Hydrogeochemical assessment of surface water and Bamboo leave ash soil stabilization of a proposed Dam site at Okeigbo - Ifetedo SW, 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 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, stabilization, lateritic soil, surface water, hydrogeochemical

1. INTRODUCTION

Dam could be seen as a solid barrier constructed at a suitable location across river channels 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. For geologic and topographic reasons, there are limited numbers of 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. 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. 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° 00' and 7°15' North of Equator and longitude 4°30' and 4° 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.

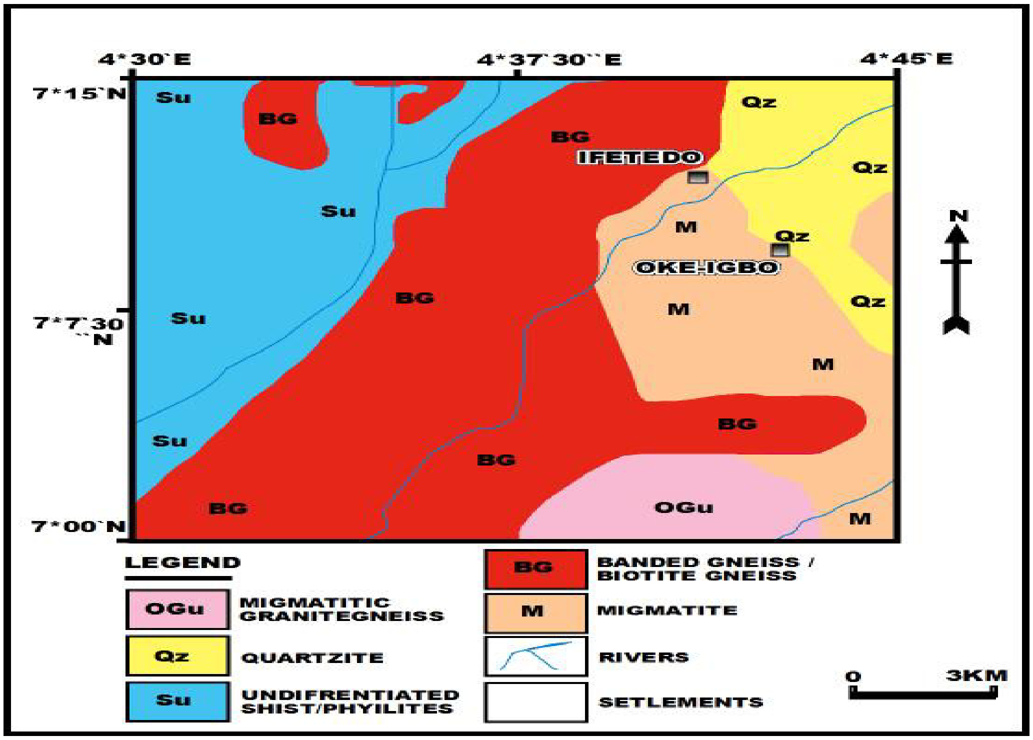

Figure 1: Geological Map of the study area

3. MATERIALS AND METHODS

Materials used for this project were soil, water, bamboo leaves ash All the method use in carrying out the fundamental engineering procedures are specified by British Standard Institution BSI 1377 (1975).

Soil samples were collected from three different locations in the study area. Samples were collected from test pits at 1.0 m depth before, at and after the proposed spillway. 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 the 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 were soil samples were collected and were using clean 2 litres plastic bottles. Hydrogeochemical tests: Each sample was analysed for 21 chemical water quality parameters, including; 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.

4. RESULTS AND DISCUSSIONS

4.1 Geotechnical properties of the soil

The results of the various laboratory analyses which include natural moisture content, Atterberg Limits, Linear Shrinkage, grain size analysis, plasticity index, compaction , California bearing ratio (CBR), unconfined compressive strength, specific gravity of un -stabilized and stabilized soil samples were carried out in accordance with the relevant British Standards: BS 1377. The results are showed in Tables 1and 2

Table 1: Results of un stabilized 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 un stabilized 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			

4.1.1 Natural Moisture Content

The results of the natural moisture content (NMC) are presented in the Table 1 above. Akpah *et al.* 2009 recommended that moisture content that range from 10% to 20% is considered good for construction. 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.

4.1.2 Atterberg Limits

From Table 1, Atterberg limits results showed that the liquid limits of unstabilized soil ranged from 37.2% to 56.0%, plastic limits ranged from, and 17.9 to 27.7%. The plasticity index of the Sample1 was 19.28% and Sample 2 and 3 were 28.00% and 28.26% respectively. 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%, plastic limits ranged from, 18.1 to 18.8% and the plasticity index ranged from 18.7% to 11.5% and the liquid limit of sample 2 ranged from 52.9% to 49.8%, plastic limits ranged from, 25.1% to 27.1 % and the plasticity index reduced from 27.8% to 22.7%, the liquid limits of sample 3 reduced from 55.9% to 51.8%, plastic limits from, 27.8% to 31.2% and the plasticity index reduced from 28.1% to 20.6% respectively indicating 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 needed to be stabilized.

4.1.3 Linear Shrinkage

The linear shrinkages of the unstabilized soil ranged from 10.7% to 15.0% (Table 1). Brink *et al., (*1982) suggested that soils with linear shrinkage below 8% would be inactive and in - expansive and so is good for construction activities. For the stabilized soils, 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%. Soil samples are likely to swell and shrink at wet and dry season.

4.1.4 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.

4.1.5 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.

4.1.6 California Bearing Ratio (CBR)
California bearing ratio is one of the common tests widely used in the design of base and subbase material for pavement design and it is used to evaluate the strength of stabilized soil (Ogunribido, 2011). From Table 2, Soaked CBR of the unstabilized soil in the studied area ranged from 3% to 15% that of unsoaked ranged from 6% to 22%. Stabilized soaked and unsoaked CBR of the soil sample 1 ranged from 12% to 14% and 23% to 28%, sample 2 ranged from 3% to 7% and 8% to 13% and sample 3 ranged from 3% to 9% and 7% to 14% respectively. The Federal ministry of works and housing (1974) specified a minimum value of 10% and 15% for soaked and unsoaked CBR for a sub-grade soil.

4.1.7 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 OMC ranged from 13.2% to 12.0%, sample 2 ranged from 1545kg/m^3 to 1623kg/m^3, OMC ranged from 22.5% to 20.5%, sample 3 ranged from 1442kg/m^3 to 1507kg/m^3, OMC ranged from 25.0% to 23.4%, The MDD of the soil sample S1, S2 and S3 were less than the recommended values of 2165kg/m^3 for Nigeria soil, therefore they are poor sub-grade materials.

4.1.8 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.

4.2 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 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

4.2. 1 pH

The pH values obtained for the water samples at different portion of the river ranges from 6.77 – 7.44. The pH values all fall within the World Health Organisation Permissible limit of 6.5 – 8.5 (WHO 2017).

4.2.2 Electrical Conductivity

Based on the result obtained from the analysis of the water sample, they fall within the permissible limit of electrical conductivity is 1000µs/cm. (WHO 2011), Guidelines for drinking water quality). The electrical conductivity ranges from 488 – 520 µs/cm. Water samples has medium conductance.

4.2.4 Hardness
Water hardness is primarily caused by the presence of metallic ions. It is the ability of water to form latter with soap. or Hardness results primarily from magnesium and calcium. It is typically recorded as total concentration Ca^{2+} and Mg^{2+} of $CaCO_3$. Hardness may be permanent or temporal. Here water samples have low hardness.

4.2.5 Sulphate
From the results obtained from the analysis carried out on the water samples, concentration of sulphate in the samples ranges from 0.38 – 0.42 ppm, which falls within the world health organization permissible limit of 250ppm (WHO 2011).

4.2.6 Nitrate
The concentration of nitrate in the various water samples ranges from 0.15 – 0.18 ppm and they fall within the world health organization permissible limit of 50ppm.

4.2.7 Chloride
The chloride of the water samples ranges from 70.90 – 85.08 ppm. The concentration of chloride in the samples falls within the world health organization permissible limit of 250ppm (WHO 2011).

4.2.8 Phosphate
From the results obtained from the analysis carried out on the water samples, the concentration of phosphate in the sample ranges from 0.69 – 0.72 ppm. All of which falls within the world health organization permissible limit of 5 ppm (WHO 2011).

4.2.9 Sodium
Results from the water analysis ranges from 24- 41 ppm. It's all falls within the world health organization permissible limit of 200 ppm.

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

4.2.11 Manganese
Concentration of manganese ranged from 0.01 – 0.03 ppm. All of which falls within the world health organization permissible limit of 0.05 ppm.

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

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

4.2.14 Aluminum

Concentration of aluminum ranged from below detection to 0.2 ppm. The recommended limit of aluminum is 0.10ppm

4.2.15 Iron

The concentration of nitrate in the various water samples ranges from 1.20 – 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.

4.2.16 Chromium

The concentration of chromium in the various water samples were below detection (BD). it fall within the world health organization permissible limit of 0.05ppm (W.H.O 2011, Guidelines for drinking water quality).

4.2.17 Lead

From the results, concentration of lead in the sample were from below detection to 0.01 ppm, these value is within the maximum permissible level of 0.03 ppm

5. CONCLUSION

Soil samples have poor engineering properties and therefore not suitable for dam construction ordinarily without stabilization, due to high moisture content, linear shrinkages and plasticity index, the soil will be susceptible to swelling, expansion and collapse when wet, Fines in the soil, indicates low bearing capacity. But the addition of bamboo leaves ash reduces the plasticity, increase the bearing capacity and the internal friction angle. The chemistry of surface water depends on several factors, which include; Geology, slope, climate, precipitation, saturation, soil type, vegetation and time. The river typically transports three types of sediment-dissolved load, suspended load, and bed load. Suspended sediments make the water look cloudy for instance the greater the suspended load the muddier the water. Bed load (silt-to boulder-sized, but mostly sand and gravel) settles on the bottom of the channel. Chemical weathering of rocks in the area produces ions in solution Examples Ca^{2+}, Mg^{2+}, HCO_3^-. The water is Ca - HCO3 type. However the water is portable on the basis on both the physical and chemical parameters except for iron which is higher than the permissible limit of the World Health Organization.

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