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Hydrogeological Implications of Environmental Devastation in Orlu and Its Evirons South Eastern, Nigeria

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Abstract
The hydro geotechnical properties of the soil at erosion prone areas and Hydrochemical properties of groundwater in Orlu and environs, Imo State, Nigeria, were determined with a view to ascertaining the effect of gullies on the water quality. Analysis of the results show that ion concentrations are below WHO standard except for heavy metals concentration of lead, mercury and cadmium in groundwater and copper, cadmium, lead and mercury in surface water. . Dominant water character in the study area using Piper Trilinear diagram and Schoeller semi logarithm diagram was analyzed to be calcium-sulphate waters for groundwater and sodium-chloride-bicarbonate waters for surface water. The heavy metal concentration in the surface water may be attributed to leachates from fertilizer application during farm activities in the study area, while the concentration in the groundwater may be attributed to the disposal of waste into the gullies. It is recommended that Afforestation should be practiced to provide vegetative cover that will reduce the impact of raindrop energy and that drinking water in the study area is treated.
Keywords: Gully, Hydrogeochemical, Hydrological And Geotechnical.

1. Introduction

The area of study comprises Orlu town, Amucha, Nkwerre, Amigbo, Umuaka, and Nduche in Imo state, south-eastern, Nigeria (Figs. 1.1 and 1.2). It lies between latitudes $5^o 39^I$ N - $5^o 50^I$ N, and longitudes $7^o 09^I$ E - $8^o 20^I$ E. It is bounded on the north by Urualla, on the east by Okigwe, on the south by Ogwa, and on the west by Mgbidi, and covers an area of about 268km$^{2.}$ The study area is accessible from numerous neighbouring towns and villages through State and Local Government roads (Fig 1)

Soil erosion is one of the major causes of land devastation in towns and villages in South-eastern Nigeria. It is a major threat to the soil resource, soil fertility, productivity, and to food and fibre production, mainly on farm and range lands. Hundreds of people are directly affected every year and needing to be re-located (Adekalu et al., 2007).

A number of studies have been conducted on the causes of gully erosion in South-eastern Nigeria and ways to control them. These studies primarily revolve around geological properties of the region, and proffering solutions that require large-scale engineering efforts with minimal regard to indigenous knowledge. Nwajide and Hoque (1979), Okagbue (1988), and Uma and Onuoha (1986) attributed the causes of gullies to the combination of physical, biotic and anthropogenic factors. Egboka and Nwankwor (1985) are of the opinion that gullies are caused by hydrogeological, hydrogeochemical and geotechnical properties of the rocks in the affected area. Akudinobi (1999) studied the implication of geotechnical and anthropogenic factors on gully erosion in Nigeria. According to him, high permeability and transmissivity of the formations in addition to bad engineering practices are contributing factors to gully erosion in Nigeria.Onweremadu (2007) carried out pedology of gully sites and its implication on the erodibility of soils in Central South Eastern Nigeria and he reveals that soils are sandy and would seem to resist soil erosion but have chemical nature predisposing them to soil erosion. He also postulated that non-soil factors like climate promote inability of these soils to resist erosion.

The main aim of this work is to evaluate the hydrogeological implications of environmental devastation in Orlu and its environs. This aim will be achieved through the following objectives; Geological mapping and identification of various rock types in the area, to access the hydro geotechnical properties of the soil at erosion prone areas and to evaluate the impacts of gully in the study area using available data.

Appropriate land management is very important in an area like Orlu and environs where the predominant geotectonical, geologic, and hydrologic characteristics of the soils make them susceptible to gully erosion. Cuestas, fractures and joints are common features in the gully-erosion-prone areas of South-eastern Nigeria and have been identified as significant factors in the formation of gully erosion (Okagbue and Uma, 1987; Gobin et al., 1999).

GEOLOGIC SETTING

Geologically, the study area is found in the Benin Formation, Ogwashi-Asaba Formation of the Niger Delta

Basin and Ameki Formation of the Anambra Basin (Fig.2), characterized by coastalplain sand (Miocene to recent) with stratigraphicsuccessive as shown in Table 1 (Uma, 1989, Avbovbo, 1978, and Reyment, 1965).The study area is accessible from numerous neighbouring towns and villages through State and Local Government roads (Fig 1). Earth roads and footpaths equally abound, both of which facilitated access to gullies located away from the major roads.

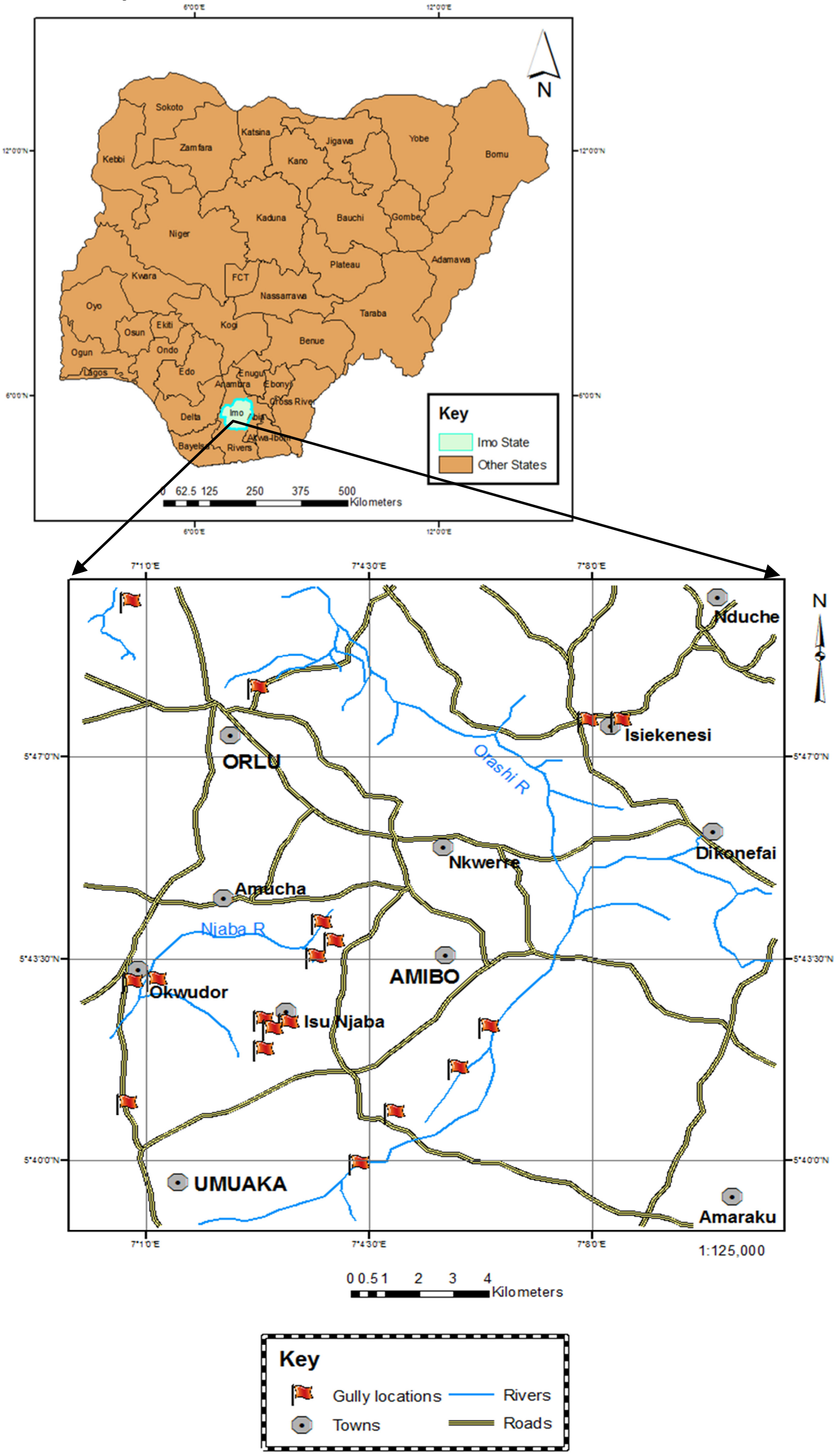

Fig.1: Accessibility map of the study area

Table 1.General Stratigraphy of the study area (After Uma, 1989, Reyment 1965).

Age	Formation	Max. (m) thickness	Characteristic
Miocene-Recent	Benin	200	Unconsolidated, yellow and white sands, occasionally pebbly with lens and grey sandy clay.
Oligocene to Miocene	OgwashiAsaba	500	Unconsolidated sand stones with carbonaceous mud stones, sandy clays and lignite seams
Eocene	Ameki	1460	Sandstones grey to green argillaceous sand stones shales and thin limestones
Paleocene	Imo	1200	Blue to dark grey shales and subordinate sandstones. It includes Two sandstone members the Umuna and Ebenebe sandstones.

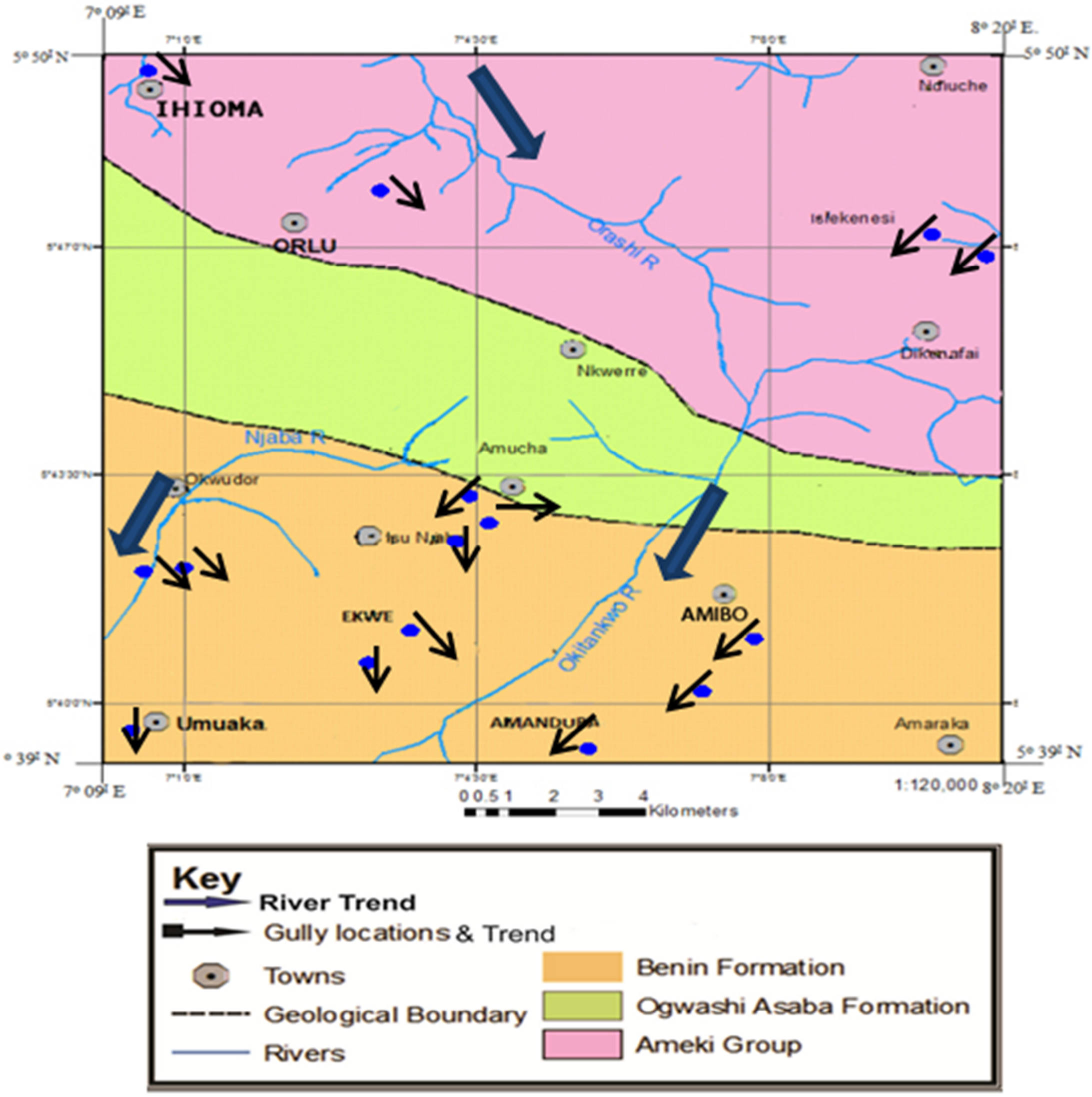

Fig.2: Geologic map of the study area showing major gully locations and river trends

2. Methodology

This work has been accomplished through literature review, field work and sample collection, laboratory and mathematical analyses and interpretation.

Field Works and Mapping of the Gullies

Field work including geological mapping and collection of water and soil samples and partially analysed data was done (Table 2). A total of fifteen (15) gully sites were located. The lengths of the gullies within the study area range from 9.6m at Amandugba, to 1500m at Orlu-Mgbee. Their width ranges from 1.5m at Amandugba to 100m at Orlu-Mgbee and their depths from 2m at Amandugba to 60m at Isunjaba. The gullies were found to have predominately V-shaped structures and the major trends are NW-SE, NE-SW and N-S. All elevation readings were taken using the Global Positioning System (GPS) in the gully sites to obtain the present elevation of the gullies. The field work started with a reconnaissance survey to locate the different gully sites. All elevation readings were taken in the gully sites using the Global Positioning System (GPS) to obtain the present elevation of the gully points. Well records and meterological data were also collected and analysed.

SAMPLE COLLECTION

These soil samples were subjected to laboratory analyses. A total of twelve distributed soil samples were collated from fifteen gully sites in the study area. The sample locations include Umuaka, Isu Njaba, Okwudor, Amibo, Amumcha, Orlu, Isiekenesi, Ihioma and Ndiuche all in Imo State.

Particle Size Distribution Analyses

Particle size distribution test (sieve analysis) was done by introducing a known weight (500g) of dry pulverized soil into a sieve set (B.S type). The whole set up was shaken for about 20 minutes manually. Weights of fractions retained on each sieve were taken and subjected to mathematical analysis. The data so obtained were used to plot the particle size distribution curves (Appendix 1). From the sieve analysis results, the data used for evaluating the permeability and hydraulic conductivity of the soil samples were obtained according to Pfannkuch and Paulson, 2006.

Atterberg Limits (Consistency Limit)

Atterberg limit analysis was carried out only on the shale members from the gully site in the study area to determine the texture and firmness of soil and is often related directly to the firm. Under this test, two basic analysis were carried out namely liquid limit and plastic limit.

Plastic Limit

About 30g of the soil aside earlier was broken into pieces and rolled between the palm and a glass plate with sufficient pressure to form a thread of uniform diameter. When the thread became 3mm, it was broken into pieces, reformed into a ball and re-rolled until the soil thread crumbled at a diameter of about 3mm. The soil thread was kept into the moisture can and covered with lid. The whole process was repeated several times and the soil added to the same moisture can, weighed and kept in the oven for drying. On the following day, the dry moisture can was weighed and the moisture content which is the plastic limit was computed.

Aquifer samples for statistical analysis of aquifer parameter

Aquifer samples were collected from gullies in the study area. The particle, size analysis involves the determination of the percentage by weight of particles within different size ranges, each fraction containing grains of approximately the same size. The sand samples (aquifer) for particle size distribution were thoroughly disintegrated and sieved through 3.35mm, 0.425mm to 0.075mm. The particle size distribution of the sand usually referred to as grading was accomplished using British standard electric shaker machine. It was determined by passing a sample of soil through a series of sieves and weighing the portions retained. The particles size distribution curves indicate the range of sizes of the various grain fractions present.

Water samples for geochemical analysis

Groundwater and surface water samples were collected for geochemical analysis. Analysis was carried out using atomic absorption spectroscopy for Ca^{2+}, Na^{+}, Mn^{2+}, Cl^{-} lead (Pb^{2+}) Cadmium (Cd),Zinc (Zn) and Copper (Cu^{2+}). This was achieved with the aid of spectrophotometer, while K^{+} was determined using photometer method. pH was measured with standard pH meter, and the concentrations of total iron (Fe^{2+}) were determined calorimetrically using Spekker absorption meter. Total dissolved solids (TDS) were determined using glass fibre filter. Anions were estimated by titrimetric method. The concentrations of Ca^{2+}, K^{+}, $mg^{2+}$and Na^{+} in milliequivalent were used to obtain percentage milli equivalents used in plotting Piper. Also, Ca^{2+}, K^{+}, mg^{2+}, Na^{+}, SO^{2+}_4, HCO^{-}_3, and Cl^{-},milliequivalents were used to plotting and Schoeller diagram. All details of analytical procedure are as reported in Omidiran (2000). Clean plastic containers were used to contain the water samples. They were rinsed several time swith the same water sample to be analysed, then covered with airtight cork and carefully labelled and sent to the laboratory for geochemical analysis within 24hours of collection.

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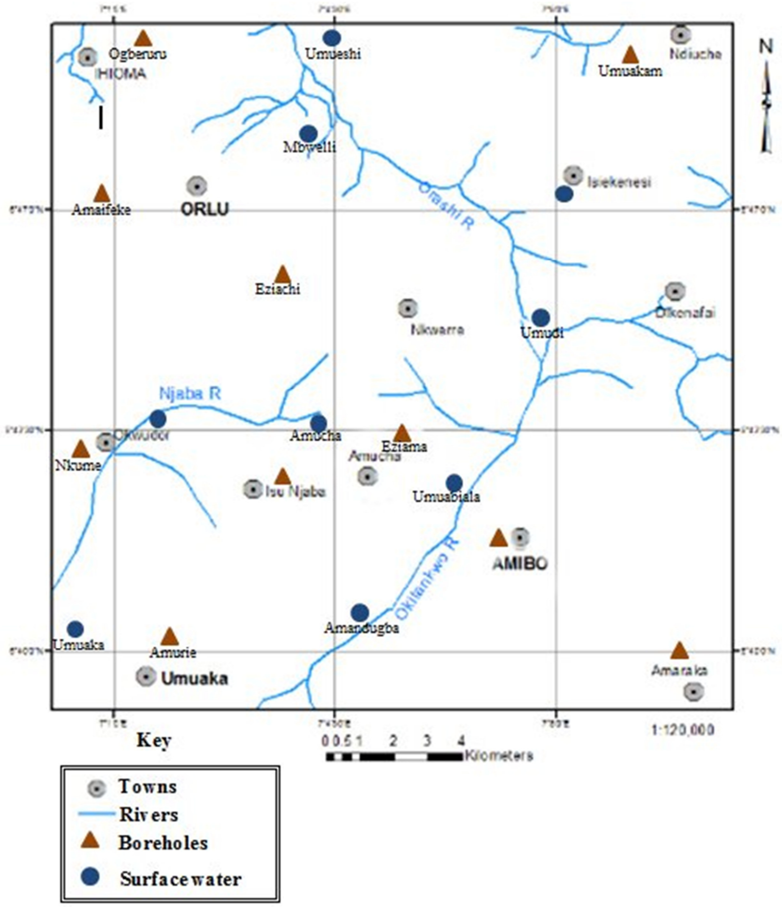

Fig. 3: The surface and groundwater sample locations and numbers.

		Surface water	
Number	**Location**	**Number**	**Location**
BH1	Amurie	**R10**	Umueshi
BH2	Isu-Njaba	**R11**	Mbwelli
BH3	Nkume	**R12**	Isiekenesi
BH4	Ogberuru	**R13**	Umuaka
BH5	Amaifeke	**R14**	Okwudor
BH6	Eziachi	**R15**	Amucha
BH7	Umuakam	**R16**	Amandugba
BH8	Amaigbo	**R17**	Umu-abiala
BH9	Eziama	**R18**	Umudi

4. Results and Discussion

Hydrogeology of the study area

The hydrogeology of an area is controlled by factors such as the geology as well as the climate of the region. The geologic formations underlying an area and their structures determine the type of aquifers that develop and the means by which they would be recharged. The aquiferous unit in the study area is the Benin Formation. It is an unconfined aquifer with an average annual replenishment of about 2.5 billion m3 per year of water (Onyegocha, 1980) and has variable thickness that ranges from about 200m at the edge of its contact with the Older Ogwashi – Asaba Formation to about 2000m. Some of the factors that affect groundwater fluctuations in the study area are rate of recharge, hydraulic conductivity, transmissivity, total discharge, groundwater velocity and specific discharge among others (Egboka 1985).

Outline of borehole data within the study area

Data from the boreholes drilled within the study (Fig. 3.3) show five to six geologic layers: the laterite, fine sand, clayey sand, clay/shale, gravely sand and gravely clay. The topsoil which is laterite is relatively thick in most places. Likewise, other geologic layers also show variation of thickness from one town to the other. Records show that the gravely sand layer is the water saturated region which is observed to be characterized by a porous and permeable layer. Generally, the water saturated layers (aquiferous units) in the region tends to be proliferous and sustainable. The geologic section shows that the aquifer type in the area is an unconfined aquifer.

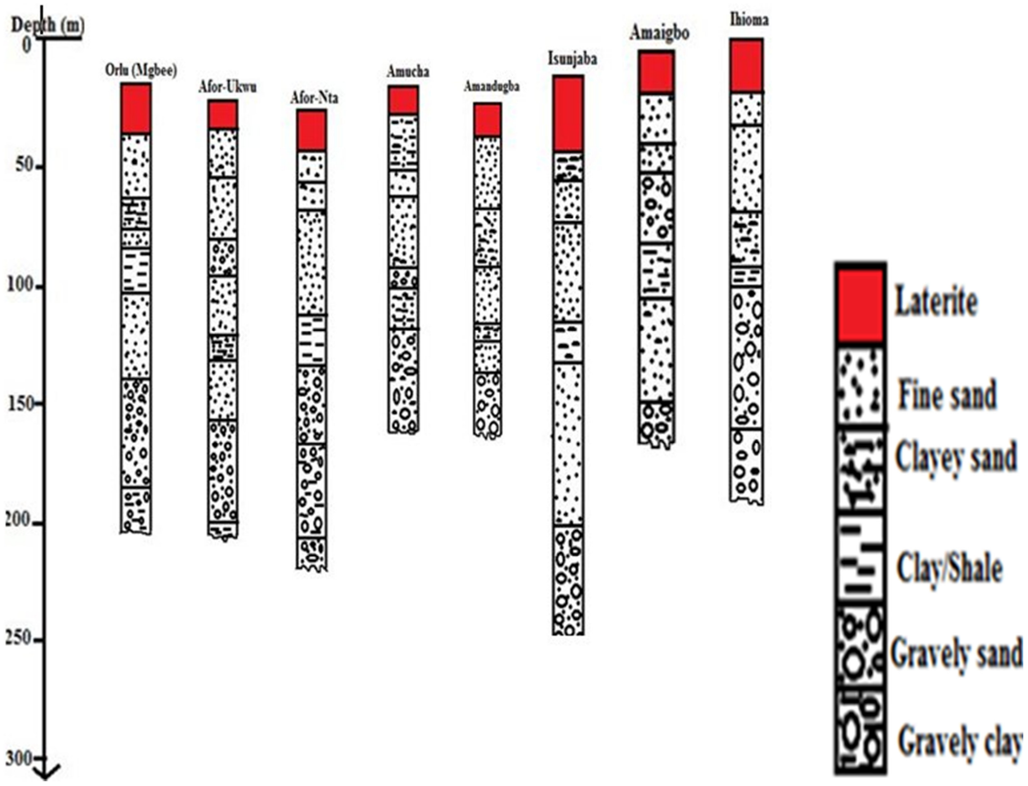

Fig.4: Lithologic logs of borehole in the study area (compiled with well records) Source: AquaSource Water Engineering Services Ltd; (2011).

Table 2: Inventory of Gully sites at the study area

S/N	Location	Co-Ordinate And Elevation	Dimension **Length (m), Depth(m), Width(m)**	Gully Trend
1	Orlu(Mgbee)	05^0 48′ 08” N 007^0 02′ 46”E 123m	Length=1500 Depth=150 Width=100	Nw-Se
2	AfforUkwuIsiekenesi	05^0 47′ 36” N 007^0 07′ 55” E 189m	Length=1050 Depth=8 Width=9	Ne – Sw
3	AfforNtaIsiekenesi	05^0 47′ 19” N 007^0 08′ 25” E 204m	Length=950 Depth=9 Width=10.5	Ne – Sw
4	Okwudor	05^0 43′ 04” N 007^0 00′ 46” E 109m	Length=500 Depth=10 Width=40	Ne – Sw
5	UmusekeOkwudor	05^0 43′ 07” N 007^0 01′ 08” E 72m	Length=50 Depth=7 Width=9	Ne – Sw
6	Amucha	05^0 44′ 06” N 07^0 03′ 44” E 127m	Length=250 Depth=14 Width=12	W – E
7	ObiatoUmuaka	05^0 40′ 59” N 007^0 00′ 41” E 95m	Length=750 Depth=12 Width=11	N – S
8	ObaraEkwe	05^0 41′ 54” N 007^0 02′ 50” E 124m	Length=80 Depth=6.3 Width=5.5	Nw – Se
9	ObamaraEkwe	05^0 42′ 20” N 007^0 03′ 13” E 145m	Length=10 Depth=3.9 Width=5.4	N – S
10	Amandugba	05^0 40′ 48” N 007^0 04′ 52” E 141m	Length=9.6 Depth=2 Width=1.5	Ne – Sw
11	Isunjaba	05^0 43′ 45” N 007^0 03′ 55” E 146m	Length=100 Depth=60 Width=80	Ne – Sw
12	AbahIsunjaba	05^0 43′ 30” N 007^0 03′ 37” E 122m	Length=80 Depth=18 Width=25	N – S
13	AmaujuAmaigbo	05^0 41′ 34” N 007^0 05′ 54” E 137m	Length=80 Depth=1.8 Width=3.5	Ne – Sw
14	UmuokwaraohaAmaigbo	05^0 42′ 16” N 007^0 06′ 22” E 147m	Length=600 Depth=8 Width=5	Ne – Sw
15	Ihioma	05^0 49′ 39” N 07^0 00′ 43” E 108m	Length=400 Depth=10 Width=12	Nw – Se

Sieve Analysis Results

Table 3: Grain size parameters for soil samples.

Sample No:	Location	Mean	Median	Sorting	Remark	Coeff. Of Uniformity Values	Coeff. Of Uniformity Remark
		Values					
1	Orlu (Mgbee)	0.87	0.90	1.2614	Poorly Sorted	3.4118	Uniformly Graded
2	AfforUkwuIsiekenesi	0.97	0.90	1.2515	Poorly Sorted	3.7500	Uniformly Graded
3	Affor-NtaIsiekenesi	2.00	1.90	2.6735	Very Poorly Sorted	11.0000	Well Graded
4	Okwudor	1.00	1.10	1.4229	Poorly Sorted	5.0000	Uniformly
5	UmusekeOkwudor	1.10	0.80	1.2720	Poorly Sorted	3.5294	Uniform Graded
6	Amucha	0.97	0.90	1.4076	Poorly Sorted	3.8000	Uniformly Graded
7	ObiatoUmuakah	1.10	1.00	1.4129	Poorly Sorted	4.4167	Uniformly Graded
8	ObaraEkwe	1.03	0.90	1.3273	Poorly Sorted	4.1538	Uniformly Graded
9	ObamaraEkwe	1.77	1.50	0.6390	Moderately well Sorted	2.3529	Uniformly Graded
10	Amandugba	1.47	1.60	0.5242	Moderately well Sorted	2.1053	Uniformly Graded
11	Isunjaba	0.80	0.70	0.7179	Moderately well Sorted	2.2222	Uniformly Grade
12	AbahIsunjaba	0.93	0.80	0.8848	Moderately well Sorted	2.4737	Uniform graded
13	AmaujuAmaigbo	0.87	0.80	0.8500	Moderately well Sorted	2.3810	Uniformly Graded
14	UmuokwaraohaAmaigbo	1.87	1.00	1.0455	Poorly Sorted	2.6667	Uniformly Graded
15	Ihioma	1.00	0.90	0.8947	Moderately well Sorted	2.5263	Uniformly Graded

Table 4: Summary of the Atterberg Limit Test within the study area

Sample No	Location Name	LL (%)	PL (%)	PI (%)
1	Orlu (Mgbee)	60	22.48	37.52
2	Afor-Ukwu, Isiekenesi	54.2	20.36	33.84
3	Afor-Nta, Isiekenesi	61	20.75	40.25
4	Okwudor	Non Plastic	Non Plastic	Non Plastic
5	Umuseke, Okwudor	Non Plastic	Non Plastic	Non Plastic
6	Amucha	64.4	18.65	45.75
7	Obiato-Umuakah	Non Plastic	Non Plastic	Non Plastic
8	Obara-Ekwe	Non Plastic	Non Plastic	Non Plastic
9	Obamara-Ekwe	Non Plastic	Non Plastic	Non Plastic
10	Amandugba	Non Plastic	Non Plastic	Non Plastic
11	Isunjaba	Non Plastic	Non Plastic	Non Plastic
12	Abah, Isunjaba	Non Plastic	Non Plastic	Non Plastic
13	Amauju, Amaibo	44.75	19.92	24.83
14	Umuokwaraoha, Amaigbo	62.5	19.6	42.9
15	Ihioma	65	16.08	48.92

Table 5: Saturated hydraulic conductivity (*K*) values found in nature (Bear, 1972)

<table>
<tr><td>K (cm/s)</td><td>10^2</td><td>10^1</td><td>10^0=1</td><td>10^{-1}</td><td>10^{-2}</td><td>10^{-3}</td><td>10^{-4}</td><td>10^{-5}</td><td>10^{-6}</td><td>10^{-7}</td><td>10^{-8}</td><td>10^{-9}</td><td>10^{-10}</td></tr>
<tr><td>K (ft/day)</td><td>10^5</td><td>10,000</td><td>1,000</td><td>100</td><td>10</td><td>1</td><td>0.1</td><td>0.01</td><td>0.001</td><td>0.0001</td><td>10^{-5}</td><td>10^{-6}</td><td>10^{-7}</td></tr>
<tr><td>Relative Permeability</td><td colspan="4">Pervious</td><td colspan="4">Semi-Pervious</td><td colspan="5">Impervious</td></tr>
<tr><td>Aquifer</td><td colspan="5">Good</td><td colspan="4">Poor</td><td colspan="4">None</td></tr>
<tr><td>Unconsolidated Sand & Gravel</td><td colspan="2">Well Sorted Gravel</td><td colspan="3">Well Sorted Sand or Sand & Gravel</td><td colspan="4">Very Fine Sand, Silt, Loess, Loam</td><td colspan="4"></td></tr>
<tr><td>Unconsolidated Clay & Organic</td><td colspan="4"></td><td colspan="2">Peat</td><td colspan="3">Layered Clay</td><td colspan="4">Fat / Unweathered Clay</td></tr>
<tr><td>Consolidated Rocks</td><td colspan="4">Highly Fractured Rocks</td><td colspan="3">Oil Reservoir Rocks</td><td colspan="2">Fresh Sandstone</td><td colspan="2">Fresh Limestone, Dolomite</td><td colspan="2">Fresh Granite</td></tr>
</table>

Sand or gravel aquifers would thus be easier to extract water from (e.g., using a pumping well) because of their high transmissivity, compared to clay or unfractured bedrock aquifers, and as such, there will be easier transportation of contaminants.

Table 6: Calculated aquifer parameters from the study area

Sample No	Location	b(m)	K(cm/s)	T(cm^2/s)
1	Orlu- Mgbee	15	0.043	0.650
2	Afor-Ukwu	8	0.038	0.307
3	Afor-Nta	9	0.001	0.012
4	Okwudor	10	0.015	0.150
5	Umuseke	7	0.043	0.303
6	Amucha	14	0.034	0.473
7	Obiato	12	0.023	0.259
8	ObaraEkwe	6.3	0.025	0.160
9	Obamara	3.9	0.043	0.169
10	Amandugba	2	0.054	0.108
11	Isunjaba	60	0.049	2.916
12	Abah-Isunjaba	18	0.054	0.975
13	Amaigbo	1.8	0.066	0.119
14	Umuokwaraoha	8	0.034	0.270
15	Ihioma	12	0.054	0.650

Piper Diagram Analysis

A piper diagram graphically represents the chemistry of a water samples. The cations and anions are shown by separate ternary plots. The apexes of the cation plot are calcium, magnesium and sodium plus potassiumcations. The apexes of the anion plot are sulfate, chloride and carbonate plus hydrogen carbonate anions. The two ternary plots are then projected onto a diamond (Piper, 1953). The diamond is a matrix transformation of a graph of the anions (sulfate + chloride/ total anions) and cations (sodium + potassium/total cations) according to Rao (1998) .

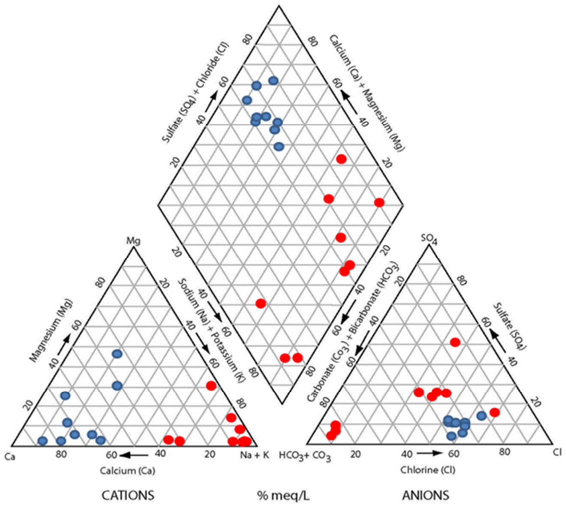

Fig. 5: Piper trilinear diagram showing the major water types surface water and groundwater
(Groundwater and Surface water)

Schoeller Diagram

A Schoeller Diagram is a semi-logarithmic diagram of the concentrations of the main ionic constituents in water (SO_4, HCO_3, Cl, Mg, Ca, and Na/K) in milli-equivalents per kg of solution (meq/kg). An equivalent being the amount of an anion or cation species needed to add or remove one mole of electrons from a system. Concentrations of each ion in each sample are represented by points on six equally spaced lines and points are connected by a line. The diagram gives absolute concentration, and also the ratio between two ions in the same sample. If a line joining two points representing ionic concentrations in a single sample is parallel to another line joining a second set of concentrations from another sample, the ratio of those ions in those samples are equal or close. The close to parallel lines of the Schoeller diagram for groundwater portrays it to be composed of equal ratio of ions, thus of one dominant type, while the groundwater is not. This is confirmed by the Table 5.10, Fig. 5.7 and 5.8, showing that the surface waters in the study area are not of one dominant type, and may have been influenced by the effects of erosive agents and the accompanying land degradation which introduced ions into the water (Schoeller, 1962).

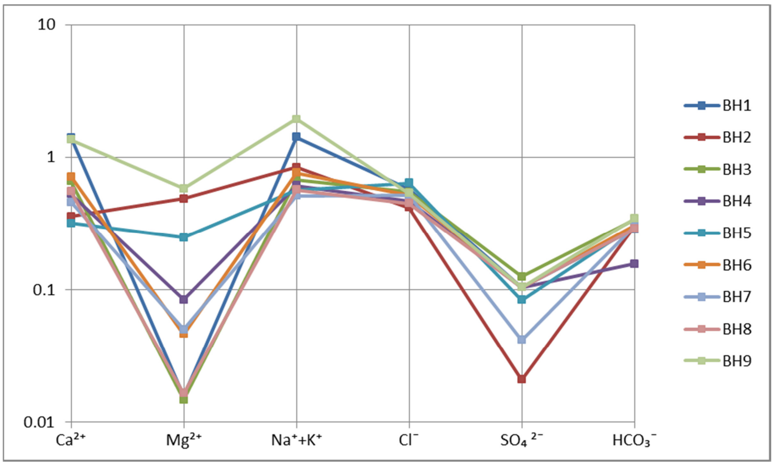

Fig. 6: Schoeller Logarithm diagram for underground water

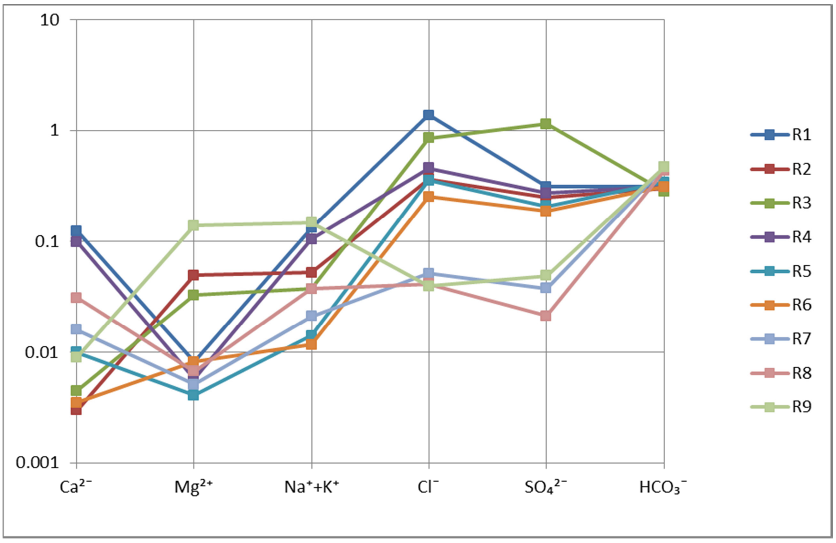

Fig. 7: Schoeller Logarithm diagram for surface water

Conclusion and Recommendations

Field studies show that the environmental hazard posed by gullying has continued to defy control measure put in place to checkmate it, as a result of the peculiar geological, hydrogeological, geotechnical, climate and anthropogenic factors prevalent in the area. Schoeller semi logarithm diagram shows that the surface waters in the study area is not of one dominant type, but may have been influenced by the effects of erosive agents and the accompanying land degradation. The conditions that favour gullying in the Ameki and the Benin Formations are complete in the study area; these include high rainfall, steep slope, friable substratum and intense human activities. The adverse effects of the intense gullying include population displacement, loss of infrastructure, and loss of farm land, land impoverishment and siltation of water sources.

It is recommended that Slope stabilization by reducing the slope angle during road construction should be encouraged, this will help in reducing failure during road construction. It is also recommended that a more detail geophysical survey such as seismic, gravity and EM should be carried out to delineate the strength of the geologic material.

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