

THE GEO-ENVIRONMENTAL MENACE BY FLOODING AROUND IKWUANO AREA, SOUTHEASTERN NIGERIA

1. Uzoegbu, M. U. and 2. Agbo, C. C.

^{1,2} Department of Geology, College of Physical and Applied Sciences, Michael Okpara University of Agriculture, Umudike, PMB 7267, Umuahia, Abia State.

¹GSM: 08030715958; Email: mu.uzoegbu@mouau.edu.ng

ABSTRACT

The effects of flooding on some part of Ikwuano Local Government Area of Rivers State were studied using soil samples to know the influence of Geology on properties of the soil. The peak of rainy season is from April to October. The data for fifteen years annual precipitation was conducted with an average rain fall of 2145. 89mm. The test carried out include natural moisture content, particle size distribution analysis, Atterberg Limit and borehole lithology shows that the subsoil are brown to reddish gray clayey sand and is moderately graded. The natural moisture content values ranges from 14.10%-27.90%. The Atterberg limit shows that the soil is an inorganic clay of intermediate plasticity index is 11.70%- 28.20% with liquid limit 29.00% - 41.60% and plastic limit of 11.10% - 19.90%, Particle size distribution analysis shows that the soil is moderately graded consisting of mainly medium to fine grains, sand in high proportion with less proportion of coarse grains, in the ranges of 6.00% - 12.80% coarse grain sand, 6.00% - 35.50% medium grain sand and 6.00% - 14.90% fines, using unified classification system this texture could be classified as clayey sand. These shows that the soil particle sizes are moderately graded and slightly poorly graded since the soil sample is of low plasticity.

KEYWORDS: Flood, Erosion, geotechnical, plasticity, Ikwuano area, Nigeria.

INTRODUCTION

Floods usually occur when there is enough rain in a short enough time to swell a river over its banks or when a storm forces large amounts of water from the ocean inland (Jagg, 2017). Flash floods can occur in dry ecosystems when water gathers in previously dry valleys and washes through them.

In many parts of the world widespread deforestation has greatly increased the intensity of flooding. This is because forests, particularly tropical rainforests, function as giant sponges that absorb and hold vast amounts of water, releasing the water slowly in streams and rivers. When the trees are removed, the water descends in the form of rain and immediately continues downhill, causing massive flooding in lower elevations. This flooding can then be followed by drought because the water that was always released over a long period by the forest has now passed through in a single flood (Jagg, 2008).

According to the ThinkQuest website, floods are the most dangerous aspect of thunderstorms, killing an average of 140 people every year. They also cause extensive damage to property, especially residential dwellings. For these reasons, members of the public find it desirable to prevent floods before they happen whenever possible. Although it is not possible to predict or stop all floods around the globe, understanding how floods form reduces the risk that lives and property will be lost. There are several types of floods, but every type of flood follows three principles. The first principle is that the amount of water in a given area (flood region) is too large for the region to accommodate--floods thus form when water percentages exceed capacity. The second principle is that weather influences the water percentage present in a flood region. Lastly, geographical factors determine how the flood behaves (Wanda, 2017).

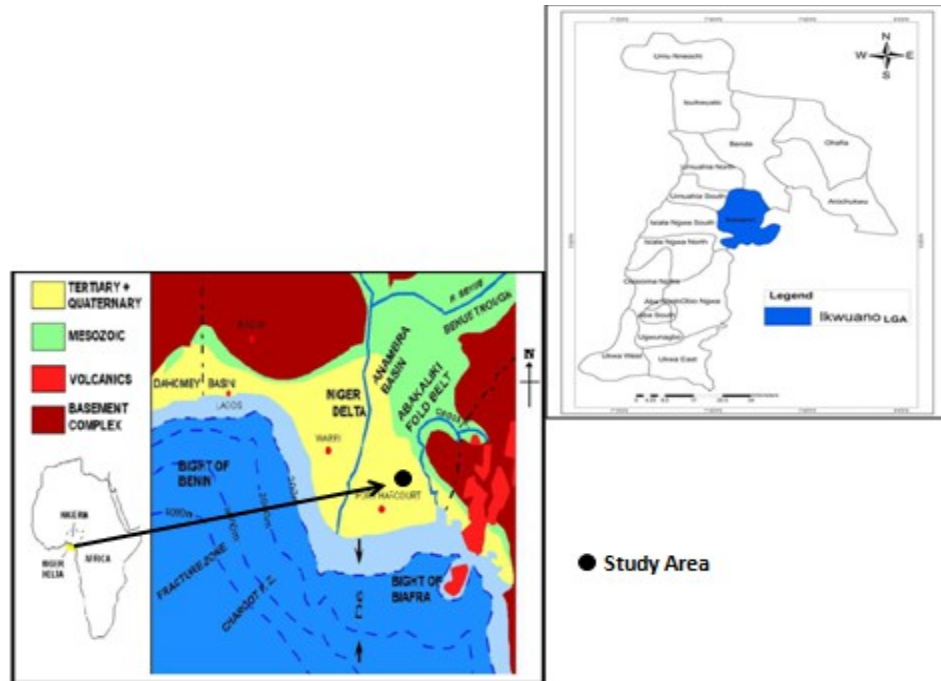


Fig. 1: Map showing location of study area modified (in set: map of Abia State with Ikwuano LGA).

As this study will show, District Ikwuano has a high exposure to flood, and these floods have had grave physical, social and economic impacts on the district's development.

Ikwuano covers an area of about 281km² between latitude 5°19' to 5°29'N and longitude 7°32' to 7°40'E (Fig.1). The area is located in a low relief area with a maximum elevation of about 150m. As a result, run-off is relatively low and infiltration rate is high.

The area is endowed with natural spring and streams including Onu-Inyang River which flows from Bende (the north boundary) through the study area in a south-westerly direction; while Iyinta-Ocha River flows from the central part (Isiala) through south-western part (Ogbuebule) into Akwa Ibom State on the western flank. Akoo River and Iyi-Oba River flow southerly from the eastern part of the study area. On the hand, Anya River traverses the entire western flank of Ikwuano and joins with Ahi (the westernmost counterpart). This formed a confluence with other rivers and tributaries to the Qua Ibo River of Akwa Ibom and Cross River States of Nigeria.

The heavy tropical rainfall which started from April and prolonged till the month of October made the rivers surge and overflow causing havoc in the target area. Areas in Ikwuano received rainfall systems in April-October were due to interaction of tropical and latitude Easterlies. It is worth mentioning here that the average annual rainfall in Ikwuano is 2145.89mm (Table 1).

The study area is excessively vulnerable to flash and human causing floods. Flash floods are a phenomenon usually found in arid and desert ecosystems. Many of these landscapes have deep gullies and canyons that have been formed by erosion. When a brief and intense rainstorm erupts, the water will naturally seek the lowest point. Water gathers and gains force as it runs into ever larger canyons and can create localized floods that rush through areas that were bone dry only moments before. Needless to say, this can present a hazard to anyone or anything that happens to be in the path of the flood (Wanda, 2017).

The water table in the area rises during rainy season (April – October). The depth to ground water in the area in eastern part is less than 10m. The continue rainfall increased the water table and made the land saturated, resulting in less absorption of water and increased surface runoff. This paper deals with the contribution of soils to flooding and menace of flooding to the Ikwuano area

GEOLOGIC SETTING

The study area is geologically situated in the Eastern Niger Delta. Its geologically fall within two out of eleven geologic units in the area (Amos-Uhegbu et al., 2013). These are Bende-Ameki Formation and the Benin Formation (Fig. 2).

The Bende-Ameki Formation was classified by Simpson (1955) into two lithological groups, namely; the lower part which consists of fine to coarse grain sandstones and intercalations of calcareous shales and thin shelly limestone and upper part which comprise coarse, cross-bedded

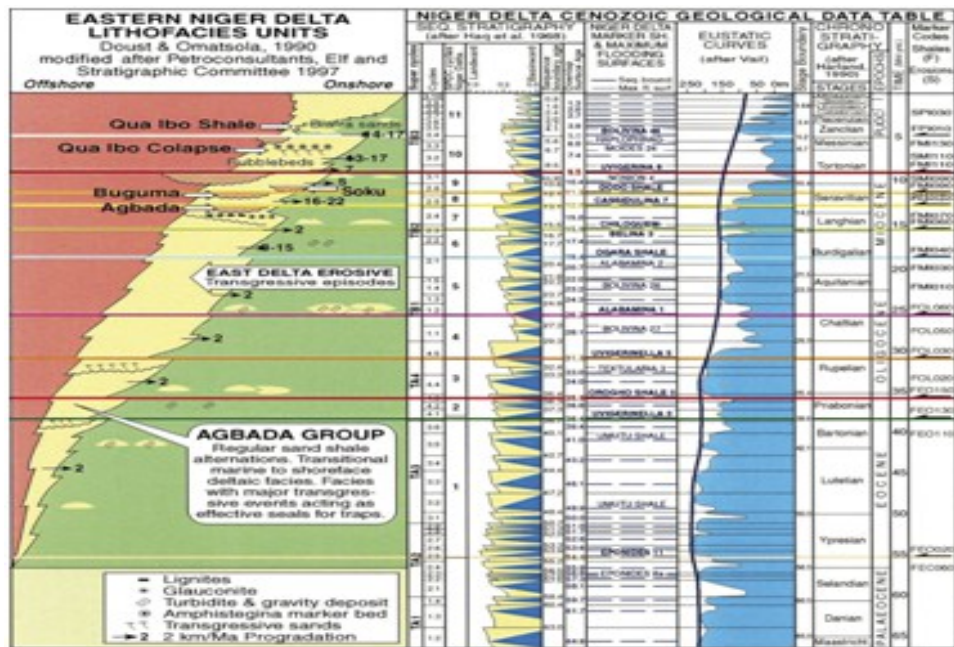


Fig. 2: Stratigraphic Column showing Eastern Niger Delta lithofacies units and Cenozoic Geological Data (Reijers, 1996).

sandstone with bands of fine, grey-green sandstone and sandy fossiliferous clays. The age of the formation has been given as Early to Middle Eocene (Reyment, 1965; Adegoke, 1969; Amos-Uhegbu et al., 2013; Obasi et al., 2015) respectively. The depositional environment of the Ameki Formation has been interpreted based on the faunal assemblage by various authors such as Adegoke (1969) in Amos-Uhegbu et al. (2013), Nwajide (1979), Obasi et al. (2015), White (1926) in Amos-Uhegbu et al. 2013. Adegoke (1969) interpreted it to be an open marine depositional system suggesting that the fish may probably have been washed into the Ameki Sea from inland waters whereas Nwajide (1979) in Obasi et al. (2015) is of the opinion that its near-shore to intertidal/sub-tidal zones of the shelf environment. White (1926) in Amos-Uhegbu et al. (2013) on the other hand, interpreted as an estuarine environment because of the presence of the fish species of known estuarine affinity. The sandstones of the study area belong to the Ameki Formation (Eocene) which underlies the Imo Shale (Paleocene) which conformably overlies the

Nsukka Formation. The Ameki Formation consists predominantly of alternating shales, clayey sandstone and fine-grained fossiliferous sandstone with thin limestone bands.

Benin Formation is one of the lithostratigraphic units in the modern Cenozoic Niger Delta (Fig. 2). Short and Stauble (1967) described the continental Benin Formation as a probable product of upper deltaic depositional environment with identifiable structural units such as point bars, channel fills, natural levees, back swamp deposits and ox-bow fills.

The age of the Benin Formation is Oligocene to Recent in the subsurface and also as surface outcrop in the northern parts western Niger Delta basin and also in some parts of Umuahia area of the Eastern Niger Delta. This upper part of the Benin Formation is known as the Ogwashi-Asaba Formation; while the younger southern part which is Miocene to Recent is known as Coastal Plain Sands.

The petrographic analysis by Onyeagocha (1980) shows that the rock composition is about 95-99% of quartz grains; 1-2.5% of Na + K mica; 0.5-1.0% of feldspar, and 2.3% of dark-coloured mineral.

MATERIALS METHODS

This research work started with a field reconnaissance survey at point where road failures were noticed. This was achieved with the aid of a topographic map of the area. Pictures of the failure portion or point were taken. Soil samples were collected at grade, sub base and base levels, with the use of geologic equipments such as geologic hammer, measuring tape, chisel and sample bags for carrying the samples. Ten (10) samples were collected at 5 different boreholes at subsurface levels. Soil samples were collected at base, sub base and grade levels, which were taken to the laboratory for geotechnical analysis. These include the Atterberg limit test and particle size distribution test. All samples were air dried and lumps broken using a rubbered pistle. This was

done to stimulate as much as possible the field condition especially as it affects the use of soil in road construction. Table 2 indicates (a) Sieve analysis test result for Ikwuano and its environs (b) Atterberg limit test result, for the various places in Ikwuano area where the samples were collected.

THE STUDY AREA

The area is endowed with natural spring and streams including Onu-Inyang River which flows from Bende (the north boundary) through the study area in a south-westerly direction; while Iyinta-Ocha River flows from the central part (Isiala) through south-western part (Ogbuebule) into Akwa Ibom State on the western flank. Akoo River and Iyi-Oba River flow southerly from the eastern part of the study area. On the hand, Anya River traverses the entire western flank of Ikwuano and joins with Ahi (the westernmost counterpart). This formed a confluence with other rivers and tributaries to the Qua Ibo River of Akwa Ibom and Cross River States of Nigeria.

Earlier studies have attributed their genesis and growth to the influence of human activities on geomorphological processes and qualitative and semi-quantitative methods were employed to produce suggestions for solving the problems (Grove, 1951). However investigations carried out by Egboka and Nwankwo (1985) and Obiefuna et al., (1999) have shown that the primary causes of gully genesis and growth lie in the hydrogeological and geotechnical properties of complex aquifer systems. The high hydrostatic pressure in the aquifers produce a reduction in the effective strength of the unconsolidated coarse sands in the walls of gullies leading to intense erosion (Egboka and Okpoko, 1984 and Obiefuna and Nur, 2003).

The development of gullies has caused extensive damage to the environment and has driven many away from their homes and farmlands. Recently, the State Government was on his address soliciting for the State Environmental Protection Agency intervention to curb the menace of

gully erosion. These exigencies prompted this assessment of geotechnical and hydrogeological of the area to proffer solutions to the devastating effects of gullies to agricultural, infrastructural and socio-economic lives of the people in the area.

It is easily accessible by the Umuahia-Ikot Ekpene, Amawom-Bende, Ndoro-Ibere, Ogbuebule-Oloko and Amaoba-Nnono-Ahuwo-Umuigwu link roads. There are numerous footpaths and tracks that provide access to the villages in the study area. The prevalent vegetation is the rain forest and mangrove swarms with two distinct seasons: the dry season which last from November to March; and a wet season which last from April to October (NIMET) 2000-2015.

The mean annual rainfall is about 2145.89mm most of which falls between the months of June to September (Table 1).

Previous works on the area are generally on a regional scale which includes the works of Offodile (1992), Igboekwe et al. (2006), Ebilah-Salmon and Partners (1994), Ijeh and Udoinyang (2013) and Ukandu et al. (2011). These workers gave details on the geology, geological structure, hydrogeology and water quality of old southeastern Nigeria. Subsequent surface an

Table 1: Meteorological data for Ikwuano and environs monthly rainfall (mm) from 2000/2001-2014/2015 water year

Year	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
2000/01	164.50	153.60	265.50	265.20	216.90	277.50	228.40	75.90	3.80	0.00	7.80	175.90	1835.00
2001/02	224.10	194.30	522.70	273.50	179.00	317.20	277.10	18.60	0.00	3.10	107.10	68.50	2185.20
2002/03	259.00	436.30	240.10	359.80	333.70	238.50	247.50	57.00	0.00	0.00	37.90	119.50	2329.30
2003/04	159.80	231.40	282.40	447.50	372.60	340.80	180.20	69.20	0.00	0.20	11.90	22.40	2118.40
2004/05	134.50	217.60	279.40	309.50	304.30	324.90	249.10	52.50	5.10	17.30	126.70	64.00	2084.90
2005/06	141.30	222.40	264.40	277.00	225.00	336.70	323.00	45.40	8.60	76.60	81.90	131.90	2134.20
2006/07	136.00	202.80	237.30	303.40	133.70	483.10	237.40	14.20	0.00	0.00	62.90	35.50	1846.30
2007/08	78.40	444.90	354.00	187.60	464.80	319.90	335.60	112.10	25.00	13.40	0.00	168.40	2504.10
2008/09	219.80	373.50	352.30	310.20	327.40	404.00	211.00	6.70	8.90	62.80	62.80	47.80	2387.20
2009/10	100.50	416.20	236.00	306.30	287.40	205.50	311.10	23.70	0.00	0.00	78.20	34.70	1999.60
2010/11	126.00	213.50	459.00	276.90	420.70	309.30	349.20	78.20	4.60	0.00	60.80	111.40	2409.60
2011/12	105.80	347.70	239.50	236.50	345.10	424.70	242.80	12.00	9.60	0.00	88.20	57.00	2108.90
2012/13	142.00	233.70	213.00	362.00	161.80	349.00	244.60	58.50	0.00	75.40	36.50	40.80	1917.30
2013/14	92.80	466.10	239.10	280.90	237.10	318.00	184.80	99.50	90.80	0.00	43.70	138.80	2191.60
2014/15	78.70	249.20	281.80	144.40	444.20	405.30	165.10	147.40	0.00	8.40	81.70	130.50	2136.70
Mean Value	144.21	293.55	297.77	289.38	296.91	336.96	252.46	58.06	10.43	17.15	59.21	89.81	2145.89

groundwater quality assessment was carried out by Ijeh and Udoinyang (2013). Geoelectric Sounding for the Determination of Aquifer Characteristics in Parts of Umuahia Area of Nigeria was carried out by Mbonu et al. (1991).

Flood is the most widespread and savage of natural disasters. In everyday usage and in ordinary hydrologic literature, a flood is referred to as any relatively high flow that over tops the natural or artificial banks above reach of stream (Obasi et al., 2015). It is also regarded as an overflow or inundation that comes from a river or other body of water and causes damage (Ukandu et al., 2011) or simply as too much water in the wrong place (Elyi, 1997). Flood can also be defined as overflowing of water over the normal confines of a stream or other body of water or the accumulation of water by drainage over areas which are not normally submerged (WMO, 1990). According to Bell (1983) floods along coasts are of two kinds, some are caused by meteorological disturbances, such as hurricanes and other storms at sea; others by seismic disturbances, such as submarine, earthquakes, landslides and other disturbances of the sea bed. Both kinds of disturbances have preferred locations. Coastal flooding occurs in the low – lying belt of mangrove and fresh water swamps along the coast. Hurricanes and typhoons commonly occur in the West Indies and the East Indies, respectively, and extra tropical cyclones occur in the Atlantic. Sea waves of seismic origin, called tsunamis, are most destructive tsunamis struck Lisbon after an earthquake (Ijeh and Udoinyang, 2013).

All over the globe there are various types of flooding incidences, for instance in the urban areas, flood occurs mostly as flash flood which is as a result of imbalance between rainfall intensity and infiltration. In Nigeria, secondary school students in Ogba / Egbema /Ndoni Local Government Area in Rivers State (October 2012) had serious and negative effects on education because many schools in Omoku especially in the submerged councils were shut down due to the effect of

flood. Many of these students were disrupted, especially those sitting for WASSCE (The Guardian, October 9, 2012).

Gobo (1990) in a work on relationship between rainfall trend and flooding in the Niger Delta river basin found out that during raining season due to the excessiveness of rainfall, the soil becomes saturated to its maximum. This in turn increases the run off or the overland flow, as it accumulates there; it becomes an increase in volume of rivers resulting in continuous flow of the land.

Adegoke (1969) traced Ogunpa flood to be humanly induced. In his study he noted that deforestation stimulated or accelerated flooding. He observed that colonial authorities deliberated reserved teak and cassia around hilly areas of Ibadan to catch and store temporally some water during rainfall. But these forests were cut down as a measure to check criminal activities within and around Ibadan especially premier hill, the exposure of this very steep sided hills led to rapid water runoff into the Ogunpa channel thereby shortening the time of peak runoff and also increasing the volume of water in the channels.

DISCUSSION

Detailed description of the lithology of the various samples was done and it was discovered that there is no significant variation in the lithology of the soil profile. The total depth drilled on BH-5 boreholes were between 0.00 to 3.00m each which is made of sandy clay showing that BH-1, 2, and 5 are of the same description while BH - 3 and 4 has a slight different as shown in Table 2.

The moisture content of soils from the area has slight differences in the value from different boreholes at different depths with their locations. The moisture content result ranges from 14.10% - 27.60%. The highest moisture content (Mc) which value is 27.60% is recorded in BH-1

at the depth of 0.50m while the lowest moisture content is also recorded in location 3 at the depth of 0.50m in the table 2, when compared to the moisture content of some soils in the southeast; the value of the moisture content is low.

The Atterberg limit result for soil in these area shown in the table where by liquid limit (LL) ranges from 24.00% - 39.00%, plastic limit (PL) ranges from 14.00% - 27.80% and plasticity index is also ranging from 9.10% – 17.20% (Table 3). The liquid limit and plastic limits were used to obtain the plasticity index, which is a measure of the plasticity of the soil. The values obtained ranged from 11.70 to 28.20 indicating medium to slightly high plasticity according to Gobo (1988). The samples are soft and could be crushed by fingers and hence erodible according to Akpokodje (2001).

Table 2: Moisture content and % passing of sand grains from sieve analysis result.

Borehole Location NO.	Boerhole Depth (m)	Moisture Content (%)	Seive Analysis % passing by Diameter (2, 1, 0.5, 0.25, 0.05, 0.07) mm			
			Sand	Fine	Medium	Coarse
BH - 1	0.50	14.10	50.00	11.00	33.00	6.00
	1.00	18.10	56.00	14.90	35.00	7.00
	1.50	21.00	41.90	10.00	24.00	7.90
	2.00	21.90	43.10	9.10	25.00	9.00
BH - 2	0.50	16.60	45.50	13.70	25.00	7.00
	1.00	16.60	53.00	114.10	32.00	6.90
	1.50	22.60	31.70	6.70	18.00	7.00
	2.00	26.90	27.40	8.60	6.00	12.80
BH - 3	0.50	27.60	43.10	13.20	23.50	6.40
	1.00	25.80	56.50	8.30	35.50	12.70
	1.50	25.90	53.00	8.20	32.00	12.80
	2.00	26.70	38.80	7.10	21.10	10.60
BH - 4	0.50	18.60	55.10	7.10	38.00	10.00
	1.00	19.90	45.80	7.80	27.00	11.00
	1.50	19.90	44.30	10.90	24.50	8.90
	2.00	20.00	45.90	10.00	25.00	10.90
BH - 5	0.50	14.20	46.00	6.00	29.00	11.00
	1.00	14.60	44.40	5.70	28.00	10.70
	1.50	15.40	6.10	6.10	26.90	12.00
	2.00	17.00	41.60	7.00	22.90	11.70

The result of grain size analysis as shown in the table 2 indicated that the soil consists mainly of silt, sand and gravel. Its value ranges from 5.70% - 14.90%, 6.00% - 38.00% and 6.00% -

12.80% respectively. From the result, it shows a moderate graded soil that cuts across sand and silt, where the sand has the lowest value of 27.40% and highest value of 56.50%. The particle size distribution result shows that soil samples from five locations consists of coarse, medium and fine grain sizes. The particle size distribution (PSD) curve is proportion to that of medium and coarse grain soil in close range and it's higher than that of fine grained soil. Therefore on the basis of unified soil classification this texture could be classified as clayey sand (CS) since more than 2% passes through sieve diameter of 500 μ m.

Table 3: Summary of Atterberg limit Test Results

Borehole	Borehole	Liquid	Plastic	Plasticity
Location	Depth	Limit	Limit	Index
NO.	(m)	(%)	(%)	(%)
BH - 1	1.0	38.4	18.4	20.0
	2.0	41.6	19.9	21.7
BH - 2	1.0	39.0	19.4	19.6
	2.0	42.0	18.6	23.4
BH - 3	1.0	22.8	11.1	11.7
	2.0	29.0	14.5	14.5
BH - 4	1.0	38.2	17.0	21.2
	2.0	39.2	18.3	20.9
BH - 5	1.0	40.7	17.2	23.5
	2.0	44.0	15.8	28.2

Reconnaissance and observation survey

For the purpose of handling, the identified causes of gully erosion in Abia State were labeled GE-Cause A: lack of drain facilities, GE-Cause B: badly constructed road pavements, GE-Cause C: negligence to rainfall and runoff volume during the design stage of drains, GE-Cause D:

dumping of municipal solid waste on drain channels and GE-Cause E: wrongly located building structures as a result of wrong planning, (where GE is Gully Erosion) and the responses from the affected local governments in Abia state were evaluated in percentage (Onyelowe, 2017).

Fig. 3 also showed the gully erosion diagrammatical effects of the different identified causes A to E in Ikwuano Local Government Area of Abia State. It could be deduced that again GE-Cause D; dumping of municipal solid waste on drain facilities was predominant in effects. This also goes to show that this does not only deface the environment, but poses lots of geoenvironmental hazards ranging from pollution and emission of poisonous metal gases to the decay it causes on the transportation facilities on a daily basis. And this adversely affects the lives of the people (Onyelowe, 2017).

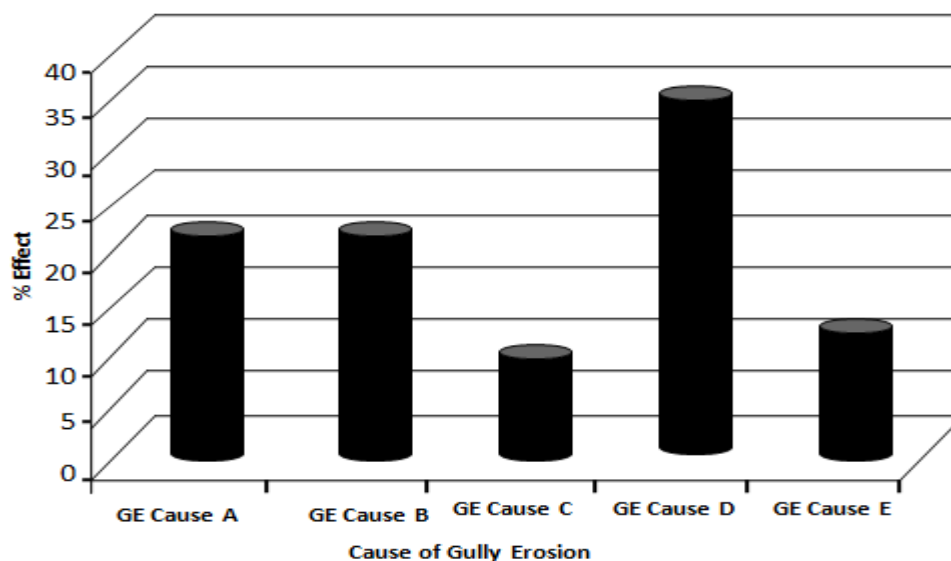


Fig. 3: Percentage effect of the causes of Gully erosion in Ikwuano LGA (After Onyelowe, 2017).

During the survey, the following causes of the gullies were identified (An-Bin et al., 2012); (i)lack of drainage facilities, (ii) badly constructed road pavements, (iii) negligence to rainfall and runoff volume during the design stage of drains, (iv) dumping of solid waste on drain channels and (v) wrongly located building structures as a result of wrong planning.

However some parts of the roads at the three sites (Numan town, New Demsa, Farei and Imbru failed probably because of poor work done during construction. The road at Dowaya site failed probably because the values of result exceed the British standard Institution (BS) and (AASHTO) recommended limits (Pictures 1 and 2).

CONCLUSION

The investigation of flood the study area shows that soils in the region are characterized by a single soil type (clayey sand) as observed from the analysis of particle size distribution (PSD). The observation from the soil samples also showed that it is of low permeability as confirmed by percentage of sand, fine, medium and coarse grains. The Atterberg limit result which was compare to the Unified Soil Classification System (USCS) and the soil samples were of low to intermediate plasticity.

Due to high rainfall and inadequate drainage systems in the study area, the region always flooded during the rainy season causing high plasticity to soil and moderate to high moisture contents as observed in the test, which could cause disaster to the environment.

Intensity of floods is the damage caused by it. It can be characterized by depth of inundation, volume of inundation, velocity of flow and rate of rise of water. The more the depth of water, more will be its volume, velocity and its damaging capacity. A high rate of rise for water also means less preparation time for people in the area (Wanda, 2017).



Picture 1: Failed portion of road site at Ndoro-Itunta (Elemaga-Ibere) road.



Picture 2: Failed portion of road site at Ariam-Usaka ring (Amaegbu-Ariam) road.

REFERENCES

- Akplokodje, E.G 2001, Introduction to Engineering Geology Paragraphics Port Harcourt. 41-81, 134, 24-136
- Amos- Uhegbu, M.U. Igboekwe, G.U. Chukwu, K.O. Okengwu & K.T. Eke.(2013): Aquifer characteristics and Groundwater Quality Assessment in Ikwuano Area of Southeastern Nigeria. Journal of Scientific Research and Reports 3(2): 366-383, November 2013.
- Bell, F.G., 1983: Fundamentals of Engineering Geology, Butterworth Publishers London, p488-524.
- Ebilah-Salmon and Partners, (1994). Investigation of the Existing Water Supply Facilities Within the University Complex, Geophysical Report and Recommendations for Reactivation and Future Exploitation for Potable Water Supply. Federal University of Agriculture, Umudike. pp25
- Egboka, B.C.E and Nwankwo, G.I. 1985: The hydrogeological and geotechnical parameters as agents for the expansion of Agulu-Nanka gully Anambra State, Nigeria. Journal of African Earth Science vol 3 (4): 417-425
- Egboka, B.C.E and Okpoko, E.I. 1984: Gully erosion in the Agulu-Nanka region of Anambra State, Nigeria. Challenges in African Hydrology and Water Resources (Proceedings of the Harare Symposium, July 1984) IAHS Publ. no 144.
- Elyi I. 1997, Response to extreme flood journal on geomorphology vol. 18 p. 175

- Gobo, A.E. 1988; "Relationship between Rainfall Trends and Flooding in the Niger Delta-Benue River Basin" *Journal on Meteorology*. Vol.13
- Gobo, A. E 1990, Rainfall Analysis in Drainage and Flood Control in Port Harcourt. *Discovery and Innovation*. Vol.2 No.4. December 1990.
- Grove, A. T 1951: Soil erosion and population problems in Southeast, Nigeria. *Geog. Jour.* 117:297-306.
- Igboekwe M.U., Okwueze E.E., & Okereke C.S. (2006). Delineation of natural aquifer zones from goelectric sounding in Kwa Ibo river watershed, south Eastern Nigeria. *Journal for Engineering and Applied Science*, 1 (4), 410 –421.
- Ijeh, B. I., & Udoinyang I.E. (2013). Assessment of the Groundwater Quality in Parts of Imo River Basin, Southeastern Nigeria: The Case of Imo Shale and Ameki Formations. *Journal of Water Resource and Protection*, 5, 715-722.
- Jagg, X. (2008), NOAA: Flood Facts and Characteristics.
http://www.wrh.noaa.gov/psr/pns/2008/August/az_ahps-brochure.pdf.
- Jagg, X. (2017), USDA Forest Service: Flooding and Its Effects on Trees.
http://www.na.fs.fed.us/spfo/pubs/n_resources/flood/toler.htm
- Mbonu, P.D.C., Ebeniro J.O., Ofoegbu C.O. and Ekine A.S, (1991). Geoelectric Sounding for the Determination of Aquifer Characteristics in Parts of Umuahia Area of Nigeria. *Geophysics*, 56, 284-291.
- Obasi, P.N, Okoro, A.U, Igwe, E.O & Edene, E.N: (2015): Petrological Characteristics and Paleo-depositional Environment of the Sandstones of the Ameki Group (Eocene) in Bende and Isimkpu Areas, Southeastern Nigeria. *Journal of Applied Geology and Geophysics (IOSR-JAGG) e-ISSN: 2321-0990, p-ISSN: 2321-0982. Volume 3, Issue 5 Ver. I (Sep. - Oct. 2015), PP 09-15*
- Obiefuna, G.I. and Nur, A., 2003: Hydrogeological and geotechnical study of Bauchi and environs, Northeast Nigeria. *Global Journal of Geological Sciences* vol 2(1):187-198.
- Obiefuna, G. I, Nur, A, Baba, A.U and Bassey, N.E., 1999 Geological and geotechnical assessment of selected gully sites Yola Area Northeast, Nigeria. *Environmental hydrology Journal* vol 7 (6):1-13 <http://hydroweb.com/jeh1999/obiefuna.pdf>
- Offodile, M.E (1992): Approach to Groundwater study and Development in Nigeria. Mecon Services Limited PP 74-77.
- Onyeagocha, A.C. (1980): Petrography and Depositional Environment of the Benin

Formation. Nig. J. Min. Geol; 1980;17(2):147-151.

Onyelowe, K. C. (2017). The menace of the Geo-Environmental hazard caused by gully erosion in Abia State, Nigeria. *Environmental Technology & Innovation*, 8, pp. 343-348.

Reijers TJA (1996). Selected Chapters on Geology-sedimentary Geology and Sequence Stratigraphy in Nigeria. SPDC Course Handbook (Field Guide) 121p.

Reyment, R.A. (1965), Aspects of the geology of Nigeria. Ibadan. Univ. Press, Ibadan, Nigeria, 145pp.

Short, K.C. and A.J. Stauble. 1967. Outline of the geology of Niger Delta. American Association of Petroleum Geology, Bull., volume 1, pages 761-776.

Ukandu J. S., Udom G. J., Nwankwoala H. O. (2011). Hydrochemistry of Groundwater in Umuahia South Local Government Area, Abia State, Nigeria. *British Journal of Applied Science & Technology*, 1(4),141-151.

Wanda, T. (2017), FEMA: Types of floods and floodplain. The ThinkQuest website, Eagan, Minn.