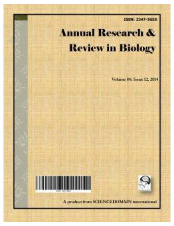

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Physicochemical Assessment of Vulnerability of the River Ebenyi in Eha-Amufu and Environs, Southeast Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Authors EIN and EEN designed this research. All authors provided used materials. Author EIN was responsible for sample collection and conveying of samples to the laboratory. Authors EIN, FJU, OCE, SUE and GUO were responsible for the statistical analysis. Finally, authors EIN and EEN drafted the manuscript while all authors proof read and corrected. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Physicochemical assessment of the surface water sourced from River Ebenyi and its tributaries in Eha-Amufu and environs, Isu-Uzo Local Government Area of Enugu State of Nigeria.
Place and Duration: Eha-Amufu and environs, Isu-Uzo Local Government Area of Enugu State of Nigeria. May to July, 2017.
Study Design: Experimental design.
Methodology: Water samples were spatially collected along the river and stream channels in Eha-Amufu and the adjoining Ihenyi, Amaede, Mgbuji, Umuhu, Agamede and Odobudo villages. Parameters analysed include pH, dissolved oxygen (DO), biological oxygen demand (BOD),

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chemical oxygen demand (COD), Total hardness (TH), Lead (Pb), Copper (Cu), Cadmium (Cd), Chromium (Cr), Zinc (Zn), Nitrate, Phosphate, Chloride, and Sulphate.

Results: The concentrations of Cd (0.02-0.05 mg/l) and Pb (0.37-0.77 mg/l) exceeded the maximum limit of the range of values considered as safe by the World Health Organisation (WHO). Conductivity (37.14 – 63.30 µs/cm), Total dissolved solids (TDS) (10.80 – 30.80 mg/l), Total suspended solids (TSS) (10.60 – 21.20 mg/l) and Total solid (TS) (20.60-41.00 mg/l) were within the lower limit of the permissible range of values. Chromium (0.26 ± 0.00 mg/l) exceeded the maximum permissible limit at Agamede village. Sulphate was statistical significantly higher (χ^2 = 25.697, $p < 0.001$) relative to the spatial concentrations of nitrate (4.28 – 11.18 mg/l), sulphate (13.68 – 25.23 mg/l), phosphate (0.00 – 0.28 mg/l) and chloride (9.11 – 15.50 mg/l) in the area.

Conclusions: The baseline results obtained from this study with regards to Cd, Cr and Pb demands that effective health education programme should be organised to emphasize on the effect of anthropogenic activities that releases pollutants. However, long term sampling covering all the months of the year is needed in order to confirm the reproducibility of our results.

Keywords: Physicochemical; River Ebenyi; vulnerability; anthropogenic activities; portability of water; statistical test.

1. INTRODUCTION

The Ebenyi River (ER) is the only natural source of water found at all villages in Eha-Amufu community. The ER permeates the sediments of the Mamu, Nkporo, Agwu and Eze-Aku formations which consist of sandstones, shales, siltstones, mudstones, limestone beds and coal measures [1]. The ER like other rivers and streams in rural and semi-urban areas of Nigeria, provide water for drinking, agricultural activities and domestic use for the residents of the communities it traverse. The surface water sources are cardinal to the survival and livelihood of the residents.

Eha-Amafu (and environs) is a semi-urban, agrarian community engaged in different economic activities including farming, fishing and animal husbandry. Palm fruits, cassava, rice, yam, cocoyam, maize and plantain are among its major agricultural output. Pesticides, herbicides, insecticides and other chemicals are commonly used for fishing and farming by the locals without recourse to the effect on the aquatic lives and the fitness of the surface water sources for human consumption. The settlement was a major hub for Donkey trading and meat selling; a major abattoir is located in Eha-Amufu. The waste produced from the butchering activities such as animal faeces, blood, skeletons and ash are leached or practically discharged into the flowing river and stream channels. The contamination of surface water occurs due to the release of pesticides, herbicides, fertilizers, human and animal faeces, used water and domestic waste into such water bodies [2,3]. The activities of butchers, farmers, fishermen and other inhabitants produced different forms of untreated waste which contaminates the environment and the waters sources. The quality of water available for consumption poses a major health concern. Contaminated surface water is associated with diseases such as Campbacteriiosis, Shigellosis, Salmollosis, Cholera, Typhoid and Paratyphoid fever, Dysentery, and Diarrhea [4,5]. The long and short term effect of the consumption of contaminated water includes weak immune system, damage to body organs and systems, poor heath state, low productivity, infertility and high mortality rate [4,5,6]. It is widely accepted that access to clean and potable drinking water is essential to good health, quality hygiene, food production and poverty reduction [7,8]. This study was motivated by the urgent need to create a public health awareness on the portability of surface water sourced from River Ebenyi considering the fact that it is the only source of water used for drinking, food processing and other domestic activities in most villages at Eha-Amufu. Hence, we conducted an assessment of the portability of the surface water sourced from River Ebenyi Eha-Amufu and environs for human consumption and domestic use from a physicochemical study.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

The town Eha-Amufu is located at 64km North-East of Enugu, the capital city of Enugu State, Nigeria. It is off Enugu-Abakiliki express way, off Nkalagu, the location of one-time famous cement factory that has ceased production. The area is located within Isu-Uzo local government area of Enugu State in South Eastern Nigeria. Enugu State, Nigeria. The climatic condition is the same as similar locations in in Nigeria with similar topography and soil structure. It is traversed by the Ebenyi River (ER) and its tributaries. Eha Amufu has a geographic location of latitude 6.65° North, longitude 7.77° East and 140 meters above elevation above sea level. The residents are dominantly of the Igbo speaking tribe and mainly rural farmers, fishermen, artisans and traders. Two distinct seasons is experienced in the area: the dry and wet seasons. The dry season stretches from November to April or May while the rainy season begins around May and ends in October.

2.2 Sample Collection

In-situ and *ex-situ* sampling and analysis of the physical and chemical parameters were carried out. Three sampling locations along Ebenyi stream and its tributaries were spatially chosen in each village to accommodate possible variations in the type, quantity and concentration of the waste. The water samples were collected from the month of May to July, at the pick of the raining season and farming activities in Eha-Amufu and environs using sterilized 1 litre plastic containers, except for dissolved oxygen (DO) and biological oxygen demand (BOD) tests, where a dark glass 300 mL capacity container was used. The in-situ investigation involved the determination of the pH, Total dissolved solids (TDS), Electrical conductivity (EC), Temperature (T), and colour of the surface water. For ex-situ analysis, the water samples were collected in clean and standard one litre plastic containers and transported within 24 hours, to Projects Development Institute (PRODA), Emene Industrial layout, Enugu State of Nigeria, for analysis.

2.3 Experimentation

The pH, T, and EC (μs/cm) were determined with HANNA Combo pH, Mercury-in-glass thermometer and EC multi meter Hi 98129. Calcium (Ca), Magnesium (Mg), Potassium (K), Iron (Fe), Cobalt (Co), Manganese (Mn), Lead (Pb), Cupper (Cu), Cadmium (Cd), Chromium (Cr) and Zinc (Zn) ions were analysed ex-situ using Atomic Absorption Spectrophotometer (AAS) model 210 VGP Buck Scientific. Lead (Pb), Cu, Cd, Hg, Cr and Zn are included in chemical components referred to as heavy metals [7]. They are known for their toxic effect [6]. They can be introduced into the environment (water bodies and soil ecosystem) from sources like seepage of municipal waste, mining waste, inorganic fertilizers, human and animal faeces. Nitrate (NO_3^-), phosphate (PO_4^{-3}), chloride (Cl^-) and sulphate (SO_4^{-2}) were also analysed to evaluate the quality of the surface water for drinking. Sulphate, phosphate and nitrate were analysed according to the procedure outlined by APHA (2012) using spectrophotometric; while EDTA titrimetric method was used to evaluate the total hardness (Calcium and Magnesium). The BOD and TDS values were determined using Winkler Azide method. Similar known protocols were used to investigate the DO, Chemical oxygen demand (COD), Total suspended solids (TSS), and Total solids (TS) [8,9,10,11].

2.4 Statistical Evaluation

The results of the *in-situ* and *ex-situ* physicochemical analysis showed variations of the parameters across the different villages. The parameters were subjected to normality test using Kolmogorov-Smirnov and Shapiro-Wilk tests. Kruskal-Wallis H test was used to compare variables between sampled stations [11]. Principal Component Analysis (PCA) and biplot for the association between physicochemical parameters was carried out [12]. Values were presented as mean ± standard error; however, the level of significance was set at $p = .05$. The statistically evaluation was performed with the aid of XLSTAT 2017, Microsoft Excel, and Statistical Packages for Social Sciences (SPSS) version 20.0.

3. RESULTS

The results express in standard units including milligram per litre (mg/l) is presented in Tables 1 and 2. There were significant ($p = .01$) variations in all the physicochemical parameters between the stations (Table 1). Generally, the pH, EC, TDS, TSS and TS values were in the range of 5.32 – 6.15, 39.50 – 63.33μs/cm, 10.20 – 21.78mgL^{-1} and 20.20 – 41.00mgL^{-1} respectively (Table 1). Acidity, Co, BOD, DO and COD respectively range between 7.38 – 20.48mgL^{-1}, 0.00 – 0.04mgL^{-1}, 0.49 – 0.76mgL^{-1}, 7.03 – 7.84mgL^{-1}, and 1.56 – 6.33mgL^{-1} (Table 1). There were significant ($p = .01$) variations in all the physicochemical parameters between the stations (Table 1). EC, TDS, TSS, TS and TH were within WHO and NSDWQ acceptable ranges of safety values.

Table 1. Physicochemical characteristics of River Ebenyi and at the sampling stations

Parameters	Sampling stations						WHO limits	NSDWQ limits
	Ihenyi	Amaede	Mgbuji	Umuhu	Agamede	Odobudo		
Colour	Variable	variable	Variable	variable	Variable	Variable	Clear	Clear
pH	5.94 ± 0.00^{b}	5.32 ± 0.00^{b}	6.07 ± 0.00^{a}	6.04 ± 0.00^{ab}	6.15 ± 0.00^{a}	5.98 ± 0.00^{ab}	6.5 - 8.5	6.5 - 8.5
Electrical conductivity (μs/cm)	41.80 ± 0.00^{bc}	43.74 ± 0.04^{bc}	63.30 ± 0.03^{a}	51.36 ± 0.02^{ab}	37.14 ± 0.02^{c}	39.50 ± 0.00^{bc}	1000.00	1000.00
TDS (mgL^{-1})	20.60 ± 0.40^{ab}	20.60 ± 0.40^{ab}	30.80 ± 0.37^{a}	10.80 ± 0.37^{b}	20.60 ± 0.40^{ab}	10.80 ± 0.37^{b}	500.00	500.00
TSS (mgL^{-1})	10.80 ± 0.37^{ab}	21.20 ± 0.58^{a}	11.20 ± 0.58^{ab}	10.60 ± 0.40^{b}	10.60 ± 0.40^{b}	10.80 ± 0.40^{b}	≤30	-
TS (mgL^{-1})	30.80 ± 0.37^{ab}	40.60 ± 0.40^{a}	40.60 ± 0.25^{a}	20.60 ± 0.40^{b}	30.60 ± 0.40^{ab}	20.60 ± 0.40^{ab}		
Acidity (mgL^{-1})	7.42 ± 0.04^{c}	22.46 ± 0.02^{a}	12.50 ± 0.03^{ab}	7.50 ± 0.00^{bc}	7.58 ± 0.03^{bc}	8.75 ± 0.00^{abc}		
TH (mgL^{-1})	9.60 ± 0.51^{bc}	9.68 ± 0.04^{bc}	11.60 ± 0.40^{abc}	14.68 ± 0.04^{ab}	8.60 ± 0.40^{c}	18.20 ± 0.20^{a}	500.00	150.00
Co (mgL^{-1})	0.04 ± 0.00^{a}	0.02 ± 0.00^{ab}	0.04 ± 0.00^{a}	0.02 ± 0.00^{ab}	0.00 ± 0.00^{b}	0.01 ± 0.00^{b}		
BOD (mgL^{-1})	0.66 ± 0.00^{abc}	0.52 ± 0.00^{bc}	0.60 ± 0.00^{abc}	0.76 ± 0.00^{a}	0.70 ± 0.00^{ab}	0.49 ± 0.00^{c}		
DO (mgL^{-1})	7.84 ± 0.00^{a}	7.69 ± 0.00^{bc}	7.82 ± 0.00^{ab}	7.03 ± 0.00^{bc}	7.81 ± 0.00^{ab}	7.72 ± 0.00^{ab}		
COD (mgL^{-1})	6.30 ± 0.03^{a}	2.40 ± 0.00^{ab}	6.02 ± 0.00^{a}	3.80 ± 0.00^{ab}	4.03 ± 0.00^{ab}	1.56 ± 0.00^{b}		

Alphabet superscript manually attached based on Kruskal-Wallis H test pairwise comparisons; values with different alphabet superscript across a row are significantly (p = .05) different. Values are presented as Mean ± S.E.M

Table 2. Cationic composition of River Ebenyiat the sampling stations

Metals	Stations						WHO limits	NSDWQ limits
	Ihenyi	Amaede	Mgbuji	Umuhu	Agamede	Odobudo		
Cd (mgL^{-1})	0.02 ± 0.00^{b}	0.03 ± 0.00^{ab}	0.01 ± 0.00^{b}	0.03 ± 0.00^{ab}	0.03 ± 0.00^{ab}	0.05 ± 0.00^{a}	0.03	0.003
Cr (mgL^{-1})	0.01 ± 0.00^{b}	0.04 ± 0.00^{ab}	0.02 ± 0.00^{ab}	0.01 ± 0.00^{b}	0.26 ± 0.00^{a}	0.01 ± 0.00^{b}	0.05	0.05
Mn (mgL^{-1})	0.01 ± 0.00^{b}	0.01 ± 0.00^{b}	0.01 ± 0.00^{b}	0.01 ± 0.00^{b}	0.04 ± 0.00^{a}	0.01 ± 0.00^{b}	0.20	0.20
Mg (mgL^{-1})	0.12 ± 0.00^{abc}	0.16 ± 0.00^{abc}	0.78 ± 0.00^{a}	0.38 ± 0.00^{ab}	0.07 ± 0.00^{c}	0.07 ± 0.01^{c}	20.00	20.00
Zn (mgL^{-1})	0.03 ± 0.00^{ab}	0.02 ± 0.00^{ab}	0.02 ± 0.00^{ab}	0.01 ± 0.00^{b}	0.04 ± 0.00^{a}	0.02 ± 0.00^{ab}	3.00	-
Ca (mgL^{-1})	0.06 ± 0.00^{abc}	0.11 ± 0.00^{ab}	0.04 ± 0.00^{bc}	0.18 ± 0.00^{a}	0.03 ± 0.00^{c}	0.05 ± 0.00^{abc}		-
Fe (mgL^{-1})	0.04 ± 0.00^{c}	0.12 ± 0.00^{abc}	0.08 ± 0.00^{bc}	0.10 ± 0.00^{abc}	0.17 ± 0.00^{a}	0.16 ± 0.00^{ab}	0.30	0.30
K (mgL^{-1})	0.05 ± 0.00^{ab}	0.03 ± 0.00^{bc}	0.01 ± 0.00^{c}	0.14 ± 0.00^{a}	0.02 ± 0.00^{bc}	0.02 ± 0.00^{bc}	200.00	
Pb (mgL^{-1})	0.77 ± 0.00^{a}	0.37 ± 0.00^{c}	0.45 ± 0.00^{abc}	0.49 ± 0.00^{abc}	0.41 ± 0.00^{bc}	0.50 ± 0.00^{ab}	0.01	0.01
Cu (mgL^{-1})	0.05 ± 0.00^{abc}	0.09 ± 0.00^{a}	0.08 ± 0.00^{ab}	0.04 ± 0.00^{abc}	0.03 ± 0.00^{bc}	0.02 ± 0.00^{c}	2.00	1.00
Co (mgL^{-1})	0.04 ± 0.00^{a}	0.02 ± 0.00^{ab}	6.02 ± 0.00^{a}	0.02 ± 0.00^{ab}	0.00 ± 0.00^{b}	0.01 ± 0.00^{b}	-	-

Alphabet superscript manually attached based on Kruskal-Wallis H test pair wise comparisons; values with different alphabet superscript across a row are significantly different (p < 0.05). Values are presented as Mean ± S.E.M

There were variations in the concentration of metallic ions between the sections of the river. The values of Mn, Mg, Zn, Fe, K and Cu were all below WHO and NSDWQ maximum requirement limits (Table 2). Chromium concentration in the water (ranges from 0.01 and 0.04) at all stations were below the maximum permissible limit recommended for drinking except at Agamede were the concentration (0.26 ± 0.00) had exceeded the maximum permissible limits recommended as safe by both WHO and NSDWQ for drinking. However, the concentration of Cadmium in water at Ihenyi and Mgbuji (0.02 ± 0.00; 0.01 ± 0.00) were below WHO maximum values, at Amaede, Umuhu and Agaemede Cd concentrations have attained the WHO maximum values (0.03) while Cd concentration in water at Odobudo (0.05) had exceeded the maximum permissible limits recommended as safe by both WHO and NSDWQ for drinking. The concentrations of Cd at all stations (ranges from 0.02 and 0.05) exceeded the maximum permissible limits recommended as safe by NSDWQ for drinking. The concentration of Lead in water at all stations (ranges from 0.37 to 0.77) exceeded the maximum permissible limits recommended as safe by both WHO and NSDWQ for drinking. These parameters correlate positively and are indicative of related source of contamination (Table 2).

The concentrations of phosphate (0.00 – 0.28 mg/l), nitrate (4.28 – 11.18 mg/l), sulphate (13.68 – 25.23 mg/l) and chloride (9.11 - 15.50 mg/l) in each village are shown in Fig. 1a, b, c and d. Significant variations of phosphate was notice along the streams at Umuhu (0.03 ± 0.00 mg/l) and Agamede (0.03 ± 0.03 mg/l) which had the least mean phosphate concentration while Odobudo had the highest concentration of phosphate (0.28 ± 0.00 mg/l).

The principal component analysis (PCA) and biplot of the data were used to study spatial variations of the parameters in the area. The results are shown in Figs. 2 and 3. From the PCA, the correlations between the variables were resolved into 5 principal components (Table 3). Correlation between conductivity (r = 0.740), TDS (r = 0.907), sulphate (r = 0.912), Mg (r = 0.782), Cu (r = 0.822), Co(r = 0.779), COD (r = 0.678) and component 1 was strong and positive. While the correlation between component 1 and Cd (r = -0.890), Fe (r = -0.623), and chloride (r = -0.501) were strong and negative. Component 2 had a strong positive correlation with pH (r = 0.831), chloride (r = 0.660), BOD (r = 0.864) and COD (r = 0.680); and a strong negative correlation with TSS (r = -0.786), phosphate (r = -0.629), and nitrate (r = -0.766). Component 3 correlated strongly and positively with Cr (r = 0.843), Mn (r = 0.787), Zn (r = 0.657), DO (r = 0.687) and Fe (r = 0.537), but negatively with Ca (r = -0.720), K (r = -0.728) and total hardness (r = -0.519). A biplot of the correlation matrix using the two principal components (PCA1 and PCA2) accounted for 54.98% (PCA 1 = 30.94%; PCA2 = 24.04%) of the variations in the concentration of the physicochemical and metal of the river (Fig. 2). Acidity, Cd, TDS, sulphate, COD and TSS were the closest to the unit cycle. The physicochemical characteristics and metal concentrations of the river were resolved into five clusters (Fig. 3).

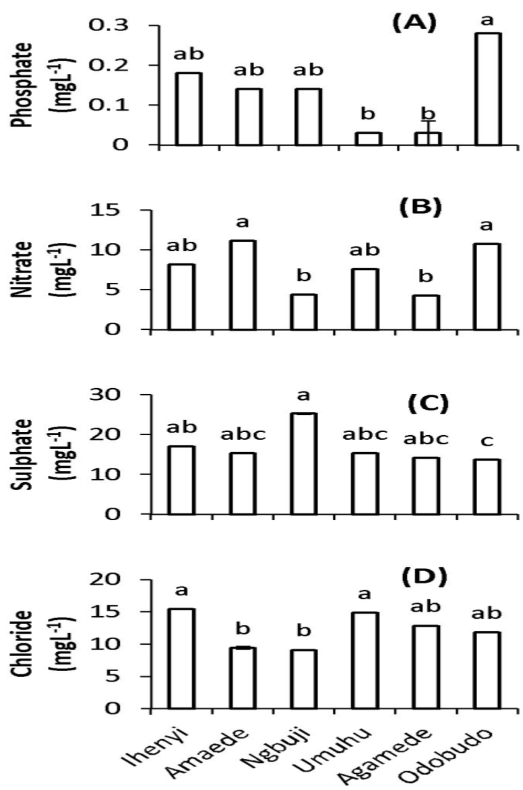

Fig. 1. Nutrient composition of Ebenyi stream at the stations. Alphabet superscript manually attached based on Kruskal-Wallis H test pairwise comparisons; bar with different superscript were significantly different (p = .05). Values are presented as Mean ± S.E.M., however. (A) Phosphate, (B) Nitrate, (C) Sulphate, and (D) Chloride

Table 3. Correlation between factors and variables from PCA

	F1	F2	F3	F4	F5
pH	-0.147	0.831	0.050	0.352	-0.398
Conductivity	0.740	0.117	-0.420	-0.067	-0.501
TDS	0.907	0.088	0.401	0.037	-0.011
TSS	0.204	-0.786	0.109	-0.465	0.265
TS	0.840	-0.288	0.388	-0.194	0.134
Chloride	-0.501	0.660	-0.328	0.005	0.449
Sulphate	0.912	0.168	-0.110	0.191	-0.299
Phosphate	-0.063	-0.629	-0.110	0.762	-0.036
Nitrate	-0.380	-0.766	-0.362	0.091	0.352
Acidity	0.404	-0.821	0.107	-0.377	0.082
Hardness	-0.478	-0.211	-0.519	0.413	-0.494
Cd	-0.890	-0.405	0.018	0.172	-0.105
Cr	-0.246	0.342	0.843	-0.288	-0.062
Mn	-0.270	0.398	0.787	-0.233	-0.077
Mg	0.782	0.158	-0.258	0.005	-0.536
Zn	-0.140	0.423	0.654	-0.053	0.265
Ca	-0.218	-0.077	-0.720	-0.646	0.000
Fe	-0.623	-0.288	0.537	-0.115	-0.459
Cu	0.822	-0.400	-0.064	-0.325	0.110
Co	0.779	0.111	-0.493	0.241	0.273
K	-0.321	0.345	-0.728	-0.494	0.034
Pb	0.011	0.420	-0.358	0.507	0.659
BOD	-0.058	0.864	-0.139	-0.470	0.057
DO	0.365	-0.153	0.687	0.546	0.260
COD	0.678	0.680	-0.058	0.105	0.245

F1 – F5 = factors 1 – 5

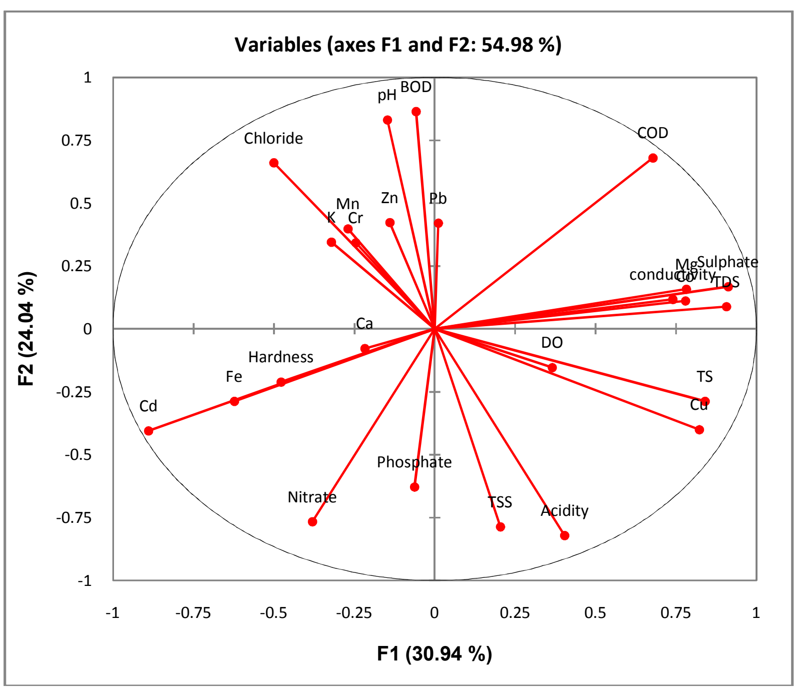

Fig. 2. Biplot of correlation of physicochemical and metal concentration of Ebenyi River

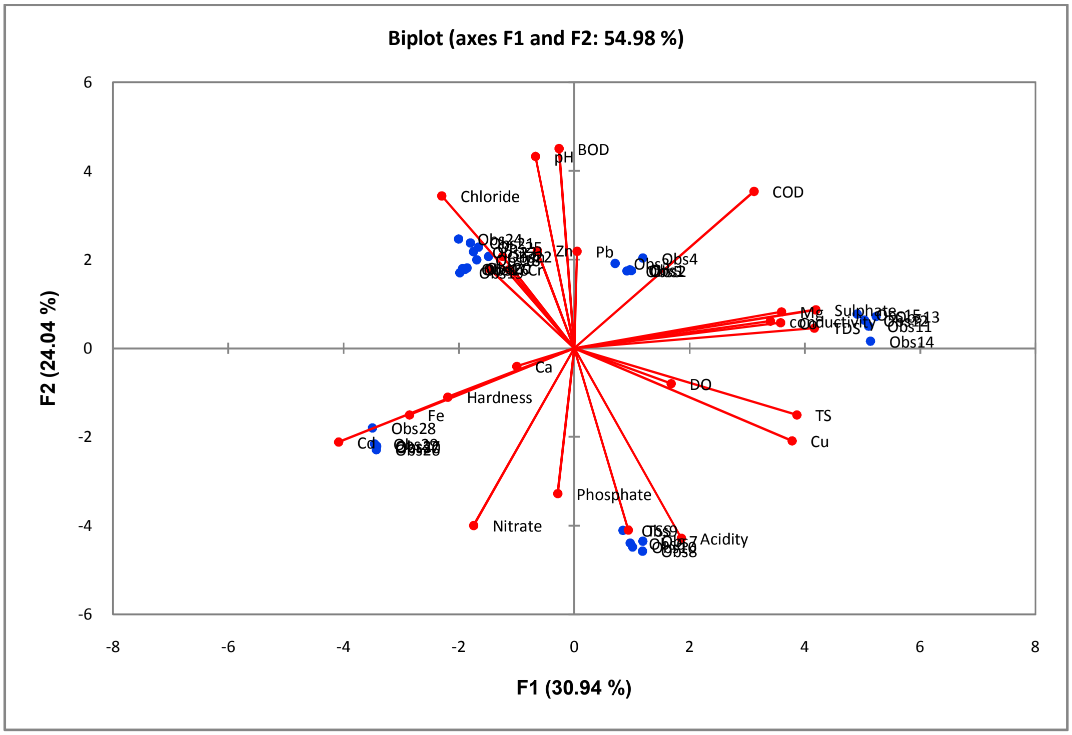

Fig. 3. Five clusters of physicochemical and metal based on PCA analysis

4. DISCUSSION

Variations in the physicochemical parameters of the surface water sourced from Ebenyi River and its tributaries in Eha-amufu and environs were indicatives of the influence of anthropogenic activities [11]. Water temperature, pH, TDS, TSS, turbidity, DO, compounds of phosphorus and nitrogen, COD and BOD are included in the main pollution parameters that have to be considered for surface water quality management [13]. The pH value of 5.98 - 6.15 obtained for the surface water in the study area was slightly below the lower limit of values acceptable to both WHO and NSDWQ as safe for drinking. It may however not be harmful for drinking purpose. Water with pH values of 6.5 to 8.5 is considered as within the safe limit set for drinking and domestic use by WHO and NSDWQ. If the pH is less than 6.5, it ceases the production of vitamins and minerals in the body [13], while water with pH value above 8.5 tend to have salty or soda-like taste and may not be corrosive. The fluctuations in optimum pH ranges may lead to an increase or decrease in the toxicity of poisons in water bodies [14]. This we view may have results from human and animal faecal waste, chemicals and domestic waste usually discharge into the ER. It is a common practice for people living along river banks or channels to discharge their domestics and agricultural waste as well as humans' excreta into these rivers and streams which also provide water for drinking, bathing, washing of clothes, aesthetic purposes and religious rituals [15,16,17].

The Cd concentration at all stations exceeded the maximum permissible limit acceptable by NSDWQ (only) for drinking water. This thus indicates contamination. The situation at Mgbuji is alarming while that of Odobudo is calling for immediate attention. Therefore, there is need for the government, stakeholders and the community to mobilise and proffer solution directed at containing any treat that could result. We suggest this because it has been pointed out that the prolonged consumption of water containing heavy metals such as Cd is associated with adverse health effect such as neurodevelopment toxicity in foetus [5,6]. It has been documented that exposure of human body to high level of lead possess health treat and is highly toxic to hematopoietic, renal, reproductive, and central nervous system [18].

The concentration of Pb (0.37 - 0.77 mg/l) in the streams of the sampled villages was far above the safe limit (0.00 – 0.01 mg/l) of the WHO values and the Nigerian Standards for Drinking Water Quality (NSDWQ) established guidelines. This is a potent danger to both human and aquatic lives. Lead poison and resultant health effect has been reported in other parts of the country due to anthropogenic activities including mining and municipal waste as well as run-off and leaching. Lead is a toxicant that accrues in the skeleton [19]. At concentration higher than the maximum permissible limits in water, fish, meat or other food substances [6], can result to serious health conditions including death [20]. The nerve system is chiefly susceptible to lead poisoning especially in young children and pregnant women. Infants, and children under the age of 5 (five) have died from the consumption of lead infected water and food items [21].

Human exposure (contact, inhalation, or ingestion) to Chromium leads to vulnerability which often results to dermatitis, allergic and eczematous skin reactions, skin and mucous membrane ulcerations, perforation of the nasal septum, allergic asthmatic reactions, bronchial carcinomas, gastro-enteritis, hepatocellular deficiency, and renal oligo anuric deficiency [22].

Land use activities such as farming with its attendant use of inorganic fertilizers are a major source of phosphate involvement in diminishing the quality of water [13]. Phosphate was statistical significantly higher (χ^2 = 25.697, p = .001) relative to the spatial concentrations of nitrate, sulphate, phosphate and chloride in the area. The maximum permissible limit of phosphate is 0.1mg/l; therefore a higher concentration of phosphate would be perilous to the health of the consumers of the water, as it has been related to muscle problems, kidney failure and breathing challenges [23]. There was no consistency in the ranking of nitrate, sulphate and chloride between the stations.

5. CONCLUSION

Variations in the physicochemical parameters of the surface water sourced from River Ebenyi and its tributaries in Eha-Amufu and environs are indicative of the influence of the anthropogenic activities. The baseline results obtained from this study with regards to Cd, Cr and Pb demands that effective health education programme should be organised to emphasize on the effect of anthropogenic activities that releases pollutants. However, long term sampling covering all the months of the year is needed in order to confirm the reproducibility of our results.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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