.4 percent in the fourth profile sample at 100 m away from the waste dumping site in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m respectively. The result indicates that the soil belongs to sandy loam texture in all the sampling locations. The higher percent of sand fraction in the soils under this study maybe due to the granite type of parent material from which these soils have been derived. Though sandy loam texture was suggested by Loughry [21] as being appropriate for waste disposal sites; soils with greater than 70 per cent sand are extremely inappropriate for waste disposal because they are highly permeable and allow large quantities of leachates to pass through the soil. Agreeing to Nyles and Ray [22] soils with high sand and low clay content have high pollutant leaching potentials. Soils of the dumpsites predominantly contain high sand fractions that may allow high permeability of water and leachates percolation through the soil which may cause surface/ground water pollution.

3.2.2 Soil chemical properties

Results indicate that soil pH varied from 6.3 to 8.32. In profile-1 soil samples the pH in the soil depth 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m recorded 8.32, 8.26 and 8.14 followed by 8.18, 8.17 and 8.14 in the second profile sample (20 m, profile-2) and 7.93, 7.81 and 7.74 in the third profile sample (30 m, profile-3) and 6.9, 6.7 6.3 in the fourth profile (100 m, profile-4). The observed values of pH in the soil samples from the four boreholes (0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m) are within the maximum allowable concentrations of chemical constituents in uncontaminated soil (6.25 – 9) [20].

The dumpsite soils 10, 20 and 30 m lateral distance were alkaline as compared to soil of far off place from the dumping site (100 m upstream). The alkaline nature of the dumping

Table 2. Mean Physico-chemical concentration of landfill soil compared with maximum allowable concentrations of chemical constituents in uncontaminated soil

Parameters	BH1*(@ 10 m)			BH2 (@ 20 m)			BH3 (@ 30 m)			Control (@ 100 m)			IEPA, 2012
	BH1 _A	BH1 _B	BH1 _C	BH2 _A	BH2 _B	BH2 _C	BH3 _A	BH3 _B	BH3 _C	BH4 _A	BH4 _B	BH4 _C	
pH	8.32	8.26	8.14	8.18	8.17	8.14	7.93	7.81	7.74	6.9	6.7	6.3	6.25 - 9.00
TOC (%)	2.16	1.61	1.42	1.80	1.58	1.18	1.40	1.21	1.09	1.55	0.60	0.24	-
TOM (%)	3.73	2.78	2.27	3.11	2.73	2.04	2.42	2.08	1.88	2.67	1.03	0.41	-
EC (μs/cm)	2018	1831	1813	1912	1910	1706	1197	1370	1341	270	268	241	-
Cd (mg/kg)	0.13	0.08	0.05	0.07	0.07	0.05	0.07	0.05	0.04	0.04	0.02	0.02	5.2
Cu (mg/kg)	1.45	0.41	0.23	0.25	0.25	0.23	0.23	0.20	0.19	0.20	0.18	0.14	2900
Pb (mg/kg)	10.27	3.83	2.13	8.81	7.67	3.45	6.87	6.08	3.08	4.11	3.24	2.33	107
Ni (mg/kg)	12.97	8.67	4.92	8.67	3.74	1.55	5.36	4.57	2.84	5.20	3.45	3.27	100
Cr (mg/kg)	1.68	1.18	0.93	1.49	0.65	0.39	1.05	0.89	0.28	0.89	0.30	0.11	21
Zn (mg/kg)	5.43	5.09	4.05	4.57	4.50	4.05	4.37	1.90	1.73	0.74	0.68	0.47	5100
Fe (mg/kg)	104.67	100.67	67.67	96.13	90.07	67.67	94.77	83.87	60.83	1.80	1.61	1.43	15900
Mn(mg/kg)	3.80	3.37	3.07	3.60	3.23	3.20	3.57	3.23	3.17	3.10	2.85	2.60	636
Cl (%)	98	82	77	87	82	80	84	80	77	72	72	67	400
Nitrate (%)	0.644	0.052	0.023	0.506	0.085	0.020	0.157	0.033	0.020	0.137	0.031	0.018	200
Sand (%)	93.8	91.8	89.7	93.1	91.8	91.8	91.8	91.8	91.8	83.2	83.2	79.2	-
Silt (%)	3.4	1.7	1.4	1.7	1.4	1.4	1.4	1.4	1.4	3.4	3.4	3.4	-
Clay (%)	4.5	4.8	6.8	4.8	5.1	6.8	6.8	6.8	6.8	13.4	13.4	19.4	-

BH1, 2, 3, 4 - Bore hole No: 1, 2, 3, 4 at 10, 20, 30 and 100 m lateral spacing and Suffix A, B, C- 0-30, 30-60 and 60-90 cm in each bore hole

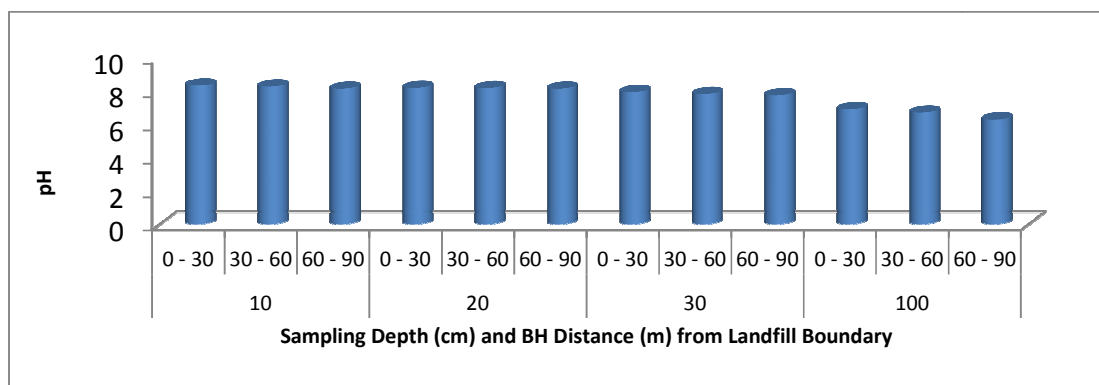


Fig. 2. Variation in concentration of pH with respect to the depth and BH distance from landfill boundary

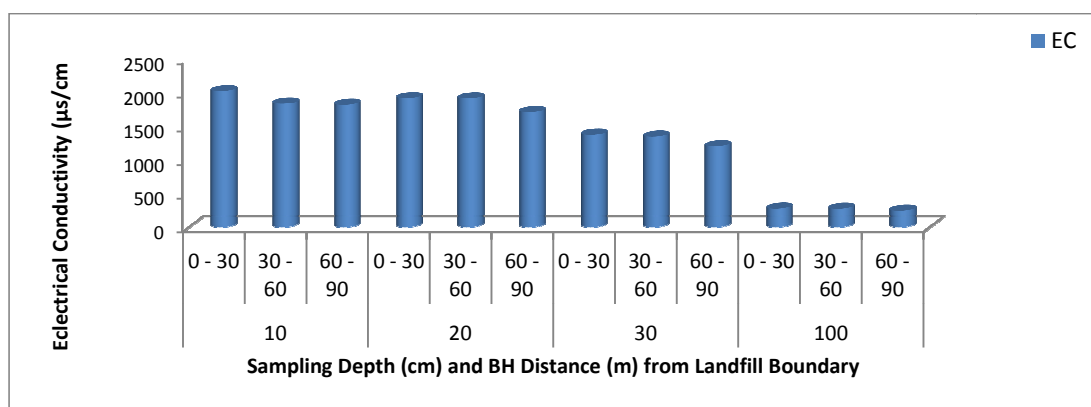


Fig. 3. Variation in concentration of electrical conductivity with respect to the depth and BH distance from landfill boundary.

site soil advocated that the soil samples were contaminated by municipal solid waste having organics which contribute the bases and presence of salts and chemicals that might have increased the pH. Alkaline nature of the dump site soil maybe attributed to more organic matter accumulated on the soils at the municipal solid waste dumping site which on disintegration discharges NH_3 and other bases. Organic colloids attract for positively charged cations also leads to attaining higher pH values. Nta and Odiong [23] reported that either of the extreme pH conditions can affect the survival of plants which has to be modified for specific crops.

The electrical conductivity varied from 241 – 2018 $\mu\text{s}/\text{cm}$ for the soil samples collected around the municipal solid waste dumping site. Electrical Conductivity recorded 2018, 1831 and 1813 $\mu\text{s}/\text{cm}$ at 10 m distance (profile-1), 1912, 1910 and 1706 $\mu\text{s}/\text{cm}$ at 20 m distance (profile-2) and 1370, 1341, 1197 $\mu\text{s}/\text{cm}$ at 30 m distance

(profile-3) and 270, 268 and 241 $\mu\text{s}/\text{cm}$ at 100 m distance (profile-4) in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 90 cm in all the profiles. IEPA [20] did not specify maximum allowable concentrations of chemical constituents in uncontaminated soil. The decrease in electrical conductivity with increase in lateral distances and also decrease with increase in depth may be due to low concentration of salts at a higher depth and distances. Higher electrical conductivity at 10, 20 and 30 m distance advocates that the soil samples were contaminated by municipal solid waste leachate migration.

Total organic matter ranged between 0.41 to 3.73%. Organic matter of the soil samples at the dumpsite (10 m away, profile-1) recorded 3.73, 2.78 and 2.27% followed by 3.11, 2.73 and 2.04% in the second soil profile samples (20 m, profile-2), 2.42, 2.08 and 1.88% in the third soil profile samples (30 m, profile-3) and 1.55, 0.60 and 0.24% in the fourth soil profile samples (100

m, profile-4) in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m, respectively. IEPA [20] did not specify maximum allowable concentrations of chemical constituents in uncontaminated soil. Soil with higher percentage of organic matter retains much higher positively charged ions. The presence of these ions in the moisture filled soil pores will improve soil electrical conductivity as informed by Triantafyllis et al. [24]. The high levels of organic matter present at the surface horizon of the dump sites were accredited to the addition of organic matter through municipal solid wastes which is accountable for increase in organic.

The organic carbon content varied from 0.24 to 2.16%. These results indicate that the organic carbon percent in soils varied from low to high. Highest organic carbon percent was observed in the dumpsite soil (10 m, profile-1) which recorded 2.16, 1.61 and 1.42% followed by 1.80, 1.58 and 1.18% in the second soil profile samples (20 m, profile -2), 1.40, 1.21 and 1.09 percent in the third soil profile samples (30 m, profile-3) and 1.55, 0.60 and 0.24 percent in the

fourth soil profile samples (100 m, profile-4) in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m, respectively. [20] did not specify maximum allowable concentrations of organic matter constituents in uncontaminated soil. Nta and Odiong [23], reported that high organic carbon content present at the dumping site may be due to decomposition of organic matter.

Generally, municipal solid waste holds 50 - 52 per cent organic matter which contributes to very high organic carbon in municipal solid waste dump site than in control site. Also release of exchangeable cations during mineralization of organic matter is liable for higher organic carbon. The high levels of organic matter present at the surface horizon of the dump sites were attributed to the addition of organic matter through municipal solid wastes which is responsible for increase in organic. As the decomposition gets completed, total organic carbon will get lowered. Thus the result showing decrease in total organic carbon as the distance and depth increases is related to the completion of decomposition of waste.

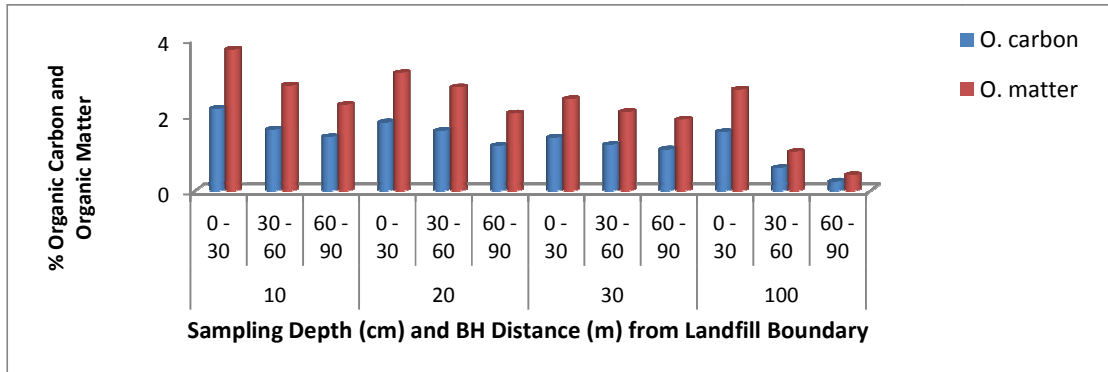


Fig. 4. Variation in concentration of total organic carbon and organic matter with respect to the depth and BH distance from landfill boundary

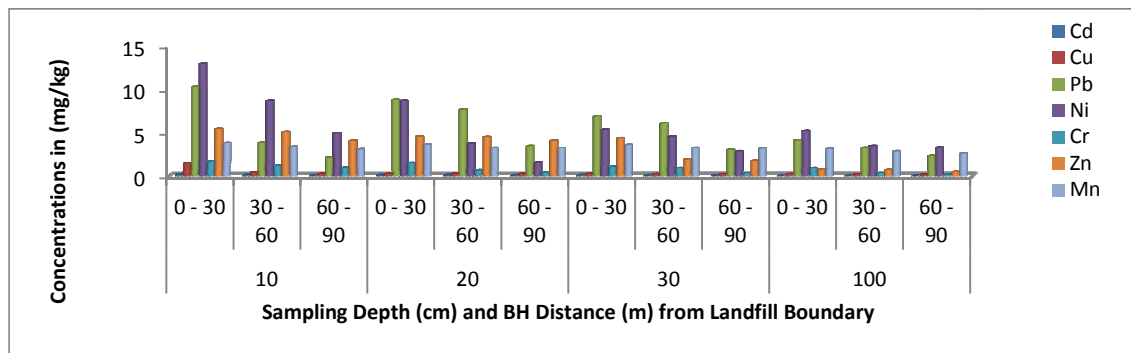


Fig. 5. Variation in concentration of heavy metals with respect to the depth and BH distance from landfill boundary

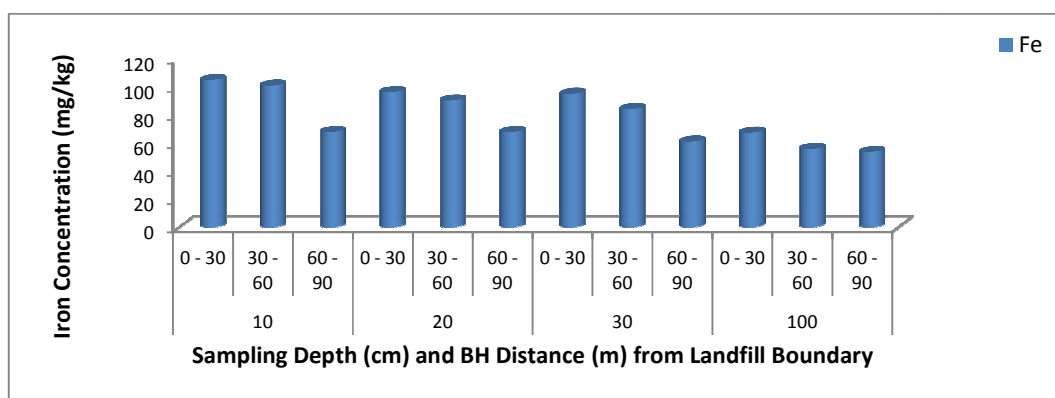


Fig. 6. Variation in concentration of iron with respect to the depth and BH distance from landfill boundary

Cadmium varied from 0.02 – 0.13 mg/kg. Cadmium of the soil samples at the dumpsite (10 m away, profile-1) recorded 0.13, 0.08 and 0.05 mg/kg followed by 0.07, 0.07 and 0.05 mg/kg in the second soil profile samples (20 m, profile-2) and 0.07, 0.05 and 0.04 mg/kg in the third soil profile samples (30 m, profile-3) and 0.04, 0.02 and 0.02 in the fourth soil profile samples (100 m, profile-4) in the depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m respectively. Cadmium is found within the maximum allowable concentration in uncontaminated soil 5.2 mg/kg [20]. The presence of cadmium might be due to the discharge of municipal solid waste at the dumpsites which contain nickel-cadmium batteries, discarded consumer electronic products such as televisions, calculators, stereos and plastics. Similar results were noticed by Izhar et al. [25] where cadmium in the soil samples ranges from 0.4 to 2.1 mg kg⁻¹ with a mean value of 0.75 mg kg⁻¹. Cadmium is a non-essential metal that is toxic even when present in very low concentrations. The poisonous effect of the metal is aggravated by the fact that it has an exceedingly long biological half-life and is therefore retained for long periods of time in organisms after bioaccumulation [26].

Chromium ranged from 0.11 to 1.68 mg/kg. Chromium concentration in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m recorded 1.68 mg/kg, 1.18 mg/kg and 0.93 mg/kg in the soil profile 10 m away from municipal solid waste dumpsite (profile-1) which was found slight higher equated to other soil profile samples. Chromium concentration recorded 1.49 mg/kg, 0.65 mg/kg and 0.39 mg/kg in the second profile soil samples (20 m, profile-2) 1.05 mg/kg, 0.89 mg/kg and 0.28 mg/kg in the third soil profile

samples (30 m, profile-3) and 0.89, 0.30 and 0.11 mg/kg in the fourth soil profile samples respectively. Sources of chromium in the soils could be waste consisting of lead, chromium batteries, coloured polythene bags, discarded plastic materials and empty paint container.

Copper concentration of soil collected 10 m, away (profile-1) recorded 1.45, 0.41 and 0.23 mg/kg in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m respectively, followed by 0.25, 0.25 and 0.23 mg/kg in the second profile soil samples (20 m, profile-2), 0.23, 0.20 and 0.19 mg/kg in the third profile samples (30 m, profile-3) and 0.20, 0.18 and 0.14 mg/kg respectively. Soil particles are strongly adsorbed by copper which result in having low mobility as compared to other trace metals. Due to the low mobility, there are tendency of having accumulation of copper in the soil as shown in this study. Copper was found within the maximum allowable concentration in uncontaminated soil 2900 mg/kg [20].

The maximum allowable concentration of lead (Pb) in uncontaminated soils is 107 mg/kg [20]. Lead concentration varied from 2.13 to 10.27 mg/kg. Lead concentration of soil collected 10 m, away (profile-1) recorded 10.27, 3.83 and 2.13 mg/kg in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 -0.9 m, followed by 8.81, 7.67 and 3.45 mg/kg in the second profile soil samples (20 m, profile-2), 6.87, 6.08 and 3.08 mg/kg in the third profile samples (30 m, profile-3) and 4.11, 3.24 and 2.33 mg/kg in the fourth profile soil samples (100 m, profile-4) respectively. Result of this study as shown in the table show that lead (Pb) decreased with increase in soil depth and distance. High Pb levels in the dumpsite soil

samples may have been facilitated by large disposal of lead-acid batteries, plastics and rubber remnants, printed papers, lead foils such as bottle closures, used motor oils and discarded electronic gadgets including televisions, electronic calculators and stereos at the landfill sites. Though lead concentration on the site is within the permissible limits, it is precarious if permissible to infiltrate towards the groundwater table.

Nickel varied from 1.55 to 12.97 mg/kg in the soil profile samples collected 10, 20, 30 and 100 m away from the municipal solid waste dumpsite and depths (0 – 0.30, 0.3 – 0.6 and 0.6 – 0.9 m). Agreeing to the data, higher nickel concentration was observed in the 10 m distance (profile-1), 12.97, 8.67, 4.92 mg/kg followed by 8.67, 3.74, 1.55 mg/kg in the second profile sample (20 m, profile-2), 5.36, 4.57 and 2.84 mg/kg in the third profile sample (30 m, profile) and 5.20, 3.45 and 3.27 mg/kg in the fourth profile soil samples (100 m, profile-4) respectively. Soil pH is the most important factor for controlling nickel solubility, sorption and mobility with the clay, iron and manganese. The larger part of all nickel compounds that are released to the environment will adsorb to sediment or soil particles and as a result become immobile.

Zinc in the soils collected 10, 20, 30 and 100 m away from municipal solid waste dumping site varied from 0.47 to 5.43 mg/kg. Concentration of zinc in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m recorded 5.43, 5.09, 4.05 mg/kg at distance (10 m, profile-1) followed by 4.57, 4.50, 4.05 mg/kg in the second profile samples (20 m, profile-2), 4.37, 1.90 and 1.73 mg/kg in the third profile samples (30 m, profile-3) and 0.74, 0.68 and 0.47 mg/kg in the fourth profile soil samples (100 m, profile-4) respectively. The presence of high concentration of zinc in the dumpsite soils might be due to zinc residue contained in waste after electroplating, smelting and ore processing dumped at the municipal solid waste dumpsite and also indiscriminate dumping of zinc containing refuse, motor oil, lubricating oil, rubber and tyres, which contain zinc as a portion of many additives such as zinc dithiophosphates.

Manganese varied from 2.60 to 3.80 mg/kg. In the dumpsite profile soil samples (10 m, profile-1) in the depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m, manganese recorded 3.80, 3.37, 3.07 mg/kg followed by 3.60, 3.23, 3.20 mg/kg in the second profile soil samples (20 m, profile-2), 3.57, 3.23

and 3.17 mg/kg in the third profile samples and 3.10, 2.85 and 2.60 mg/kg in the fourth profile soil samples (100 m, profile-4) respectively. The manganese concentration was found to decreased with increase in the soil depth and also with increase in distance from the dumping site and increase in manganese content at the dumping site might be due to release of manganese from organic amendment during decomposition or due to dissolution of native manganese from soil. The major source of manganese in dumpsite soils are batteries, glass, fireworks, fertilizers, fungicides etc. wastes which are dumped. It was found within maximum allowable concentrations of chemical constituents in uncontaminated soil.

Iron varied from 53.43 to 104.67 mg/kg. Iron concentration in the soil depth of 0 – 0.3, 0.3 – 0.6 and 0.6 – 0.9 m recorded 104.67, 100.67, 67.67 mg/kg at 10 m distance (profile-1) followed by 96.13, 90.07, 67.67 mg/kg in the second profile soil samples (20 m, profile-2), 94.77, 83.87 and 60.83 mg/kg in the third profile soil samples (30 m, profile-3) and 67.25, 55.61 and 53.34 mg/kg in the fourth profile soil samples (profile-4) respectively. Iron containing wastes such as lead acid batteries, solder, alloys, cable sheathing, pigments, glass and plastic stabilizers are the major source of iron in dumpsite soils. The iron concentration determined around the municipal solid waste dumping site were found to be the highest among all the heavy metals since it is the most abundant metal in the earth crust and also a source of wastes dumped by electroplating industries at the dumpsite.

3.3 Engineering Properties of Soil Samples

Table 3 gives the engineering properties of collected soil samples.

Liquid limit, plastic limit and plasticity index varied from 36 to 63%, 12 to 24% and 17.3 to 23.7% respectively. In conventional soil mechanics, it is presumed that Atterberg limits remain constant for a given soil, but these properties are subject to change when the pore fluid changes. Liquid limits, plastic limits and plasticity index in this study were found to increase with increase in distance and depth. The changes in Atterberg limits depend on interaction or reaction which happens in soil specific gravity varied from 2.4 to 2.87%. The values of the specific gravity of the contaminated

Table 3. Engineering properties of soil samples

Parameters Location	Specific gravity	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)	Hydraulic conductivity (m/Sec)	
BH1	BH1 _A	2.4	36	12	23.7	1.656×10^{-5}
	BH1 _B	2.5	38	13	21.3	
	BH1 _C	2.6	40	15	20.7	
BH2	BH2 _A	2.78	47	15	22	1.741×10^{-5}
	BH2 _B	2.78	47	16	18	
	BH2 _C	2.8	48	17	17.3	
BH3	BH3 _A	2.82	55	17	22	1.872×10^{-5}
	BH3 _B	2.83	57	19	21	
	BH3 _C	2.83	62	19	20.3	
BH4	BH4 _A	2.86	63	22	22	1.931×10^{-5}
	BH4 _B	2.87	63	22	21	
	BH4 _C	2.87	63	24	20.5	

*BH1, 2, 3, 4- Bore hole No: 1, 2, 3 at 10, 20, 30 m lateral spacing, control 100 m upstream and Suffix A, B, C- 0-30, 30-60 and 60-90 cm in each bore hole

soils were lower than those obtained from the uncontaminated soil. The hydraulic conductivity recorded 1.656×10^{-5} , 1.741×10^{-5} , 1.872×10^{-5} and 1.931×10^{-5} m/sec respectively at 10, 20, 30 and 100 m distance away from the boundary of municipal solid waste dumpsite. The increase in borehole distance and depth reduces the hydraulic conductivity of soil. The engineering and chemical properties of soil is being affected by the solid waste dump as shown in the result. The foundation material may be affected. The percolation of poisonous and precarious chemical result in pollution of the ground water sources.

4. CONCLUSION

The physical properties of the soil nearby the dumpsite indicated that the soil belongs to sandy loam in texture. pH of the soil samples was found to be alkaline on the dumpsite soil. Electrical conductivity was high adjacent the dumpsite and decreased as the sampling distance increased. Organic carbon and organic matter contents were higher near the vicinity of the dumping site and decreased along with soil depth and distance from the dumping site. Extractable micro nutrient and heavy metal concentration (Zn, Cu, Mn, Fe, Pb, Cd, Cr, Cl and Ni) were found to be high near the dumpsite and decreased along the soil depth and distance from the dumping site. The variance in the geotechnical properties of soil revealed by the test results was impacted by the dumped municipal solid waste. These effects decrease with increase in depth. These findings will help in facilitating the invention and introduction of site specific technologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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