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Assessment of Microbial and Heavy Metal Concentration per Distance and Depth at a Municipal Solid Waste Landfill

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ABSTRACT

The field study involved 4 sites and 15 samples according to the wind directions: North, East, South and West. The analysis was conducted through the use of Atomic Absorption spectroscopy (AAS). Ten types of heavy metals were identified as indicators for pollution namely Mg, Ca, Mn, Fe, Cu, Zn, Pb, Ni, Cr, and Cd. The results indicated that the concentration of Fe was the most dominant per specific distances and depths and exceeded the minimum standard in North, East and West directions. While Cu was the second most dominant with concentration exceeding minimum standard per specific distance and depth, mainly in the West direction. The results have shown presence of bacterial species including *Pseudomonas, Mirococcus, Actinomyces, Neisseria, Bacillus and Klebsiella*. These pathogens can infect wounds and cause sepsis and mortality and can even occur with such organisms to cause secondary infection. These groups of organisms are almost impossible to control since they are ubitiquous.

***Keywords*: Heavy metals; land contaminated; open landfill site; bacterial**

1. INTRODUCTION

Soil is a vital resource for sustaining basic human needs, a quality food supply and a livable environment (1). It serves as a sink and recycling factory for both liquid and solid wastes. Municipal solid waste has been found to contain appreciable quantity of heavy metals such as Cd, Zn, Pb, and Cu, all which may eventually end – up in the soil and are leached down the profile (2). This qualifies municipal solid wastes among the principal sources of heavy metals in the environment. Other identifiable sources include atmospheric deposition, manure and fertilizers, pesticides and industrial discharge (3). The concern about these heavy metals is that they are not biodegradable and may therefore accumulate in the environment. Thus, one of the development challenges facing this decade is how to achieve a cost effective and environmentally sound strategies to deal with the global waste crisis facing both the developed and developing countries (4). The crisis has threatened the assimilative and carrying capacity of the earth, which is our life support system. Studies on heavy metals (density >5.54 gcm-3) in ecosystem have shown an indication of a silent epidemic of environmental metal poisoning of ever increasing metals in sub humid tropical soils (5). With increasing pressure on agricultural and the proliferation of urban and peri-urban farming, waste dump sites are becoming attractive because of their rich deposits of organic matter and plant nutrients. Although the nutrient content of wastes makes them attractive as fertilizers, land application of many industrial wastes and sewage is constrained by the presence of heavy metals, hazardous organic chemicals, salts, and extreme pH (6).

Heavy metal pollution is a component of environmental pollutant closely related to human activities. Studies on the pollution have been conducted by various researchers of various fields such as chemistry, biology, geography, engineering and environment. Among studies on the heavy metal pollution were those conducted by (7), (8), and (9). Other than general studies on heavy metal, heavy metal pollution studies also covered various sources of ecosystem such as the aquatic ecosystem (10) and terrestrial ecosystem (11). Studies on heavy metal pollution also combined analysis of specific metal concentration and aspects on management of the sources of pollution. Examples are studies on relationship between heavy metal pollution and its management and specific study on factors influencing distribution, management and control of heavy metal pollution was conducted by (12). Therefore, the objective of this study was to examine the effects of municipal solid waste open dump site on soil physic-chemical properties and therefore to assess the occurrence of microbial pathogens of waste dumpsite per the distance and depth of up to 30 cm from the soil surface around the landfill and discuss its impact on public health.

2. MATERIALS AND METHODS

The location of the dumpsite was at altitude N7°37.064[1], E5°15.134[1] and N7°37.059[1], E5°15.138[1] at the Odo Aremu dumpsite, Ado Ekiti Nigeria. The geology of the area forms a complex pattern of coarse and fined grained gneisses. The soil is derived from material of the old basement complex, which is mainly made up of granitic metamorphosed sedimentary rock. The dumpsites have been existing for over 50 years. The sampling was done in parallel according to the distance from the dumpsite, leading outward with the marked distances of 0, 10, and 20 m, respectively. The soil samplings were taken using Auger instrument and the depth of the soil per soil surface was marked at 0 and 30 cm. 50 g of the soil was taken from each point from the depths and distance prescribed. The soil samples were equally analysed for the following parameters: organic matter, particle size, exchangeable cations, pH and heavy metals content. Soil organic matter was determined, particle size distribution was determined by the hydrometer method using sodium hexametaphosphate as the dispersant, exchangeable bases were extracted with ammonium acetate at pH 7 and the Ca, Na and K contents of the extracts were determined with a Jenway flame photometer while the Ca, and Mg contents were determined using AAS. Heavy metals were extracted using a mixture of 1 ml HNO_3 and 3 ml of HCl (*aqua regia*) and the content heated on a hot plate in a fume cupboard to dryness at 105 °C, allowed to cool and leached with 0.5 M HCl before analysis using a Perkin Elmer Atomic Absorption Spectrophotometer (AAS) as described (13).

2. 1. Microbial Analysis

10 g of five soils from each sample was thoroughly shaken in 10 ml of sterile normal saline. 1.0 ml of soil sample was transferred into the next tube and diluted serially in a one – tenth step wise to 10^{-17} dilution. The organism were isolated and identified using standard Bacteriological methods. Each sample (10 g) of fine soil was thoroughly shaken in 10 ml of sterile distilled water. Aliquot (1.0 ml) of it was transferred into next test – tube and diluted serially in one – tenth stepwise to 10^{-4} dilution. From the dilution of 10^{-3} of each soil sample, 0.1 ml aliquot was transferred aseptically onto freshly prepared dextrose agar plates to which

0.2 ml of 0.5 %. Ampicillin has been added to inhibit the growth of bacteria and allowing the growth of fungi (14). The inoculums were spread with a sterile bent glass rod. The dilution of 10^3 was used in planting for fungi because the dilution of 10^{-4} gave fewer growths. The inoculated plates were inverted and incubated at 28 °C (room temperature) for 5 to 7 days.

The colonies which developed were counted and counts for duplicate cultures were recorded as total viable fungi in the sample.

Geoaccumulation index (I_{GEO}) was use in determining metal pollution in soils following the formula proposed by (15). It is expressed as

$$Igeo = \log2\ Cm/1.5\ Bn \text{ or } \ln (Cn/1.5\ Bn)$$

where:
Cm = Measured concentration at sampling point
Bn = Background concentration value for the element
1.5 = the background matrix correction factor due to lithogenic effects.

The geoaccumulation index consists of seven grades (0-5) ranging from uncontaminated to very highly contaminate (15). These seven descriptive classes are as follows;
<0 = practically uncontaminated
0-1 = uncontaminated to slightly contaminated
1-2 = moderately contaminated
2-3 = moderately to highly contaminated
3-4 = highly contaminated
4-5 = highly to very highly contaminated
>5 = very highly/strongly contaminated

The control samples were taken to represent the background.

Table 1. Description of the site.

Town	Description of Location	Geo-position system (GPS)	Type	Age (years)
Odo Aremu	North	N7°37.062[1] E5°15.134[1]	Domestic, mechanic dumpsite	≥ 30
Odo Aremu	East	N7°37.064[1] E5°15.134[1]	Domestic, mechanic dumpsite	≥ 30
Odo Aremu	South	N7°37.063[1] E5°15.133[1]	Domestic, dumpsite	≥30
Odo Aremu	West	N°37.059[1] E°15.138[1]	Domestic, mechanic dumpsite	≥30

Table 2. Allowable Limits of Metal Concentrations in Soil (mg/kg).

Heavy metal (mg/kg)	Austria	Germany	France	Denmark	Netherlands	Sweden	Spain (pH<7)
Cd	1-2	1	2	0.5	0.5	0.4	1
Cr	100	60	150	30	30	60	100
Co	50	-	-	-	-	-	-
Ni	50-70	50	50	15	15	30	30
Pb	100	70	100	40	40	40	50

Source: ECDGE (2004)

3. RESULTS

3. 1. Concentration of heavy metal in North direction

Table 3 shows the results of the analysis for the concentration of the heavy metals per the distance and depths detected at the site the North direction of the dumpsite. Generally, the concentration of Fe was dominant for all distances and depths compared to other metals. The concentrations per distances for 0 cm, 10 cm and 20c m were respectively at 3973.44, 3058.18 and 2869.12 respectively. The Fe concentration detected exceeded minimum standard this might be as a result of background concentration of Iron. It has been confirmed that natural soils contains significant concentration of iron (16). (17) suggested that the pollution of the environment by iron cannot be conclusively link to waste materials alone but other natural sources of iron must be taken into consideration. The second highest concentration was Cu at 540.13 mg/kg at the depth of 30 cm at 0 m from the landfill. This was caused by soil properties around the north side of station which contained calcite, gypsum and fluorite containing calcium carbonate. For Ni, Cd, Mn, Zn and Pb, the lab analysis indicated that their concentration were very low for every distance and depth.

Table 3. Heavy metal concentration based on distance and depth from landfill (North direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm	Control 0 – 30 cm
Ca (mg/kg)	16.44 ± 0.02	14.75 ± 0.01	11.86 ± 0.02	3.68 ± 0.04
Mg (mg/kg)	22.22 ± 0.02	20.89 ± 0.07	18.14 ± 0.03	1.16 ± 0.01
Na (mg/kg)	21.04 ± 0.01	20.06 ± 0.02	19.35 ± 0.01	1.31 ± 0.03
Pb (mg/kg)	181.00 ± 0.62	128.11 ± 0.01	113.02 ± 0.01	118.72 ± 0.06
Ni (mg/kg)	108.22 ± 0.01	86.58 ± 0.04	64.40 ± 0.01	19.96 ± 0.12
Cr (mg/kg)	116.33 ± 0.11	102.39 ± 0.07	84.22 ± 0.04	8.75 ± 0.01
Cd (mg/kg)	10.16 ± 0.02	10.03 ± 0.01	8.32 ± 0.06	0.10 ± 0.00
Cu (mg/kg)	540.13 ± 0.03	485.80 ± 0.01	219.65 ± 0.03	30.50 ± 0.01
Fe (mg/kg)	3973.44 ± 1.04	3058. 18 ± 2.02	2869. 12 ± 1.04	1593.50 ± 1.02
Zn (mg/kg)	261.36 ± 0.02	180.87 ± 0.03	101.20 ± 0.01	99.25 ± 0.01
Mn (mg/kg)	498.37 ± 0.03	410.14 ± 0.02	384.33 ± 0.03	92.36 ± 0.03
N (cmol/kg)	0.16 ± 0.02	0.11 ± 0.02	0.11 ± 0.01	0.12 ± 0.02

3. 2. The concentration of heavy metal in the east direction

Based on the lab analysis, the concentration of heavy metals in the eastern side showed similar trend per distance and depth as the results for the northern side. The concentration of Fe was found dominant towards the East at 30 cm depth. Table 4 shows the high Fe concentration for all depths per the distances. An example is at 10, the concentration of Fe was at 4236.12 ±2.72 mg/kg. Meanwhile the concentration of Fe at 20 cm exceeded minimum standard. The lab analysis also indicated that the Cu concentration was a little higher compared to Mg, Ca, Mn, Zn and Pb. High Cu concentration was detected at the surface level at distance 0 cm from the landfill (548.80 mg/kg), which exceeded the minimum standard. High concentration of the Cu was due to the presence of electronic wastes such as disused wires in the eastern side of the landfill.

Concentration of Ni was found highest at a distance of 0 cm of soil surface (116.41 mg/kg) and at distance of 10 cm with a depth of 30 cm (98.70 mg/kg). The Ni concentration for both distances exceeded the minimum standard (0.9 mg/kg) set by FEPA. The presence of Ni in the area was influenced by the small scale industrial environment. Hence this condition directly affected the concentration of Ni in the soil. Henceforth, the mean analysis of Mn and Zn indicated that both metals had lowest concentration in the soil. Laboratory analysis indicated that at all depths and distances from the landfill, both heavy metals were weighed less than 1 ml/g.

Analytical results indicated that in the values for Cd, Cu, Cr, Zn, Co and Pb were grossly above the literature levels of a typical soil. The high level for Cu (116.41 mg/kg) conforms to a similar finding where a value of 31.2 mg/kg was reported for Cu in landfill soil in Ibadan in South-West Nigeria (18)

Table 4. Heavy metal concentration based on distance and depth from landfill (East direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm	Control 0 – 30 cm
Ca (mg/kg)	6.64 ± 0.02	6.02 ± 0.03	5.82 ± 0.03	1.12 ± 0.02
Mg (mg/kg)	8.86 ± 0.02	8.11 ± 0.01	6.43 ± 0.01	1.02 ± 0.01
Na (mg/kg)	7.03 ± 0.01	6.70 ± 0.02	6.12 ± 0.02	1.28 ± 0.02
Pb (mg/kg)	179.12 ± 0.12	131.33 ± 0.11	122.12 ± 0	23.42 ±
Ni (mg/kg)	116.41 ± 0.10	98.70 ± 0.12	87.52 ± 0.03	21.12 ± 0.02
Cr (mg/kg))	117.12 ± 0.12	114.81 ± 0.08	94.81 ± 0.11	12.04 ± 0.06
Cd (mg/kg)	11.30 ± 0.02	10.82 ± 0.02	9.14 ± 0.01	0.14 ± 0.01
Cu (mg/kg)	548.80 ± 0.06	501.04 ± 0.22	410.22 ± 0.12	31.25 ± 0.05
Fe (mg/kg)	3871.13± 1.13	4236.12 ± 2.72	4013.15 ± 1.15	1665.30 ± 2.04
Zn (mg/kg)	301.22 ± 0.04	276.16 ± 0.02	242.33 ± 0.03	96.41 ± 0.01
Mn (mg/kg)	221.23 ± 0.03	201.11 ± 0.01	174.83 ± 0.01	90.11 ± 0.01
N (cmol/kg)	0.36 ± 0.01	0.31 ± 0.01	0.28 ± 0.02	0.21 ± 0.02

3. 3. Concentration of Heavy Metal in South Direction

The lab analysis indicated that Cu, Mn and Fe showed highest concentration at all distances and depths. For instance, the concentration of Cu was highest at the distance of 0 cm at the depth of 30 cm (549.72 mg/kg). Compared to distance of 10 m and 20 m, the high concentration of Cu was at 361.24 and 204.11 mg/kg, respectively. The concentration at distance 10 m was higher compared to other distances, this occurred due to the influence of the composition of the soil samples mix. Henceforth, the concentration of Fe was dominant at all distances and depths. Based on Table 5, it shows that Fe concentration at distance of 0cm was higher than any other distances. The trend was similar to the concentration of Cu at 10 m, which was due to the composition of soil samples mix. An instance of concentration at 30 cm depth was 4021.18 mg/kg, the highest concentration of Fe at 10 m and for other distances.

Meanwhile, Pb, Zn and Mn indicated high concentrations compared to other heavy metals for all distances and depth around the landfill site. Even though Cu and Mn showed slight difference of concentration at distance 10m with concentration exceeding 1.0 mg/kg. For Pb, the concentration at 0 cm, 10 and 20 cm depths were respectively at 187.12, 150.22 and 123.15 mg/kg, respectively which is higher than the minimum allowable limit.

Table 5. Heavy metal concentration based on distance and depth from landfill (South direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm	Control 0 – 30 cm
Ca (mg/kg)	16.73 ± 0.03	74.20 ± 0.00	13.14 ± 0.02	3.63 ± 0.01
Mg (mg/kg)	23.62 ± 0.02	19.41 ± 0.03	21.02 ± 0.02	1.21 ± 0.01
Na (mg/kg)	21.58 ± 0.06	18.11 ± 0.03	17.49 ± 0.03	1.36 ± 0.03
Pb (mg/kg)	187.12 ± 0.24	150.22 ± 0.14	123.15 ± 0.35	18.84 ± 0.02
Ni (mg/kg)	112.33 ± 0.11	106.20 ± 0.05	84.32 ± 0.06	19.92 ± 0.02
Cr (mg/kg))	116.95 ± 0.23	95.54 ± 0.16	80.61 ± 0.07	8.93 ± 0.01
Cd (mg/kg)	10.55 ± 0.03	7.33 ± 0.01	6.12 ± 0.02	0.10 ± 0.02
Cu (mg/kg)	549.72 ± 0.24	361.24 ± 0.18	204.11 ± 0.13	30.52 ± 0.06
Fe (mg/kg)	3958.12 ± 3. 22	4021.18 ± 6.28	3814.06 ± 4.02	1593.25 ± 3.15
Zn (mg/kg)	259.74 ± 0.12	197.13 ± 0.03	201.82 ± 0.08	79.70 ± 0.02
Mn (mg/kg)	502.10 ± 0.00	422.12 ± 0.22	301.33 ± 0.11	92.33 ± 0.13
N (cmol/kg)	0.18 ± 0.01	0.11 ± 0.01	0.12 ± 0.01	0.10 ± 0.03

3. 4. Concentration of heavy metals in west direction

The West direction concentration of Fe was consistently high at all distances and depths from the landfill (Table 6). The highest concentration of Fe was detected at distances 0 m and at 30 cm depth, particularly at 0 m distance (4387.52 mg/kg) and 10 m (4263.23 mg/kg), respectively. The concentration of Fe for both samples exceeded the minimum FEPA and allowable minimum standard in some country (4387.52 mg/kg). The effect of Fe occurred due to mechanical work shop process conducted around the landfill site. Meanwhile the Cu showed high concentration at surface level for every distance. The high Cu concentration at 0 m distance (550.92 mg/L) exceeded the minimum allowable standard in some country (Table 2). High concentration of Cu at this distance occurred due to the effect of recycling activities nearby the sampling stations, particularly the disintegration of electronic wastes (Table 6). In contrast, the Mg and Ca concentration was a little higher at distance nearer to the landfill site compared to the farther ones. This occurred due to the influence of drier soil surface nearer to the station vicinity compared to the more watery ones farther outward. The watery condition was a factor which influenced the concentration of the heavy metal for it reduced their viscosity. The metals with the lowest concentration, with less than 10.0 mg/kg were Mg, Ca and Na. Based on Table 6, the laboratory analysis of surface soil around the landfill vicinity for all distances indicated the concentration of Mn to highest at distance 0m and depth 30cm (221.36 mg/kg) which exceeded the minimum standard, set by FEPA.

Table 6. Heavy metal concentration based on distance and depth from landfill (West direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm	Control 0 – 30 cm
Ca (mg/kg)	6.81 ± 0.01	6.08 ± 0.01	5.90 ± 0.02	1.14 ± 0.02
Mg (mg/kg)	8.85 ± 0.03	8.32 ± 0.02	7.11 ± 0.01	1.05 ± 20.3
Na (mg/kg)	7.18 ± 0.02	6.82 ± 0.02	6.21 ± 0.01	1.25 ± 0.01
Pb (mg/kg)	182.05 ± 1.25	144.85 ± 2.20	136.91 ± 1.13	23.68 ± 0.04
Ni (mg/kg)	118.35 ± 0.23	101.22 ± 0.12	89.76 ± 0.06	20.84 ± 0.02
Cr (mg/kg))	115.86 ± 0.08	115.22 ± 0.14	98.11 ± 0.03	12.10 ± 0.02
Cd (mg/kg)	11.62 ± 0.02	11.02 ± 0.02	10.13 ± 0.01	0.16 ± 0.01
Cu (mg/kg)	550.92 ± 1.12	521.30 ± 1.00	426.25 ± 0.32	315.02 ± 0.02
Fe (mg/kg)	4387.52 ± 3.12	4263.23 ± 2.51	3981.51 ± 2.23	1892.43 ± 1.33
Zn (mg/kg)	311.06 ± 0.12	280.32 ± 0.10	251.76 ± 0.16	99.12 ± 0.08
Mn (mg/kg)	221.36 ± 0.04	202.41 ± 0.11	181.14 ± 0.02	87.42 ± 0.04
N (cmol/kg)	0.36 ± 0.02	0.25 ± 0.01	0.23 ± 0.01	0.20 ± 0.00

Table 7. Geo-accumulation index factor based on distance and depth from landfill (North direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm
Ca	1.09	0.98	0.77
Mg	2.55	2.49	2.34
Na	2.37	2.32	2.29
Pb	0.02	-0.33	-0.46
Ni	1.32	1.20	0.80
Cr	2.18	2.05	1.86
Cd	4.23	4.20	4.02
Cu	2.47	2.36	1.57
Fe	0.51	0.25	0.18
Zn	0.56	0.19	-0.39
Mn	1.28	1.09	1.02

Table 8. Geo-accumulation factor based on distance and depth from landfill (East direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm
Ca	1.37	1.28	1.24
Mg	1.76	1.67	1.44
Na	1.30	1.25	1.16
Pb	1.63	1.32	1.25
Ni	1.30	1.14	1.02
Cr	1.87	1.85	1.66
Cd	3.99	3.94	3.77
Cu	2.46	2.37	2.17
Fe	0.53	0.47	0.44
Zn	0.73	0.65	0.52
Mn	0.49	0.40	0.26

Table 9. Geo-accumulation factor based on distance and depth from landfill (south direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 -30 cm	Distance 20 m Depth 0 – 30 cm
Ca	1.12	2.61	0.88
Mg	2.56	2.37	2.45
Na	2.36	2.18	2.15
Pb	1.89	1.67	1.47
Ni	1.32	1.27	1.04
Cr	2.17	1.96	1.79
Cd	4.25	3.89	3.71
Cu	2.49	2.07	1.50
Fe	0.52	0.51	0.16
Zn	0.78	0.50	0.52
Mn	1.29	1.11	0.77

Table 10. Geo-accumulation factor based on distance and depth from landfill (West direction).

Parameter	Distance 0 Depth 0 – 30 cm	Distance 10 m Depth 0 – 30 cm	Distance 20 m Depth 0 – 30 cm
Ca	1.38	1.27	1.24
Mg	1.72	1.66	1.50
Na	1.34	1.29	1.20
Pb	1.63	1.41	1.35
Ni	1.33	1.18	1.06
Cr	1.85	1.85	1.69
Cd	3.88	3.83	3.74
Cu	0.15	0.10	-0.10
Fe	0.44	0.41	0.34
Zn	0.74	0.63	0.53
Mn	0.52	0.43	0.32

The present study shows the types of bacteria and their frequency of isolation from the waste dumpsite in Odo Aremu Ado Ekiti. The bacterial isolated from the dumpsite include the species of fungi identified were *Aspergillus niger, Aspergillus flavus, Aspergillus fumigatus, Penicillium notatum, Mucor pusillus and Fusarium sporotrichioides.*

The bacterial include *Pseudomonas aeruginosa, Escherichia coli, Micrococcus sp, Bacillus megatarium, Chromatium violasceus, Bacillus subtilis, Klebsiella rhinosderomalis, Kurthia zopfii, Clostridium spirogenes, Bacillus licheniformis, Xanthomanas fragenee, Bacillus cereus, Gemella haemolysans* and *Serratia sp.* were isolated from Odo Aremu Ado Ekiti dumpsite.

Table 11. Cultural and Morphological Characteristics of bacterial isolates from the Dumpsites.

Probable Organism	1	2	3	4	5	6	7	8	9	10
Colour	White	White	White	Cream	Grey	Cream	White	Yellow	White	Cream
Surface	Rough	Rough	Rough	Smooth	Rough	Rough	Rhizoid	Smooth	Rough	Smooth
Edge	Rhizoid	Circular	Rhizoid	Entire	Lobate	Lobate	Lobate	Entire	Rhizoid	Entire
Elevation	Flat	Raised	Flat	Flat	Flat	Flat	Flat	Raised	Flat	raised
Shape	Rod	Ovoid	Rod	Rod	Rod	Rod	Rod	Rod	Rod	Rod
Gram stain	+	-	+	-	+	+	+	-	+	-
Catalase	+	+	+	-	+	+	+	+	+	-
Starch hydrolysis	+	+	+	-	-	+	+	-	+	-
Motility	+	+	+	-	+	+	+	-	+	-
Spare	+	-	+	-	-	+	+	-	+	-
Indole	-	-	-	-	-	-	-	-	-	-
Methyl red	+	-	-		+	-	-	-	-	-
Vogesproskauer	-	-	-	-	-	-	-	-	+	-
Glucose	-	A	A	-	A	AG	A	A	A	-
Lactose	A	A	-	-	-	-	A	-	-	A
Mannitol	-	A	A	-	-	A	A	AG	-	A
Galactose	-	A	A	-	-	-	-	AY	A	A
Fructose	A	-	A	A	-	-	-	-	AY	AG
Maltose	A	-	A	-	A	A	AG	A	A	-
Sucrose	AG	A	-	A	-	-	-	-	-	-
Surbitol	A	-	-	A	-	-	AG	-	-	-

Key: + = Positive; - = negative; A = Acid production; AG = Acid and gas production
1 = Bacillus megatarium, 2 = Chromatium violasceus, 3 = Bacillus subtilis, 4 = Klebsiella rhinosderomalis, 5 = Kurthia zopfii, 6 = Clostridium spirogenes, 7 = Bacillus licheniformis, 8 = Xanthominas fragenee, 9 = Bacillus cereus, 10 = Gemella haemolysans

4. DISCUSSION

The study indicated that the concentration of heavy metals around the landfill vary per the sampling stations. Fe concentration was found to be highest at the Northern site, followed by Mg and Ca. Other metals were found only in small concentration. The same was with the Eastern direction, which also showed Fe dominating compared to other metals. Analysis of soil samples in the southern direction indicated an increase in Ca and Fe as metals with the highest concentration. Collectively, the analysis of samples in the West direction, indicated high concentration of heavy metals compared to those in the North and East directions, except for Fe which was the most dominant heavy metals at all sampling stations around the landfill. Geo-accumulation index factor shown in Tables 7, 8, 9 and 10 respectively that the soils were uncontaminated to slightly contaminated by iron, zinc and lead but were moderately contaminated by nickel, and manganese in all the sites. Copper, chromium and cadmium showed generally highly contaminated except in few sites, where they showed high contamination.

All the bacterial isolates reported in this study have been reported to be associated with waste and waste biodegradation. *Bacillus species* were reported by (19), to be associated with waste *Klebsiella species* were also reported to be soil bacterial and they are potential pathogen. The presence of these potential pathogens reported in the present investigation may be attributed to the disposal of raw human faecal discharges and other human wastes at the waste – dumpsite. These observations compares favourably with the study conducted by (20)

5. CONCLUSION

Heavy metal pollution at the landfill is a chronic environmental problem. The pollution not only prevails around its vicinity during its period of operation but may linger on for a long time after the landfill or dumpsite ceased operations. To overcome the problem, the management aspect should be systematic and efficient not only at the early phase of operation but also during and after the landfill is closed from active operation. A regime of actions required to manage the issues of heavy metal pollution require substantial reduction of the waste sources through application of integrated management of waste through reducing generation of wastes at their respective source; recycling, compositing and thermal burning which could reduce the concentration of heavy metal in the wastes.

Finally, a sanitary landfill or dumpsite is a viable alternative to reduce the concentration of heavy metals for its design and water caption pond using High-Density Polyethylene (HDPE) may prevent leachate from seeping into the soil around the landfill and larger environment.

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