Influence of Waste Dump on Geotechnical Properties of Soil in Ibadan, Southwestern Nigeria

Akintola Oluwatoyin Opeyemi[1]*; Bodede Adewunmi Idayat[1]; and Adekoya O. Oluwatoyin[2]

[1]Forestry Research Institute of Nigeria, Ibadan, Nigeria.
[2]Department of Geology, University of Ibadan, Nigeria.

E-mail: toyinakintola73@gmail.com*

ABSTRACT

Solid wastes are composed of varying complex and highest amounts of organic fractions that are decomposed into a liquid (leachates) component. These percolates and migrate contaminants into the soil, thus affecting the strength and stability of soil. This study investigated the characteristics of dumpsite soil and compared it with the control soil.

Soil samples collected from four test pits in the dumpsites and one from control site at depths of 0.5m to 2.0m were subjected to specific gravity, natural moisture content, particle size analysis, consistency limits and permeability tests using standard instrumentation techniques. The results of study showed that dumpsite soils have lower values of specific gravity and plastic limits than the control soil. Higher values of natural moisture content, liquid limits, plasticity index, amounts of fines, and permeability coefficients were observed in soils from dumpsite than control site.

A significant difference was observed between the control and dumpsite soils ($p<0.05$) for specific gravity, moisture content and plastic limit. The change in the properties of the dumpsite soils when compared with control soil indicated the influence of wastes on the geotechnical properties of soils. This study has shown that the contaminants from deposited wastes that percolate and migrate into the soil have affected the natural condition of the soils Thus, there is a need for construction engineered sanitary landfill system with liner system, leachate collection and treatment system, gas collection facility and final cover system to avoid the percolation of leachate into the soil and hence to prevent future environmental contamination.

(Keywords: dumpsite, geotechnical properties, natural conditions, waste, soils, sanitary landfill)

INTRODUCTION

Solid waste management has become an obstinate environmental problem in many developing countries of the world (1,2,3). This problem is associated to the rapid urbanization and increase in population which has resulted into generation of enormous quantity of solid waste which are indiscriminately discarded by open dumping (4).

On the basis of population, Ibadan is the largest city in Nigeria with about 2.9 million people in the year 2011 according to United Nations (5). This has consequently put pressure on the dumpsites in the city and may in turn lead to increase in environment metal contamination and health hazards. Lack of proper management of solid waste is very common in Nigeria with the absence of appropriate data including volume of generation, collection, transportation and disposal of solid wastes generated. Open dumps, being the major cause of environmental dilapidation such as air, soil and water pollution as well as fire hazards and explosion, release of green house, rats and flies invasion and irritation effects has elicited public health concern in recent times.

Land and soil degradation resulting from dumpsites have earlier been reported by some researchers (6, 7, 8, 9, 10, 11). The most environmental problems associated with open dumps is the infiltration of leachates into the soil resulting into soil contamination and subsequently percolate into the groundwater resource which in turn can result into groundwater contamination (12, 13, 14, 15, 16).

A significant number of diseases facing people today occur through protracted exposure to soil contamination and water contamination through the food chain. Unfortunately, there is no urgent attention on how to deal with these dumpsites in a sustainable manner, particularly in Nigeria where the impact of environmental pollution seems to be high.

There is an urgent need to develop amenities for the disposal of severely augmented volume of municipal solid wastes to improve public health and prevent environmental resources including surface water, groundwater, air and soil from being polluted. This study assessed geotechnical properties of soils within dumpsite and their comparison with those of the natural soil to evaluate the impact of contaminants form open dumping on soil in Ibadan, southwestern Nigeria.

MATERIALS AND METHOD

Description and Geology of the Study Area

The study area, Ajakanga dumpsite is a major open waste disposal site and located between 7˚18´41.32˝ N (latitude) and 3˚50´29.34˝ E (Longitude) within Oluyole local government, Ibadan south-western Nigeria (Figure 1).

Out of the four dumpsites in Ibadan, Ajakanga recorded the highest (162 117 metric tons) of annual waste (17). Increase in population and rapid urbanization has opened the dumpsite to build up areas.

The study area falls within the humid and tropical climate of southwestern Nigeria with a mean annual rainfall of about 1270 and a mean maximum temperature of 32 ºC. The study area is well drained by rivers and streams and the drainage pattern is dendritic.

Geologically, the study area falls within the basement complex terrain of southwestern Nigeria. The basement complex rocks consist of crystalline igneous and metamorphic rocks forming part of the African crystalline shield.

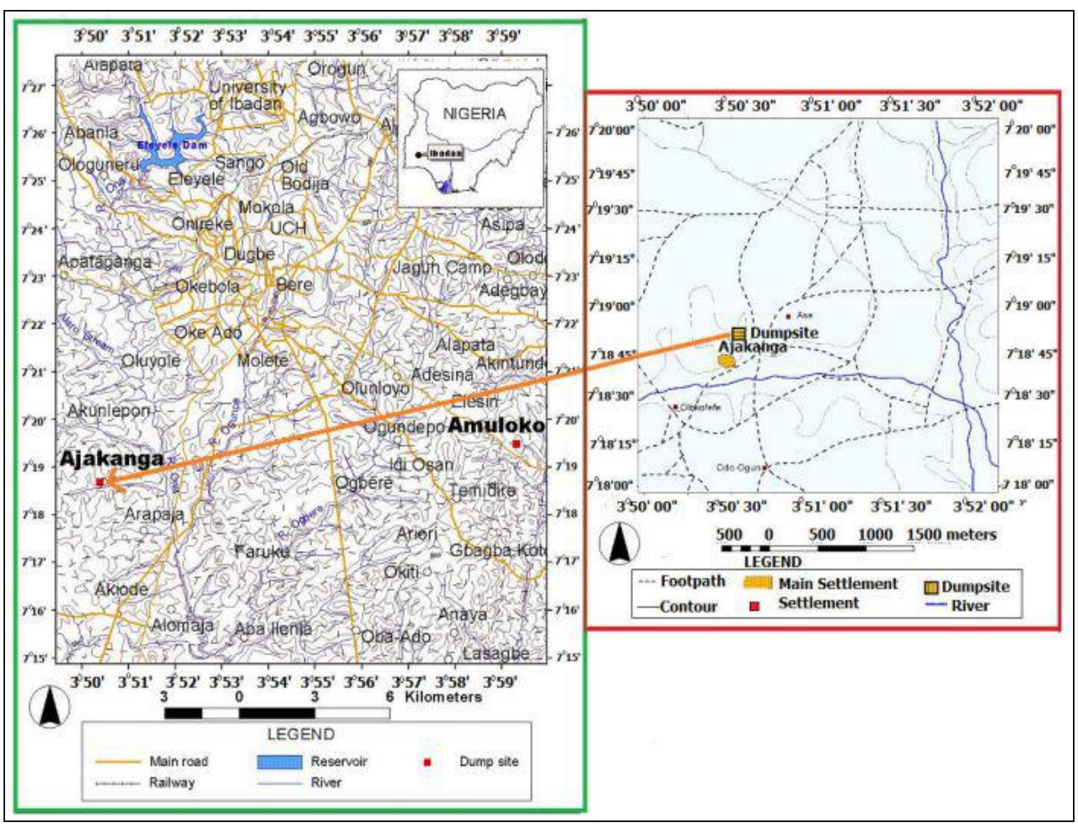

Figure 1: Location Map of the Study Area After (18).

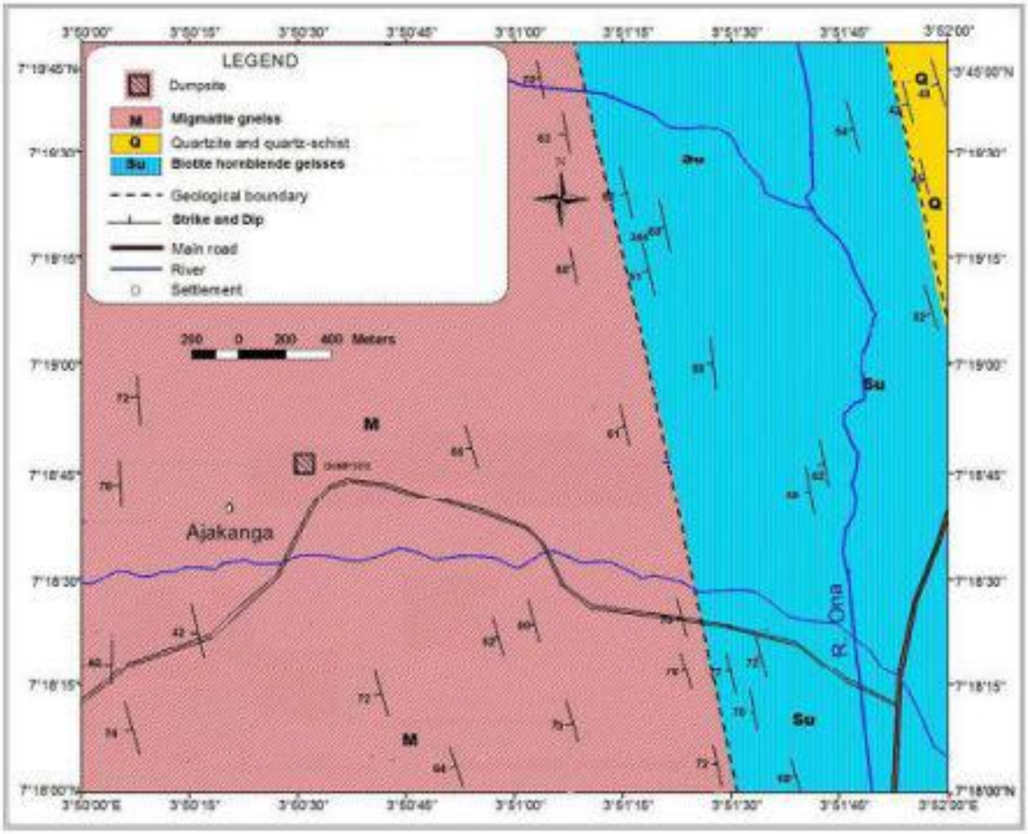

Figure 2: Geological Map of the Study Area After (18).

These rocks belong to the youngest of the three major provinces of the West African Craton. These rocks according to Elueze (2000) occur either exposed or covered by shallow mantle of superficial deposits. They are droopily characterized into three main subdivisions namely the migmatite- gneiss complex; the schist belt and Pan-African (Ca600 Ma) Older granite series. Ajakanga waste dumpsite and its environs are underlain by biotite-hornblende gneiss, migmatite gniess and quartzite (Figure 2).

Sampling Collection

Six sampling locations were selected within the Ajakanga dumpsite and from 500m at the upslope side of the dumpsite. Collection of samples were done between the months of January and February before the onset of the rainy reason to prevent the influence of the rainwater on the results.

Soil samples were collected from four test pits in selected locations within the dumpsite at the vertical depth of 0.5 to 2.0m and from two test pits located at 500m upslope side of the dumpsite which serve as control site.

Control site were located at the upslope side of the waste dump in order to be relatively free from leachates decomposing from the solid wastes. Thirty-six soil samples comprising eighteen disturbed soil samples and undisturbed soils samples at 0.5m interval up to the depth of 2.0m were collected. The disturbed soil samples were collected in samples bag with the use of digger and shovel while undisturbed soils were obtained using core cutters (10mx 150m) with a Marshall rammer ramming it into place. The core cutters were immediately sealed on both edges with candle wax melted on the field to prevent loss of moisture.

Laboratory Analysis

Disturbed soil samples were subjected to natural moisture content, specific gravity, Atterberg limits and grain size distribution tests while undisturbed soil samples were analyzed for permeability characteristics. All tests were carried out in accordance with standard guidelines given in (20).

Data Analysis

The data obtained in this study were analyzed using SPSS version 15 for windows. Descriptive statistics were used in this study. And one-way analysis of variance (ANOVA) was used to compare the mean values of the determined parameters in soils from control and dumpsites.

RESULTS AND DISCUSSIONS

Moisture Contents of the Studied Soils

Soil natural moisture content is the amount of water contained in a sample of soil. The mean natural and optimum moisture content values of the soil samples from the dumpsite ranged from 19.01±0.10 % to 23.45 ±0.33 % and 17.43±0.12 % to 21.22±0. 49 % while those from the control site were 12.99 ± 0.12 % to 15.45 ±0.19 % and 12.01 ±0.11 % to 14.75 ±0.25 % respectively (Table 1).

A significant difference was obtained for values of moisture content in soils from control and dumpsites at $p<0.05$. Soils that have lower moisture content than the optimum tends to have a proportion of pore spaces which in turn results in low dry density while in soil with higher moisture content, the dry density is reduced by the additional water which occupies the space that could have been occupied by solid particles (21).

The values of natural moisture content (NMC) is higher than optimum moisture content (OMC) (Table 1), Moisture content values of the soils from the dumpsite were higher than those from the control site and this could be attributed to the decomposition of the wastes which resulted into leachates containing water, thus making the soil to be damper than those from control site.

Specific Gravity

This is an important index property that is closely linked with mineralogy and chemical composition. The specific gravity values of the soil samples from dumpsite and control site at the depth of 0.5 to 2 m were 2.61 to 2.68 and 2.65 to 2.72 respectively (Table 2).

There was a significant difference between the specific gravity values of soils from control and dumpsites at $P<0.05$. The specific gravity values of soils from dumpsite were a little lower than those from control sites (Table 2) and this can be attributed to presence of high organic content in the soil due to decomposition of the wastes.

This could also be due to the decomposition of the organic matter and the percolation of leachate through voids into the soil, which changes the engineering properties of the soil. This agreed with the similar works conducted by (22) where they stated that the dump soils have lower specific gravity than those of control soils. The overall mean specific gravity values of the soil samples were higher than 2.2 recommended by ONORM S2074 (23) for soils to be suitable for use as liner in sanitary landfills.

Table 1. Mean Values of the Moisture Content of the Studied Soil Samples.

Location	Moisture Content	Depth in m			
		0.50	1.00	1.50	2.00
Control site	Natural moisture (%)	12.99 ± 0.12	13.99 ±0.14	14.56 ±0.16	15.45 ±0.19
	Optimum moisture (%)	12.01 ±0.11	12.66 ±0.29	13.99 ±0.31	14.75 ±0.25
Dumpsite	Natural moisture (%)	19.01±0.10	20.22±0.35	21.51 ±0.21	23.45 ±0.33
	Optimum moisture (%)	17.43±0.12	18.54 ±0.15	19.67 ±0.42	21.22±0. 49

Table 2: Values of Specific Gravity

Location	Statistical parameters	Depth in m			
		0.50	1.00	1.50	2.00
Control site	Minimum	2.68	2.66	2.66	2.65
	Maximum	2.72	2.71	2.71	2.70
	Mean	2.70 ± 0.20	2.69 ± 0.25	2.69 ± 0.25	2.68 ± 0.20
	Std Deviation	0.008	0.035	0.035	0.035
Dumpsite	Minimum	2.67	2.65	2.63	2.61
	Maximum	2.68	2.67	2.66	2.64
	Mean	2.67 ± 0.01	2.65 ± 0.02	2.64 ± 0.02	2.62 ± 0.02
	Std Deviation	0.014	0.021	0.028	0.028

Table 3: Liquid, Plastic, and Plasticity Index Values.

Location	Atterberg limits	Statistical parameters	Depth in m			
			0.50	1.00	1.50	2.00
Control Site	Liquid limits	Minimum	36.01	36.31	36.09	36.91
		Maximum	37.81	38.11	37.67	38.21
		Mean	36.58± 0.57	37.44± 0.61	37.51± 0.52	37.71± 0.62
	Plastic limits	Minimum	19.20	19.72	19.88	19.97
		Maximum	19.98	19.99	20.10	20.22
		Mean	19.57± 0.65	19.86± 0.75	19.99± 0.81	20.01± 0.86
	Plasticity index	Minimum	17.45	17.55	17.61	17.66
		Maximum	17.99	18.10	18.41	18.50
		Mean	17.87± 0.34	17.99± 0.21	18.09± 0.46	18.12± 0.31
Dumpsite	Liquid limits	Minimum	38.08	37.20	36.17	36.09
		Maximum	39.56	38.16	37.81	37.57
		Mean	38.82± 0.74	37.68± 0.48	36.99± 0.82	36.81± 0.74
	Plastic limits	Minimum	19.45	18.86	18.57	18.47
		Maximum	20.11	19.56	19.01	18.89
		Mean	19.78± 0.33	19.21± 0.35	18.79± 0.22	18.68± 0.21
	Plasticity index	Minimum	18.63	18.34	17.60	17.62
		Maximum	19.45	18.60	18.80	18.68
		Mean	19.04± 0.41	18.47± 0.13	18.20± 0.60	18.15±0.53

Atterberg Limits

Liquid limit, plastic limit and plasticity index are the most useful indicators of engineering behavior of soils. Liquid limit is an imperative index property used in geotechnical investigation. The values of liquid limits (LL) of dumpsite and control site soil samples ranged from 36.09% to 39.56% and 36.01% to 38.21%, respectively (Table 3).

The results were within the similar works carried out by some researchers (Ige, 2014; Harshar et al., 2015; Ajai and Brajesh, 2016). The values are above the recommended minimum liquid limit of 20% given by Benson et al. (1994) for barrier materials and less than 90% stipulated value given by Declan and Paul (2003). The plastic limit (PL) values of the dumpsite and control site soil samples were 18.47 % to 20.11% and 19.20 % to 20.22% respectively (Table 3). The plasticity index (PI) values of the soil samples were 17.60 % to 19.45 % (dumpsite) and 17.45 % to 18.45 % (control site). Slight change noticed in the liquid limits, plastic limits and plasticity index values obtained in the soil samples from dumpsite control site may be attributed to effect of leachates on the soil constituents (Sunil et al. 2009).

A significant difference was observed between the plastic limit values of soils from control and dumpsites while there was no significant difference observed between the values of liquid limit and plasticity index. However, the increase in the liquid limit and plasticity index of the soil with depth in the dump site agreed with the work of Al-fares and Al-jarallah (2011).

The results were also in line with the findings of Goswami and Choudhury (2013) where he stated that the Atterberg limit values increased by increasing the leachate concentration. This is attributed to the leachate characteristics which increase the pH of the soil and this in turn increase the cation exchange capacity of the soil. PI values of all the studied soil samples are higher than minimum 10% value recommended by Daniel (1993a, 1993b), Benson et al. (1994) and Rowe et al (1995). All the soil samples fall in the zone of inorganic clay of medium plasticity based on the classification of casagrande (1948).

The PI values of the soil samples in this study may have been attributed to the small amount of clay present in the soil particles and also may be due to reduction in the porosity that led to blockage of pore spaces as a result of increase in the amount of microorganisms in the leachate from the dumpsite (Essienubong ,2019).

Grain Size Distribution Characteristics

The percentage of clay, silt, sand, amount of fines of the soil samples were presented in Table 4. Mean values of particle size distributions in the soil samples from dumpsite were gravel (9±2 to 13±1 %), sand (54±3 to 59±4 %), silt (18±2 to 24±2 %) and clay (10±1 to 14±2 %) with finer amounts ranging from 29±1 to 38±4 %. It was observed that the amounts of gravels, clay and fines in the soil samples from dumpsite were slightly higher than those from control site (Table 4).

There was no significant difference observed between the amount of fines at $P<0.05$ in soils from control and dumpsites. The higher percentage of amount of fine recorded for the dumpsite soils can be attributed to the smaller particles emanating from the high organic matter in the dumpsite soil (34). This could also be as a result of smaller particles arising from the decayed municipal solid waste which covers the soil. This agreed with the findings of (35) and (36). Thus, it can be stated that both chemical and biological processes that take place during the degradation processes of the wastes in the dumpsite affect the physical properties of the soils. Thus, in this study it can be inferred that there are chemical reactions between the leachate and soil particles.

Coefficient of Permeability (K)

The permeability characteristics of soils is an important parameter that must be considered for the design of the landfill containment systems (25, 37). This geotechnical parameter is important because of its influence on leachate pressure distributions in the waste body and hence on the magnitude and distribution of effective stresses and therefore on shear strength (38).

Soil samples investigated have the permeability coefficient ranging from 1.22 x 10-6 to 4.64 x 10-5 m/s (control site) and 2.05 x 10-6 to 5.97 x 10-5 m/s (dumpsite). These researchers 31, 32,39, 40) in their separate works indicated that a soil to be used as isolation barrier must have a maximum permeability of 1 x 10-9m/s while (41) stated that natural geological barriers are low permeability clay-rich geological unit which can perform the function of attenuating layer, enabling slow percolation of leachates and simultaneously undergoing attenuation by filtration, sorption and exchange processes.

Table 4: Mean Values of Particle Sizes of the Studied Soils.

Locations	Parameters	Depth in m			
		0.50	1.00	1.50	2.00
Control site	Gravel (%)	5±1	9±1	11±2	16±2
	Sand (%)	65±2	61±3	62±4	55±1
	Silt (%)	20±2	18±1	16±2	16±1
	Clay (%)	10±1	12±1	11±2	13±2
	Percent finer (%)	30±3	30±2	27±1	29±2
Dumpsite	Gravel (%)	9±2	12±2	13±1	12±1
	Sand (%)	54±3	55±2	58±3	61±4
	Silt (%)	24±2	20±1	18±2	17±1
	Clay (%)	14±2	13±1	11±1	10±1
	Percent finer (%)	38±4	33±2	29±3	27±1

Table 5: Permeability Characteristics of the Studied Soil.

Locations	Parameters	Depth in m			
		0.50	1.00	1.50	2.00
Control site	Minimum	1.22×10^{-06}	1.56×10^{-06}	2.55×10^{-06}	2.88×10^{-05}
	Maximum	2.11×10^{-06}	3.06×10^{-06}	4.44×10^{-06}	4.64×10^{-05}
Dumpsite	Minimum	2.05×10^{-06}	2.56×10^{-06}	3.01×10^{-05}	3.26×10^{-05}
	Maximum	3.11×10^{-06}	3.55×10^{-06}	4.87×10^{-05}	5.97×10^{-05}

It was observed that the studied soils from all the pits at all the depths investigated have the coefficient of permeability greater than the recommended value.

Since the permeability of the soils is high, infiltration of rain water, water already present in the waste and water generated by biodegradation from waste dump may move laterally or vertically and infiltrate into the groundwater thereby causing contamination.

Slight increase in the permeability characteristics of the soils noticed from dumpsite when compared with control soils (Table 5) could be attributed to the chemical reaction between the soil minerals and the leachate constituents resulting into dissolution of particles and increased the effective pore space (42). This result was similar with similar studies by some researchers (22,43 44).

Permeability characteristics of the municipal solid waste soils not only varies significantly with the factors such as waste composition, compaction and overburden stress but also with the extension of the degradation process, which results in significant changes in the composition and particle size distribution of the waste dump soils (45).

CONCLUSION

A change in the geotechnical properties of the dumpsite soils when compared with those from the control site indicated influence of wastes on the soil properties. Also, low amounts of fines and high permeability characteristics of dumpsite soils when compared with recommended values for landfill seals suggests likely migration of leachates through the soils into the surrounding surface and groundwater sources.

This study has shown that the deposited wastes have affected the natural condition of the soils and the presence condition of the site is not suitable for waste dump. Thus, there is need for insistent upgrading of the site to a modern engineered sanitary landfill to prevent future environmental hazard in the area.

REFERENCES

1. Sharholy, M., K. Ahmad, G. Mahmood and R. Trived. 2008. “Municipal Solid Waste Management in Indian Cities – A Review”. *Waste Management*. 28(2):459-67. 2008.

2. Guerrero, L.A.,G. Maas, and W. Hogland. 2013. “Solid Waste Management Challenges for Cities in Developing Countries”. *Waste Management*. 33(1):220-232.

3. Oladejo, O A. and J. Otenne. 2018. “Environmental Hazards of Dumpsites in Ibadan, Nigeria”. *International Journal of Health, Safety and Environments*. 4(3): 257-268.

4. Ayininuola, G.M., O.A. Agbede, and S.O. Franklin. 2009. “Influence of Calcium Sulphate on Subsoil Cohesion and Angle of Friction”. *J Appl Sci Res.* 5(3):297–304.

5. UN-Habitat. 2014. “The State of African Cities 2014: Re-imagining Sustainable Urban Transitions”. 1-9. Retrieved from http://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=3528.

6. Raman, N. and S. Rayanan. 2008. “Impact of Solid Waste Effects on Ground Water and Soil Quality Nearer to Pallavaram Solid Waste Landfill Site in Chennai”. *Rasayan Journal*. 1(4): 828-836.

7. Sharholy, M., K. Ahmad, G. Mahmood, and R. Trivedi. 2008. “Municipal Solid Waste Management in Indian Cities: A Review. *Waste Management*. 28(2):459-67.

8. Yazdani, M., M. Monavari, G.A. Omrani, M. Shariat, and M. Hosseini. 2015a. “Landfill Site Suitability assessment by means of Geographic Information System Analysis. – Solid Earth 6: 945–956.2015a.

9. Yazdani, M., M. Monavari, G.A. Omrani M. Shariat, and M. Hosseini. 2015b. “Municipal Solid Waste Open Dumping, Implication for Land Degradation. Solid Earth Discussion. 7 1097-1118.

10. Martínez-Murillo, J F., P. Hueso-González, J.D. Ruiz-Sinoga, and H. Lavee. 20156 “Short-Term Experimental Fire Effects in Soil and Water Losses in Southern of Spain”. *Land Degradation and Development*. 27(5):1513-1522.

11. Pereira, P., A. Cerdà , A.J. Lopez, L.M. Zavala, J. Mataix-Solera, V. Arcenegui, I. Misiune, S. Keesstra, and A. Novara. 2016. “Short-Term Vegetation Recovery After a Grassland Fire in Lithuania: The Effects of Fire Severity, Slope Position and Aspect”. *Land Degradation and Development*. 27(5):1523-1534.

12. Akintola, O.O. and A.I. Bodede. 2019. “Impact of Waste Dumpsite on Groundwater Quality in Ibadan, Southwestern Nigeria”. *Pacific Journal of Science and Technology*. 20(2):242-258.

13. Novara, A., L. Gristina, F. Guaitoli, A. Santoro, and A. Cerdà. 2013. “Managing Soil Nitrate with Cover Crops and Buffer Strips in Sicilian Vineyards”. *Solid Earth*. 4:255-262.

14. Kale, S.S., A.K. Kadam, S. Kumar, and N. Pawar. 2010. “Evaluating Pollution Potential of Leachate from Landfill Site, from the Pune Metropolitan City and its Impact on Shallow Basaltic Aquifers”. *Environmental Monitoring and Assessment*. 162(1-4): 327-346.

15. Nema, A.K., M. Datta, and R.K. Singh. 2009. “A New System for Ground Water Contamination Hazard Rating of Landfills”. *Journal of Environmental Management*. 91(2): 344-357.

16. Dimitriou, F., I. Karaouzas, K. Saratakos, I. Zacharias, K. Bogdanos, and A. Diapoulis. 2008. “Ground Water Risk Assessment at a Heavily Industrialized Catchment and Management”.. *Journal of Environmental Management*. 88(3): 526-538.

17. Oyowma, A. 2015. “Information on Ajakanga Dumpsite”. Oyo State Waste Management Authority: Ibadan, Nigeria.

18. Ewemoje, T.A., O.E. Ewemoje, and S.P. Majolagbe. 2017. “Urbanisation Effects on Surface and Groundwater Resources: An Assessment of Approved Dumpsite in Ibadan, Nigeria”. An ASABE meeting presentation. DOI: 10.13031/aim.201701388, 2017.

19. Elueze, A.A. 2000. “Compositional Appraisal and Petrotectonic Significance of the Imelu Banded Ferraginous Rock in Ilesha Schist Belt, South western, Nigeria”. *J. Min Geol*. 36(1):9–18.

20. BSI. 2015. British Standard 1377. British Standards Institute: London, UK. ISBN: 9780580960864, 9780580934698 1 2016.

21. Anikwe, M.A.N. and K.C.A. Nwobodo. 2002. “Long Term Effect of Municipal Waste Disposal on Soil Properties and Productivity of Sites used for Urban Agriculture in Abakaliki Nigeria”. *Bio Resour. Technol.*, 83:241-250.

22. Ajai, K.R. and M. Brajesh. 2016. “Geotechnical Properties Based Characterization of Closed Dumpsite: A Case Study of Lucknow City of Uttar Pradesh”. *International Journal of Innovative Research in Science, Engineering and Technology*. 5(3): 2958-296.

23. Onorm, S. 1990. “Geotechnik in Deponieb au-Erdarbeiten”. *Osterreichisches Normungsinstitut, Wien*, 1990.

24. Ige, O.O. 2014. “Hydro-Geotechnical Assessment of an Open Waste Disposal Site in Ilorin, Nigeria”. *Ethiopian J. Environ. Stud. Manage*. 7:859-869.

25. Benson, C.H., H. Zhai, and X. Wang. 1994. “Estimating Hydraulic Conductivity of Clay Liners”. *Journal of Geotechnical Engineering ASCE*. 120(2): 366-387.

26. Declan O. and Q. Paul. 2013. “Geotechnical Engineering and Environmental Aspects of Clay Liners for Landfill Projects”. Retrieved 3rd March 2019 from www.igsl.ie/ Technical/Paper3.doc Fehily Timoney & Co. & IGSL Limited.

27. Sunil, B.M., S. Shrihari, and S. Nayak. 2009. “Shear Strength Characteristics and Chemical Characteristics of Leachate-Contaminated Lateritic Soil”. *Eng Geol J.* 106(1-2):20–25.

28. Al-Fares, R. and R. Al-Jarallah. 2011. “Geo-Environmental Site Characterization at a Waste Disposal Site using Traditional Geotechnical *in-situ* Techniques: The State of Kuwait”. *Kuwait J Sci Eng*. 38(1B):55–77.

29. Goswami, D. and B.N. Choudhury. 2013. “Atterberg Limits and Shear Strength Characteristics of Leachate Contaminated Lateritic Soil”. *Indian J Res*. 3(4):91–93.

30. Daniel, D.E. 1993a. “Landfill and Impoundments. Geotechnical Practice for Waste Disposal”. David E. Daniel. Eds. Chapman & Hall, London Inc. 97-112.

31. Daniel, D.E. 1993b. "Clay Liners. Geotechnical Practice for Waste Disposal". David E. Daniel. Eds. Chapman & Hall: London, UK.137-163.

32. Rowe. R.K, R.M. Quigley, and J.R. Booker. 1995. *Clay Barrier Systems for Waste Disposal Facilities*. E &FN Spon: London, UK.

33. Casagrande, A. 1948. "Classification and Identification of Soils". *ASCE Trans*. 113:901–930.

34. Okeke, I.E., T.T. Okagu, V.O. Okonkwo, and A.C. Ezeagu. 2019. "Effect of Municipal Solid Waste Leachate on the Geotechnical Properties of Soil". *International Journal of Engineering Science Invention*. 8: 40-52.

35. Ugwu, E.I., A.C. Ekeleme, O. Awoyera, H.O. Ozioko, and U. Osinachi. 2018. "Effect of Municipal Solid Waste Contamination on Some Geotechnical Properties of Soil". *J. Mater. Environ. Sci*. 9(2): 585-590.

36. Estabragh, A.R., I. Beytolahpour, M. Moradi, and A. Javadi. 2014. "Consolidation Behavior of Two Fine-Grained Soils Contaminated by Glycerol and Ethanol". *Engr. Geol*. 178: 102-108.

37. Sharma, H.D. and K.R. Reddy. 2004. *Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies*. Wiley: Hoboken, NJ.

38. Dixon, N. and D.R.V. Jones. 2005. "Engineering Properties of Municipal Solid Waste". *Geotextiles and Geomembranes Journal*. 23(3): 205–233.

39. Clayton, K.C. and J.M. Huie. 1973. *Solid Wastes Management: The Regional Approach*. Ballinger Pub. Co: Cambridge, MA. xvii, 140 p..

40. Mark, Y. 2002. *Geology and Geotechnical Investigation of the Proposed Anterbury Regional Landfill Kate Valley, North Canterbury*. Transwaste Canterbury Ltd. Canterbury, UK. 147.

41. Allen, A.R. 2000. "Attenuation Landfills the Future in Landfilling". Retrieved March 10, 2019 from wbiis.tu.koszanlin.pl/towarzystwo/ 2000/17alle n_t.pdf, 2000.

42. Nayak, S., B.M. Sunil, and S. Shrihari. 2007. "Hydraulic and Compaction Characteristics of Leachate-Contaminated Lateritic Soil". *Eng Geol J.* 94(34):137–144.

43. George, M. and K.S. Beena. 2011. "Geotechnical Characteristics of Leachate Contaminated Lateritic Soil". *Proceedings of Indian Geotechnical Conference*. Koch. 769–772.

44. Alhassan, M. 2012. "Effect of Solid Waste on Geotechnical Properties of Soils". *Int J Env Sci Manag Eng Res*. 1(5):204- 210.

45. Reddy, K.R., H. Hettiarachchi, A.N. Parakall, J. Gangathulasi, J. Bogner, and T. Lagier. 2009. "Hydraulic Conductivity of MSW in Landfills". *Journal of Environmental Engineering*. 135(8): 677–683.

SUGGESTED CITATION

Akintola, O.O., Bodede, I.A., and Adekoya, O.O. 2020. "Influence of Waste Dump on Geotechnical Properties of Soil in Ibadan, Southwestern Nigeria". *Pacific Journal of Science and Technology*. 21(1):352-360.

Pacific Journal of Science and Technology