International Journal of Environmental Science, Management and Engineering Research Vol. 1 (5), pp. 204 - 210, Sept. - Oct., 2012
Available online at http://www.ijesmer.com

EFFECT OF MUNICIPAL SOLID WASTE ON GEOTECHNICAL PROPERTIES OF SOILS

Musa Alhassan

Department of Civil Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria
Correspondence to: alhassankuta@yahoo.com

Accepted 28th September, 2012

ABSTRACT

The paper presents results of laboratory investigation of the effects of municipal solid waste on the geotechnical properties of soils. Soil samples taken from three trial pits at depths of 0.5, 1.0 and 1.5 m, were used for the investigation. Two of the trial pits were located around the studied dump site to serve as control points or uncontaminated soil, while the third trial pit was located within the dump site to serve as contaminated soil. Soil samples collected were subjected to specific gravity, natural moisture content, particle size analysis, consistency, compaction, permeability, triaxial and consolidation tests. Results of the investigation show that Municipal Solid Waste (MSW) lowers the specific gravity, increases the natural moisture content, increases the fine particles content, lowers the maximum dry density with higher optimum moisture content, lowers both the cohesion and the angle of internal friction, increases the coefficient of permeability, coefficient of consolidation and coefficient of volume compressibility of the soil. These effects reduced with depth.

Keywords: Geotechnical properties of soil, Leachate, Municipal solid waste.

INTRODUCTION

Municipal Solid Waste (MSW) is complex refuse consisting of various materials with different properties. Some of the components are stable while others degrade as a result of biological and chemical processes. Leachate resulting from this is hazardous pollutant to the soil and ground water underlying. Leaching of this leachate and heavy metals into the soil leads to the contamination of both soil and groundwater.

While the developed countries of the world, such as Germany, have in place effective systems for MSW management (Schwarz-Herion et al, 2009), in many developing countries, such as Nigeria, management of MSW is a major concern, even in major cities of the country. The increasing level of solid waste is a serious problem in the urban areas of the world. This is compounded by the high rate of population growth and increasing per-capita income, which results in the generation of enormous solid waste posing serious threats to quality of soil and water. These threats are even more in the developing countries where large quantities of solid waste are dumped haphazardly, thereby, putting pressure on scarce land and water resources and at the same time affecting the properties of soils (Edward and James, 1987; Nanda, 2011).

While many researchers have worked on the characterization and management of MSW in Nigeria (Agunwamba et al, 2003; Ogwueleka, 2004; 2009; Nabegu, 2010; Nkwachukwu et al, 2010) and their effect on groundwater, little attention has been given to the effect of these wastes on the geotechnical properties of soils. This has become even more necessary as the demand for space for residential buildings to meet up with the country's rapidly increasing population, has resulted in the utilization of former dump sites within cities centers for building purposes. Therefore, the need to assess how the geotechnical (engineering) properties of soils on these dump sites are affected by wastes cannot be over emphasized.

Location, Climate and Geology of the Study Area

The dump site studied was located in Jikpa area of Bosso,in Minna, the capital city of Niger State, Nigeria. The area lies between longitudes 6° E and 7° E and latitudes 9° N and 10° N. According to

Wright (1989), the residual soil in this area is underlain by a granite basement and is surrounded to the North and South by the older basement rocks of the Precambrian to Upper Cambrian age and illo-group formation to the north-west. The area is drained by several rivers which are the tributaries of river Niger. Rainfall in this area varies considerably from station to station. The maximum rainfall per year varies from 1000 mm to 1500 mm for different locations (Mustapha and Alhassan, 2012).

MATERIALS AND METHODOLOGY

The soil used for this study was collected in and around a MSW dump site. Enquiries from residents around the dump site put its age at between 8 and 10 years. The soil samples were collect from three trial pits, with two of the trial pits (TP 1 and TP 3) located just around the dump site to serve as control (uncontaminated) soil sample and the third trial pit (TP 2) was located approximately in the center of the dump site to serve as contaminated soil sample. In order for the control trial pits to be relatively free from the leachate of the decomposing MSW, they were carefully located, so as not to be along the direction of the horizontal flow of the leachate (fig. 1).

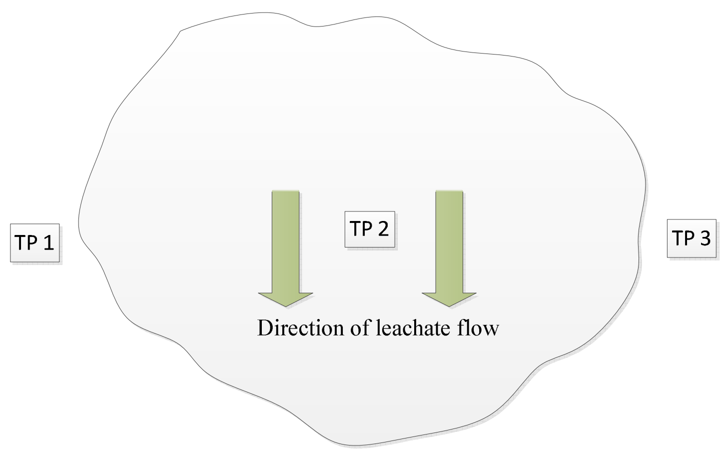

Figure 1: Sketch of the arrangement of trial pits on the studied dump site

Both disturbed and undisturbed soil samples were collected at 0.5, 1.0 and 1.5m depths. Samples from the trial pit in the center of the dump site were collected from the natural ground (soil) beneath the MSW. Tests conducted on the disturbed samples include: Natural moisture content test, specific gravity test, sieve analysis, consistency and compaction tests. While on the undisturbed samples, permeability, triaxial and consolidation tests were performed. All tests were conducted in accordance with BS 1377 (1990).

RESULTS AND DISCUSSION

Natural Moisture Content

The results of the Natural Moisture Content (NMC) test are presented in fig. 2. The results show that the difference between the values of the NMC of the uncontaminated soil samples collected from TP 1 and TP 3 at corresponding depths is generally lower compared to those of the contaminated soil samples obtained from TP 2 (dump site), at corresponding depths. The NMC of the contaminated soil was generally higher than the uncontaminated soil (TP 1 and 3). This trend could be attributed to two reasons: first, the contaminated soil is generally expected to be more damp (moist), since the natural ground level is covered by the MSW, thereby preventing direct evaporation of moisture from the soil below; secondly, from the results of the sieve analysis, the contaminated soil, contains more fine particles (fig. 4 and 5) than the uncontaminated soil, and since fine soil particles have more affinity for water, this could be responsible for the observed trend.

Specific Gravity

The results of the specific gravity test are presented in fig. 3. The results shows that the difference between the values of the specific gravity of the uncontaminated soils at corresponding depths is generally lower compared to those of the contaminated soil at corresponding depths. The values of the specific gravity of the contaminated soil were generally lower than those obtained for the uncontaminated soil (TP 1 and 3).

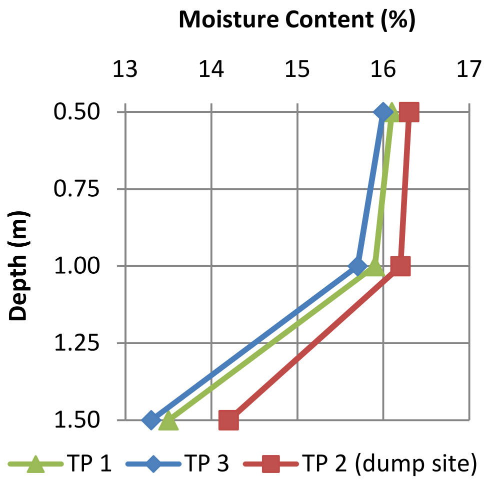

Figure 2: Variation of NMC of the soils with depth

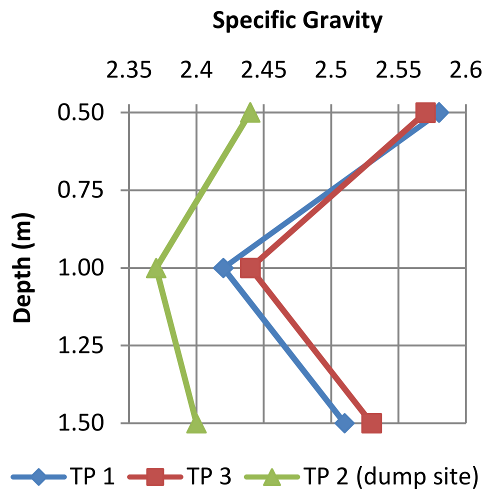

Figure 3: Variation of specific gravity of the soils with depth

Particle Size Distribution

The results of the particle size distribution are presented in fig 4. The results show that the curves for the uncontaminated soil samples are generally closer to each other, indicating that the uncontaminated soil is relatively homogeneous within the studied depth and trial points. The appearance of the curves for the contaminated soil samples, on the upper part of the distribution curves, indicates higher content of fine fraction. Fig. 5 shows the variation of percentage fine fraction of the soil samples with depth. The figure shows that the contaminated soil generally have more fines than the uncontaminated soil. Although, the fine content reduces with depth, it is more pronounced at 0.5 m depth. The higher percentage of fine content recorded for the contaminated soil can be attributed to the fines emanating from the decomposed MSW above the soil. The decomposed material, which increases the fine content of the soil, is carried to the soil layers below by infiltrating water, and therefore, the content reduces with depth.

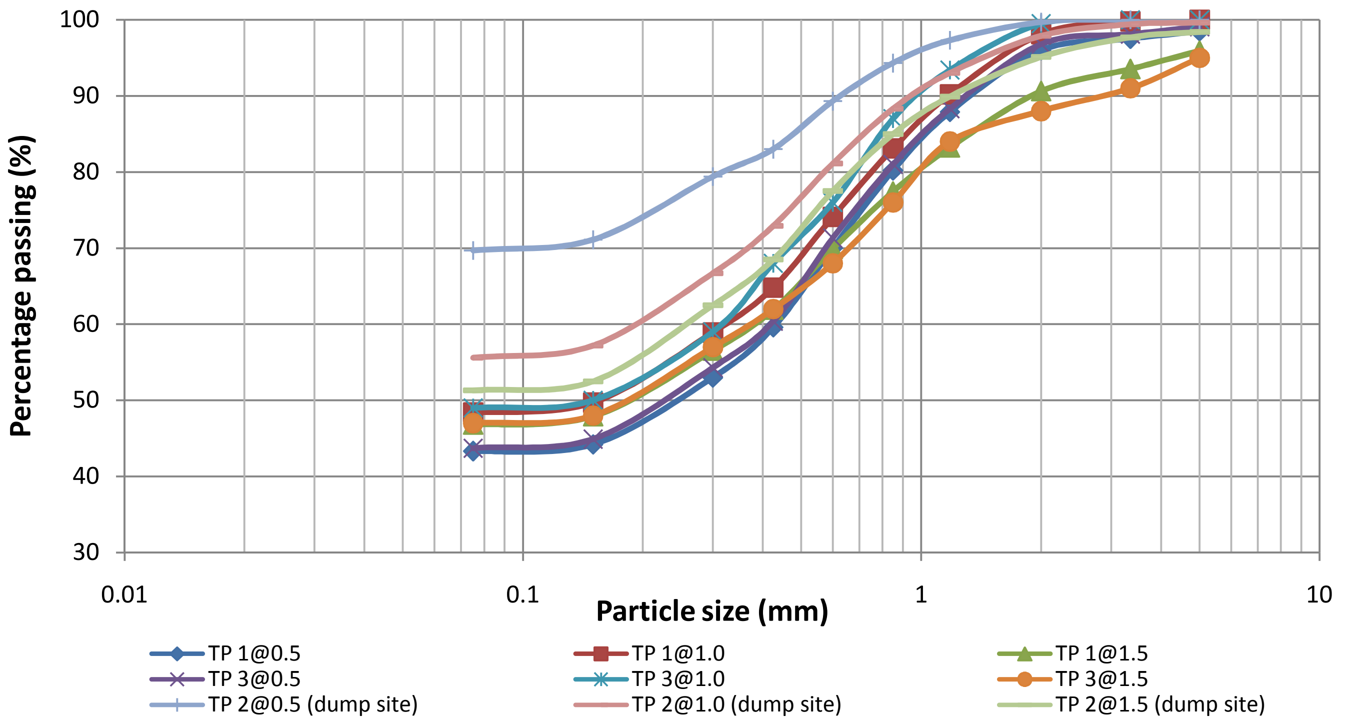

Figure 4: Particle size distribution curves of the soil samples

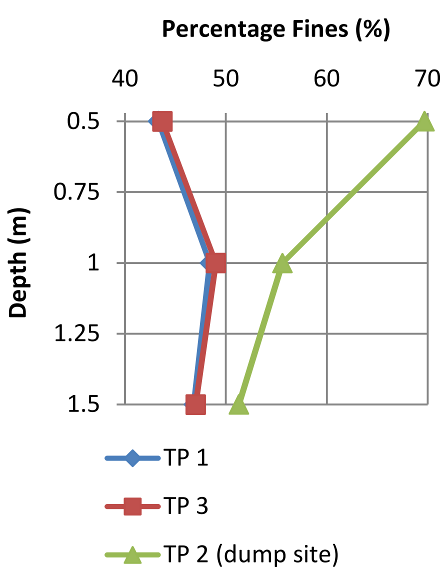

Figure 5: Variation of percentage fine content of the soils with depth

Consistency Limits

Results of the consistency limits are presented in table1. The results show that the contaminated soil generally has relatively lower consistency limits than the uncontaminated soil. This results show that, although, the contaminated soil has more fine content, the consistency of these fines may have been slightly affected by the leachate from the MSW. This also suggests that the fines resulting from the decomposed MSW are non-plastic.

Compaction Characteristics

The soil samples were compacted at British Standard Light (BSL) energy level, also known as Standard Proctor. Results of the compaction characteristics test are presented in fig. 6. The results show that the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the uncontaminated soils from the two trial pits (TP 1 and TP 3) are very similar, confirming the relatively homogeneity of the soil in the study area. The MDD of the contaminated soil is generally lower than that of the uncontaminated soil, while the OMC of the contaminated soil is generally higher. This result conforms with the results of the particle size distribution, which indicates higher percentages of fine fractions in the contaminated soil. Since fine particles within soil have more affinity for water, and from the classical theory of soil mechanics, the higher the OMC, the lower the MDD. This result conforms to earlier findings by Nayak et al (2007), Sunil et al (2008) and Nanda (2011).

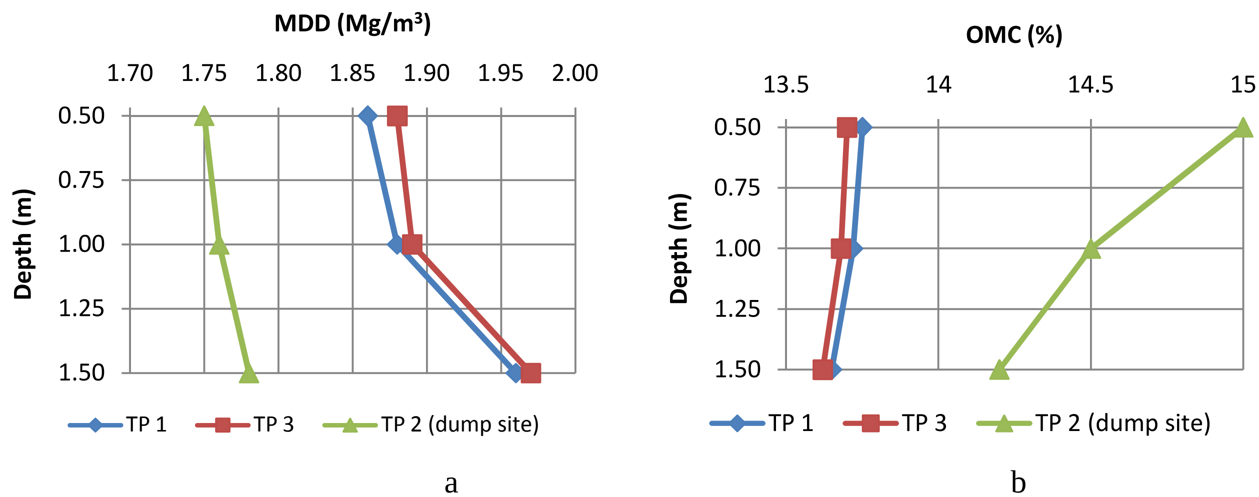

Figure 6: Variation of MDD (a) and OMC (b) of the soils with depth

Shear Strength Parameters

The shear strength parameters (c and Φ) were determined by undrained triaxial test using undisturbed soil samples. The results are presented in table 2. From the results, it was observed that values recorded for both cohesion (c) and angle of internal friction (Φ) for uncontaminated soil, are generally higher than those recorded for the contaminated soil. The lower values recorded for Φ is in conformity with the results of the particle size distribution, which indicate higher content of fine particles in the contaminated soil. The lower values recorded for the cohesion suggests that the fines, resulting from the decomposed MSW are non-plastic. The relatively high value of cohesion recorded for contaminated soil sample at 0.5 m depth is as a result of *pseudo-cohesion*, brought about by leachate from the decomposing MSW. This may be due to particle flocculation as a result of contamination with MSW.

Coefficient of Permeability

Laboratory falling head method was used in the determination of the coefficient of permeability of the soils. The results are presented in table 3. From the results, the contaminated soil has higher values of coefficient of permeability than the uncontaminated soils. These results somehow contradict the fact that the contaminated soil has more fine soil particles, which would have ordinarily reduced the pore space in the soil. This anomaly may be due to particles' flocculation as a result of contamination with MSW. The flocculation process may have altered the behaviors of the fine particles from clay-like to silt-like and consequently, making the soil more permeable. This also confirms to the results of the consistency limits.

Compressibility Characteristics

Consolidation test on the undisturbed samples was use to investigate the effect of the MSW on the compressibility characteristics of the soils. The results are presented in table 4. The results show that the contaminated soil has relatively higher values of both coefficient of consolidation (c_v) and coefficient of volume compressibility (m_v) than the uncontaminated soil. These results conform with the results obtained from the permeability tests. The lower values for m_v obtained for contaminated soil at 0.5 m depth, in comparison with the values obtained for uncontaminated soil, can be attributed to the soil immediately beneath the MSW undergoing compression as a result of the weight of the MSW above.

Table 1: Consistency limits of the soils

Soil sample		Depth (m)	Liquid Limit (%)	Plastic Limit (%)	Plasticity index (%)
Uncontaminated soil	TP 1	0.5	38.5	15.0	23.5
		1.0	39.5	25.4	14.1
		1.5	36.5	19.65	16.85
	TP 3	0.5	37.5	15.7	21.8
		1.0	38.4	22.6	15.8
		1.5	35.8	18.3	17.5
Contaminated soil	TP 2	0.5	33.6	14.8	18.8
		1.0	35.4	20.9	14.5
		1.5	34.5	19.0	15.5

Table 2: Shear Strength Parameters of the soils

Soil sample		Depth (m)	Cohesion, c (kN/m^2)	Angle of internal friction,Φ (degree)
Uncontaminated soil	TP 1	0.5	15	6
		1.0	15	7
		1.5	18	7.5
	TP 3	0.5	15.5	7
		1.0	15.5	8
		1.5	17	8
Contaminated soil	TP 2	0.5	20	5
		1.0	10	4.5
		1.5	10.25	6

Table 3: Coefficient of permeability of the soils

Soil sample		Depth (m)	Coefficient of permeability (cm/s)
Uncontaminated soil	TP 1	0.5	0.074
		1.0	0.035
		1.5	0.018
	TP 3	0.5	0.75
		1.0	0.041
		1.5	0.021
Contaminated soil	TP 2	0.5	0. 18
		1.0	0.086
		1.5	0.044

Table 4: Compressibility characteristics of the soils

Soil sample		Depth (m)	Coefficient of consolidation, c_v (m^2/yr)	Coefficient of volume compressibility, m_v (m^2/kN)
Uncontaminated soil	TP 1	0.5	0.283	1.00
		1.0	0.215	0.45
		1.5	0.232	0.36
	TP 3	0.5	0.277	0.98
		1.0	0.231	0.31
		1.5	0.221	0.22
Contaminated soil	TP 2	0.5	0.997	0.58
		1.0	0.865	0.45
		1.5	0.395	0.36

CONCLUSION

Based on the results of the study, the following conclusions can be drawn:

•The Natural (uncontaminated) soil within and around the dump site is relatively homogeneous.

•The contaminated soil has lower specific gravity, contains more fine particles, lower MDD with higher OMC, both lower cohesion and angle of internal friction,

•The contaminated soil has higher NMC, higher coefficient of permeability and both coefficient of consolidation and coefficient of volume compressibility are higher than the uncontaminated soil.

•The difference in the geotechnical properties exhibited by the contaminated soil, as depicted by the test results was impacted by the dumped MSW. These effects reduce with depth.

•These findings will help in guiding geotechnical engineers when designing and constructing foundations for buildings and other related structures on these types of soils.

REFERENCES

Agunwamba, J. C., "Egbuniwe, N. and Ogwueleka, T.C. (2003). “Least Cost Management of Solid Waste Collection”, Journal of Solid Waste Technology and Management, 29(3) pp.154-167.

B.S.1377 (1990).“Methods of testing soil for Civil Engineering Purposes”, British Standards Institute, London, England.

Edward J. M., James H. J.Jr, (1987). Hazardous Waste Management Engineering, published by Van NostrandReihold Company Inc. New York.

Mustapha, A. M. and Alhassan, M. (2012).“Chemical, Physico-chemical and Geotechnical Properties of Lateritic Weathering Profile Derived from Granite Basement”, Electronic Journal of Geotechnical Engineering (EJGE), Vol. 17(J), pp. 1885-1894.

Nabegu, A. B. (2010). “An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria” Journal of Human Ecology, 31(2) pp. 111-119.

Nanda, H. S.(2011).“Impact of Municipal Solid Waste Disposal on Geotechnical Properties of Soil”, Proceedings of Indian Geotechnical Conference December 15-17, Kochi. Paper NoL-183, pp. 715-716.

Nayak, S., Sunil B. M. and Shrihari, S. (2007). “Hydraulic and Compaction Characteristics of Leachate-Contaminated Lateritic Soil”, Journal of Engineering Geology, 94, Science Direct, ELSEVIER, pp. 137-144.

Nkwachukwu, O. I., Chidi, N. I. and Kanno O. C. (2010). “Issues of Roadside Disposal Habit of Municipal Solid Waste, Environmental Impacts and Implementation of Sound Management Practices in Developing Country “Nigeria”, International Journal of Environmental Science and Development, 1 (5), pp. 409-418.

Ogwueleka, T. C. (2004). “Planning Model for Refuse Management”, Journal of Science and Technology, **3** (2) Pp. 71-76.

Ogwueleka, T. C. (2009).**“**Municipal Solid Waste Characteristics and Management in Nigeria”, Iran. J. Environ. Health Sci. Eng. 6(3), pp. 173-180.

Schwarz-Herion, O., Omran, A. and Rapp, H. P.(2008).“A Case Study on Successful Municipal Solid Waste Management in Industrialized Countries by the Example of Karlsruhe City, Germany”, Journal of Engineering Annals, of the Faculty of Engineering Hunedoara. 6 (3) pp. 266-273.

Sunil, B. M, Shrihari. S and Nayak, S. (2008). “Soil –Leachate Interaction & their Effects on Hydraulic Conductivity and Compaction Characteristics”, the 12th International Conference of International Association, for Computer Methods & Advances in Geomechanics (IACMAG), Goa, India, pp. 2380-2386.

Wright, J. B. (1989). Volcanic Rocks in Nigeria, In Geology of Nigeria, edited by Kogbe, C. A. Abiprint& Pak Limited, Ibadan. Pp. 125-175.