ISSN 2350-1030

International Journal of Recent Research in Physics and Chemical Sciences (IJRRPCS)
Vol. 9, Issue 2, pp: (22-27), Month: October 2022 – March 2023, Available at: www.paperpublications.org

SUITABILITY ASSESSMENT OF SOLID WASTE DISPOSAL SITES USING SOME PHYSICO-CHEMICAL AND GEO-MORPHOLOGICAL PROPERTIES OF SOILS

[1]ONWUGBUTA, GODPOWER CHUKWUEMEKA, [2]GODSON NNAMDI JOHN

[1,2] DEPARTMENT OF BIOCHEMISTRY/CHEMISTRY TECHNOLOGY, SCHOOL OF SCIENCE LABORATORY TECHNOLOGY, UNIVERSITY OF PORT HARCOURT, NIGERIA.

DOI: https://doi.org/10.5281/zenodo.7491522

Published Date: 29-December-2022

Abstract: **The soils of six locations (Rumuokoro, Eastern by-pass, Oyigbo, Bundu, Yenagoa and Bonny) indiscrimately used for disposal of wastes were evaluated for suitability classification using some physico-chemical and geo-morphological properties of the soils. The soils showed remarkable physico-chemical variability between the locations and also within the soil horizons. Yenagoa, Bonny and Bundu sites were most limited for use in landfilling of wastes and are more prone to both surface and ground water pollution due to their porosity, infiltration rate, pH, flooding, drainage and textural limitations. Rumuokoro site which was most suitable for landfilling of wastes was limited by pH, while Eastern by-pass site was limited by both the texture and porosity. This assessment shows that, no location possessed all the characteristics of waste landfilling. However, when a comparative study of the suitability of soils for waste landfilling was rated, the locations showed variable suitability in the following order: Rumuokoro > Eastern Bypass > Oyigbo > Bundu > Bonny > Yenagoa.**

Keywords: **Suitability, Assessment, Waste, Disposal, Sites.**

1. INTRODUCTION

Disposal of solid waste has always posed a serious problem in Nigeria and several parts of the world. Leachate from municipal solid waste landfills contain a variable mixture of solutes, including inorganic ions like Cl^-, SO_4^{2-}, Ca, Mg, K, heavy metals and volatile/semi-volatile organic compounds. Hazardous materials such as heavy metals, pesticides and hydrocarbons that are dissolved in this liquid often contaminate soil and water (Khamehchiyan et al. 2011). If organic waste is allowed to accumulate and is exposed to rain, its decomposition produces noxious odors, thereby constituting health hazards. If the leachate finds its way into the natural waters, it becomes a serious threat to the ecosystem (Kapilan and Elangovan, 2018). Separate disposal systems exist for disposing of the solid and liquid wastes. Except in very cold or dry climate, most soils provide a suitable natural environment for biodegradation of waste. Soil serves as a cover, as a lining for the site, as a sink for the adsorption and absorption of ions, as a medium for restoring vegetation and normal land use (Loughry, 1973). Of all the technologies that are either available or potentially available for disposal of Municipal, Industrial and Agricultural wastes the sanitary landfill system is the most common (Weiss 1974; Islam et al. 2020). Ideally, sites should be located in silt and clay soils that restrict leachate and gas movement. A landfill constructed over a permeable formation such as gravel, sand or fractured bedrock can pose a significant threat to groundwater quality (Philip and Patrick, 2002; Eskandari et al. 2016). Selection of poorly suited soils may cause irreparable damage to land and water resources. Kumar, 1987; Rahmat et al. 2016, identified stoniness, ponding, flooding, slope and soil depth as having an important

ISSN 2350-1030

International Journal of Recent Research in Physics and Chemical Sciences (IJRRPCS)
Vol. 9, Issue 2, pp: (22-27), Month: October 2022 – March 2023, Available at: www.paperpublications.org

bearing on the suitability of a soil for a particular disposal system. For a soil to serve as a cover for a landfill site, the soil must:

1. Be fine enough to make a compact cover that does not readily admit insects and flies, but does not stop diffusion of air and water.

2. Not be very sticky or cannot be handled with mechanical equipment during rainy season.

3. Not shrink on drying as in clay or open the fill to insects and to escape of odors.

4. Not be loose and non-cohesive, else it will be subject to wind and water erosion.

Loughry (1973) therefore recommended a loamy soil which avoids the extremes of clay, silt and sand. When a landfill area is underlain by gravel, there is extreme hazard of pollutants being carried down to the underground water. Sand on the other hand, has a high percolation rate, but does not provide sufficient protection against groundwater pollution. Hence, sand and silt mixed in proportion would be an acceptable soil system for waste treatment. For cover material, soils with very friable and friable consistence are good; soils with loose and firm consistence are fair, while soils with extremely firm consistence are poor. Good soil texture for use as cover materials include sandy loam; loam, silt loam and sandy clay loam, fair textures include silt clay, muck, peat and sand. Limestone, sandstones, alluviums, and terraces are unsuitable materials for construction of landfills. Materials with low permeability (shale, marl, clay, stone, and schist), are very suitable for landfill site, soil having low porosity and impermeability is best for landfill (El-Maguiri et al. 2016; Rahmat et al. 2016). This research is therefore aimed at assessing the suitability of the soils for waste disposal based on their physic-chemical and geo-morphological characteristics.

2. MATERIALS AND METHODS

Potential sampling locations were selected by examining the topographic and geo-morphological maps of old Rivers State (Fig. I). The state is located between latitudes 4° 15' N and 5°47'N and longitudes 5°22'E and 7^{0}37`E. The upland locations are; East-West Road, Rumuokoro; Eastern-bypass, and Imo gate (Oyigbo) while the wetland locations are, Bundu Waterside, Bonny main town and Ekenpie Epie (Yenagoa).

Six profile pits were dug, one in each location with length x width x depth measurements of 2m x 1m x 2m respectively. Each profile pit was described morphologically in-situ, after which, soil samples were collected with a core sampler (for bulk density determination) and secondly with a scooping knife (for proximate soil analysis) from each discrete soil horizon. The soil samples were bagged separately in accordance with Hodgson (1983). The samples were air-dried, crushed and sieved for physico-chemical analysis.

Particle size analysis was done using the hydrometer method (Juo, 1979). Bulk density was determined by the core method as modified by Evans et al. (1982). The pycnometer method described by Black (1965) was used to determine the particle density. Total porosity was calculated from particle density and Bulk density. Moisture content was determined by gravimetric (direct) method whereby, the sample was dried to constant weight. The double ring infiltrometer method as reported by Ahuja et al. (1976) was used to determine infiltration rate. Stickiness, plasticity and consistence were determined by feeling the sample with the fingers. The soil pH was determined by the electrometric method. Organic matter was determined by the Walkley and Black (1934) method. Available phosphorus was determined by the Bray and Kutz No.I (1945) method. Cation exchange capacity was determined by the micro-Khjeldahl method.

3. RESULTS AND DISCUSSION

Selected physico-chemical and geo-morphological properties of soil profiles used in assessing the suitability of the soils under study for waste landfilling are presented in the Tables below.

The mean texture of Rumuokoro, Eastern by-pass, and Oyigbo sites was predominantly Sandy Loam (Table I). Excessive sand fractions (> 70%) as seen in Oyigbo and Eastern by-pass soils make the soils unsuitable for waste landfilling (in agreement with Loughry, 1973; Islam et al. 2020). This is true because they are rapidly permeable and allow large quantities of water to invade the deposited refuse. Similarly, Bundu, Yenagoa and Bonny sites did not meet textural requirement for waste landfilling since they contain mean clay fractions greater than 31%. High clay concentrations (>31%) encourage surface water flooding and pollution (Bonarius, 1975). Mean bulk density of the soils ranged between 1.18g/cm^3 in Yenagoa and 1.45g/cm^3 in Oyigbo. High bulk density (> 1.5cm^3) reduces water infiltration and plant root penetration, resulting in increased surface flooding, poor aeration and surface water pollution (Adeli and Khorshiddoust, 2011; Anifowose et al.

2011). Mean total porosity of the soils ranged between 44.25% in Oyigbo and 55.62% in Yenagoa. Very high porosity causes high-infiltration rate and underground water pollution (Weiss, 1974; Ali and Ahmad, 2020; Zhang et al. 2010). The soils of Bundu, Eastern by-pass, Yenagoa and Bonny sites with mean porosity greater than 50% are not suitable for waste landfilling since their values exceeded the acceptable limits of 30% (Tables I & 2). Infiltration rate less than 0.9 cm/min and greater than 4.0cm/min were recommended by Bonarius (1975) as unsuitable for sanitary landfilling of wastes. Mean infiltration rates (cm/min) were also high in Yenagoa, Bonny, Oyigbo and Bundu sites (Table I), and therefore are not suitable for waste landfilling, the reason being that, surface water that infiltrates their soil cover increases the rate of wastes decomposition and eventually cause leachate to leave the solid waste and create pollution problems.

Moisture contents within the range of 5.1 to 30% are suitable for sanitary landfilling of wastes (Table 2). All the locations studied met moisture requirements for waste landfilling. However, Yenagoa pedon with the highest mean moisture content (27.40%) was found to. be more prone to ponding, surface flooding and underground pollution (in agreement with Jhamnani and Singh, 2009). Flat or gently rolling land not subject to flooding is best for landfilling of wastes. Slope ranging from 0 - 8% was recognized by Bonarius (1975) as highly suitable. However, the higher slope (8%) of Eastern .by-pass site could cause high surface runoff and attendant surface water pollution. The low slope (2%) of Bonny site is characteristic of groundwater pollution. Invariably, slope <5.7% is best, while slope >8.5% is unsuitable (Khamehchiyan et al.2011). Higher and longer slopes can fail and cause catastrophic results. The pH of the soils ranged from 3.56 to 5.73 (Table 1). Weiss (1974) and Bonarius (1975) recognized that strongly alkaline and strongly acidic soils are unsuitable for waste landfilling. The comparatively lower pH of the wetland soils (Bundu, Yenagoa, and Bonny) may be due to the longer period of saturation by submergence in water. The soils of Yenagoa site were extremely acidic with mean pH of 3.87. At such pH level, there tends to be an increased micronutrient solubility and mobility, as well as increased heavy metals concentration in the soils, and therefore, Yenagoa site is not suitable for waste landfilling.

A high level of organic matter (>2%) was found to be conducive for heavy metals chelate formation, but increased cation exchange capacity, as well as increased infiltrability of surface water to avoid surface flooding. All the locations met this requirement (Table 3) for waste landfilling. The values obtained are within acceptable limits for waste dumping (Table 2). Mean cation exchange capacity of the soils ranged from 3.86 to 15.88meq/100g soil, and also falls within the acceptable limit for landfilling of wastes. Very high cation exchange capacity (CEC) lowers infiltration rate thereby increasing surface flooding (Loughry, 1973; Jhamnani et al. 2009).

4. CONCLUSION

When all the parameters were taken up at a glance, the six locations showed appreciable degree of variability in terms of their suitability for wastes disposal by landfilling. The low infiltration rate, good texture, good structure, and consistence, seasonal flooding and fairly well drained to moderately drained characteristics of Rumuokoro and Eastern by-pass sites, added to their suitability for wastes disposal by landfilling. The poor drainage status of the wetland soils (Yenagoa, Bonny and Bundu) arising from their aquic moisture regime and low slope, reduced their suitability for waste landfilling (in agreement with Bonarius, 1975; Jhamnani and Singh, 2009). The sandy texture of Oyigbo site contributed in reducing its suitability for landfilling of wastes (in agreement with Swapan and Sasanka, 2022). Summarily, it was found that no location possessed all the characteristics for landfilling of wastes. However, when all the locations were rated for municipal solid waste disposal by landfilling (Table 3) using selected physico-chemical and geo-morphological properties of the soils, they appeared in decreasing suitability order as follows:

Rumuokoro > Eastern by-pass > Oyigbo > Bundu > Bonny > Yenagoa.

It is therefore, recommended that elluvial, colluvial, fluvial and krast relief, structural hills, flood plains should be restricted from the landfill site.

REFERENCES

[1] Adeli,Z & Khorshiddoust, A. (2011). Application of Geomorphology in Urban Planning: Case Study in Landfill Site Selection; *Proceeding of Social Behavioural Science,* 19: 662- 667.

[2] Ahuja,LR; El-Swaify,SA & Rahman, A. (1976). Measuring Hydrologic Properties of Soil with Double Ring Infiltrometer and Multiple Depth Tensiometers; *Soil Science Society American Journal,* 40:49-99.

[3] Ali,SA & Ahmad, A. (2020). Suitability Analysis for Municipal Landfill Site Selection Using Fuzzy Analytic Hierarchy Process and Geospatial Technique; *Environmental Earth Science:* 79(10).

[4] Anifowose,Y; Omole, K & Akingbade, O. (2011). Waste Disposal Site Selection Using Remote Sensing and GIS: A Study of Akure and its Environs; Southwest- Nigeria: *Coler. Process:* 527- 534.

[5] Bonarius, HM. (1975). Suitability Guide for Rating of Soils for Waste Disposal; *German Agency for Technical Corporation*, West Germany: 68.

[6] El-Maguiri,A; Kissi, B; Idrissi, L & Souabi, S. (2016). Landfill Site Selection Using GIS, Remote Sensing and Multi-Criteria Decision Analysis: Case of the City of Mohammedia. Morroco. Bulletin of Engineering Geological Environment, 75(3):1301-1309.

[7] Eskandari,M; Homaee, M. & Falamaki, A. (2016). Landfill Site Selection for Municipal Solid Wastes in Mountainous Areas with Landslide Susceptibility, *Environmental Science Pollution Resources, 23 (12): 12423 – 1234.*

[8] Hodgson,JM. (1983). Soil Sampling and Soil Descriptions, *Monographs on Soil Survey*. Clarendon Press; 120- 130.

[9] Islam,MA; Murshed, S & Hasan, M. (2020). Selecting Suitable Landfill Site with Multi – Criteria Evaluation and GIS; A case of Savar Upazila in Bangledish, *Arabian Journal of Geosciences*: 13(18).

[10] Jhamnani,B & Singh, S. (2009). Groundwater Contamination due to Bhalaswa Landfill Site in New Delhi, *International Journal of Environmental Science and Engineering;* 1:121-125.

[11] Kapilan,S & Elangovan, K. (2018). Potential Landfill Site Selection for Solid Waste Disposal using GIS and Multi-Criteria Decision Analysis (MCDA); *Journal of Central South University*, 25:570-585.

[12] Khamehchiyan,M; Nikoudel, MR. & Boroumandi, M. (2011). Identification of Hazardous Waste Landfill Site: A Case study from Zanjan Province. Iran. *Environmental Earth Science*, 64 (7):1763-1776.

[13] Kumar,R. (1987). Evaluation of Soil Resource Data for Waste Disposal; *Soil Survey and Land Use Evaluation*, 7 (3): 147- 1(55).

[14] Loughry,FG. (1973). The Use of Soil Science in Sanitary Landfill Selection and Management; *Geoderma*, 10:131-139.

[15] Philip,O & Patrick, W. (2002). Landfilling as the Corner Stone of an Integrated Waste System, Department of Engineering; University of Wisconsin: 432N. Lake Street, Madison, WI 53706.

[16] Rahmat,ZG; Niri, MV; Alavi, N; Goudarzi, G; Babaei, AA., Baboli, Z & Hosseinzadeh, M. (2016). Landfill Site Selection using GIS and AHP: A Case Study: Behbahan Iran. *KSCE J. G.V. Eng*., 21 (1):111-118.

[17] Swapan,P & Sasanka, G. (2022) Identification of Solid Waste Dumping Site suitability of Kolkata Metropolitan Area using Fuzzy- AHP model. 3 (100030)

[18] Weiss,A. (1974). Sanitary Landfill Technology Noyes Data Corporation, England.

[19] Zhang,DQ; Tan, SK & Gersberg, RM. (2010). Municipal Solid Waste Management in China: Status, Problems and Challenges. *Journal of Environmental Management*; 1623-1633.

Table 1: Physico-chemical characteristics of the soils

Location	% Slope	Bulk Density g/cm^3	Particle Density g/cm^3	%Total Porosity	Infiltration Rate (cm/min)	% Moisture	% Stoniness	% Sand	% Silt	% Clay	Textural Class	Drainage Class	% Total Nitrogen	% Organic Carbon	% Organic Matter	pH	PO_4 (Meq/100g soil)	Ca (Meq/100g soil)	Mg (Meq/100g soil)	K (Meq/100g soil)	Na (Meq/100g soil)	Exch. Acidity (Meq/100g soil)	ECEC (Meq/100g soil)	CEC (Meq/100g soil)	% Base satiation
RUMUOKORO	6	1.36	2.46	44.61	2.46	13.96	1.41	67.35	11.78	20.87	SL	FWD	0.28	1.26	2.17	4.42	4.63	3.86	4.12	0.30	0.21	1.83	10.33	10.33	81
EASTERN BY- PASS	8	1.30	2.64	50.84	3.65	13.68	1.70	73.93	10.15	15.92	SL	MD	0.27	1.28	2.21	5.02	3.94	3.08	2.50	0.21	0.18	2.84	8.81	8.81	59
OYIGBO	5	1.45	2.61	44.25	4.70	14.36	2.82	75.65	9.75	14.60	SL	MD	0.06	1.27	2.19	5.41	4.35	0.16	0.05	0.23	0.21	2.90	3.54	3.54	55
BUNDU	3	1.23	2.63	53.20	4.08	15.30	0.81	37.88	21.38	40.75	SCL	PD	0.17	1.28	2.20	4.09	3.67	1.13	0.41	0.24	0.06	5.41	7.25	15.73	15
YENAGOA	3	1.18	2.65	55.62	8.10	27.40	0.00	10.75	20.25	69.00	C	VPD	0.36	1.67	2.88	3.87	3.77	5.41	4.58	0.37	0.29	9.32	19.96	15.88	34
BONNY	2	1.20	2.65	54.91	4.69	21.40	1.20	59.40	3.60	37.00	S	PD	0.38	2.58	4.45	4.21	3.09	5.10	5.73	0.48	0.33	7.89	19.48	12.83	25

TABLE 2: CLASSIFICATION KEY FOR WASTE LANDFILLING

SOIL CHARACTER	UNSUITABLE	MODERATELY SUITABLE	HIGHLY SUITABLE
Slope (%)	16 – 100%	9 – 15%	0 – 8%
Water table (cm)	0 – 100cm	100 – 200cm	> 200cm
Stoniness (%)	30 – 100%	11 – 29%	0 – 10%
Bulk density (g/cm^3)	> 1.5g/cm^3	1.0 – 1.4cm^3	0 – 9g/cm^3
Porosity (%)	0 – 10% and 50 – 100%	31 – 49%	11 – 30%
Particle density (g/cm^3)	0 – 1.9g/cm^3	2.59g/cm^3	2.6 – 2.7g/cm^3
Infiltration rate (cm min^{-1})	> 40cm min^{-1} and 0 – 9cm min^{-1}	3.1 – 3.9cm min^{-1}	1.0 – 3.0cm min^{-1}
TEXTURE			
(i) Sand (%)	0 – 40% and 71-100%	41 – 59%	60 – 70%
(ii) Clay (%)	0 – 10% and 31% - 100%	11 – 20%	21 – 30%
Organic matter (%)	0 – 1.9%	2.0 – 3.0%	> 3.0%
pH	1.0 – 4.9 and 9.0 – 14.0	5.0 – 6.0	6.10 – 8.9
Stickiness/Plasticity (wet)	Very plastic to very sticky	Plastic/Sticky to slightly plastic/slightly sticky	Non sticky and non-plastic
Moisture content (%)	0 – 5% and > 31%	5.1 – 10%	10.1 – 30%
Consistence (Moist)	Extremely firm and too loose	Firm to loose	No flooding
Flooding	Highly flooded	Seasonally flooded	No flooding
Drainage	Poorly drained	Moderately drained	Fairly well drained to well drained

Source: Weiss (1974); Bonarius (1975).

TABLE 3: SUITABILITY RATING OF WASTE LANDFILLING SITE OF THE STUDY AREA USING SOIL PHYSICO-CHEMICAL AND GEOMORPHOLOGICAL PROPERTIES

Soil characters	Rumuokoro	Eastern by-pass	Oyigbo	Bundu	Bonny	Yenagoa
Slope (%)	3	3	3	3	3	3
Stoniness (%)	3	3	3	3	3	3
Bulk Density (g/cm^3)	2	2	2	2	2	2
Porosity (%)	2	1	2	1	1	1
Particle Density (g/cm)	2	3	3	3	3	3
Infiltration Rate (cm/min^{-1})	3	2	1	1	1	1
Moisture (%)	3	3	3	3	3	3
TEXTURE						
(i) Sand %	3	1	1	1	1	1
(ii) Clay %	2	2	1	1	1	1
Organic matter (%)	2	2	2	2	3	2
pH	1	2	2	1	1	1
Flooding	2	2	2	1	1	1
Drainage	3	2	2	1	1	1
Water table	3	3	2	2	1	2
Plasticity / Stickiness (wet)	3	3	3	2	2	1
Consistence	3	3	3	3	2	1
TOTAL SCORE	40	37	35	30	29	27
%TOTAL SCORE	83.3	77.08	72.22	62.50	60.52	56.25

Suitability Order = Rumuokoro > Eastern by-pass > Oyigbo > Bundu > Bonny > Yenagoa

Key

Unsuitable 1

Moderately suitable 2

Highly suitable 3

ISSN 2350-1030

International Journal of Recent Research in Physics and Chemical Sciences (IJRRPCS)
Vol. 9, Issue 2, pp: (22-27), Month: October 2022 – March 2023, Available at: www.paperpublications.org

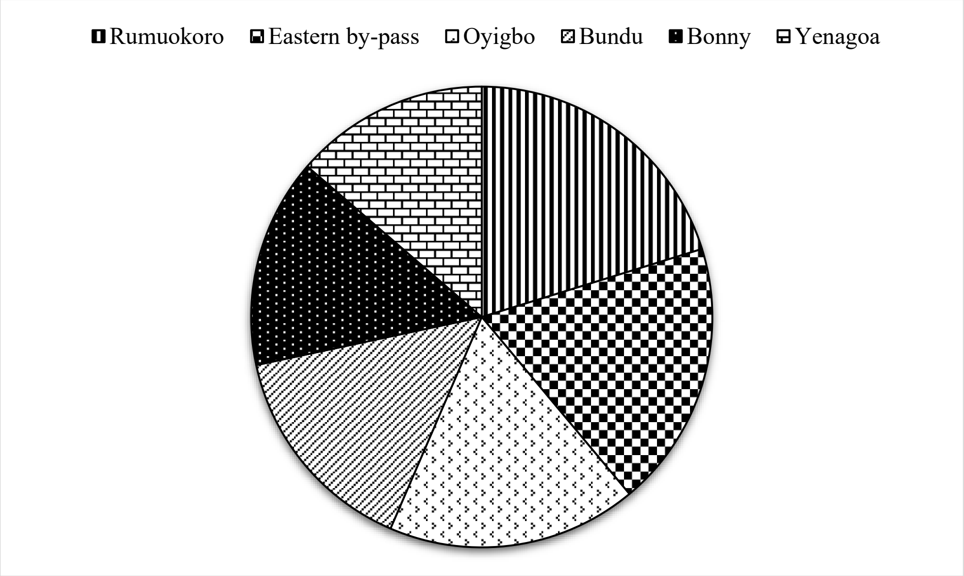

Figure 1: Pie Chart Illustrating the Waste Landfilling Suitability of the Sites