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Effect of depth and age on leachate characteristics of Achan Landfill, Srinagar, Jammu and Kashmir, India.

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Abstract: *Periodic monitoring of leachate quality at variable depths(0.3,2.0,5.0 and 60m) at seven different sites was carried out for a period of two years at Achan Landfill site operational from last twenty years. The leachates were monitored for changes in pH, EC, TDS, TSS, HCO_3^-, chloride, Ca^{2+} , Mg^{2+}, Na^+, K^+, phosphorus, nitrogen, BOD, COD, and heavy metals(Cu, Cr, Ni, Zn, Pb,Cd) . Comparing the results the concentration at 2m depth varied significantly among the sites(p<O.5) . Parameters like NO_2,NO_3,NH_4 and TKN showed positive correlation within first three depths i,e 0.3m to 5m while as other parameters like pH, EC, TDS, , HCO_3^-, chloride, Ca^{2+} , Mg^{2+}, Na^+, K^+, BOD, COD, show negative correlation with respect to depth at 2m and other depths except for surface leachate collected at 0.3 m. Regarding the stabilization of the land fill two important indicating parameters viz, BOD_5/NH_4 and BOD_5/COD ranged between 0.002 and 1 and 0.03 to 0.29 which implies that the landfill has attained stabilization. Results revealed that the stabilization of leachate constituents (Inorganic and Organic) correlates well with the age of the dumping site because of well developed methanogenic conditions*
Key Words: *leachate,landfill,BOD,COD and methanogenic*

I. Introduction

The oldest and most widely used method for ultimate disposing of solid waste is Landfilling. It is the most common method for municipal and industrial solid waste disposal (Tchobanoglous et al-1997). Landfills generate significant amount of a highly contaminated liquid called leachate. The composition of the leachate varies widely dependably on waste type and waste age (Christensen et al-1994). Leachate from young sites is much more of a contaminated nature than that of mature landfill. pH moves from slightly acid to neutral, BOD_5 to COD ratio and SO_4 to Cl ratio decreases with the age of landfill (Chian and DeWalle, 1997). Various methods to evaluate the leachate quality variations were reported by EL-Fadel et-al 2002. A technique developed by Kumar & Alappat (2003), quantifies the landfill leachate pollution in terms of leachate pollution index (LPI).A higher value than 7.5 indicates a polluting leachate. LPI is also useful to monitor the leachate trends over the life time of the site.

The paper is aimed to study the leachate characteristic and stabilization at various depths and its impact on ground water quality.

II. Material And Methods

Study Area

The present study was carried out at municipal solid waste landfill at Achan, Srinagar lying between 34^0 09`N Latitude and $74^0$ 79` E Longitude that is being used for last twenty (20)years. Table.1. presents the salient features of the dump site. The landfill in its present state is hazardous to its surroundings because it is neither insulated from the bottom by any liner nor demarcated from the surrounding by any concrete barrier. The runoff from the landfill contributes to the pollution of nearby fresh water Anchar Lake.

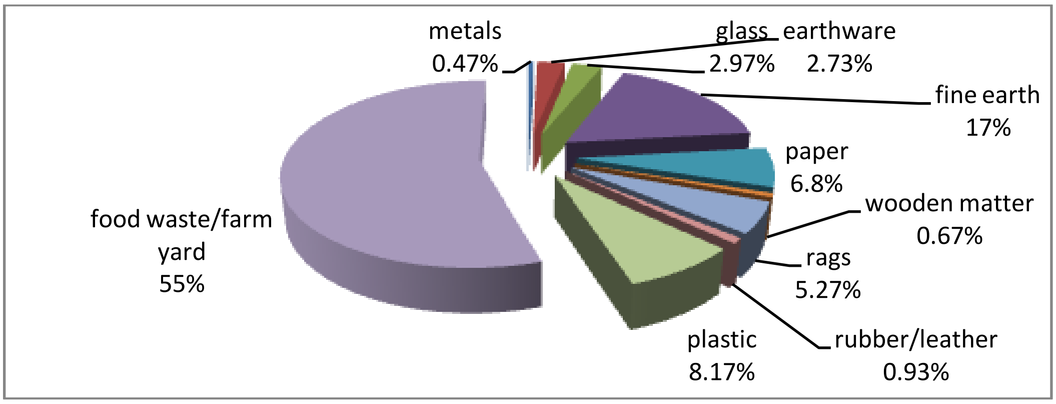
Leach ate Characterization

The samples were collected on monthly basis at variable depth of 0.3 m, 2 m, 5 m, and 60 m from seven different sites of landfill for a period of 2 years in clean bottles with proper labeling as detailed by Elasakku et al, 2006. Leachate characteristics such as pH, TDS, TSS, EC, HCO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, NO^{3-}, BOD_5, COD, and heavy metals (Cu, Cr, Ni, Zn, Pb,Cd) were determined as per standard methods of APHA, 1998.
The data obtained were subjected to stastical analysis employing standard stastical procedures.

Table 1: Site Characteristics of Achan, Saidpora.

Total site area (ha)	13.03 ha
Waste filled area (ha)	Approx. 10.8 ha
Disposal quantity (MT/d)	Approx. 600
Ownership	Srinagar Municipal Corporation
Waste disposal method	Open dumping and leveling by bulldozer
Average depth of waste dump (m)	Approx. 1.5 m
Ground condition	Silty-clay soil
Hydrology	Water table at 7-8 feet (max.)
Age	26 years

Source: *Srinagar Municipal Corporation.*



Source: *Economic Reconstruction Agency,Srinagar,Jammu and Kashmir, 2010.*

Fig.1.Average Physical composition of MSW of Srinagar City

III. Results And Discussions

The mean and ± standard error for each analyte is given in Table 2-7. The graphical representation of the same data is shown in figure 2-7.

Table 2. Physico-chemical characteristics of leachates at various depths.

Parameters	Depths			
	0.30 m	**2 m**	**5 m**	**60 m**
TDS mg/L	3301 ±120	**3414** ±232	2457 ±156	1090 ±133
TSS mg/L	322 ±17	347 ±24	358 ±16	**1639** ±238
HCO^{3-} mg/L	2877 ±407	**3574** ±755	1505 ±82	898 ±66
pH	6.78 ±0.22	**7.62** ±0.15	6.94 ±0.09	7.22 ±0.06
EC	4480 ±221	**4862** ±356	3361 ±278	819 ±88

± represents standard error

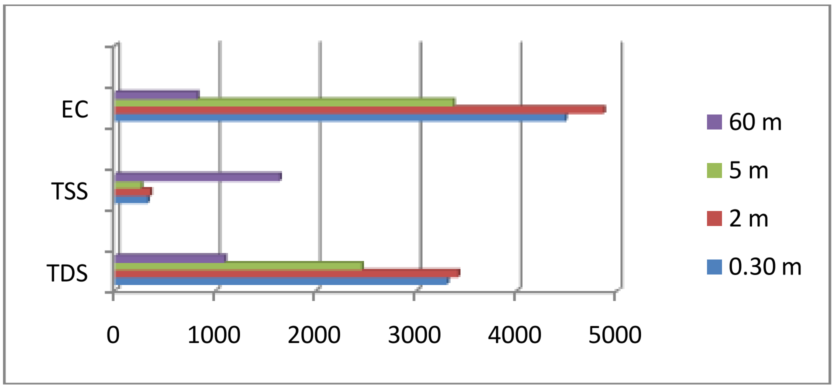


Fig.2.. Physico-chemical characteristics of leachates at various depths

TDS,TSS and BICARBONATES

As evident from Table 2, fig. 2, the mean concentration of TDS decreases with increase in depth from values of 3414 mg/l at 2m to 1089mg/l at 60m ($r=-0.94;r^2=0.88$). The mean values of TSS in contrast to TDS, increases with increase in depth with strong positive correlation ($r=0.99$; $r^2=0.98$).The values ranged from 322mg/l at 0.3m to 1638mg/l at 60m ($p<0.05$) as shown in Table 2 and Fig.2.

Both TSS & TDS increases with increase in precipitation ($r=0.65$; $r^2=0.42$ and $r=0.92$; $r^2=0.85$) as a result of percolation that leaches dissolved and suspended components from the waste through several physical and chemical reactions. These components can further provide adsorptive site for certain chemical and biological agents (Abbas et al., 2009 and Aluko et al., 2003). The decreasing trend of TDS at greater depths may be related to the increase in liquid portion of leachate that tends to accumulate at the base of landfill while losing the solute portion continuously through decomposition, interaction with soil components and distribution processes. Longer time is required for distribution of leached material to reach lower levels (Qasim and Chiang, 1994 and Lu et al, 1985).

Bicarbonates result from the action of CO_2 upon basic materials in solid wastes (Shivahumar et al, 2004).During the study period the overall pattern of bicarbonates was similar to those of TDS, TSS, EC and some ionic pollutants with no significant difference within first 2 meters ($p< 0.05$).

The mean values of HCO_3^- decrease with increase in depth ($r = -0.75$; $r^2 =0.56$) from about 3225mg/l within first 2 meters to 897mg/l at 60m. The mean value of bicarbonates concentration near surface was reduced by about 19.5% compared to concentration at 2m.The bicarbonates also showed direct relationship with precipitation with concentrations increasing with increase in precipitation($r= 0.94$; $r^2= 0.88$).A direct relation between alkalinity and precipitation and our observations are in agreement with the results obtained by Me Bean et al, 1995.

pH and electrical conductivity

The mean pH values at different depths did not show any significant variation. The mean values range from 6.78 at 0.3m depth to 7.6 at 2m depth. The pH near the surface is slightly acidic as compared to other depths. An acidic pH near the surface may be related to the to the oxidation of organic waste by aerobic bacterial (Shivakumar et al., 2004).These conditions are apparently less dominant at greater depths thus contributing to observed alkalinity. The coefficient of variation tends to decrease with increase in depth ($r = -0.70$; $r^2= 0.49$) indicating increase in stability conditions with increase in depth.

The mean values of conductance have decreased from about 4480 μScm^{-1}near surface (0.3m) to 819 μScm^{-1} at 60m ($r = -0.95$; $r^2= 0.9$). The significant differences were observed between the mean values of conductance and depths except within first 2m as observed with TDS and TSS ($p<0.05$). The variation in the conductivity values are related to alterations in ion concentration at different depths.

Electrical conductivity also increases with increase in precipitation($r = 0.98$; $r^2 = 0.96$) as in case of TDS and TSS. These results are in agreement with the results obtained by Karthikeyan et al (2007) who has recorded high conductivity values at the beginning of monsoon period which got reduced drastically due to dilution towards the end of monsoon period.

Ionic Pollutants:

Ionic pollutants like chloride, calcium, magnesium, sodium and potassium showed similar trends of decrease with increase in depth except for first two i,e 0.3m and 2m which showed increasing trend. The observed concentrations for all the ionic pollutants at 2m depth are significantly higher than that at 0.3m ($p<0.5$) as shown in Table 3 and fig.3 .The higher concentration of these ions at the base of waste bed i,e 2 m is in agreement with the findings of Qasim and Chaing et al,1994.

Table 3. Ionic pollutant concentration in leachate in mg/L.

Parameters	Depths			
	0.30 m	**2 m**	**5 m**	**60 m**
Cl^-	624 ±33	**1868** ±175	648 ±51	237 ±42
Ca^{++}	127 ±13	**280** ±26	144 ±15	65 ±8
Mg^{++}	286 ±31	**515** ±37	346 ±34	129 ±13
Na^+	140 ±10.62	**244** ±17.26	154 ±13.3	77 ±11.37
K^+	122 ±14	**636** ±29	283 ±40	33 ±5
PO^{4-}	**37.5** ±3.3	19.14 ±1.9	5.88 ±0.68	1.9 ±0.45

± represents standard error

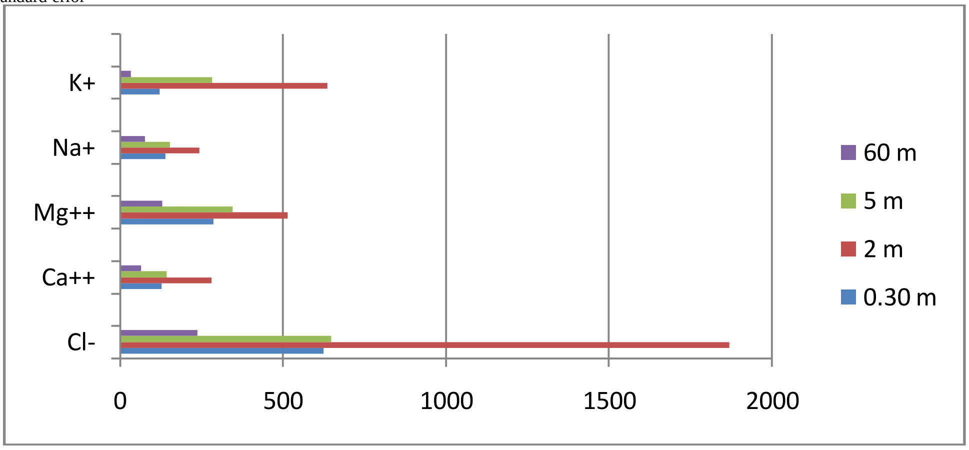


Fig.3.Ionic pollutant concentration in leachate in mg/L.

The observed chloride concentration of leachate are very high with mean concentration decreasing with increasing depth from 1868 mg/l at 2m to 237 mg/l at 60m depth ($r = -0.73$; $r^2 = 0.53$). However, the mean values near the surface (0.3m) were significantly reduced to about 67% than at 2m depth. The coefficient of variation for the analyte also tends to increase with increase in depth. These results are in agreement with that of Chu et al (1994) and Komilis et al (1999).

Similar trends were observed for calcium and magnesium with concentrations of 65 mg/l at 60m and 280mg/l at 2m ($r = -0.80$; $r^2= 0.65$) for calcium and129 mg/l at 60m to 515 mg/l at 2m for magnesium ($r = 0.092$; $r^2= 0.85$). The concentration at the surface (0.3m) show considerable reduction with those at 2m for both calcium (55%)and magnesium (44%).The observed concentration of magnesium was always higher as compared to calcium.The result are in agreement with those of Robinson el al. (2007) and Stuart and Klink (1997) for landfills undergoing methanogenesis.

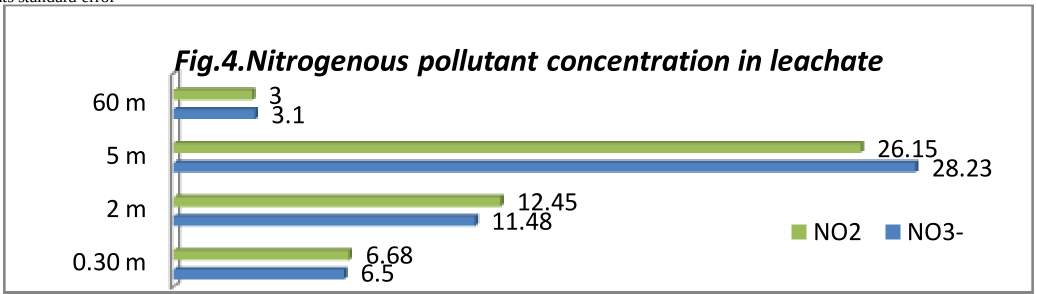
Like Cl^-, Ca^2, and Mg^{2+}, sodium and potassium tends to increase with decrease in depth upto 2m from about 77mg/l at 60m to 244mg/l at 2m ($r = -0.87$; $r^2= 0.75$) for sodium and from about 333mg/l at 60m to about 636mg/l at 2m ($r=-0.84$;$r^2=0.7$) for potassium. The mean concentrations near the surface (0.03m) are significantly lower (43% for Na^+ and about 81% for K^+) than the concentrations at 2m depth ($p< 0.05$). Alterations in concentrations of Na^+ and K^+ may be related to addition of fresh leachate as well as to the continuous washout due to precipitation. Similar observations are on record by Karthikeyan et al., (2007); Qasim and Chiang (1994) and Mor et al., (2006).

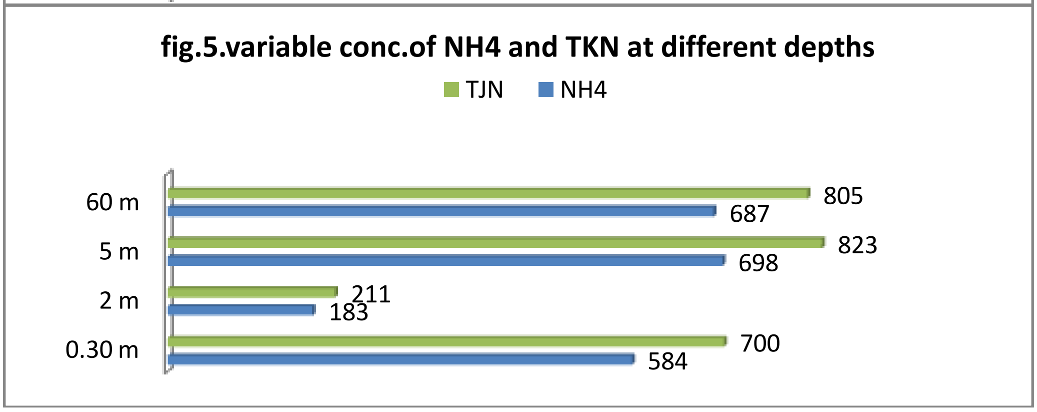
Low concentrations of ortho-phosphates are indicator about the degree of an-aerobics that is predominant in the landfill (Karthikeyan et al., (2007). The mean concentrations of PO_4^- tend to decrease with increase in depth from about 2mg/l at 60m to about 38 mg/l at 0.03m. The change is highly correlated over 0.03m to 5m ($r = -0.97$; $r^2= 0.14$) compared to 0.3m to 60m ($r = -0.64$; $r^2= 0.41$). The coefficient of variation for the analyte tends to increase with increase in depth ($r = 0.99$; $r^2= 0.99$) with significant difference in concentrations between the depths ($p< 0.05$).

Table 4. Nitrogenous pollutant concentration in leachate in mg/L.

Parameters	Depths			
	0.30 m	**2 m**	**5 m**	**60 m**
NO_3^-	6.50 $\pm$0.88	11.48 $\pm$0.7	**28.23** $\pm$2.6	3.10 $\pm$0.3
NO_2	6.68 $\pm$ 0.92	12.45 $\pm$ 0.99	**26.15** $\pm$ 1.75	3.0 $\pm$0.23
NH_4	584 $\pm$55	183 $\pm$17	**698** $\pm$26	687 $\pm$30
TKN	700 $\pm$63.1	211 $\pm$ 29.30	**823** $\pm$ 67.5	805 $\pm$62.0

± represents standard error





Nitrogenous pollutants :

The mean concentrations of NO_3-N show linear decrease with decrease in depth from 28.23 mg/l at 5m to 6.5mg/l at 0.3m (r = 0.99; r^2= 0.98) as illustrated in Table 4,fig.4 and 5.. However, the concentrations at 60m are nearly 50% of the concentration formed near the surface. The mean concentrations vary significantly between the depths ($p< 0.05$).

The increasing trend of nitrate nitrogen concentration, with increasing depth upto 5m may be attributed to the high solubility and good leaching potential of nitrates. Concentrations of NO_3-N are significantly lower than that of NH_3-N, which is in agreement with the observation of Mc Bean et al (1995) and Karthikeyan (2007). This may be attributed to the reducing environment prevailing in the landfill.

The mean concentrations of ammonical nitrogen do not show any correlation with change in depth. The recorded concentrations at 0.03,2.5 and 60m are of the order of 584,183,698 and 687mg/l. Low concentrations of ammonical nitrogen at 2m may be attributed to its low retention due to effect of leaching by precipitation and/or due to its utilization in other chemical or biochemical reactions. This is because aerobic decomposition may occur at and just below the landfill surface (Mc Bean et al., 1995). The concentrations at 2m are significantly lower (72%) than at other depths ($p< 0.05$). However, a positive correlation exists between the mean concentrations with increase in precipitation (r = 0.95 r^2= 0.89).

Ammonia is identified as the most critical pollutant in leachate as its concentration does not change with time (Christensen et al., 1994; Christensen et al., 1999; Hartmann and Hoffmann, 1990; Krumpelbeck and Ehrig, 1999; and Robinson, 1995).However the only known mechanism for its decrease during waste decomposition is washout by precipitation (Robinson, 1995; Burton and Watson-Craik, 1998).

Similarly the concentration of TKN showed same trend as that of NO_3-N and NH_3-N as shown in Table 4.and Fig.4.The mean values of TKN at 0.3,2m,5m and 60 meters were 700 , 211,823 and 805 mg/L with standard error of ± ±63.1, ± 29.30, ± 67.5 and ±62.0 respectively

Table 5. Carbonaceous pollutant concentration ..

Parameters	Depths			
	0.30 m	**2 m**	**5 m**	**60 m**
BOD_5 mg/L.	102 ±7	**138** ±12.37	66 ±5.23	2.62 ±0.28
COD mg/L.	757 ±33	**1234** ±78	530 ±39	58 ±2.32
BOD_5/NH4	0.18 ±0.017	**0.754** ±0.109	0.094 ±0.0075	0.0036 ±0.00048
BOD_5/COD	0.13 ±0.0119	0.111 ±0.00654	**0.124** ±0.0185	0.04 ±0.00408

± represents standard error

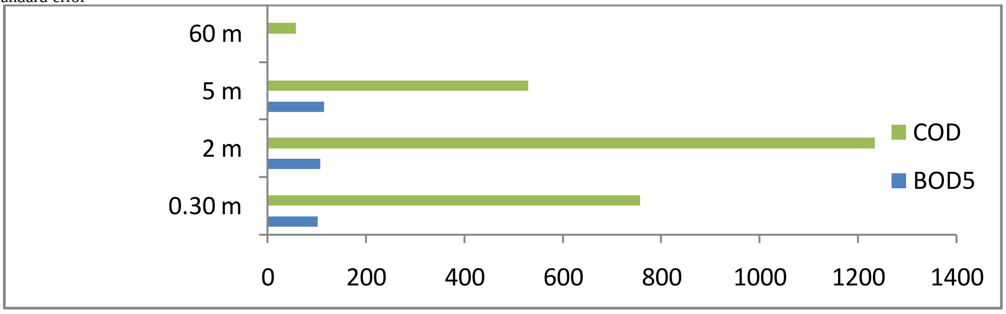


Fig.5. comparative concentration of BOD and COD at different depths

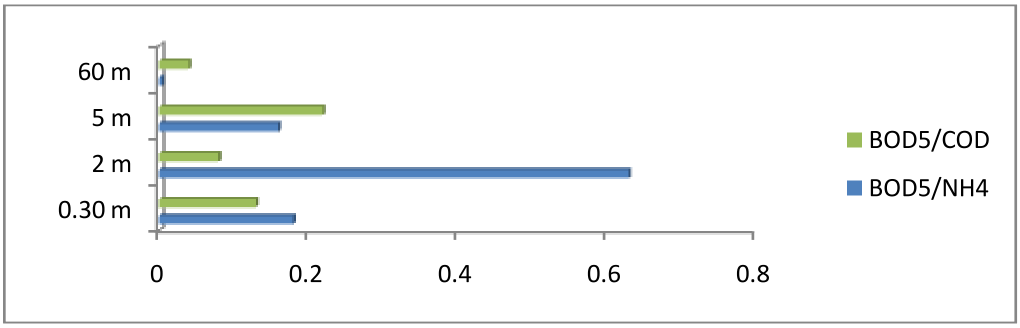


Fig.6. ratios of BOD_5/NH4 and BOD_5/COD at at different depths

Carbonaceous pollutant

BOD and COD are indicative of organic content in leachate and is known to decline with increasing age of landfill (Ehrig, 1989; Mc Bean et al., 1995; Akyurek, 1995; Lee et al., 2010); and Chen, 1996). Relatively lower values of BOD and COD may be attributed to the reduction of organic matter in waste and increased degradation of organic matter (Krug and Ham, 1995; and Lee et al., 2010).

The mean values of BOD_5 were far lower about 1/40th of the concentrations found at deeper depths (60m) compared to other depths ($p< 0.05$).The mean COD values tend to show decrease with increase in depth from 1234 mg/l at 2m to 58 mg/l at 60m ($r= - 0.83$; $r^2 = 0.69$). However, the concentrations near the surface (0.3m) are about 40% lower than those observed at 2m depth that shows significant differences between depths ($p< 0.05$).

Significantly lower values of BOD and COD at 60m depth (97% & 92% respectively) may be attributed to anaerobic or anoxic conditions prevalent at greater depths. Decline in BOD and COD concentrations has also been linked to washout and degradation (Reinhart and Grosh, 1998).

The ratio of BOD_5/NH_4 and BOD_5/COD are an important indicator of the age and stability of a landfill and its leachate. The ratio of BOD_5/NH_4 is generally greater than 1 for younger leachates and closer to 1 or lesser for older leachates. During the studied period the mean ratio of BOD_5/NH_4 ranged between 0.002 and 1,which implies the landfill has attained stabilization. During the study the mean ratio of BOD_5/NH_4 decreases from 0.63 at 2m to 0.04 at 60m ($r= - 0.73$; $r^2= 0.53$). The mean ratios at surface are less than 30% than the levels observed at 2m depths ($p< 0.05$).

Comparing the mean value of BOD_5/COD the ratio show decrease with increase in depth over 0.3,2m and 60m ($r=-0.85$;$r^2=0.7$) while the concentration at 5m depth are unusually highest nearly 81% from the concentration at 60m ($p< 0.05$). The overall mean values differ significantly with respect to depth ($p<0.05$).Our results are in agreement with those of Lee et al.,(2010) and Chain and DeWallace et al., (1997) for mature landfills. Young and unstabilized leachate have a ratio of 0.05 or more and partially stabilized leachates have ratio 0.1to 0.5 while old and stabilized leachates tend to have ratio less than 0.1 (Al Fadel et al., 2002).Our ratios have ranged over 0.03 to 0.29 that reflects the increasing maturity of landfill owing to metanogenesis.these results are in complete agreements with the findings of Jedrezak and Haziak, 1994.

Heavy Metals

Table 5. Heavy metal concentration at variable depths in mg/L

Parameters	**Depths**			
	0.30 m	**2 m**	**5 m**	**60 m**
Ni	BDL	BDL	BDL	BDL
Pb	BDL	BDL	BDL	BDL
Cu	**0.45** ±0.012	0.22 ±0.008	BDL	BDL
Cr	**0.43** ±0.009	0.37 ±0.011	BDL	BDL
Zn	**0.48** ±0.019	0.29 ±0.012	BDL	BDL
Cd	BDL	BDL	BDL	BDL
Hg	BDL	BDL	BDL	BDL

± represents standard error and BDL represents below detectible limits

Heavy metal concentration at all the sites were recorded at below detectible levels except for samples collected at surface i,e 0.30 meters with concentration of O.45,0.43,0.48 for Cu,Cr, and Zn with standard error of ±0.012, ±0.009 and ±0.019.The findings are in correlation to the composition of the solid waste that contains heavy metals in lesser proportions.

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