INFLUENCE OF MSW ON SOIL ENVIRONMENT OF GRA DUMPSITE IN MAKURDI-NIGERIA

Enokela O.S, M.J.Ayotamuno and R.N Opkaranma

Department of Agricultural and Environmental Engineering University of Agriculture Makurdi Nigeria

Department of Agricultural and Environmental Engineering River State University of Science and Technology Port Harcourt Nigeria

ABSTRACT

Municipal solid waste (MSW) was investigated in new GRA dumpsite of Makurdi municipality in attempt to investigate possible influence on properties of subsurface soil. Soil samples from the dumpsites and outside the dumpsite were analyzed for physiochemical characteristics. Ammonia and sulphate were highest in dumpsites due to degradation processes of degradable materials. Higher values of cohesion(17.94KN/m^2), compressibility(1.1m^2/KN) and low coefficient of compaction 0.26 were recorded because of overburden from the weight of MSW and traffic from compaction equipment that bring in the waste giving rise to higher value of liquid limit, friction angle and plasticity index. The consistency limits considered the liquid limits of the studied soils at dumpsite to be 2% higher than that of non dumpsite but fall within the standard range of 20%-90 %. However higher value of friction angle (25.5^0) directly translated to higher value of bearing capacity (qf) of 4122.84 KN/m^3 at dumpsite. The dumpsite is 39% more strength than required therefore stand as good site for landfill development.

Keywords; Municipal solid waste, Dumpsite, soil environment, Hydro and biomechanical characteristics and Makurdi.

INTRODUCTION

Municipal solid waste (MSW) dumpsites must have structural stability that will generally maintain its physical dimensions and its form, under the expected disposal conditions such as weight of overburden and compaction equipment. Structural stability on dumpsites can be provided by the waste form itself. Placing the waste in a dumpsites or structure that provides stability after disposal is paramount. Notwithstanding this provisions, MSW contains little free standing and noncorrosive liquid that contribute significantly to the soil environment at dumpsites. It was reported by Hendron et al.(1999) and Caicedo et al.(2002a) independently that high pore water pressure in an excessively wet waste body were mainly responsible for the instability and failure of the Dona Juana landfill in Bogota, Colombia. Void spaces within the waste and between the waste and its package must be reduced to the extent practicable.

Numerous studies have been previously conducted on the geotechnical properties of landfill in terms of Landfill settlement, failure mechanism and mode of stability (Eid et al., 2000, Stark et al., 2000, Merry et al 2005, Gunn et al., 2013).

However, it is not well understood how MSW affects the dumpsite environments as limited research has been conducted to investigate the geotechnical properties of dumpsites. This study therefore investigated the soil environment in dumpsite and compares the result with the soil environment outside dumpsite.

THE STUDY AREA

New GRA in Makurdi lies between latitude 70° 44' N and longitude 80° 54' E. Owing to its location in the valley of River Benue, it experiences moderate temperatures between 27 °C to 35 °C most of the year. The period from November to January (harmattan weather) is relatively cool as reported in Isikwue and Oyilo,(2010). The overall topography of this province is plain (the slope about 0-2%) and the aquifer groundwater level is low. The soil characteristic of this province is dominated by Makurdi sandstone which is part of the sedimentary basin of Nigeria in the same proportion (Isikwue and Oyilo, 2010) and slightly acidic (pH about 6-4.5). Rainfall characteristics classified the patterns into dry season (low amount of rainfall) in November-April and wet season (high amount of rainfall) in May-October. The average monthly rainfall in dry season and wet season are 17.88 and 120.85mm respectively (Isikwue and Oyilo, 2010).

Figure 1; New GRA Dumpsite

Much of the study area falls within the Benue Valley/trough, which is believed to be structurally developed. During the tertiary and possibly the interglacial periods of the quaternary glaciation, the Benue and Niger Valleys, otherwise known as the Niger/Benue trough, were transgressed by the waters of the Atlantic Ocean. As a result, marine sediments form the dominant surface forms the geology of much of Makurdi (Isikwue and Oyilo, 2010). These sediments have undergone varying degrees of metamorphism as these sedimentary materials are underlained at variable depth by basement complex rocks and the meta-sediments may be more than 20m thick.

MATERIALS AND METHODS

Soil Sampling and analytical procedure

The spot sampling method presented by Ityona *et al.* (2012) was adopted in the sampling of the soil. The spot sampling method requires that equal amount of the samples be taken at different locations within the dumpsite and put together to form a composite sample. Soil profile pits of depths, 0-60cm were dug within and outside the selected dumpsites. Field characterization of the profiles was carried out. The temperature of each sample was taken in situ by immersing the bulb of the thermometer in the soil and the reading in degree Celsius (°C) taken after one minute. The initial dry density were determined using the equations.

$$\rho_i = \frac{M_i}{v_i} \quad (1)$$

$$\rho = \frac{M}{V} \quad (2)$$

$$M = \sum M_i \quad (3)$$

$$V = \sum V_i \quad (4)$$

Where

ρ_i= dry density of component samples
M_i= dry mass of component samples
v_i = dry volume of component samples
ρ = dry density of composite sample
M = dry mass of composite sample

V= volume of composite sample

The samples were preserved in polyethylene bags to the laboratory for physicochemical, mechanical and mineralogical analyses. Soil samples were air-dried for 48hrs at ambient laboratory temperature, sieved with a 2mm mesh according to Allen *et al.* (1974) and subjected to laboratory analysis for determination of hydro-mechanical properties. Compressive strength, tensile strength and bearing capacity which are relevant to design of sanitary landfill as reported by Akpan *et al.* (2013) and Obasi et al.(2015) were evaluated.

Determination of soil Moisture Content

The principle of weighing the loss in mass of the test piece on drying to constant mass was adopted to determine the soil moisture content. The test piece of approximately 30 mm wide, 30 mm long and 10 mm thick was weighed to an accuracy of 0.01g and then dried in an oven at a temperature of 103 ± 2°C in an environment of 33°C temperature and 60% relative humidity. The calculation of the loss in mass as a percentage of the mass of the test piece after drying was carried out using equation (3). Particle size was determined by hydrometer method. pH was determined using glass electrode pH meter. Organic carbon was determined by Walkley and Black method. Exchangeable acidity was determined by titrating 1M of KCl extract. Effective cation exchange capacity was estimated by summing the exchangeable bases.

Determination of the Compressive Strength

The compressive strength of 'Agaraba' was evaluated using the specimen made parallel to the fiber direction. AC162 (2000) test technique was used for the evaluation of the compressive strength properties. The specimens were tested on a universal testing machine of capacity 100kN with a loading rate of 0.9mm/min. The ultimate compressive strength was calculated using the data from the failure load and cross sectional area of the specimens. The ultimate compressive strength for the top, middle and bottom locations of 'Agaraba' were determined by:

$$\boldsymbol{ultC = \frac{FultC}{A}} \quad (4)$$

$$A = \{4[D^2 - (D-t)^2]\} \text{ and} \quad (5)$$

$$\boldsymbol{avg\ ultC = \frac{(ultCT+ultCM+ultCB}{3}}, \quad (6)$$

where:

FultC = maximum load at which specimen failed when compressed (KN);

ultC = ultimate compressive strength of the material (MPa);

ultC T = ultimate compressive strength of the top position (MPa);

ultC M = ultimate compressive strength of the middle position (MPa);

ultC B = ultimate compressive strength of the bottom position (MPa);

avg ultC = average compressive strength of the material (MPa);

A = cross sectional area of the specimen (mm^2);

D = outer diameter of the specimen (mm); and

t = thickness of the specimen (mm);

Determination of the Tensile Strength

The tensile test specimens were prepared to shape with the use of file and surface planer. A 1.5mm thick metal plate was glued to the specimens in order to avoid slip during the test. The ultimate tensile strength for the top, middle and bottom locations of 'Agaraba' was determined by:

$$\boldsymbol{ultT = \frac{FultT}{A}} \quad (7)$$

$$\boldsymbol{A = W \times t, \text{ and}} \quad (8)$$

$$\boldsymbol{avg\ ultT = \frac{ultTT+ultTM+ultTB}{3}} \quad (9)$$

where:

FultT = maximum load at which specimen failed at tension (kN);

ultT= ultimate tensile strength (MPa);

ultT T = ultimate tensile strength of the top position (MPa);
ultT M = ultimate tensile strength of the middle position (MPa);
ultT B = ultimate tensile strength of the bottom position (MPa);
avg ultT = average tensile strength of the material (MPa);
A = cross-sectional area of the gauge length (length of exposed portion of specimen) (mm^2);
W = width of the gauge length (mm); and
t = thickness of the gauge length (mm)

Determination of the bearing capacity of sub surface soil

The evaluation of the ultimate bearing capacity of rough shallow foundations reported by (Das, 2007) was used in calculating the maximum allowable load a subsurface soil in sanitary landfill can sustain for foundations with a depth measured from the ground surface, equal to 3 to 4 times their width. According to Das and Sivakugan, (2007), Terzaghi developed a method for determining bearing capacity for the general shear failure case in 1943 with these equations taken into account soil cohesion, soil friction, embedment surcharge, and self-weight.

For square foundations:

$$q_{ult} = 1.3c'N_c + \sigma'_{cD}N_q + 0.4\gamma' BN_\gamma \quad (10)$$

For continuous foundations:

$$q_{ult} = c'N_c + \sigma'_{cD}N_q + 0.5\gamma' BN_\gamma \quad (11)$$

For circular foundations:

$$q_{ult} = 1.3c'N_c + \sigma'_{cD}N_q + 0.3\gamma' BN_\gamma \quad (12)$$

Where;

$$N_q = \frac{e^{2\pi(0.75-\phi'/360)\tan\phi'}}{2\cos^2(45+\phi'/2)} \quad (13)$$

(29)

$$N_c = 5.7 \text{ for } \varphi' = 0 \quad (14)$$

$$N_c = \frac{N_q - 1}{\tan\phi'} \text{ for } \varphi' > 0 \quad (15)$$

$$N_\gamma = \frac{\tan\phi'}{2}\left(\frac{K_{p\gamma}}{\cos^2\phi'} - 1\right) \quad (16)$$

c' = effective cohesion.
σ_{zD}' = vertical effective stress at the depth the foundation is laid.
γ' = effective unit weight when saturated or the total unit weight when not fully saturated.
B = width or the diameter of the foundation.
φ' = effective internal angle of friction.
$K_{p\gamma}$ is obtained graphically. Simplifications have been made to eliminate the need for $K_{p\gamma}$. one such was done by Coduto as given below and it is accurate to within 10%.

RESULTS AND DISCUSSION

Physco-chemical characteristic of subsurface soil.

The physical appreciation of the physco-chemical properties of the subsurface soils is presents Figure 1, Percentage sand was found to be higher in MSW dumpsite than non dumpsite where as %clay and silt are lower in dumpsite than non dumpsite which could be as a result of higher anthropogenic activities in dumpsite leading to more % of sand. Significant difference was noticed in the concentration of NH_4 and SO_4 which was as a result of biodegradation and biomethanization of biodegradable components of the MSW.

Consistency limit

Consistency means the relative ease with which a soil can be deformed; it has to do with the relationship or interaction between soil and water. The results of the consistency limits test (Tables 1) considered the liquid limits of the studied soils to be above the minimum 20% and are less than the maximum 90 % as standard. Thus the soils are expected to exhibit low hydraulic conductivity and are suitable for landfill development which has been supported by findings of Kabir and Taha, (2004), they reported that soils with high liquid limit generally have low hydraulic conductivity. Liquid limit, Plastic limit and the Plasticity Index are the most useful indicators of engineering behaviour of soils. Declan and Paul (2003) stipulated that the liquid limit of soil liners should be less than 90 %.

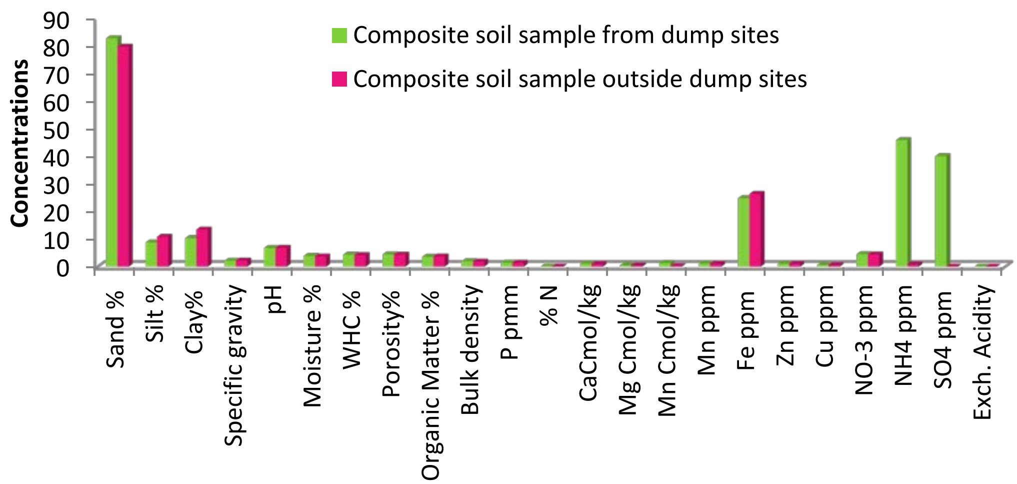

Figure 1; Physico chemical characteristics of dumpsite soil

Compressive Strength

Mohr circle diagram of triaxial compression test at consolidated pressures of 0-210 kN/m^2 , compressive strengths of 186kN/m^2 - $360KN/m^2$ and moisture content of 40 – 100% presented the cohesion of 17.94KN/m^2 and 13.38KN/m^2 and angle of internal friction of 25.5^o and 20^o for dumpsites and outside dumpsites respectively. These indices were used for the determination of bearing capacity and factor of safety for the GRA dumpsites using equation (11).

Bearing Capacity

The result of the bearing capacity (Table 1) indicated 4122.84KN/m^3 for the dumpsite attesting to the highest value of compressive strenght. Lower value of C, K, Cv because of over burden from the weight of MSW and traffic from compaction equipment that bring in the waste giving rise to higher value of LL, FI and PI. C is lower in dumpsite because of anthropogenic activities of microbes, however higher value of FI directly translated to higher value of bearing capacity at dumpsite. The dumpsite is 39% more strength than required, it stand as good site for landfill development.

Table1. Mechanical characteristics of soil within and outside dumpsites (0 – 60 cm depth).

Property	Outside dumpsite	within dumpsite
MDD(g/m^3)	1.64	1.94
OMC(%)	12.53	14.54
LL(%)	24.04	26.01
PL(%)	15.20	13.26
PI(%)	16.8	18.04
K(m/s)	0.15	0.07
C(KN/m^2)	13.38	17.94
C_V	0.77	0.26
M_V(m^2/KN)	0.43	1.10
FI	20.00	25.52
qf(KN/m^3)	3211.00	4122.84

Maximum dry density(MDD), Optimum moisture content(OMC), Liquid limit(LL), Plastic Limit(PL), Plasticity index(PI), Coefficient of permeability(K), Consolidation(C_V), Compressibility(M_V), Cohesion(C) and Angle of internal friction(F_I).

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