Assessment of Air Quality, Physicochemical Characteristics and Heavy Metal Conditions of Soil and Waters of Ogbe-Okwe Gully Erosion in Ukwu Nzu in Delta State, Nigeria

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ABSTRACT: This study assessed the air quality and physicochemical conditions of soils and water of Ogbe-Okwe gully in Ukwu-Nzu, Delta State of Nigeria. Air quality after analysis with AeroQual Series 500 Air Sampler showed that Total Suspended Particulate ranged from 15.43 - 28.55 µg/m^3, Nitrogen dioxide ($0.00 \pm 0.0 - 0.01 \pm 0.0$ µg/m^3), Sulphur dioxide ($0.00 \pm 0.0 - 0.27 \pm 0.0$ µg/m^3), Ozone ($0.00 \pm 0.0 - 0.01 \pm 0.0$ µg/m^3), Volatile Organic Compounds ($0.010 \pm 0.0 - 0.61 \pm 0.0$ µg/m^3), Carbon monoxide ($0.010 \pm 0.0 - 0.01 \pm 0.0$ µg/m^3) and Methane ($0.010 \pm 0.0 - 0.01 \pm 0.0$ µg/m^3). Physicochemical characteristics of soils samples showed that clay ranged from $24.00 \pm 1.92 - 36.00 \pm 2.96$ %, silt ($24.00 \pm 1.92 - 33.00 \pm 2.83$ %), sand ($33.00 \pm 2.83 - 51.00 \pm 3.89$ %). pH ranged from $6.70 \pm 0.50 - 7.88 \pm 0.93$, organic matter ($0.91 \pm 0.37 - 2.00 \pm 1.00$ %), organic carbon ($0.51 \pm 0.25 - 0.89 \pm 0.37$ %) and total nitrogen ($0.01 \pm 0.00 - 0.05 \pm 0.00$ %). Electrical conductivity ranged from $4.12 \pm 1.45 - 4.81 \pm 0.36$ µS/cm, available phosphorus ($150.00 \pm 5.00 - 180.00 \pm 5.74$ mg/kg), total exchangeable bases ($1.60 \pm 0.42 - 1.99 \pm 0.69$ cmol/kg), calcium ($1.20 \pm 0.15 - 1.22 \pm 0.17$ mg/kg), magnesium ($0.40 \pm 0.00 - 0.51 \pm 0.10$ mg/kg), sodium ($0.02 \pm 0.00 - 0.05 \pm 0.00$ mg/kg) and potassium ($0.04 \pm 0.03 - 0.08 \pm 0.00$ mg/kg). In soil samples, cadmium values ranged from $0.16 \pm 0.13 - 0.30 \pm 0.13$ mg/kg, Lead ($1.26 \pm 0.33 - 3.50 \pm 0.51$ mg/kg), Zinc ($25.12 \pm 2.82 - 79.02 \pm 3.29$ mg/kg), Copper ($27.89 \pm 2.49 - 63.08 \pm 3.68$ mg/kg), Iron ($191.16 \pm 5.07 - 212.16 \pm 5.92$ mg/kg) and Manganese ($10.80 \pm 0.49 - 18.00 \pm 0.81$ mg/kg). The results obtained from this study showed high levels of heavy metals. It is very necessary for government to enact very strict laws that would help minimize the adverse effect of these activities.

The formation of gullies has become one of the greatest environmental disasters facing many towns and villages in southern parts of Nigeria (Pitman and Golovchenko, 2001). It is an ecological, environmental, economic, and humanitarian disaster resulting in land degradation, loss of lives and properties worth millions of dollars. The estimated number of gullies in the country is about 3,000. Gullies and areas exposed to erosion in Southeastern Nigeria tripled from about 1.33% (1,021 km2) in 1976 to about 3.7% (2,820 km2) in 2006 making the region the most affected region in the country (Costard *et al.*, 2012). Several non-responsive human activities by both the Government and the inhabitants have culminated in devastating gully erosion in this area. Some of these activities include excavation of the earth for laterite

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and sand in the process of sand/regolith mining, construction of roads without drainage channels and poor agricultural practices. Buildings are congested on top of groundwater recharge areas. The geology of the area is composed of weak, friable soils which are poorly consolidated (Joshi *et al*., 2007). Erosion is the action of surface processes (such as water flow or wind) that remove soil, rock, or dissolved material from one location on the Earth's crust, and then transport it to another location (Costard *et al*., 2003). This natural process is caused by the dynamic activity of erosive agents, that is, water, ice (glaciers), snow, air (wind), plants, animals, and humans. In accordance with these agents, erosion is sometimes divided into water erosion, glacial erosion, snow erosion, wind (aeolic) erosion, zoogenic erosion, and anthropogenic erosion. The particulate breakdown of rock or soil into clastic sediment is referred to as physical or mechanical erosion (Jones *et al*., 2008). This contrasts with chemical erosion, where soil or rock material is removed from an area by its dissolving into a solvent (typically water), followed by the flow away of that solution. Eroded sediment or solutes may be transported just a few millimetres, or for thousands of kilometres. Hence this study aims assessed the air quality, physicochemical characteristics and heavy metal conditions of soil and waters of Ogbe-Okwe gully erosion in Ukwu Nzu in Delta State.

MATERIALS AND METHODS

The Ogbe-Okwe Erosion Site is located at Ukwu-Nzu in Aniocha North LGA, Delta State with coordinates of Latitude N 6° 23' 10.6" and Longitude E 6° 28' 52.7" with estimated length and depth of 600 m and 11 m respectively. The severe flooding and erosion problems that occur in this area has been investigated by concerned environment personnel and noted as one of the ecological priority zones for flooding and erosion control in Delta State. A geotechnical investigation was conducted on March 2017 at the Ogbe-Okwe Erosion Gully Site Delta State, Nigeria, where six soil samples were taken and tested in the laboratory. The laboratory results indicated that the site is underlain by clayey sands and are classified as 'SC' by the unified soil classification system (USCS).
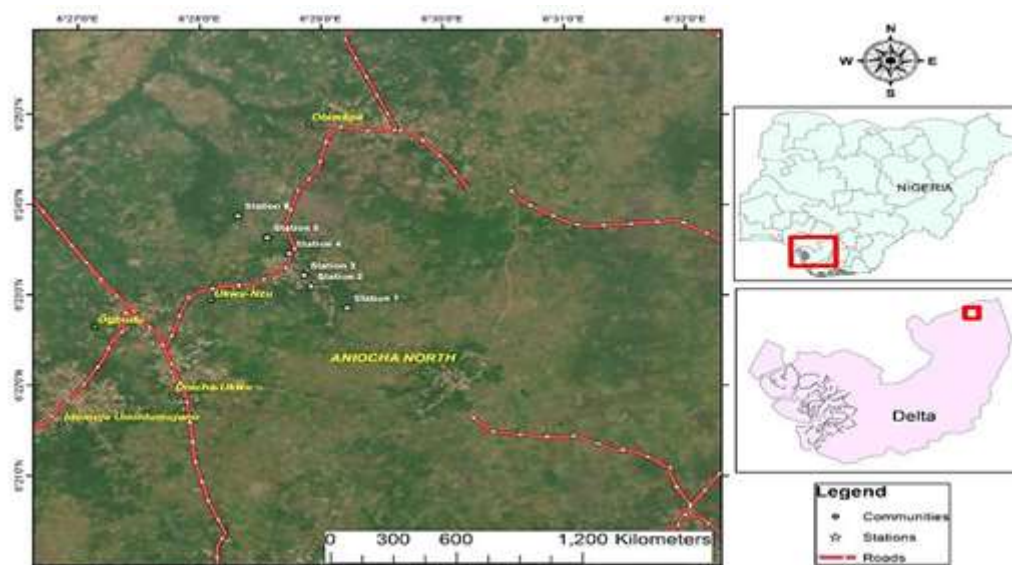
Fig 1: Map showing sampling location at Ogbe-Okwe gully erosion site located in Ukwu-Nzu in Aniocha North LGA, Delta State, Nigeria

After reconnaissance survey of the study area, the six stations were selected. Three replicates of soil and water samples were collected from each station monthly from March to October, 2017 using standard procedures. Soil samples were collected with an auger at a depth of 0 – 30 cm. The air pollutants (SPM, NO_2, SO_2, H_2S, O_3, VOCs, CO and CH_4), commonly used in air quality index (AQI) assessment were sampled using AeroQual Series 500 gas monitors, England, while SPM was measured with Haze-dust particulate monitor 10 µm, model HD 1000, Environmental Device Corporation, USA.

Physicochemical parameters such as pH, colour, particle size, soil organic matter, soil organic carbon, total nitrogen, phosphorus, electrical conductivity, total exchangeable bases, calcium, magnesium, sodium and potassium were determined for soil and water according to the method of APHA (1999).

In analysing total dissolved solids (TDS) in water, a portion of water was filtered out and 10mls of the filtrate was measured into a pre-weighed evaporating dish which was then dried in an oven at a temperature of 103 to 105℃ for two and half hours. The dish was transferred into a desiccator and allowed to cool at room temperature and was weighed (APHA, 1999). Electrical Conductivity (EC) was analyzed in accordance with the method described by Ademoroti (1996). The conductivity meter was switched on by pressing the power bottom; it was then allowed to stabilize for 10 minutes. It was calibrated by pressing CND and immersing the probe in the KCl solutions prepared. The probe was then rinsed and immersed into the sample solution. The conductivity was read by pressing CND. In analysing for pH, the electrode was cleaned, dried and dipped into the different samples and the reading was recorded when the reading became stable. After the pH of the first sample was recorded, the electrode were re-washed with distilled water before dipped into subsequent samples until all the samples was tested. It was standardized with a buffer solution of pH range between 4-9 (Singh *et al,* 2012). Turbidity was determined using a standardized Turbidimeter (Singh *et al,* 2012). Water Temperature was measured using a thermometer and expressed as °C. The total suspended solids were obtained by simple calculation (APHA, 1999). Dissolved Oxygen, Biological Oxygen Demand and Chemical Oxygen Demand were determined using the method describe by APHA, 1999.

In the physicochemical analysis for soil samples, total organic carbon (TOC) and total organic matter (TOM) contents were calculated and determined using the method of Osuji and Nwoye, 2007 and Nelson and Sommers, 1982. In determining soil pH, twenty grams (20 g) of air-dried soil were sieved and 20 ml of distilled water was added to it and allowed to stand for 30 minutes. The mixture was stirred occasionally with a glass rod. The pH was determined by inserting the pH meter into the suspension.

Total Nitrogen was obtained by digestion of soil nitrogen using micro-Kjeldahl digestion. Conductivity meter was used in the determination of Electrical conductivity level of the soil samples. In determining available phosphorus, soil sample (5g) was weighed into the plastic bottle. Then 40ml of the extracting solution was added and stoppered. It was then rocked manually for 1 minute. The solution was then filtered with Whatman filter paper No. 42. When filtrate was seen not to be clear, the filtration process was repeated. If after filtering again the solution is not clear, then 3-5 drops of conc. H_2SO_4 was added and let to stand for about 2 hours. The clear supernatant was then easily

decanted. The filtrate or supernatant was then kept and determined for the available phosphorus. For total exchangeable bases, Five (5) g air-dried soil was weighed into a 5 g plastic bottle. 100 ml of neutral 1 M ammonium acetate was added, and the mixture was shaken mechanically for 30 minutes and filtered thereafter, using a No 42 Whatman filter paper, into a 100 ml volumetric flask. This was made up with the acetate to the mark. Na (589-nm wavelength) and K (766.5nm wavelength) were determined with a Flame Photometer, and then Ca and Mg by Atomic Absorption Spectrophotometer. Ten to twenty mls of soil saturation extract was pipetted, having not more than 1.0 meq Ca, into a 250-ml Erlenmeyer flask. This was diluted to 20 - 30 mL with distilled water; and 2 - 3 ml 2 N NaOH solution was added; and about 50 mg ammonium purpurate indicator. This was titrated with 0.01 N EDTA. The color change was from red to purple. Near the end point, EDTA was added, one drop every 10 seconds, since the color change was not instantaneous.

For Magnesium determination, ten to twenty mls soil saturation extract was pipetted into a 250-mL flask, and diluted to 20 -30 mL with distilled water. Then 5 mL buffer solution was added, and a few drops of Eriochrome Black Indicator. This was titrated with 0.01 N EDTA until the color changed from red to blue.

Calcium (Ca): Fifty mls of the sample filtrate was taken and 0.1N HCl was added to decompose bicarbonates. It was then boiled to expel CO_2 after which it was cooled and 2ml of NaOH was added to produce a pH of 12-13, Miroxide indicator was added and then the solution was titrated with EDTA titrant slowly with continuous stirring to the proper end point. The solution then changed from pink to purple. The concentration of calcium was then calculated. For heavy metals analysis, soil samples were oven-dried at 70–80°C for 24hrs, to remove all moisture. Dried samples were milled into a fine powder of 80 μm. Then 1.0g of the dried sample was weighed into a digestion tube and 10ml of 98% nitric acid was added. This was then placed in a water bath and allowed to boil for about 72 hours after which it was allowed to cool and the content transferred into a 100 cm^3 volumetric flask and made-up to the volume mark with water. The solution was used for determination of mineral elements. The solution was also analyzed for cadmium, lead, zinc, copper, iron and manganese using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer model 2130).

For water samples, the triple acid digestion method of Sahrawat *et al.* (2002) was employed. Each sample (1ml) was weighed into a micro-kjeldahl digestion

flask to which 20cm^3 of mixture of concentrated HNO$_3$, H$_2$SO$_4$, and 60% HClO$_4$ (9:2:1 v/v) were added. The flask was put on a heating block and digested to a clear solution, cooled and the content transferred into a 100 cm^3 volumetric flask and made-up to the volume mark with water. The solution was used for determination of mineral elements. The solution was also analyzed for cadmium, lead, zinc, copper, iron and manganese using Atomic Absorption Spectrophotometer (AAS, Perkin Elmer model 2130) For air quality sampling, the air pollutants (SPM, NO$_2$, SO$_2$, H$_2$S, O$_3$, VOCs, CO and CH$_4$), commonly used in air quality index (AQI) assessment were sampled using AeroQual Series 500 gas monitors, England, while SPM was measured with Haze-dust particulate monitor 10 μm, model HD 1000, Environmental Device Corporation, USA. Sampling was carried out during dry season.

Statistical Analysis: Statistical analyses were done using general descriptive statistics, one-way analysis of variance (ANOVA) at the P<0.05 significant level. If significant differences were found, Duncan's multiple range and SNK analysis were used to locate the significant differences among the different experimental groups. Significant difference was defined at P<0.05 using a computer software (Microsoft Excel). The statistical package for social scientists (SPSS) was also used.

RESULTS AND DISCUSSION

The physicochemical characteristics of Ogbe-Okwe gully erosion soil is presented in Table 1. The physicochemical parameters analysed for the six stations showed that the range of physicochemical parameters for the six stations were as follows: clay (24.00 ± 1.92 − 36.00 ± 2.96 %), silt (24.00 ± 1.92 − 33.00 ± 2.83 %), sand (33.00 ± 2.83 − 48.00 ± 3.50 %),

pH (7.50 ± 0.90 − 7.88 ± 0.93), organic matter (0.91 ± 0.37 − 1.55 ± 0.41 %), organic carbon (0.51 ± 0.25 − 0.88 ± 0.29 %), total nitrogen (0.01 ± 0.00 − 0.02 ± 0.00 %), electrical conductivity (4.12 ± 1.45 − 4.24 ± 1.50 μS/cm), available phosphorus (159.00 ± 5.31 − 167.01 ± 5.63 mg/kg), total exchangeable bases (1.60 ± 0.42 − 1.74 ± 0.60 cmol/kg), calcium (1.20 ± 0.15 − 1.21 ± 0.17 mg/kg), magnesium (0.40 ± 0.00 − 0.40 ± 0.00 mg/kg), sodium (0.02 ± 0.00 − 0.04±0.00 mg/kg) and potassium (0.06 ± 0.00 − 0.07 ± 0.03 mg/kg) respectively. The heavy metal properties of Ogbe-Okwe gully erosion soil is presented in Table 2. The range of heavy metal content for the six stations is as follows: cadmium (0.17±0.04 − 0.29±0.11 mg/kg), lead (1.26±0.33 − 3.40±0.62 mg/kg), zinc (25.12±2.82 − 78.01±3.59 mg/kg), copper (27.89±2.49 − 60.25±3.30 mg/kg), iron (192.15±5.61 − 211.15±5.81 mg/kg) and manganese (11.80±0.24 − 17.00±0.64 mg/kg). Also station 5 had the highest concentration of cadmium and lead, while station 6 had the highest concentration of iron and manganese respectively. The physicochemical characteristics of surface water at Ogbe-Okwe gully erosion site is presented in Table 3. The physicochemical parameters analysed for the six stations shows that the range of physicochemical parameters for the six stations are as follows: Air temperature (28.30±2.75 − 29.50±2.87 °C), water temperature (25.20±2.02 − 27.00±2.63 °C), turbidity (3.10±0.24 − 4.20±0.46 NTU), pH (6.10±0.28 − 6.35±0.30), salinity (20.00±1.00 − 21.0±1.10 g/l), total dissolved solids (38.00±2.89 − 50.00±3.65 mg/l), electrical conductivity (65.00±3.72 − 100.00±5.00 μS/cm), total suspended solids (15.00±0.48 − 20.00±1.00 mg/l), Biochemical oxygen demand (12.00±0.28 − 20.00±1.00 mg/l), chemical oxygen demand (50.10±3.64 − 65.30±3.41 mg/l) and dissolved oxygen (3.00±0.22 − 4.00±0.25 mg/l), respectively.

Table 1: Physicochemical characteristics of soils from sampling stations at Ogbe-Okwe erosion site

Soil Quality Index	(Station 1)	(Station 2)	(Station 3)	(Station 4)	(Station5)	(Station6)
Soil Colour	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish
Soil Texture	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand	Clayey/sand
Clay (%)	25.00±2.01^b	25.00±2.01^b	34.00±2.85^{bc}	24.00±1.92^a	25.00±2.01^b	36.00±2.96^c
Silt (%)	24.00±1.92^a	28.00±2.72^b	30.00±2.75^{bc}	24.50±1.96^a	28.00±2.72^b	33.00±2.83^c
Sand (%)	48.00±3.50^c	43.00±3.05^b	33.00±2.83^a	48.00±3.50^c	46.00±3.10^{bc}	35.00±2.88^{ab}
pH	7.80±0.93^c	7.70±0.91^b	7.70±0.91^b	7.50±0.90^a	7.70±0.93^b	7.88±0.93^c
Organic Matter (%)	1.52±0.40^c	0.99±0.38^b	1.03±0.39^c	1.55±0.41^c	0.91±0.37^a	1.06±0.40^c
Organic Carbon (%)	0.87±0.35^c	0.77±0.37^b	0.61±0.26^a	0.88±0.29^c	0.78±0.34^b	0.51±0.25^a
Total Nitrogen (%)	0.02±0.00^a	0.02±0.00^a	0.01±0.00^a	0.02±0.00^a	0.02±0.00^a	0.01±0.00^a
EC (μS/cm)	4.22±1.55^b	4.12±1.45^a	4.13±1.46^a	4.24±1.50^b	4.13±1.46^a	4.13±1.46^a
AP (mg/kg)	159.00±5.31^a	159.00±5.31^a	167.00±5.63^b	159.03±5.11^a	159.03±5.11^a	167.01±5.63^b
TEB (cmol/kg)	1.61±0.44^a	1.60±0.42^a	1.70±0.58^b	1.61±0.44^a	1.61±0.44^a	1.74±0.60^b
Calcium (mg/kg)	1.20±0.15^a	1.20±0.15^a	1.21±0.17^a	1.20±0.15^a	1.20±0.15^a	1.21±0.17^a
Magnesium (mg/kg)	0.40±0.00^a	0.40±0.00^a	0.40±0.00^a	0.40±0.00^a	0.40±0.00^a	0.40±0.00^a
Sodium (mg/kg)	0.03±0.01^a	0.03±0.01^a	0.02±0.00^a	0.04±0.00^a	0.03±0.01^a	0.02±0.00^a
Potassium (mg/kg)	0.07±0.03^a	0.06±0.00^a	0.06±0.00^a	0.07±0.03^a	0.06±0.00^a	0.06±0.00^a

EC = Electrical Conductivity (μS/cm); AP = Available Phosphorus (mg/kg); TEB = Total Exchangeable Bases (cmol/kg); *Values are mean ± SEM . Mean values with similar superscripts within each row are not significantly different, P>0.05.*

Table 2: Heavy metals properties in soils from sampling stations at Ogbe-Okwe erosion site

Parameters	Unit	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	NESREA Limit
Cd	mg/kg	0.22±0.06[a]	0.25±0.09[a]	0.18±0.05[a]	0.28±0.12[a]	0.29±0.11[a]	0.17±0.04[a]	3
Pb	mg/kg	2.50±0.24[b]	2.80±0.22[b]	1.55±0.36[a]	3.00±0.48[c]	3.40±0.62[c]	1.26±0.33[a]	30
Zn	mg/kg	65.20±3.41[b]	25.12±2.82[a]	76.56±3.63[c]	65.9±3.65[b]	26.12±2.20[a]	78.01±3.59[c]	30
Cu	mg/kg	40.51±3.10[b]	28.12±2.34[a]	60.25±3.30[c]	41.11±3.17[b]	27.89±2.49[a]	58.78±3.44[c]	14
Fe	mg/kg	201.36±5.13[bc]	192.15±5.61[a]	206.00±5.50[c]	208.36±5.68[c]	197.15±5.24[a]	211.15±5.81[c]	100
Mg	mg/kg	14.3±0.19[b]	11.80±0.24[a]	15.00±0.26[b]	12.30±0.67[ab]	10.9±0.45[a]	17.00±0.64[c]	50

Values are mean ± SEM. Mean values with similar superscripts within each row are not significantly different, P>0.05.

Table 3: Physicochemical characteristics of surface water from sampling stations at Ogbe-Okwe erosion site

Parameters	Unit	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	NESREA Limit
Appearance	Sighting	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	
Odour	Smell	Slight odour	Slight odour	Slight odour	Slight odour	Slight odour	Slight odour	
AT	°C	28.50±2.72[a]	29.20±2.82[b]	29.30±2.86[b]	28.30±2.75[a]	29.20±2.86[b]	29.50±2.87[b]	-
WT	°C	25.20±2.02[a]	26.00±2.03[b]	27.00±2.63[c]	25.50±2.41[a]	26.1±2.04[b]	27.00±2.63[c]	-
Turbidity	NTU	3.50±0.27[a]	4.10±0.45[b]	3.10±0.24[a]	3.60±0.29[b]	4.20±0.46[a]	3.10±0.24[b]	5
pH		6.35±0.30[a]	6.20±0.29[a]	6.10±0.28[a]	6.34±0.31[a]	6.20±0.29[a]	6.10±0.28[a]	6.0- 9.0
Salinity	g/l	20.00±1.00[a]	20.00±1.00[a]	21.0±1.10[a]	20.00±1.00[a]	20.00±1.00[a]	21.00±1.10[a]	0.5
TDS	mg/l	44.00±3.50[b]	50.00±3.65[c]	39.00±3.09[a]	45.00±3.59[b]	50.00±3.56[c]	38.00±2.89[a]	10
EC	µS/cm	85.00±4.02[b]	65.00±3.72[a]	100.00±5.00[c]	84.00±4.00[b]	65.00±3.72[a]	101.00±5.10[c]	40
TSS	mg/l	18.00±0.45[b]	20.00±1.00[c]	15.00±0.48[a]	19.00±0.91[bc]	20.00±1.00[c]	15.00±0.48[a]	10
BOD	mg/l	12.00±0.28[a]	14.00±0.31[b]	20.00±1.00[c]	12.00±0.28[a]	15.00±0.48[b]	20.00±1.00[c]	50
COD	mg/l	60.00±3.43[b]	50.10±3.64[a]	65.20±3.32[c]	61.00±3.12[b]	50.20±3.18[a]	65.30±3.41[c]	35
DO	mg/l	3.00±0.22[a]	3.80±0.46[b]	3.70±0.51[b]	3.10±0.20[a]	3.80±0.39[b]	4.00±0.25[c]	4

AT = air temperature; WT = water temperature, TDS = total dissolved solids; TSS = Total suspended solids; EC = Electrical conductivity; BOD = Biochemical Oxygen demand; COD = Chemical Oxygen Demand; DO = dissolved Oxygen; Values are mean ± SEM. Mean values with similar superscripts within each row are not significantly different, P>0.05.

The heavy metal properties of surface water at Ogbe-Okwe gully erosion site for the month of March is presented in Table 4. The range of heavy metal content for the six stations is as follows: Cadmium (0.001±0.0 – 0.002±0.0 mg/l), lead (0.001±0.0 – 0.002±0.0 mg/l), zinc (1.5±0.0 – 2.0±0.0 mg/l), copper (0.001±0.0 – 0.001±0.0 mg/l), iron (0.001±0.0- 0.002±0.0 mg/l) and manganese (0.001±0.0 – 0.001±0.0 mg/l) respectively. The air quality parameters of Ogbe-Okwe gully erosion site is presented in Table 5. The range of air quality parameters for the six stations is as follows: Total suspended particulate (15.43±2.21 – 21.00±4.03 µg/m³), Nitrogen dioxide (0.00±0.0 – 0.01±0.0 µg/m³), Sulphur dioxide (0.00±0.0 – 0.03±0.0 µg/m³), Hydrogen sulphide (0.00±0.0 – 0.00±0.0 µg/m³), Ozone (0.00±0.0 – 0.01±0.0 µg/m³), Volatile Organic Compounds (0.010±0.0 – 0.025±0.0 µg/m³), Carbon monoxide (0.01±0.0 – 0.01±0.0 µg/m³) and Methane (0.01±0.0 – 0.01±0.0 µg/m³) respectively. This study investigated the physicochemical characteristics and heavy metal properties of Ogbe-Okwe gully erosion

site in Delta State. Soil erosion is perhaps the most serious mechanism of land degradation in the Southern part of Nigeria, especially in Delta State where hundreds of people are directly affected every year. Consequently, large areas of agricultural lands are becoming unsuitable for cultivation as erosion destroys farmlands and lowers agricultural productivity (Apollo *et al.,* 2018). The results of the physicochemical analysis carried out on soil samples from six stations showed that the pH ranged from 6.70 – 7.88 for all stations measured in the eight months of the study. Slessarev *et al.* (2016) reported that in high rainfall seasons the pH of soils typically ranges from 5 to 7, while in dry seasons the range is from 6.5 to 9. This could be the reason why a pH range 6.70 – 7.88 was recorded in the present study. Wijnen *et al.* (2014) stated that soil pH is a master variable in soils as it affects many chemical processes, specifically plant nutrient availability by controlling the chemical forms of the different nutrients and influencing the chemical reactions they undergo.

Table 4: Mean values of some heavy metals in surface water from sampling stations at Ogbe-Okwe erosion site

Parameters	Unit	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	NESREA Limit
Cd	mg/l	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	
Pb	mg/l	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.002±0.0a	0.001±0.0a	0.001±0.0a	0.01- 0.1
Zn	mg/l	1.5±0.0a	1.8±0.0b	1.6±0.0a	1.7±0.0a	1.8±0.0b	2.0±0.0c	5 – 15
Cu	mg/l	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.05- 1.5
Fe	mg/l	0.002±0.0a	0.002±0.0a	0.001±0.0a	0.002±0.0a	0.002±0.0a	0.001±0.0a	20
Mg	mg/l	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	0.001±0.0a	

Values are mean ± SEM. Mean values with similar superscripts within each row are not significantly different, P>0.05.

Table 5: Mean values of air qualities from sampling stations at Ogbe-Okwe erosion site

Stations	Air Quality Parameters							
	TSP (µg/m3)	NO2 (µg/m3)	SOx (µg/m3)	H2S (µg/m3)	O3 (µg/m3)	VOCs (µg/m3)	CO (mg/m3)	CH4 (mg/m3)
1	21.00±4.03[c]	0.01±0.0a	0.03±0.0b	0.00±0.0a	0.01±0.0a	0.025±0.0c	0.01±0.0a	0.01±0.0a
2	18.02±3.50[b]	0.01±0.0a	0.00±0.0a	0.00±0.0a	0.01±0.0a	0.022±0.0b	0.01±0.0a	0.01±0.0a
3	15.43±2.21[a]	0.00±0.0a	0.00±0.0a	0.00±0.0a	0.00±0.0a	0.010±0.0a	0.01±0.0a	0.01±0.0a
4	16.32±2.31ab	0.00±0.0a	0.00±0.0a	0.00±0.0a	0.00±0.0a	0.010±0.0a	0.01±0.0a	0.01±0.0a
5	19.04±3.63b	0.01±0.0a	0.00±0.0a	0.00±0.0a	0.01±0.0a	0.023±0.0c	0.01±0.0a	0.01±0.0a
6	17.50±3.10ab	0.00±0.0a	0.00±0.0a	0.00±0.0a	0.01±0.0a	0.011±0.0a	0.01±0.0a	0.01±0.0a
NESREA Limits	26	75	75	11.4-22.8	NS	NS	1.0	250

Values are mean ± SEM. Mean values with similar superscripts within each column are not significantly different, P>0.05.
Key: - CH4: Methane, CO: Carbon monoxide, H₂S: Hydrogen sulphide, NO2: Nitrogen dioxide, O3: Ozone, SO₂: Sulphur dioxide,
TSP: Total Suspended Particulate, VOCs: Volatile Organic Compounds

The results also showed that soil organic carbon in soil samples across the six stations ranged from 0.60 – 0.89%. Similarly, Jobbágy and Jackson (2000) reported ranges from 0.5% to 3.0% of organic carbon for upland soils. Panagos *et al.* (2013) stated that soils containing greater than 12 - 18% organic carbon are generally classified as organic soils, and high levels of organic carbon develop in soils supporting wetland ecology, flood deposition, fire ecology and human activity. Soil organic carbon affects the chemical and physical properties of soil such as water infiltration ability, moisture holding capacity, nutrient availability, and the biological activity of microorganisms (Hosseinpur and Pashamokhtari, 2013). The results also show that the available phosphorus in soil samples across the six stations ranged from 150.00 – 180.00 mg/kg. Arai and Sparks (2007) reported a higher range of 500-800 mg/kg available phosphorus in soil. The value of available phosphorus obtained in this study could have been dependent on phosphorus cycle as microorganisms are involved in important soil processes, such as decomposition and mineralization of soil organic matter. Thus, the release of phosphorus through mineralization is important since it makes phosphorus more easily accessible for plant uptake (Kraal *et al.,* 2017). Furthermore, a concentration of phosphorus above can encourage vigorous root and shoot growth, promote early maturity, increase water use efficiency and yield of plants. Thus, P- deficiency may result in stunted vegetative growth and yield of plants. The concentration of calcium in soil samples across the six stations in this study ranged from 1.20 – 1.22 mg/kg. Komar and Zeebe (2016) reported much higher concentrations in the range of 400 to 500 mg/kg calcium in soil. Fantle and Tipper (2014) stated that calcium is an essential plant nutrient that contributes to soil fertility by helping maintain a flocculated clay and therefore with good aeration. Plants require Ca to develop strong cell walls and membranes. Insufficient Ca in plants leads to a breakdown of cell walls and membranes, susceptibility to a variety of diseases and post-harvest problems particularly in fresh produce such as apples and celery (Ridgwell and Zeebe, 2005). The results of the physicochemical analysis carried out on surface water samples from six stations showed that the turbidity ranged from 2.70 – 4.20 NTU. This range is lower than NESREA limit of 5 NTU. Mann *et al.* (2007) reported a range of 0.5 to 1.0 in drinking water. Changes in turbidity could be due to phytoplankton, sediments from erosion, re-suspended sediments from waste discharge, algae growth and urban runoff. Wijnen *et al.* (2014) stated that excessive turbidity in drinking water is aesthetically unappealing as it supports the growth of pathogenic organisms if not treated, thereby leading to waterborne disease outbreaks, which have caused significant cases of intestinal diseases throughout the world. The concentrations of salinity in water samples across the six stations ranged from 20 – 21.00 g/l. Anati (1999) reported a range of 50–80 mg/l in surface water. He stated that salinity affects the chemistry of natural waters and biological processes within it. The reason for the salinity value obtained in the present study could have been caused by natural processes such the accumulation of salt from rainfall over many years or from the weathering of rocks. People exposed to high salinity water seemed to lack awareness regarding salinity-inducing health effects. Van Niekerk *et al.* (2014) confirmed that by drinking saline water, people suffer from various health problems including high blood pressure, diarrhea, cholera, skin diseases, and infant growth, and mortality. The range of temperature of water samples of the study area was 24.20 – 28.10 °C. Temperature in this study was found within permissible limit of WHO (30 °C). Ezeribe *et al.* (2012) reported 29 °C for well water in Nigeria. The concentration of TDS in present study was observed in the range of 38.00 – 50.00 mg/l and it is above the limit of 10 mg/l for NESREA standards. Similar values were reported by (Singh *et al.,* 2012), drinking water of Turkey. High values of TDS in ground water are generally not harmful to human beings, but may affect persons who are suffering from kidney and heart diseases. Water containing high solid particles may cause laxative or constipation effects.

According to NESREA standards, EC value should not exceed 40 μS/cm. The current study showed that EC value was 65.00 – 101.00 μS/cm. A similar value was reported by Thyssen *et al.* (2007) in drinking water. These results clearly indicate that water in the study area was not considerably ionized and has the lower level of ionic concentration activity due to small dissolve solids. Results of this study show that the concentration of iron in water ranged from 0.001 – 0.002 mg/l, while in soil it was from 191.16 – 211.16. This is in agreement with reports made by some researchers (Zambelli and Ciurli, 2013; Watling, 2006). These results did not meet the NESREA standards maximum limits of 100 mg/kg concentration of iron in soil. Iron is necessary for living organism functioning hence found in all human, animal tissues and in plants cells. The total amount of iron in human body lies between 110 and 140 g. Iron is vital for human body functions like heart protection, regulation of blood pressure, protein dissolution, muscle contraction, nerve stimulus etc. Iron deficiency may led to depression, muscle weakness, heart rhythm disorder etc. According to NESREA standards the permissible limit of iron is 100 mg/1. Zinc is essential for proper functioning of living organisms. The human body contains about 25 g of zinc. According to NESREA standards, the permissible range of zinc should be 30 mg/l. In this study zinc ranged from 1.50 – 3.0 in water and 25.11 – 79.02 in soil. Similar values were reported by Thyssen *et al.* (2007) for drinking water and soil. The results showed that concentration of iron in soil was higher than the standard limit of NESREA. Results showed that the concentration of cadmium ranged from 0.001 – 0.001 in water and 0.16 – 0.29 in soil. These results indicate that the concentration of cadmium in this study was within the acceptable limit of NESREA (3 mg/l). Cadmium is one of the most toxic metals and caused itai-itai disease in Japan evidenced by bone distortions and pains. The sources of cadmium are industrial waste, fertilizers etc. In this study, the values of lead ranged from 0.001 to 0.002 mg/l. It is lower than the standard limit of 0.01 – 1.0 mg/l approved by NESREA 2011. Rzymski *et al.* (2014) reported that lead is toxic to living organisms including man. Its toxicity is exerted even in small amounts. Pb impairs the proper functioning of the reproductive and nervous systems, including kidney damage, high blood pressure and anemia (WHO 2011). Diseases related to contamination of drinking-water constitute a major burden on human health. Interventions to improve the quality of drinking-water provide significant benefits to health. Water is essential to sustain life, and a satisfactory supply must be available to all (Pitman and Golovchenko, 2001). Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable. Excessive amount of physical and chemical parameters accumulated in surface water and soil in the present study can affect human health. In this study, nitrogen dioxide levels ranged from 0.00 – 0.001 μg/m^3 in all air sampled stations, when compared with NESREA standard limit of 75μg/m^3. The values of nitrogen dioxide obtained in this study were found within the permissible limits of NESREA 2011. However, Njoku *et al.* (2016) reported a value range of 0.0 - 3000 μg/m^3 of nitrogen dioxide in Lagos State metropolis. In this study Total Suspended Particulate had a range of 15.26 – 28.55 μg/m^3. This was above the NESREA standard limit of 26 μg/m^3. Njoku *et al*. 2016 reported a much higher range of 140 – 4820 μg/m^3. Researches have reported that the level of suspended particulate matter in cities are high due to wind-blown dust from the roads, emissions from machineries in the industry and industrial vehicles (Akuro, 2012). Major components of fine particles are SO_4^-, H^+, NO_3^-, NH_4^+, organic compounds, trace elements (including metals that volatize at combustion temperatures), elemental carbon, and water. USEPA reported that effects of inhalation of particulates include premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms such as irritation of the airways, coughing and difficulty breathing. Sulphur dioxide ranged from 0.00 – 0.16 μg/m^3.

This is lower than the benchmark of 425 μg/m^3 by USEPA and lower than 10 μg/m^3 set by FEPA 1991. Carbon monoxide ranged from 0.01 – 0.01 μg/m^3. Volatile Organic Compounds ranged from 0.010 – 0.47 μg/m^3. Carbon monoxide, methane and ozone ranged from 0.00 – 0.01 μg/m^3. The USEPA benchmark for carbon monoxide is 35000 μg/m^3 which is well above the range obtained in this study. The reason for the high levels may be attributed to higher traffic density and higher vehicular emissions in the study area.

Conclusion: The results obtained from this study indicate the presence of pollutants in the soil, air and water samples analysed in the study. This could be attributed to the anthropogenic activities (agriculture, cattle rearing, logging, drilling of borehole, construction of high storey building and digging of borrow pits) of the Ukwu-Nzu people. If these activities are not regulated, it may results to a wide range of environmental degradation which can have harmful impact on human and its residences. Hence it is very necessary for government to enact very strict

laws that would help minimize the adverse effect of these activities.

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