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Bamboo Leaves Ash Soil Stabilization and Hydrogeochemical Assessment of a Proposed Dam Site at Okeigbo-Ifetedo South-West, Nigeria

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Abstract

Soil stabilization using bamboo leave ash (BLA) and hydrogeochemical assessment of surface water of Okeigbo damsite were carried out. Three samples each of water and soil were collected for analyses. Soil samples collected at 1.0 m depth were mixed with BLA in proportion of 2%, 4%, 6% and 8% respectively and tests such as NMC, grain size, specific gravity, CBR, compaction and UCS were performed on them. Results showed that NMC ranged from 14.3% to 20.1%, the PI from 19.28% to 28.26%, LS from 10.7 to 15.0%. Soaked CBR of sample 1 ranged from 12% to 14%, sample 2 from 3% to 7% and sample 3 from 3% to 9%, shear strength of sample 1 from 25.11 to 31.64 kpa, sample 2 from 12.70 to17.80 kpa and sample 3 from 31.49 to 38.73 kpa, MDD of sample 1 ranged from 1923kg/m^3 to 1968kg/m^3 and OMC from 13.2% to 12.0%, sample 2 MDD from 1545kg/m^3 to 1623kg/m^3 and OMC from 22.5% to 20.5% for sample 3. The addition BLA improves the geotechnical properties at optimum of 4% by weight of the soil. Hydrogeochemical involves determination of temperature, pH, EC, hardness, Ca^{2+}, Al^{3+}, Mg^{2+}, Mn^{2+}, K^+, Cr^{6+}, Fe^+, Cu^{2+}, Na^+, Cl^-, HCO_3^- , NO_3^- , SO_4^{2-} and PO_4^{3-} in water samples. The pH value ranged from 6.77 to 7.44, EC ranged from 5.20 to 49.90 µs/cm, hardness, 52.97 to 57.12, i dominant ions are Ca^{2+} and HCO_3^- . The result of physico-chemical analyses revealed surface water samples are not potable

Keywords: Geotechnical properties, stabilization, lateritic soil, surface water, hydrogeochemistry

1.0 Introduction

Dams generally are found in many parts of the world both in the developing and developed countries. Dam could be seen as an artificial barrier constructed across river or streams; valleys with a view of impounding the flowing water for various uses. Dams are built to control floods, for irrigating lands, electricity generation and water supply to cities and industries. Okeigbo-Ifetedo dam was proposed for supply of water for domestic consumption and industrial uses. Geologic formation and climate determine the ideal sites for dam construction. Dams for domestic and industrial uses must meet up with the requirement for drinking water standard and industrial water usage if is to serve optimally for the purpose for which is built. Sometimes it may be necessary to improve the geotechnical properties of dam site by stabilization (Ankit *et al.*, 2013; Bergodo *et al.*, 1996; Amadi *et al.*, 2015; Ali, 2013; Ogunribido, 2018; Oloruntola, 2018; Amu, 2011). An integrated hydrogeochemical assessment and geotechnical soil investigation were carried out at the study area to determine whether the soil has the bearing capacity that will prevent the seepage of water or collapse of the dam and also if the water quality meet up with the international drinking water standard. Lateritic soils have been successfully used in the construction of embankment and earth dams, the degree of success in each case depend on the genetic characteristic of the soil and the specific purpose for which they have been used. Various genetic lateritic soils have been used for the construction of earth dams and embankment to date, when properly evaluated.

2.0 Materials and Methods

2.1 Geology, Location and Physiography of the Study Area.

The study area belongs to the Basement Complex of Southwestern Nigeria (Figure 1). The major rock types present are quartzites, charnockites and older granites (Rahman, 1976; Rahaman, 1988). The area lies between latitudes 7^{o} 00’ and 7^{o} 15’ North of Equator and longitude 4^{o} 30’ and 4^{o} 45’ East of Greenwich Meridian. The drainage pattern is a combination of trellis and dendritic. The climate is tropical rain forest with alternate dry and wet seasons. The wet season is from April to October and dry season is from November to March.

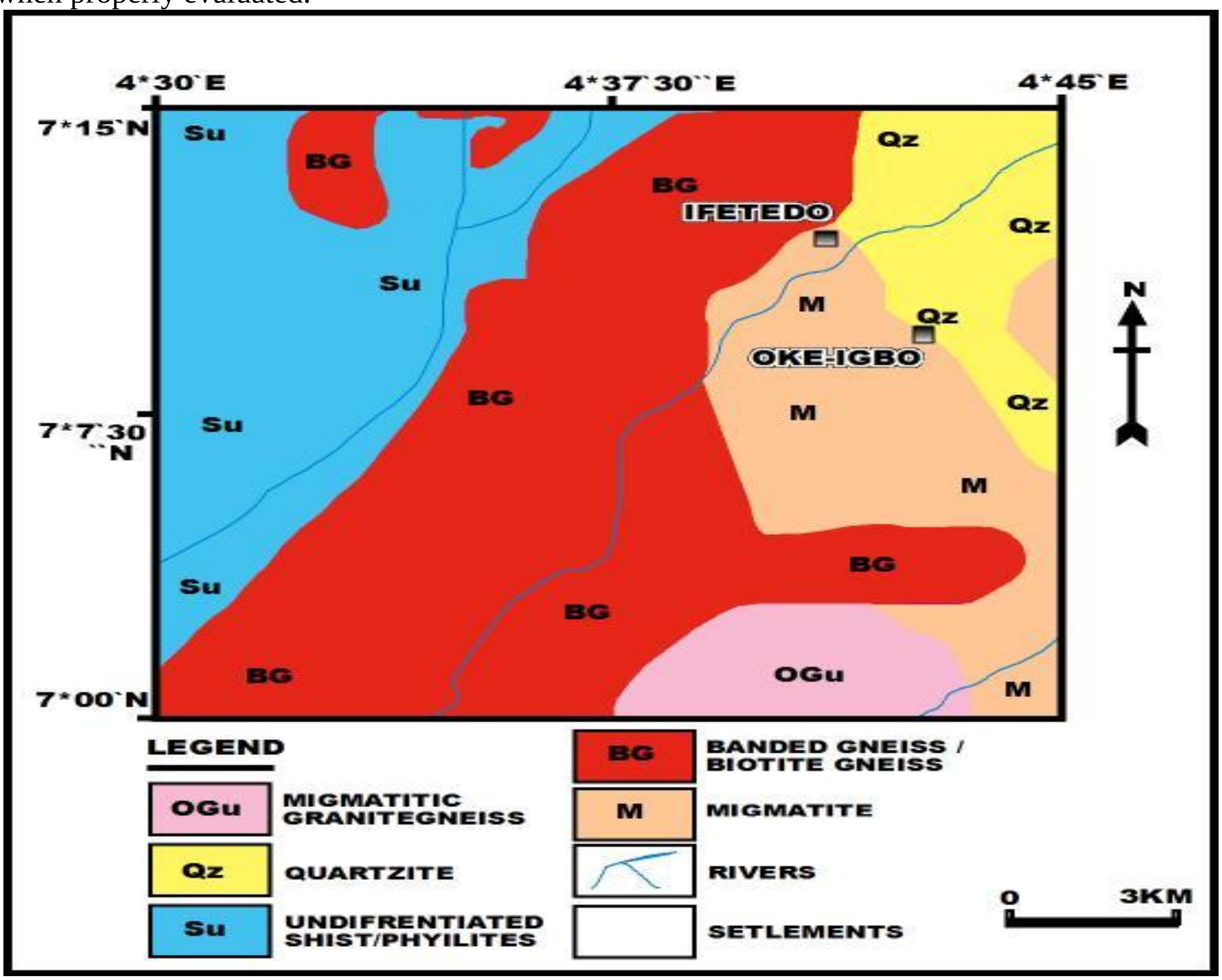

Figure 1: Geological Map of the Study Area

2.2 Methods

Three soil and water were collected in the study area for analyses, bamboo leaves ash was used for stabilisation Method used in analyses are contained in the fundamental engineering procedures as specified by the British Standard Institution BSI 1377 (2022). Samples collected from test pits at 1.0 m depth before and after the proposed spillway. Geotechnical test carried out on soil samples includes: natural moisture content, Atterberg limits, linear shrinkage, grain size analysis, compaction, California bearing ratio, unconfined compressive strength and specific gravity and thereafter they were also stabilized by bamboo leave ash at 2, 4, 6, and 8% by weight of the soil. Samples collected were immediately stored in a polythene bag to prevent escape of moisture.

Water samples were collected adjacent to soil samples using clean 2 litres plastic bottles. Hydrogeochemical test was carried out to determine the following parameters: Total hardness, Total Alkalinity, Calcium hardness, Calcium, Chloride, Magnesium, Manganese, Copper, Zinc Nitrate, Sulphate, Sodium, Potassium, Bicarbonate, Carbonate, Hydroxide, Phosphate, Aluminium, Chromium, Lead, Silicon, Aluminium and Iron

3.0 Results and Discussions

3.1 Geotechnical Properties of the Soil

The results Geotechnical properties are showed in Tables 1 and 2 and hydrogeochemical properties in Table 3

Table 1: Results of Unstabilized and Stabilized soil for Atterberg Limits, Specific Gravity, Moisture Content and CBR Data

S/N	Stabilizer BLA	LL%	PL%	PI%	LS	CBR soaked %	CBR unsoaked %	Gs	NMC %
S1	0%	37.2	17.9	19.3	10.7	15	22	2.67	14.3
	2%	36.8	18.1	18.7	10.7	12	23		
	4%	35.6	18.3	17.4	11.4	13	24		
	6%	31.7	18.2	13.5	10.0	13	26		
	8%	30.3	18.8	11.5	8.6	14	28		
S2	0%	53.0	25.0	28.0	15.0	3	8	2.68	15.3
	2%	52.9	25.1	27.8	14.3	3	8		
	4%	52.0	25.6	26.4	12.1	5	10		
	6%	51.8	26.2	25.7	10.7	7	11		
	8%	49.8	27.1	22.7	9.3	7	13		
S3	0%	56.0	27.7	28.3	12.9	3	6	2.75	20.1
	2%	55.9	27.8	28.1	12.1	3	7		
	4%	55.1	28.5	26.6	11.4	3	10		
	6%	53.6	29.6	24.0	10.7	5	12		
	8%	51.8	31.2	20.6	10.0	9	14		

Table 2: Results of Unstabilized and Stabilized Soil for Compaction, UCS, Grain Size and Shear Strength

S/N	Stabilizer BLA	UCS qu kpa	SS kpa	MDD Kg/m^3	OMC %	Gravel %	Sand %	Fines %
S1	0%	49.9	24.9	1919	13.3	9.9	48.3	41.3
	2%	50.2	25.1	1923	13.2			
	4%	63.3	31.6	1968	13.1			
	6%	59.1	29.6	1939	12.7			
	8%	54.6	27.3	1927	12.0			
S2	0%	24.0	12.0	1524	23.0	2.9	52.4	44.7
	2%	25.4	12.7	1545	22.5			
	4%	35.6	17.8	1623	21.9			
	6%	32.3	16.1	1594	21.2			
	8%	28.8	14.4	1569	20.5			
S3	0%	62.9	31.4	1438	25.1	1.5	46.9	51.6
	2%	63.0	31.5	1442	25.0			
	4%	77.5	38.7	1507	24.6			
	6%	73.0	36.5	1475	24.2			
	8%	68.0	33.9	1458	23.4			

3.1.2 Atterberg Limits

Results showed that the liquid limits of unstabilized soil ranged from 37.2% to 56.0%, plastic limits from, and 17.9 to 27.7%. The plasticity index of the sample 1 was 19.28% and Sample 2 was 28.0% and sample 3 was 28.3%. The clay in sample 1 has medium plasticity while 2 and 3 has high plasticity. The liquid limits of the stabilized soil with bamboo leaves ash for sample 1 reduced from 36.8% to 30.3%, sample 2 from 52.9 to 49.8% and sample 3 from 55.9 to 51.8% while plasticity index ranged from 18.7% to 11.5% for sample 1, sample 2 from 14.3 to 9.3% and sample 3 from 28.1 to 10.0%. This showed that the clay in S1 when stabilized is medium, S2 and S3 remained high. However, the soil samples are not good for construction work due to high plasticity index and they are to be stabilized with the stabilization agent.

3.1.3 Linear Shrinkage

The linear shrinkages of the unstabilized soil ranged from 10.7% to 15.0% (Table 1). The linear shrinkage for any soils to be used for sub-grade of any road pavement should not exceed 8% (Madebor, 1983). Soil with linear shrinkage between 0 and 8% would not be expansive so such soil would be good for construction activities.

When the soils were stabilized with the bamboo leaves ash, the linear shrinkage for soil sample 1 reduced from 10.7 to 8.6%, sample 2 from 14.3 to 9.3% and sample 3 from 12.9 to 10.0%. Since these linear shrinkages are higher than 8%, soil samples are likely to swell and shrink at wet and dry season respectively.

3.1.4 Grain Size Distribution

The fines of the soil samples ranged from 41.3% to 51.6%, sand from 48.3% to 52.4% and gravel ranged from 1.5% to 9.9% for soil samples in the study area. Soil samples are fined to medium grained.

3.1.5 Specific Gravity

The specific gravity of the tested soil samples in the area ranges from 2.67 to 2.75 (Table 1). Wikipedia (2014) stated that the standard range of values of specific gravity of soils lies between 2.60 and 2.80. However, lower specific gravity values indicate a coarse soil, while higher values indicate a fine grained soil.

3.1.6 California Bearing Ratio (CBR)

California bearing ratio is widely used in the design of base and subbase material for pavement. CBR is used to evaluate the strength of stabilized soil (Ogunribido, 2011). Soaked CBR of the unstabilized soil in the studied area ranged from 3% to 15% and unsoaked ranged from 6% to 22% (Table 2). Stabilized soaked ranged from 3 to 14% and stabilized unsoaked CBR ranged from 7% to 28%. The Federal ministry of works and housing (1997) specified a minimum value of 10% for soaked CBR and 15% for unsoaked CBR for a suitable material as sub-grade soil.

3.1.7 Compaction

The soils were compacted at the standard proctor AASHTO level of compaction for the dam sub-grade materials. The maximum dry density (MDD) of unstabilized soil samples ranged from 1438kg/m^3 to 1919kg/m^3, optimum moisture content (OMC) ranged from 13.3% to 25.1%. The MDD of stabilized soil of sample 1 ranged from 1923kg/m^3 to 1968kg/m^3 and OMC from 13.2% to 12.0%, for sample 2 MDD ranged from 1545kg/m^3 to 1623kg/m^3 and OMC from 22.5% to 20.5%, for sample 3MDD ranged from 1442kg/m^3 to 1507kg/m^3 and OMC from 25.0% to 23.4%, The MDD of the soil samples S1, S2 and S3 were less than the recommended values of 2165kg/m^3 for Nigeria soil, therefore they are poor sub-grade materials.

3.1.8 Unconfined Compressive strength (UCS)

This term is used in expressing the strength of sub-soil. The unconfined compressive strength is generally used to determine the consistency of clayey soil (Oguribido 2012 a & b). Their value for a particular soil is a measure of sustainability of such soil such as a foundation soil material. It is a test used to determine the soil shear strength capacity. For unstabilized soli, the UCS for sample 1 was 49.87 kpa, sample 2 was 23.98 kpa and sample 3 was 62.85 kpa.

3.1.9 Natural Moisture Content

Akpah *et al*. 2009 recommended that moisture content that range from 10% to 20% should be consider good for construction purposes. The natural moisture content of the soil samples ranged from 14.3% to 20.1%, which indicates that the soils in the study area are fairly good for dam construction based on moisture content values

3.2 Hydrogeochemical Assessment of Surface Water

The results for physical and chemical parameters of the surface water from the proposed dam site in the study area are presented in the Table 3 below:

Table 3: Analysis of Physical and Chemical Parameters of Water Samples 1, 2 and 3.

S/N	Parameters	WHO (2011) standard	Location 1 Conc. (ppm)	Location 2 Conc. (ppm)	Location 3 Conc. (ppm)
1	Ca^{2+}	200	17.64	13.63	15.23
2	Mn^{2+}	0.2	0.01	0.03	0.01
3	Mg^{2+}	50	4.37	5.35	3.89
4	Na^{+}	200	24	25	41
5	K^{+}	50	32	36	29
6	Fe^{+}	0.3	1.25	1.20	1.50
7	Pb^{2+}	0.01	BD	BD	BD
8	Cr^{3+}	0.05	BD	BD	BD
9	Cu^{2+}	2	0.20	0.18	0.22
10	Zn^{2+}	3	0.12	0.10	0.13
11	Al^{3+}	0.2	BD	BD	BD
12	Cl^{-}	250	85.08	85.08	70.90
13	NO_3^{-}	50	0.18	0.16	0.15
14	HCO_3^{-}	1000	158.6	109.8	97.6
15	CO_3^{-}	200	BD	BD	BD
16	SO_4^{-}	<250	0.40	0.42	0.38
17	PO_4^{-}	5	0.72	0.71	0.69
18	Total hardness	Nill	66.01	52.97	57.12
19	Total alkalinity	Nill	158.6	109.8	97.6
20	pH	6.5-8.5	6.77	7.44	7.42
21	EC (µs/cm)	1000	520	488	499
22	Temperature (^{O}C)		28	30	29
23	G.P.S readings		7° 10' 17"N 4 ° 43' 04" E	7 ° 10' 17" N 4 ° 43' 03"E	7 ° 10' 15"N 4 ° 43' 03" E

3.2.1 pH
The pH values of the water samples ranged from 6.77 to 7.44. All the pH values fall within the World Health Organization Permissible limit of 6.5 - 8.5 (WHO, 2017).

3.2.2 Electrical Conductivity
Electrical conductivity drinking limit is 1000µs/cm. (WHO 2011). The electrical conductivity ranged from 488 to 520 µs/cm. Water samples has medium conductance.

3.2.4 Hardness
Water hardness is primarily caused by the presence of metallic ions. It is the ability of water to form latter with soap. It is typically recorded as total concentration carbonate of Ca^{2+} and Mg^{2+} Hardness may be permanent or temporal. Here water samples have low hardness. That ranged from 52.97 to 66.01ppm.

3.2.5 Sulphate
Results obtained from water analyses, concentration of sulphate in the study area ranged from 0.38 to 0.42 ppm, which falls within the drinking limit of 250ppm (WHO, 2011).

3.2.6 Nitrate
The concentration of nitrate in the water samples ranged from 0.15 to 0.18 ppm and they fall within the world health organization permissible limit of 50ppm.

3.2.7 Chloride
The chloride in the water samples ranged from 70.90 to 85.08 ppm. The concentration of chloride in the samples falls within the world health organization permissible limit of 250ppm (WHO, 2011).

3.2.8 Phosphate
In the water samples, the concentration of phosphate ranged from 0.69 to 0.72 ppm. All of which falls within the world health organization permissible limit of 5 ppm (WHO, 2011).

3.2.9 Sodium
Concentration of sodium ranged from 24 to 41 ppm. Concentrations of sodium were within the world health organization permissible limit of 200 ppm.

3.2.10 Potassium
Results from the analysis carried out on the water samples, show that the concentration of potassium ranged from 29 to 36 ppm. These values which fall within the world health organization permissible limit of 50 ppm.

3.2.11 Manganese
Concentration of manganese ranged from 0.01 to 0.03 ppm. All of which falls within the world health organization permissible limit of 0.02 ppm.

3.2.12 Zinc
Concentration of zinc in the water samples ranged from 0.10 to 0.13 ppm. These falls within the world health organization permissible limit of 3 ppm.

3.2.13 Copper
Copper concentration ranged between 0.18 and 0.22 ppm. World health organization permissible limit is 2 ppm

3.2.14 Aluminum
Concentration of aluminum ranged from below detection, the recommended limit of aluminum is 0.2ppm

3.2.15 Iron
The concentration of iron in the various water samples ranges from 0.3 to 1.50 ppm and the various concentrations thus falls outside the world health organization permissible limit of 0.1 ppm, therefore water samples will stain laundry and pipes.

3.2.16 Chromium
The concentration of chromium in the various water samples were below detection (BD), this value falls within the world health organization permissible limit of 0.05ppm WHO (2017), guidelines for drinking water quality).

3.2.17 Lead
Concentration of lead in the sample were below detection, this value is within the maximum permissible level of 0.01 ppm (WHO, 2011).

4.0 Conclusion
Fines in the soil, indicates low bearing capacity. But when bamboo leaves ash was added, this reduces the plasticity and there was an increase in the bearing capacity and the internal friction angle. CBR and linear shrinkage showed that the soil has poor engineering properties, therefore soil is not suitable for dam construction, because the soil will still be susceptible to swelling and expansion when wet. The chemistry of surface showed that the water was contaminated by iron, but all other parameter tested were within the drinking limit of WHO, $(2011)^{-}$. The water type in the study area is Ca - $HCO_{3.}$ Water here is not potable; therefore, it should be discarded or treated before use.

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