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Research Paper

Land Suitability Rating for Sanitary Facilities within the Vicinity of Uyo Urban, Nigeria.

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Abstract: Urban land use suitability research is extremely relevant and has been neglected in many places. The study was conducted to establish land suitability rating for sanitary facilities in Uyo, Southeastern Nigeria. Soil samples of coastal plain sands origin were collected from pedogenetic horizons of five areas within the vicinity of Uyo. The areas include; Use Offot, Ntak Inyang, Uyo village road, Use Atai and Ikot Ekpene road. The soil samples were prepared in laboratory and analyzed for important properties to be used in rating using standard rating guides of the USDA-NRCS (NSSH Part 620). The descriptive statistics showed that the saturated hydraulic conductivity of the study area were very highly variable (>100% variation). Very coarse sand, coarse sand, medium sand, fine sand, very fine sand, clay, bulk density and coefficient of linear extensibility (COLE) varied moderately (CV ≥ 22% ≤ 48%) in the study area. The evaluation showed that the soils had no limitation for use as sanitary landfill area and septic tank absorption fields. A restrictive feature of "acid" was indicated for the soils for its use for disposal of manure and food processing waste because the soils could have serious acidity problems if manure and food processing wastes are continually disposed on them. Urban land use suitability rating is absolutely relevant and reliability of determination of the important morphological, physical and chemical properties for the rating becomes very essential.

Keywords: Urban land use, sanitary facilities, coastal plain sands, rating, suitability

INTRODUCTION

Nature of soils influences their suitability for specified kinds of land use. A good understanding of soils is therefore vital for the management, preservation, and restoration of soil health. Soils are intimately connected with the quality of the surface and ground water that flows beneath. Soils form a mediating layer between the non-living mineral world, the atmosphere, water and the living community on the surface of the land (Caroline and David, 2000). Considerably across country, region, landscape, field, and sometimes even a backyard, each soil may have markedly different land use capabilities. While the soil in Carolina Bays makes prime wetland wildlife habitat, they are miserable places to build a home. The land use suitability of a soil is usually not this obvious; however knowing how to use the information in a soil survey can save people from costly and, in some cases, dangerous mistakes.

Because a landfill can now be designed with a geosynthetic liner to replace or back up a soil liner someone might feel that a landfill could be sited anywhere. While new technologies can increase the technical acceptability of some potential landfill sites, there are a variety of factors that must be assessed when determining site acceptability (Wilcomb and Hickman, 1986). Wilcomb and Hickman (1986) further stated that sound technology alone will be an insufficient basis on which to evaluate and compare all potential sites. There are many other factors to consider, including public opinion, health and safety, hauling distance, accessibility, climate, drainage, zoning and land use, economics and ultimately the soil itself. However, this paper discussed only about suitability of the soil. Patrick and Philip (2010) emphasized the possibilities for potential sanitary landfill sites as; a site in an area zoned for industry, a site that serves a region of several communities and is located some distance from residential development, a site that would have economic or aesthetic value if filled with solid wastes and then landscaped, a site that after construction of an above ground landfill, can be put to recreational use. They further emphasized that an ideal sanitary landfill area will have the following properties including its conformation with land use planning of the area, have safeguards against potential surface and groundwater pollution, have safeguards against uncontrolled gas movement originating from disposed solid waste, have an adequate quantity of earth cover material that is easily handled and compacted, will be located in an area where landfill's operation will not detrimentally impact environmental sensitive resources, will be large enough to accommodate community wastes for a reasonable time interval.

The United States Department of Agriculture (USDA) – Natural Resources Conservation Service (NRCS) (Soil Survey Staff, 2007) has generally evaluated soils for the most common uses in community development. These evaluations consist of the severity and kind of limitations inherent in each mapping unit with respect to several possible land uses. USDA-NRCS (Soil Survey Staff, 2007) emphasized that soil interpretations for sanitary facilities are a tool for guiding the user in site selection for the safe disposal of household effluent and solid waste. The interpretation guides are applicable to both heavily populated and sparsely populated areas. Septic tank absorption fields are subsurface systems of tile or perforated pipe that distribute effluent from a septic tank into the natural soil. The centerline depth of the tile is assumed to be 60 cm. Only the soil between depths of 60 cm and 150 cm is considered in making the ratings (Soil Survey Staff, 2007). Soil interpretations for waste management provide a means to use organic wastes and waste-water as productive resources. The use of these soil interpretation guides for sanitary facilities is important in site selection to minimize the potential for pollution and health hazards in local or regional areas.

In Uyo urban, Nigeria, there are burrow pits already in use for solid waste disposal, land uses in the area also include waste disposal on lands as well as septic tank absorption fields. Suitability assessments are required for other areas yet to be exploited for these uses. The objective of this study was therefore to evaluate the soils within the vicinity of Uyo Urban for three sanitary facilities land uses including, sanitary landfill area, septic tank absorption fields and waste management. For this purpose, soils from five representative areas in Uyo urban were sampled and characterized.

MATERIALS AND METHODS

Description of the Study Area

The study was carried out in five different areas in Uyo capital territory, namely; University of Uyo permanent site axis (Use Offot), Uyo village road, Ntak Inyang (Itu road), Uyo-Ikot Ekpene road and Use Atai. Soils of the five locations were all derived from coastal plain sands and have been altered by cultivation. In Use Offot, the soils have been cultivated but under fallow during the sampling period and were dominated by *Pennisetum digitatum* and many stands of oil palm, in the Uyo village road, the soils are under fallow dominated by *Panicum maximum* but could also have been cultivated, the Ntak Inyang soils were used solely for commercial production of rubber (rubber plantation), the soils in the sampling area of Uyo-Ikot Ekpene road had arable crops such as *Manihot esculenta* and *Zea mays* while the Use Atai soils were under fallow. Uyo is located between latitude 4˚ 50' and 5˚ 07' N and longitude 7˚ 45' and 8˚ 05' E within a humid tropical climate characterized by rainy season (February/March – November) and dry season (November – February/March). Annual rainfall ranges from 3000 mm along the Atlantic coast to 2000 mm in the hinterland (SLUS-AK, 1989).

Soil Sampling and Laboratory Analysis

Reconnaissance field trip was undertaken and routine materials and methods to be used in the field study were noted. In the field, profile pits were prepared (one each for the five different areas), described and sampled according to genetic horizons for characterization and evaluation according to Keys to Soil Taxonomy (Soil Survey Staff, 2006). The soil samples were air dried, crushed and made to pass through 2.0 mm mesh sieve. Samples were also collected with core samplers for bulk density and hydraulic conductivity analysis. The slope of each of the sampling sites was measured in the field with an abney level. Percentage gravel in the soils was determined by sieving and calculated as a percentage of the whole soil mass that passed through the 2 mm sieve. Particle size analysis was performed using the Bouyoucous hydrometer method (Gee and Bauder, 1986). Particles were also separated into various sizes using sieves as very coarse sand (VCS), coarse sand (CS), medium sand (MS), fine sand (FS), very fine sand (VFS), silt and clay expressed in gram per kilogram. Bulk density was determined using the core method as described by Blake and Hartge (1986). Hydraulic conductivity was determined using the constant head permeameter method (Topp and Dane, 2002). Coefficient of linear extensibility was calculated from differences in bulk density of undisturbed core samples when moist (33kPa or 10kPa if coarse sandy soil) and oven dry (Esu, 2010). Exchangeable base cations (Ca, Mg, K, and Na) were extracted with 1 N NH_4OAc (pH 7) (Thomas, 1982). Exchangeable calcium and magnesium were determined by ETDA complexio-metric titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). Cation Exchange Capacity (CEC) was determined by ammonium saturation (NH_4OAc) displacement method conducted at pH 7.0 as was explained in the Laboratory Manual for Agronomic Studies in Soil, Plant and Microbiology, University of Ibadan (Odu *et al*; 1986). Cations at the exchange sites of 5 g soil were displaced using 50 ml of I N NH_4OAc. Methyl alcohol (50 ml) was used to wash the samples by transferring methyl alcohol to the soil held by the filter paper on a beaker. The 5 g sample was transferred into a distillation flask, 100 ml of water was added and then 4 g of MgO was added to the mixture. The mixture was distilled into a boric acid beaker containing 10 ml of boric acid. It was distilled to a 50 ml mark and the mixture was titrated with 0.1 N HCl to a sharp pink end point. The CEC was then calculated using a simple mathematical formula. Soil organic carbon was analyzed by Walkley and Black wet digestion method (Nelson and Sommers, 1982). Thereafter, organic matter was derived by multiplying the value of organic carbon by a factor of 1.724 (Factor of Splenycl). Soil pH was measured potentiometrically in both water and 0.1 N KCl at the soil- liquid ratio of 1:2.5. Electrical conductivity was determined in the same ratio using the conductivity bridge.

Evaluation

The mean values of results of physical and chemical properties of the soil samples collected from the five representative study sites were used for rating soils within the vicinity of Uyo urban for sanitary landfill area, septic tank absorption fields and waste management, using the suitability criteria of the National Soil Survey Handbook (NSSH), Part 620 of the USDA-NRCS (Soil Survey Staff, 2007) Soil Taxonomy system. The observable morphological properties in the study area were the major properties used for rating the soils. Some of the properties include depth to high water table, depth to bedrock and slope.

Statistical Analysis

Measured variables in the data set were analyzed using classical statistical methods to obtain the minimum, maximum, mean, median, skewness, kurtosis and standard deviation. Coefficient of variation was determined to find out how variables varied in the study sites. All statistical analysis was carried out with the aid of SAS (1999).

RESULTS AND DISCUSSION

The mean and median of the soil properties were used as primary estimates of central tendency, while standard deviation, coefficient of variation (CV), skewness, kurtosis, minimum and maximum were used as estimates of variability (Table 1). Despite skewness and kurtosis, the mean and median values were similar (Table 1). These showed that outlier did not dominate the measure of central tendency but a true indication of soils formed from similar parent material. The descriptive statistics show that the saturated hydraulic conductivity of the study area were very highly variable (>100% variation). Very coarse sand, coarse sand, medium sand, fine sand, very fine sand, clay, bulk density and coefficient of linear extensibility (COLE) varied moderately (CV ≥ 22% ≤ 48%) in the study area. There was little variation (CV = 4%) in the total sand content of the soils. Moderate variability of particle sizes had previously been reported by Obi *et al*. (2011) on the soils of coastal plain sands origin in Okija, southeastern Nigeria. The limitation rating provided in each interpretation is based on the influence of existing soil properties for location of the aforementioned sanitary facilities. For the soils, the rating identifies the degree of limitation, such as slight, moderate, or severe. If the soil has a slight limitation for a specific use, no restrictive feature is noted. The restrictive feature(s) is identified for each moderate or severe limitation rating.

Table 1: Descriptive Statistics of Physical and Chemical Properties of the Uyo Soils

Variable	CV	SD	SE	Skewness	Kurtosis	Mean	Median	Min.	Max.
VCS (gkg^{-1})	45.54	23.53	4.80	0.57	-0.29	51.67	40.00	20.00	100.0
CS (gkg^{-1})	23.05	53.33	10.89	-0.29	-0.62	231.42	246.00	114.0	326.0
MS (gkg^{-1})	20.04	39.42	8.05	0.69	0.00	196.67	200.00	140.0	280.0
FS (gkg^{-1})	38.77	50.73	10.35	-0.13	-0.58	130.83	140.00	40.00	220.0
VFS (gkg^{-1})	26.24	62.97	12.85	0.46	-0.44	240.00	220.00	140.0	380.0
TS (gkg^{-1})	4.10	34.90	7.12	-0.33	-0.68	850.58	853.00	780.0	906.0
Silt (gkg^{-1})	46.77	9.32	1.90	0.07	-1.18	19.91	20.00	6.00	34.00
Clay (gkg^{-1})	26.91	34.86	7.11	0.53	-0.35	129.54	122.00	74.00	206.0
CEC/Clay	27.37	0.12	0.02	0.49	-0.96	0.42	0.39	0.26	0.65
BD (gcm^{-3})	23.93	0.31	0.06	0.94	-0.63	1.31	1.18	0.96	1.93
COLE	34.89	0.001	0.00	0.08	-0.89	0.005	0.005	0.002	0.01
HC	143.13	0.29	0.06	2.32	4.69	0.20	0.09	0.01	1.10
pH (H_2O)	1.87	0.10	0.02	1.13	1.02	5.48	5.44	5.33	5.76
pH (KCl)	1.09	0.05	0.01	0.17	-0.11	5.37	5.37	5.25	5.50
EC (dSm^{-1})	71.04	0.11	0.02	2.09	4.41	0.15	0.12	0.06	0.48
Ca ($CMolkg^{-1}$)	20.74	0.24	0.05	0.29	1.99	1.17	1.12	0.53	1.67
Mg ($CMolkg^{-1}$)	56.79	0.45	0.09	0.99	2.38	0.79	0.79	0.13	2.13
Na ($CMolkg^{-1}$)	26.28	0.02	0.004	-0.16	-0.39	0.07	0.07	0.03	0.10
K ($CMolkg^{-1}$)	116.67	0.03	0.007	1.89	2.24	0.03	0.01	0.01	0.11
TEB ($CMolkg^{-1}$)	23.42	0.48	0.10	-0.18	1.73	2.06	2.14	0.85	3.25
CEC ($CMolkg^{-1}$)	18.09	0.94	0.19	-0.15	-0.43	5.18	5.10	3.20	6.80
BS (%)	19.39	7.82	1.60	-2.00	6.16	40.32	41.43	12.50	48.72
OM (%)	39.59	1.15	0.23	-0.56	0.44	2.91	2.92	0.14	4.95
SAR	37.44	0.02	0.004	0.75	0.76	0.05	0.05	0.02	0.09

PG- Percent gravel, VCS- Very coarse sand, CS- Coarse sand, MS- Medium sand, FS-Fine sand, VFS- Very fine sand, TS- Total sand, BD- Bulk density, COLE- Coefficient of linear extensibility, HC- Hydraulic conductivity, EC- Electrical conductivity, TEB- Total exchangeable bases, CEC- Cation exchange capacity, BS- Base saturation, OM- Organic matter, SAR- Sodium adsorption ratio.

Sanitary landfill area

The suitability rating of soils within the vicinity of Uyo urban for location of sanitary landfill area is shown in Table 2. Depth to bedrock and cemented pan were not encountered in any of the sites but based on the emphasis of the USDA-NRCS (Soil Survey Staff, 2007), soils with depth to bedrock and depth to cemented pan of >150 cm could be suitable for use. Slope, flooding and ponding would not pose limitations for the specified use. Also, a depth to high water table (apparent) was not encountered in any of the representative sites but any depth >150 cm could be suitable for use. A depth to perched water table >90 cm could be justified a suitable property for the specified use. Therefore, the soils do not have any limitation for use as a sanitary landfill area.

Table 2: Suitability Rating of Pedons for Sanitary Landfill (Area) and Septic Tank Absorption Field

Property	Pedons					Restrictive Feature
	UO	NI	UV	UA	IK	
1.USDA texture	Slight	Slight	Slight	Slight	Slight	---

2. Flooding	Slight	Slight	Slight	Slight	Slight	---
3. Depth to bedrock (cm)	Slight	Slight	Slight	Slight	Slight	---
4. Depth to cemented pan (cm)	Slight	Slight	Slight	Slight	Slight	---
5. Ponding	Slight	Slight	Slight	Slight	Slight	---
6. Depth to high water table apparent (cm)	Slight	Slight	Slight	Slight	Slight	---
6a. Depth to high water table perched (cm)	Slight	Slight	Slight	Slight	Slight	---
7. Slope (%)	Slight	Slight	Slight	Slight	Slight	---

UO = Use Offot, NI = Ntak Inyang, UV = Uyo Village Road, UA = Use Atai, IK = Ikot Ekpene Road.

Septic tank absorption fields

The suitability rating of the soils for location of septic tank absorption fields is shown in Table 2. A depth to bedrock and cemented pan were not encountered in any of the sites but based on the emphasis of the USDA-NRCS (Soil Survey Staff, 2007), soils with depth to bedrock and depth to cemented pan of >180 cm could be suitable for use. Also a depth to high water table was not encountered, any depth to high water table >180 cm could be suitable (Soil Survey Staff, 2007). Slope and flooding could not pose limitations for the specified use. Generally, the soils do not have any limitation for construction of septic tank absorption fields.

Waste Management

The suitability rating of soils of Uyo capital territory for; application of manure and food processing waste, and land application of municipal sewage sludge are shown in Table 3. The discussion and inferences made about land application of municipal sewage sludge can only be used in the near future in Uyo, Nigeria since there was no central sewage treatment plant as at the time of writing this article. The soils had no limitation for use for disposal of manure and food processing wastes except that of acidity of the coastal plain sands parent material from which the soils are derived (Table 3). However, on-site evaluation needs to be done in a particular site for the intended use. The restrictive feature of "acid" was indicated for the soils for the specified use because according to the National Soil Survey Hand-book of USDA-NRCS (Soil Survey Staff, 2007) soils having a pH between 5.0 – 6.0 could have serious acidity problems if manure and food processing wastes are disposed on them. No depth to high water table was encountered in the sites but any depth greater than about 120 cm could still be suitable for use (Soil Survey Staff, 2007). More so, depth to bedrock and depth to cemented pan were not encountered in the sites but any depth greater than about 100 cm could be suitable. The Sodium
Adsorption Ratio (SAR) showed that the soils had no sodicity problems (SAR = 0.05) and based on the emphasis of the USDA-NRCS (Soil Survey Staff, 2007), soils with SAR values < 4 has a slight limitation for the specified use and thus suitable. The soil rating guide is based on utilizing the nutrients in the wastes for crop production and is not directed toward reclaiming or restoring critical areas or making the most efficient use of moisture (Soil Survey Staff, 2007).

Table 3: Suitability Rating of Pedons for Land Application of Manure, Food Processing Wastes and Land Application of Municipal Sewage Sludge

	Pedons					
Property	UO	NI	UV	UA	IK	Restrictive Feature
1.USDA texture	Slight	Slight	Slight	Slight	Slight	---
2. Depth to high water table (cm)	Slight	Slight	Slight	Slight	Slight	---

3. Ponding	Slight	Slight	Slight	Slight	Slight	---
4. Slope (%)	Slight	Slight	Slight	Slight	Slight	---
5. Depth to bedrock (cm)	Slight	Slight	Slight	Slight	Slight	---
6. Depth to cemented pan (cm)	Slight	Slight	Slight	Slight	Slight	---
7. Sodium Adsorption Ratio (0-50 cm)	Slight	Slight	Slight	Slight	Slight	---
8. Flooding	Slight	Slight	Slight	Slight	Slight	---
9. Clay activity (CEC/clay)	Slight	Slight	Slight	Slight	Slight	---
10. Soil reaction (pH, Surface layer)	Mo	Mo	Mo	Mo	Mo	Too acid

UO = Use Offot, NI = Ntak Inyang, UV = Uyo Village Road, UA = Use Atai, IK = Ikot Ekpene Road.
Mo = Moderate limitation

CONCLUSION

The mean and median of the soil properties were largely similar which indicated that the soil properties were from a similar parent material. There was no limitation for use of the soils as sanitary landfill area and thus the soils are suitable for the use. Also, the soils had no limitation for construction of septic tank absorption fields. A restrictive feature of "acid" was indicated for the soils for its use for disposal of manure and food processing waste because the soils could have serious acidity problems if manure and food processing wastes are continually are disposed on them. Land suitability rating of soils for sanitary facilities within the vicinity of Uyo urban, Southeastern Nigeria will effectively depend on reliability of determination of some important morphological, physical and chemical properties that characterize the soil for such uses.

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