GEOTECHNICAL INVESTIGATIONS IN SOME COMMUNITIES OF SOUTH SOUTH NIGERIA TO AID DESIGN AND CONSTRUCTION OF LATRINES

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ABSTRACT

Geotechnical Investigation for appropriate excreta disposal system in riverine areas was piloted in Uta Ewa in Ikot Abasi Local Government Area and Ibaka in Mbo Local Government Area of Akwa Ibom State. Soils in both communities were characterized by high water levels and poor drainage because of nearness to water bodies. Within the depths of 1.0m and 2.0m, the underlying soil material tested was classified as ML representing organic silt and very fine sandy clay. Construction of septic tank/soak away pit is therefore not possible in these areas but would require some improvement to enable it give satisfactory support to the appropriate latrine facility.

KEY WORDS: *Bearing capacity, Excreta, Geotechnical, Hydraulic conductivity, Morbidity, Mortality, Plasticity index, Shrinkage limit, Subsurface horizon.*

INTRODUCTION

Efforts have been directed to achieving sustainable success to improved sanitation facilities in Nigeria over the decades. Governments at all levels and donor agencies have been investing huge resources towards this noble course. However, a lot of people, particularly rural dwellers do not see sanitation as a worthy course to invest on. According to Abogan (2014), "National estimates show that less than half of Nigeria's 160 million people have access to improved sanitation facilities and situation is worse in the riverine areas of south Nigeria because of the ecological factors which include loose soil type, high underground water level which leads to run-off water that collapse toilets, and shallow rocky basement which inhibits excavation of pits for toilets construction to any reasonable depth in some areas".

More than five hundred millions of people in the developing countries lack access to potable water, and access by households to sufficient and safe water combined with adequate sanitation and hygiene could result in a substantial reduction of the 5 million deaths due to diarrheal diseases that occur each year (WHO, 1992). WHO, 2008 reported that 88% of the 4 billion annual cases of diarrheal diseases are attributed to unsafe water and inadequate sanitation and hygiene and 1.8 million people die from diarrheal disease each year. The significance of water to human and other biological systems cannot be over emphasized and its pollution can cause severe decrease in productivity and deaths of living species (Garba *et al.,* 2008; Garba *et al.,* 2010). Reports by Food and Agricultural Organisation revealed that in African countries, particularly Nigeria, water related diseases had been interfering with basic human development (FAO, 2007). The level of sanitation and hygiene coverage in Nigeria is generally poor. The 2006 Joint Monitoring Programme (JMP) report puts the coverage at 53% in 2004 for urban areas and 36% for rural areas. Today 2.6 billion people, including almost one billion children, live without even basic sanitation. Every 20 seconds, a child dies as a result of poor sanitation and 1.5 million preventable deaths each year (WSSCC, 2008).

The sanitation and hygiene situations are worse in the riverine communities than other parts of the country due to the very difficult terrain, especially very shallow water table, prevalent in the region. As a result, a large number of people in the riverine areas of south Nigeria suffer sanitation-related and water-borne diseases. The global health burden associated with these conditions is staggering, with an estimated 4000–6000 children dying each day from diseases associated with lack of access to safe drinking water, inadequate sanitation and poor hygiene (Moe and Rheingans, 2006). Therefore, there is a dire need of holistic approach to call for hygienic, eco-friendly and sustainable technology system for excreta disposal, hence the option of Eco-San toilet. Eco-San toilets are found as one of the most appropriate and proven technological options, as they are cost effective, environmentally as well as socially sounds and reliable in solving the existing and emerging sanitation problems of riverine areas.

The basic objective of this paper is to present the geotechnical investigation findings, and determine an appropriate technology option for safe excreta disposal system in parts of the riverine areas of south Nigeria.

PROJECT AREA

The project was piloted in two riverine communities of Akwa Ibom State, namely, Uta Ewa in Ikot Abasi Local Government Area and Ibaka in Mbo Local Government Area. UtaEwa community is situated along the shores of Imo River and the people speak the Ibibio language. The fishing settlement was reclaimed to enable the inhabitants settle there. Ibaka community on the other hand is a major fishing settlement along the coast of the Atlantic Ocean and has a population of about 3,136 (NPC, 1996). They speak the Oro dialect. Vegetation is tropical rainforest and mangrove in both places.

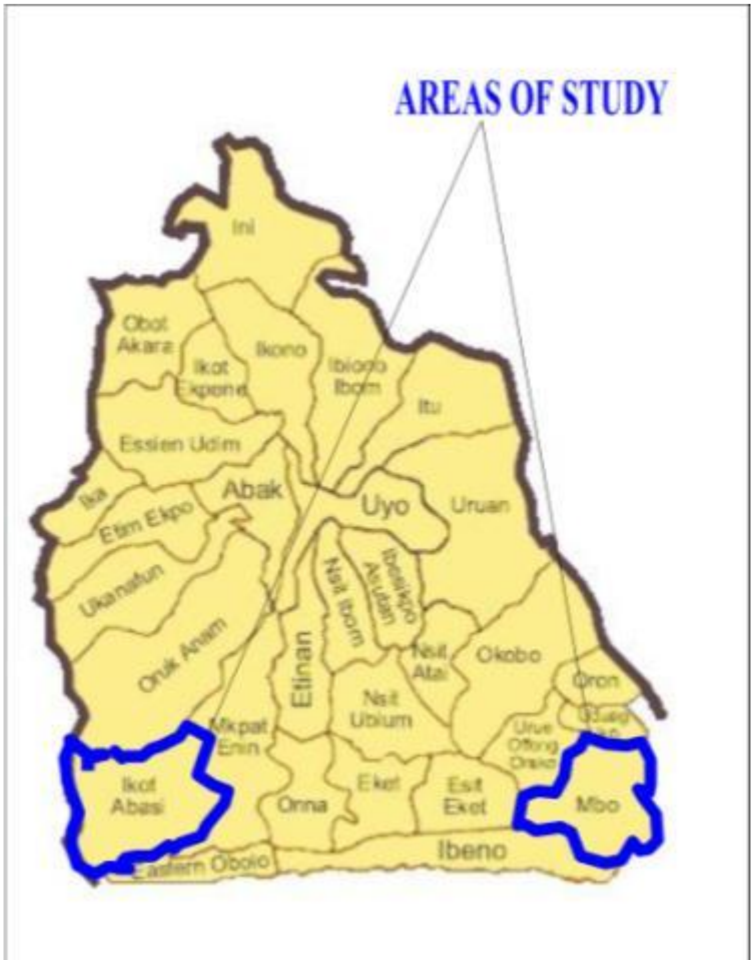

Fig. 1.1: Map of AkwaIbom State showing LGAs under study

Akwa Ibom State is located between Cross River, Abia, and Rivers States on the sandy coastal plain of the Gulf of Guinea. It is bordered on the south by the Atlantic Ocean which stretches from Ikot Abasi to Oron. Akwa Ibom State lies between latitude 4^{o} 32' and 5^{o} 53' North; and Longitudes 7^{o} 25' and 8^{o} 25' East. In terms of structural make up, Akwa Ibom is triangular in shape and covers a total land area of 8,412 km^2, encompassing the Qua Iboe River Basin, the western part of the lower Cross River Basin and the Eastern part of the Imo River Basin (Fig. 1.1). With an ocean front which spans a distance of 129 kilometers from Ikot Abasi in the west to Oron in the east, Akwa Ibom presents a picture of captivating coastal, mangrove forest and beautiful sandy beach resorts; a sprawling volume of water seemingly kissing the skyline from flank to flank.

The location of Akwa Ibom just north of the Equator and within the humid tropics and its proximity to the sea makes the state generally humid. On the basis of its geographical location the climate of Akwa Ibom State can be described as a tropical rainy type which experiences abundant rainfall with very high temperature. The mean annual temperature of the state lies between 26°C and 29°C and average sunshine cumulates to 1,450 hours per year, while mean annual rainfall ranges from 2,000 mm to 3,000 mm, depending on the area. Relative humidity is in the range 60 to 90%. Thick cloud cumulonimbus type is commonly experienced in the months of March to November. Evaporation is high with annual values that range from 1500 mm to 1800 mm.

METHODOLOGY

Soil Profile

The study was conducted to assess the soil characteristics of Ibaka (Mbo LGA) and Uta Ewa (Ikot Abasi LGA) communities in Akwa Ibom State. Two soil profiles were sited at two different locations in each selected community. One was located in the Fishing Port near water bodies while the other was located in the upland area. Each pit was described according to FAO (1990) guidelines for soil profile description. Soil samples were collected at each genetic horizon from the four pits for laboratory analysis. Undisturbed bulk soil samples were also taken from each horizon using core ring for bulk density and saturated hydraulic conductivity determinations.

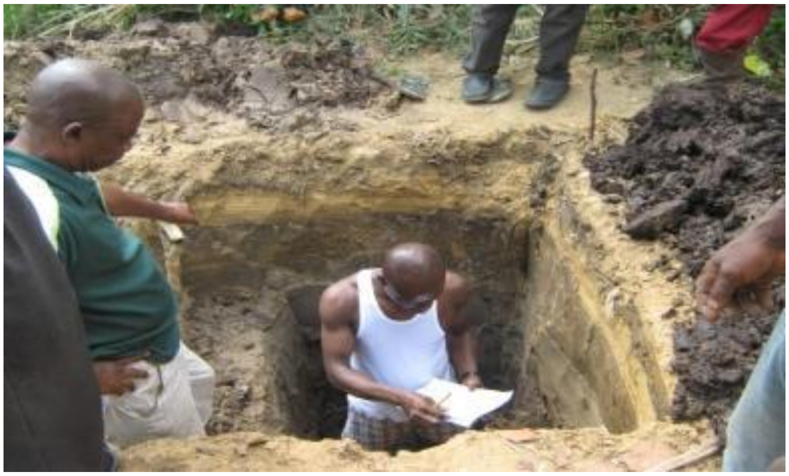

Plate 1: Soil profile

The following laboratory analyses were carried out on the soil samples collected from the pits: *Saturated hydraulic conductivity* using constant head permeameter method of Klute (1986); *Bulk density* using non- stony soil method of Blake (1965) and *Particle size analysis* using hydrometer method of Buoyoucos (1951).

Geotechnical Investigation for Foundation (In-Situ Unconfined Compression Test)

The test was carried out to ascertain the minimum safe bearing capacity or pressure of the soil for foundation design in respect of latrine facility. For in-situ unconfined compression test, undisturbed soil sample at 1 m and 2 m respectively are recovered by means of Shelby tube.

The tube was driven into Auger boring hole below ground surface and the sample extruded from Shelby tube into split mould of 38 mm diameter and 76 mm long (Plate 2). Extruded undisturbed sample was placed on a portable unconfined compression apparatus (Plate 3).

The load was applied manually by a rotary handle and lead screw through a calibrated spring on the sample mounted between lower and upper 38 mm diameter flat polished metal plates and the corresponding compression was autographically recorded on the chart. A 150 mm Auger head was utilized manually to recover samples at 1 m and 2 m depths respectively below ground surface.

Plate 2: Hand auger boring Plate 3: In-situ unconfined compression test

Laboratory Testing

Samples recovered from hand Auger borings holes were processed for some selected routine laboratory tests. Given the constrains associated with this particular sub-soil investigation, tests performed on the samples were limited to all the basic index property, the result of which were evaluated side by side with the measured in-situ responses recorded from the deposit. Tests performed include: soil moisture content, Atterberg Limits test, linear shrinkage test, soil mechanical analysis

RESULTS AND DISCUSSIONS

Soil texture

The results of the soil texture analysis for Ibaka, as shown in Table 1, indicate that percentage coarse sand was higher than percentage fine sand throughout the profile depths. In profile 1 (Fishing Port), sand content ranged from 94.1% in the surface horizons to 53.9- 54.9% in the subsurface horizons. Silt ranged from 0.48% in the surface horizon to 8.9 - 12.4% in subsurface horizons. Clay ranged from 5.5% in the surface horizon to 33.7 - 36.1% in the subsurface horizons. In profile 2 (Upland), sand content ranged from 85% in the surface horizons to 83% in the subsurface horizons. Clay ranged from 11.5% in the surface horizons to 15.5% in the subsurface horizon. Silt ranged from 3.5% in the surface horizons to 1.5% in the subsurface horizons.

In UtaEwa the percentage coarse sand was higher than percentage fine sand throughout the profile depth (see Table 2). In profile 1 (Fishing Port), sand content ranged from 90.9% in the surface horizons to 88.9 - 90% in the subsurface horizons. Silt ranged from 3.6% in the surface horizon to 1.6 - 5.6% in subsurface horizons. Clay ranged from 5.5% in the surface horizon to 5.4 - 7.4% in the subsurface horizons. In profile 2 (Upland), sand content ranged from 84.9 - 86.9% in the surface horizons and 82.9% in the subsurface horizons. Clay ranged from 7.4 - 9.4% in the surface horizons and 11.4% in the subsurface horizon. Silt was constant throughout the horizon (5.6%). The study revealed that sand content decreases with soil depth while silt and clay increases with soil depth in both communities

Saturated hydraulic conductivity

The results shown in Table 1 for Ibaka indicate that in profile 1 (Fishing Port), saturated hydraulic conductivity varied from rapid to slow (0.1 - 37.2 cm/hr) in the surface horizons and very slow (0.0 cm/hr) in the subsurface horizons. In profile 2 (Upland), saturated hydraulic conductivity varied from moderately rapid (6.8 cm/hr) in the surface horizons, to very slow (0.00 cm/hr) in the subsurface horizons.

For UtaEwa, saturated hydraulic conductivity in profile 1(i.e. Fishing Port) varied from moderately rapid (2.6 - 3.4 cm/hr) in the surface horizons to slow (0.2 - 0.4 cm/hr) in the subsurface horizons. In profile 2 (Upland), saturated hydraulic conductivity varied from slow to rapid (1.9 - 8.1 cm/hr) in the surface horizons, and very slow (0.00 - 0.7 cm/hr) in the subsurface horizons as shown in Table 2.

The study revealed that water movement was moderately rapid in the surface horizons and slow to very slow in the subsurface horizons in both communities.

Bulk density

Table 1 shows that bulk density of the soils from profile 1 (Fishing Port) in Ibaka ranged from less compact (1.2 - 1.4 g/cm^3) in the surface horizons to more compact (1.5 - 1.7 g/cm^3) in the subsurface horizons in. Similarly, in profile 2 (Upland), bulk density ranged from less compact (1.2 - 1.4 g/cm^3) in the surface horizons to more compact (1.7 - 1.8 g/cm^3) in the subsurface horizons.

Table 1: Soil physical characteristic of Ibaka in Mbo LGA

Location	Horizon Depth (cm)	BD (g/cm^2)	KS (cm/hr)	FS(%)	CS (%)	Total Sand (%)	Silt (%)	Clay (%)	Texture Class
Ibaka (Profile 1)	0-40	1.23	0.12	34.18	59.88	94.06	0.48	5.46	Sand
	40-65	1.44	18.30	34.18	59.88	94.06	0.48	5.46	Sand
	65-76	1.51	37.19	17.72	76.34	94.06	0.48	5.46	Sand
	76-103	0.96	0.00	8.80	85.26	94.06	0.48	5.40	Sand
	103-150	1.60	0.00	8.20	45.71	53.90	12.41	33.68	Sand clay loam
	150-185	1.68	0.00	10.92	43.96	54.88	8.99	36.12	Sand clay
Ibaka (Profile 2)	0-13	1.61	6.78	19.56	65.46	85.02	3.52	11.46	Loamy sand
	13-110	1.70	0.00	10.49	75.53	85.02	3.52	11.46	Loamy sand
	110-150	1.76	0.00	20.46	64.56	85.02	1.52	13.46	Loamy sand
	150-185	1.70	0.00	20.46	64.56	85.02	1.52	13.46	Loamy sand
	185-200	1.77	0.00	20.89	62.13	85.02	1.52	15.46	Loamy sand

* BD = Bulk density; FS = Fine sand; CS = Coarse sand; KS = Saturated Hydraulic Conductivity

In UtaEwa (Table 2), bulk density of the soils from profile 1 (Fishing Port) ranged from less compact (1.3 - 1.4 g/cm^3) in the surface horizons to more compact (1.5 g/cm^3) in the subsurface horizons. In profile 2 (Upland), bulk density ranged from less compact (1.2-1.4 g/cm^3) in the surface horizons to more compact (1.6 g/cm^3) in the subsurface horizons.

Table 2: Soil physical characteristic of UtaEwa in IkotAbasi LGA

Location	Horizon Depth (cm)	BD (g/cm^2)	KS (cm/hr)	FS(%)	CS (%)	Total Sand (%)	Silt (%)	Clay (%)	Texture Class
UtaEwa (Profile 1)	0-20	1.26	3.36	33.86	57.09	90.96	3.64	5.40	Sand
	20-30	1.60	2.55	34.58	56.38	90.96	3.64	5.40	Sand
	30-60	1.36	3.24	29.62	59.34	88.96	3.64	7.40	Sand
	60-90	1.46	0.42	28.33	58.63	86.96	5.64	7.40	Sand
	90-120	0.71	0.23	38.94	54.02	92.96	1.64	5.40	Sand
	120-200	1.54	0.23	20.40	70.56	90.96	3.64	5.40	Sand
UtaEwa (Profile 2)	0-10	1.24	1.91	26.44	60.52	86.96	5.64	7.40	Sand
	10-76	1.39	8.10	16.76	68.00	84.96	5.64	9.40	Loamy sand
	76-120	1.63	0.96	26.49	58.47	84.96	5.64	9.40	Loamy sand
	120-153	1.61	0.20	19.93	63.03	82.96	5.64	11.40	Loamy sand
	153-200	1.60	0.00	23.62	59.34	82.96	5.64	11.40	Loamy sand

* BD = Bulk density; FS = Fine sand; CS = Coarse sand; KS = Saturated Hydraulic Conductivity

The variation in bulk density values from horizon to horizon is due to variability in organic matter content and soil structure of the different horizons (Edem, 2007). Generally, bulk density increases with soil depth.

In-situ unconfined compression test result

Stratography of the investigated profile in both communities revealed a sub soil which is generally consistent, underlying the whole site. The Layer of the subsurface deposit is dull brown to reddish brown, very fine silt sandy clay. Throughout the field investigation, water table existed at a shallow depth of between 0.8 m and 2.0 m.

Table 4: Summary of laboratory tests of soil samples

Auger Boring Test No.	Sample Depth (m)		Percentage Passing B.S Sieve (%)								Atterberg Limit %				NMC (%)	UCS KN/m^2	USCS Classification
	From	To	2.0mm	1.18mm	600 µ	425 µ	300 µ	212 µ	150 µ	75 µ	LL	PL	PI	LS			
Ibaka Town – Mbo L.G.A.																	
BH-1	0.0	0.5	100	98.5	97.9	78.4	69.4	59.3	54.4	52.3	47.2	34.7	12.5	1.4	9.8	--	ML
BH-1	0.5	1.2	100	96.8	95.2	80.2	72.3	60.5	48.5	39.9	35.1	30.0	5.1	1.4	20.3	--	ML
BH-2	0.0	1.0	100	97.0	78.6	59.0	40.9	29.4	22.2	19.3	26.1	24.9	1.2	1.4	11.2	20	ML
BH-2	1.0	2.1	100	99.3	93.5	79.7	63.5	55.8	50.3	43.3	39.9	29.8	10.1	2.0	13.3	40	ML
BH-3	0.0	1.0	100	99.0	98.2	81.8	71.8	58.1	49.9	40.5	36.8	28.1	8.7	1.6	15.2	10	ML
BH-3	1.0	2.0	100	98.2	91.1	85.5	72.5	60.1	51.7	48.1	41.1	36.6	4.5	1.7	18.2	30	ML
BH-4	0.0	1.2	100	96.3	89.2	80.1	70.5	59.9	52.1	41.1	38.2	37.0	1.2	1.6	21.1	--	ML
Uta Ewa Town – Ikot Abasi L.G.A.																	
BH-1	0.0	1.0	100	99.4	95.1	89.3	76.0	58.5	49.0	46.0	35.1	30.8	4.3	2.9	24.5	40	ML
BH-1	1.0	2.0	100	99.1	97.6	96.1	76.2	55.1	42.9	39.0	33.5	31.7	1.8	2.9	29.3	60	ML
BH-2	0.0	1.0	100	99.3	96.8	90.3	77.3	56.2	47.7	42.8	32.1	28.3	3.8	2.0	23.8	40	ML
BH-2	1.0	2.0	100	99.5	94.3	85.2	73.5	51.3	45.1	38.3	30.2	24.9	5.3	2.3	31.1	55	ML
BH-3	0.0	1.0	--	100	92.1	80.2	57.6	46.1	39.8	38.7	32.4	25.6	6.8	2.9	29.1	45	ML
BH-3	1.0	2.0	--	100	93.2	82.3	60.0	48.5	40.6	37.1	34.2	28.5	5.7	2.7	32.2	60	ML

NOTE:

LL: Liquid Limit PL: Plastic Limit PI: Plasticity Index LS: Linear Shrinkage U.S.C.S: Unified Soil Classification System

µ= Micron UCS: Unconfined Compression Strength ML: Organic Silt and very fine sand clay NMC: Natural Moisture Content

Laboratory testing

Laboratory measurement of index properties performed on undisturbed samples recovered from auger boring holes at a depth of about 1 m and 2 m respectively below ground surface revealed the results presented in Table 4. In addition, hand auger boring logs and Atterberg limit/particle size distribution curves were generated. The summary of the parameters are given in Table 3.

Table 3: Index soil properties determine from undisturbed samples in the laboratory

S/N	Parameter	UtaEwa	Ibaka
i)	Liquid limit	30.2% - 36.2%	26. 1% - 47.2%
ii)	Plasticity index	1.8% - 6.8%	1.2% - 12.5%
iii)	Linear Shrinkage	2.0% - 2.9%	1.4% - 2.0%
iv)	Percentage Fines	37.1% - 46.0%	19.3% - 52.3%
v)	Natural Moisture Content	23.8% - 33.2%	9.8% - 21.1%

CONCLUSION

Soil type in both communities was characterized by high water levels and poor drainage because of nearness to water bodies. Within the depths of 1.0 m and 2.0 m the underlying soil material tested classified as ML under the unified soil classification system, that is, organic silt and very fine sandy clay. This means that the soil on topmost 1.0 m to 2.0 m depth below ground surface would require some improvement to enable it give satisfactory support to the proposed latrine facility. Installation of septic tank/soak away pit is therefore not possible in these areas.

RECOMMENDATION

It is recommended that a safe bearing pressure of 25 KN/m^2 (for Ibaka) and 50 KN/m^2 (for Uta Ewa) should be applied for the foundation of the proposed latrine facility. The latrine options for the riverine areas are elevated concrete chambers to receive the faeces, and urine is diverted out of the chamber; vent pipes are added to control odour. Based on the results of the field studies, three Ventilated Improved Pit (VIP) latrine options are suggested.

1) For areas that are not flooded daily, but are flooded during periods of very high water tides like Uta Ewa in Ikot Abasi LGA. The proposed facility option is an elevated

ventilated improved latrine about 1 m high from the ground level and can be accessed through the steps.

2) For areas that are flooded daily by high water tides like the fishing ports of Ibaka in Mbo LGA. The proposed facility option is an elevated latrine about 2 m high from the ground and can be accessed through the steps. The height may be less than 2 m in some areas which depending on the topography and other physical facilities.

3) For an upland in the riverine areas. The latrine is a normal communal latrine but should not be too deep because of the high water table expected in the area during the rainy season.

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