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Impacts of Anthropogenic Activities on Heavy Metal Levels in Surface Water of Nun River around Gbarantoru and Tombia Towns, Bayelsa State, Nigeria

Ogaga Augustine Aghoghovwia[1], Faith Ayakpo Miri[1] and Sylvester Chibueze Izah[2*]

[1]*Department of Fisheries and Aquatic Studies, Faculty of Agriculture, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria*
[2]*Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria*

***Corresponding Author:** Sylvester, Department of Biological Sciences, Faculty of Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.*

ABSTRACT

This study assessed the impacts of anthropogenic activities on level of heavy metals in surface water of lower Nun River at Gbarantoru and Tombia town in Yenagoa local Government Area of Bayelsa state, Nigeria. Triplicate samples of surface water were collected from three locations (viz: Location A around oil and gas installations, B- Gbarantoru and C- Tombia town). The samples were processed and analyzed using atomic adsorption spectrophotometer. Results of the surface water were 0.002 – 0.011mg/l cadmium, 0.000 – 0.002mg/l chromium, 0.001 – 0.002mg/l cobalt, 0.001 – 0.002mg/l nickel, 0.011 – 0.013mg/l lead, 0.112 – 0.205mg/l zinc and 0.122 – 0.159 mg/l iron. There was significant variation ($P<0.05$) among the various locations for each of the heavy metals. Correlation showed positive significant relationship ($P<0.05$) for majority of the heavy metals. This suggests that heavy metals in the water and sediment are from similar source. The heavy metals concentration was within the standard for drinking water except for cadmium and lead as specified by World Health Organization, European Union and Standard Organization of Nigeria. Higher concentration of cadmium and lead in the water suggested that they could bioaccumulate in aquatic organisms such as fisheries. As such, caution should be exercised in the drinking of surface around the study area because of possible cadmium and lead toxicity over a prolong period of time.

Keywords: *Contaminants, Health risk, Runoff, surface water, Toxicity;*

INTRODUCTION

The rate of environmental pollution associated with anthropogenic activities has increased in the recent time. This could be probably due to population growth, industrialization and urbanization. Several developmental projects are continually carried out in several regions of the world. But in developing countries the level of environmental degradation due to human activities appears to be more. These involve the destruction of natural ecosystem (in search of wildlife, fuel wood, timber, and food during agricultural practices etc), oil and gas exploration, water transportation, dredging and canalization, use of "chemicals", inorganic fertilizers and synthetic pesticides, food processing, inadequate waste management system, and emissions from electroplating, textile, storage batteries, lead smelting, mining, ceramic and glass industries. These activities could lead to introduction of toxicants such as heavy metals to the various environmental components (viz: sediment, surface water, soil and even air).

Typically, heavy metals are metalloids with relatively high atomic weight (Butu and Iguisi 2013) and specific gravity of ≥ 5 cm^3 (Idris et al., 2013; Izah et al., 2016, 2017). Most heavy metals such as chromium, nickel, iron, zinc, copper, manganese are essential elements because they have biological functions; while others such as cadmium, mercury, lead, arsenic are non-essential because they do not have any biological function. Essential heavy metals become toxic when their concentration exceeds tolerable limits, while non-essential metals are highly toxic even at low concentration.

Heavy metals enters the surface water through both natural (volcanic activity, weathering, geology of the area) and human activities (through careless discharge of untreated wastes into the surface water and runoff resulting from rainfall) (Seiyaboh and Izah, 2017a; Seiyaboh et al., 2017a,b; Aghoghovwia et al., 2015). Direct human activities such as dredging (Ohimain et al., 2008), oil exploration in offshores (Seiyaboh and Izah, 2017a), poor waste management's (Angaye et al., 2015a; Izah and Angaye, 2016), mining (Muhammad et al., 2014) are some of the methods through which heavy metals enter the environment.

Surface water is a major source of potable water, and other domestic purpose (Izah and Angaye, 2016; Izah et al., 2016; Izah and Srivastav, 2015; Izah and Ineyougha, 2015; Agedah et al., 2015; Ogamba et al., 2015a-c), and also habitat to several aquatic organisms such as fisheries and macrophytes (Izah and Srivastav, 2015). Contamination of surface water resources has relationship with sediment pollution level (Seiyaboh et al., 2016a; Kigigha et al., 2018). This is because most surface water pollutant often sinks in the sediment. As such, heavy metal contamination of surface water and its sediment could have overall effects on aquatic organisms such as fisheries.

Typically, fisheries have the tendency to bioaccumulate heavy metals in different parts of their body (Aghoghovwia et al., 2016; Ogamba et al., 2015d, 2016a,b, 2017a).Fisheries is a major source of animals protein (Izah and Angaye, 2015; Ineyougha et al., 2015; Ogamba et al., 2016a,b, 2017a). Hence there is the need to frequently assess the level of contaminants such as heavy metals in water. High concentration of heavy metals above permissible level in drinking water and fish food could cause pathological health effects among individuals that may consume the water and fishes from such contaminated water over a long period of time.

Hence there is the need to investigate the heavy metals in surface water frequently to ascertain the level of pollution. To this effects several studies have been conducted with regard to water quality of Nun River at different locations including Amassoma axises (Ogamba *et al*., 2015a; Agedah *et al*., 2015; Nyananyo *et al*., 2007; Seiyaboh *et al*., 2017c), Ikoli creek (Seiyaboh *et al*., 2016b; Seiyaboh and Izah, 2017a; Ogamba *et al*., 2015b), Nun River and Taylor creek (Daka et al., 2014). Furthermore, in Yenagoa metropolis, studies have been carried out with regard to effect of anthropogenic activities and runoff on water quality (Izonfuo and Bariweni, 2001; Ben-Eledo *et al*., 2017a,b) of Epie creek. The impacts of human activities have also been widely reported in Kolo creek (Seiyaboh and Jackson, 2017; Ogamba et al., 2015c, 2017b; Inengite et al., 2010). Therefore this study focused on heavy metal quality of surface water and sediment of lower Nun River at Gbarantoru and Tombia towns in Yenagoa local Government Area of Bayelsa state, Nigeria. The results were compared with World Health Organization (WHO), European Union (EU) and Standard Organization of Nigeria (SON) standards.

Materials and Methods

Study Area

Tombia and Gbaratoru towns are in Yenagoa local Government area of Bayelsa state. River Nun passes through Tombia, Agudama Ekpetiama towns. The State lies in the sedimentary basin (Kigigha et al., 2018). Several anthropogenic activities including installation of oil and gas facilities, dredging (using motorized and artisan methods) are within the area.Like other coastal communities, the surface water is a major recipient of domestic wastes generated by most of the inhabitants of communities aligning the lower Nun river. The lower Nun river is also a major recipients of storm water through runoff.During the end of Wet season (viz: September/October), the water level rises and almost entering the buildings of the residents aligning the water bank (Kigigha et al., 2018). Farming including fishing is the major source of livelihood of indigenes of the area. The climatic condition is similar to other regions of Bayelsa state previously reported by Ogamba *et al*. (2015a,b,c; 2016a,b), Seiyaboh *et al*. (2016a,b), Agedah et al. (2015).

Sampling Techniques

Triplicate samples of water samples were collected from three different locations (A – around oil and gas installations, B-Gbarantoru and C- Tombia town for three consecutive months (December 2017 to February 2018). The water samples were collected with 1 litre containers which were thoroughly washed with detergent and soaked overnight with dilute acid to prevent adsorption. The samples were well labeled and transported to the laboratory in an ice pack less than an hour after sample collection where they we preserved prior to analysis. The process of sample collection to data generation is presented in Figure 1.

Sample Preparations

The wet digestion method was employed for the water samples. 100ml aliquots of the water samples were placed in 250ml conical flask. Then 25ml aliquots of 2M nitric acid were also added to the water sample and it was well mixed. The mixture was allowed to evaporate to dryness over a six-hole water bath, which was then cooled at room temperature. 25ml aliquots of concentrated nitric acid were added to the residues in the flasks and it was heated to dryness in a hot –plate to near boiling, and this continued until the solution is dry. This was repeated until the residue turned white. Distilled water was then added and the residue was washed and filtered into 100ml volumetric flask, which was made up to the mark with distilled water.

Sample Analysis using Atomic Adsorption Spectrophotometer

Atomic absorption spectrophotometer (AAS) was used to analyze the heavy metals in digested water samples. The AAS was set at their different wavelengths gas flow rates. The digested samples were aspirated into the AAS and the metals concentrations were displayed and recorded.

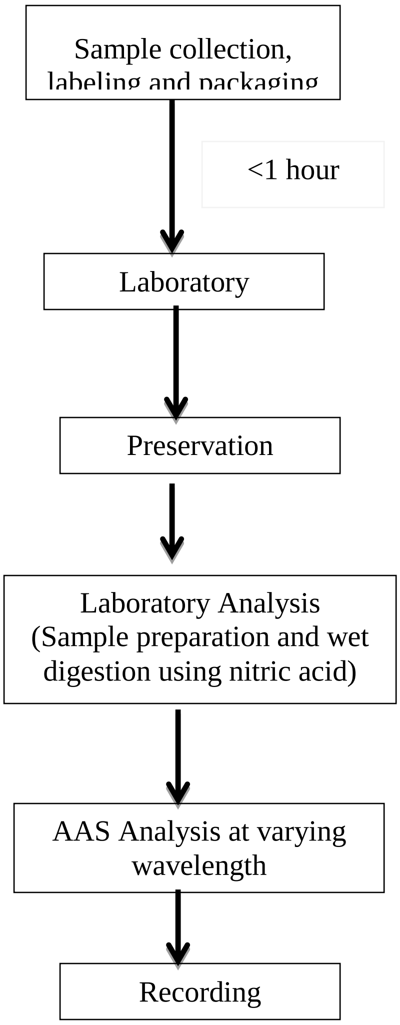

Figure1. *Sampling process to data generation*

Statistical Analysis

Statistical package for social sciences version 20 was used for the statistical analysis. Data was expressed as mean ± standard error. One way analysis of variance (ANOVA) was carried out and significant variation was established at P=0.05. Tukey Honestly Significance Difference test statistics was used to show differences among the various mean values. Spearman rho Correlation matrix was used to show relationship among the various heavy metals of the water samples.

Results and Discussion

The level of heavy metals in surface water along selected areas in lower Nun River in Bayelsa state, Nigeria is presented in Table1.The Spearman's rho of the water quality studied parameters is presented in Table 2, while the overall mean with the permissible limit for drinking water is presented in Table 3.

The concentration of cadmium in the water sample ranged from 0.002 – 0.011mg/l, being significantly different among all the locations (Table 1). Cadmium showed positive significant relationship with chromium (r=0.822), zinc (r=0.850) and iron (r=0.967) at P<0.01, and cobalt (r=765) at P<0.05) (Table 2). The cadmium concentration were slightly above the permissible limit of 0.003mg/l by SON, WHO and 0.005mg/l by EU for drinking water (Table 3)

The level of chromium in the water sample ranged from 0.000 – 0.002mg/l, being not significantly different (P>0.05) apart from location A (Table 1). Chromium showed positive significant relationship with nickel (r=0.822), cobalt (r=0.829) and iron (r=0.842) at P<0.01, and zinc (r=0.782) at P<0.05 (Table 2). The level of chromium was lower than the permissible limit of 0.05 mg/l by SON, WHO and EU for drinking water (Table 3).

Cobalt concentration in the water sample ranged from 0.001 – 0.002mg/l, being not significantly different (P>0.05) except for location A (Table 1). Cobalt showed positive significant correlation with iron (r=0.798) and zinc (r=0.824) at P<0.01 (Table 2). No specific limit for cobalt in drinking water. However, based on the concentration reported in this study, it is within tolerable concentration for human health owing to the fact that cobalt is an essential element.

Nickel level in the water sample ranged from 0.001 – 0.002mg/l, and was not significantly different (P>0.05) across the stations except for location A (Table 1). However, the values were lower than the permissible limit specified by SON, WHO and EU (Table 3).

The concentration of lead sample ranged from 0.011 – 0.013mg/l, with no significant difference (P>0.05) across the stations except for location B (Table 1). The values were slightly above the permissible limit specified by SON, WHO and EU for drinking water (Table 3).

Zinc in the water sample ranged from 0.112 – 0.205mg/l. There was significant difference (P<0.05) among all the locations (Table 1). Zinc showed positive significant correlation with iron (r=0.883; p<0.01) (Table 2). The overall value of zinc was within the permissible limit specified by SON, WHO and EU for drinking water (Table 3).

The iron concentration in the water sample ranged from 0.122 – 0.159 mg/l. There was significant variation (P<0.05) among all the locations (Table 1). The iron value was within the permissible limit specified by SON, WHO and EU for drinking water (Table 3).

Table1. *Levels of heavy metal in surface water along selected locations of lower Nun River in Bayelsa state*

Parameters	Around oil and gas installations (Location A)	Gbarantoru (Location B)	Tombia (Location C)
Cd, mg/l	0.011±0.000c	0.008±0.000b	0.002±0.000a
Cr, mg/l	0.002±0.000b	0.000±0.000a	0.000±0.000a
Co, mg/l	0.002±0.000b	0.001±0.000a	0.001±0.000a
Ni, mg/l	0.022±0.001b	0.004±0.001a	0.007±0.001a
Pb, mg/l	0.011±0.000a	0.013±0.000b	0.011±0.000a
Zn, mg/l	0.205±0.001c	0.119±0.001b	0.112±0.001a
Fe, mg/l	0.159±0.002c	0.140±0.001b	0.122±0.001a

Data is expressed as mean ± standard error; Different letters across the row indicate significant difference (P<0.05) according to Tukey Honestly Significance difference statistics

Table2. *Spearman's rho correlation matrix of the heavy metals studied in the water samples*

Parameters	Cd	Cr	Co	Ni	Pb	Zn	Fe
Cd	1.000						
Cr	0.822**	1.000					
Co	0.765*	0.829**	1.000				
Ni	0.467	0.822**	0.563	1.000			
Pb	0.517	-0.020	0.193	-0.433	1.000		
Zn	0.850**	0.782*	0.824**	0.383	0.433	1.000	
Fe	0.967**	0.842**	0.798**	0.467	0.500	0.883**	1.000

***. Correlation is significant at the 0.01 level (2-tailed).*

**. Correlation is significant at the 0.05 level (2-tailed). N=9; n=3*

The result of the study showed that there was significant variation among most of the locations for each of the heavy metals. Furthermore, the results of water quality depict that location A had significantly higher values compared to location B and C in that order for majority of the parameters. The significant higher concentration in surface water in location A could be due to higher effect of oil and gas effluents that may have resulted from runoff into the river after precipitation. According to Kigigha et al. (2018), Seiyaboh et al. (2017a-c), Seiyaboh and Izah (2017a,b), Ben-Eledo et al. (2017a,b) direct deposition of wastes materials and runoff after rainfall is a major cause of surface water contamination. This suggests that the physical nature of the contaminants affected the concentration of the recipient environmental components.

Based on Table 2, there was high significant relationship among majority of the metals for both sediment and water quality. This suggests that the heavy metals in the surface water are from similar source. Owing to the fact that there are several human activities (motorized and artisanal dredging, fishing, canoeing, bathing, swimming) and discharge of untreated municipal wastes in the water bodies in the different locations appears similar and could be possible reason for high significant correlation.

Table3. *Overall mean of heavy metals in surface water in selected area along lower Nun River in Bayelsa state in comparison with standard limits*

Parameters	This study	SON	WHO	European Union (EU)
	Mean ± standard error (n=9)	**SON 2007**	**WHO 2011; Azizullah et al. 2011**	**Lenntech 2014**
Fe	0.140±0.005	0.30	0.30	0.20
Zn	0.145±0.015	3.00	3.00	0.02
Cd	0.007±0.001	0.003	0.003	0.005
Cr	0.001±0.000	0.05	0.05	0.05
Pb	0.012±0.000	0.01	0.01	0.01
Co	0.001±0.000	-	-	-
Ni	0.011±0.003	0.02	0.07	0.02

Based on Table 3, the water heavy metals are within the limits specified by World Health Organization (WHO), European Union (EU), Standard Organization of Nigeria (SON) apart from cadmium and lead which were slightly above the limits. Typically, there are several parameters for monitoring the potability of water (Izah and Ineyougha, 2015). Water may be free from contamination due to a specific parameters but may not be so to another parameters. Hence, based on heavy metal concentration of the surface water of the study area prolonged ingestion of the water may lead to some disease condition associated with cadmium and lead. Typically, these two metals are non-essential heavy metals as such they have no biological function in living organisms (Izah et al., 2016, 2017; Izah and Angaye, 2016). Several disease have been associated with the toxicity of this metals including Liver and kidney damage, bone demineralization (Muhammad et al., 2014; Fu and Wang, 2011; SON, 2007; Izah et al., 2016) (cadmium) and damage to liver, kidney, nervous, reproductive, renal and cardiovascular system, birth defects miscarriage in women and death (Idris et al., 2013; Muhammad et al., 2014; Fu and Wang, 2011; SON, 2007; Izah et al., 2016) (lead).

The concentration of the heavy metals in water samples had some similarity with the values previously reported in Warri river (Aghoghovwia *et al*., 2015), River Ijana Ekpan, Delta state (Emoyan et al., 2006), Nun River and Taylor creek (Daka et al., 2014). The slight variation that exist could be due to difference in anthropogenic activities peculiar to the areas.

Furthermore, fishes are major source of animal protein (Ineyougha et al., 2015; Angaye et al., 2015b; Izah and Angaye, 2015). In many coastal regions of Bayelsa state many people still harvest fishes in the wild. Fishes have the tendency to bioaccumulate toxicants such as heavy metals in the various parts of their body including gills, muscles, kidney, liver (Aghoghovwia et al., 2016; Ogamba et al., 2017a; Ogamba et al., 2015d, 2016a,b). Over prolong period of time of consuming fishes that have bioaccumulated heavy metals it could predisposed the exposed individuals to possibility of suffering from heavy metals related diseases especially cadmium and lead that was above the safe limit levels for drinking water in the study area.

Typically, bioaccumulation of heavy metals by fisheries is influenced by internal factors such as species genetic makeup, body size, sex, exposure duration, mechanisms of heavy metal uptake**,** feeding mode among others (Ezemonye *et al.*, 2009; Ada et al. 2012; Eneji et al. 2011; Aghoghovwia et al. 2016; Izah and Angaye, 2016; Perera *et al.* 2015), other external factors such as solubility of the metals, physicochemical characteristics of the water and its associated contaminants, sediment quality, seasonal influence.

Conclusion

In the last few decades the level of pollution associated to anthropogenic activities has increased. Several human activities are carried out in and within surface water bodies in most coastal areas of Bayelsa state. Nun River is a major river in Bayelsa state. It has several tributaries and is often referred to as lower Nun with many creeks and creeklets emanating from the river. This study investigated the level of heavy metals in surface water of lower Nun River at Gbarantoru and Tombia town in Yenagoa Local government area of Bayelsa state. The results revealed that the water quality parameters analysed was significantly different among the various locations. Furthermore, the water samples from location A, an area close to oil and gas installation had higher mean heavy metals values.

Most of the heavy metals for the water quality showed high positive correlation indicating that they are from similar source (anthropogenic effects). Cadmium and lead concentration slightly exceeded the level for drinking water quality. These suggests the tendency of these two metals (cadmium and lead) to bioaccumulate in body of aquatic organisms such as fisheries over a prolong period of time. Typically lead and cadmium are non-essential and as such they have no biological function. Their presence in water and fish found depicts possible health risk to individuals that consumes fisheries from the area and drink the water. Therefore, there is need for caution in consumption of fisheries and drinking of surface water from that section of lower Nun River due to possible heavy metals (cadmium and lead) toxicity.

References

[1] Ada, F.B., Ekpenyong, E. and Bayim, B.P-R., 2012. Heavy metal concentration in some fishes (*Chrysichthys nigrodigitatus, Clarias gariepinus and Oreochromis niloticus*) in the Great Kwa River, Cross River State, Nigeria. Global Advanced Research Journal of Environmental Science and Toxicology1 (7), 183-189.

[2] Agedah, E.C., Ineyougha, E.R., Izah, S.C. and Orutugu, L.A., 2015. Enumeration of total heterotrophic bacteria and some physico-chemical characteristics of surface water used for drinking sources in Wilberforce Island, Nigeria. Journal of Environmental Treatment Techniques, 3(1), 28 – 34.

[3] Aghoghovwia, O.A., Ohimain, E.I. and Izah, S.C., 2016. Bioaccumulation of Heavy metals in different tissues of some commercially important fish species from Warri River, Niger Delta, Nigeria. Biotechnological Research 2(1), 25-32.

[4] Aghoghovwia, O.A., Oyelese, O.A. and Ohimain, E.I.,2015. Heavy metal levels in water and sediment of Warri River, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Sciences, 3(1), 20 -24.

[5] Angaye, T.C.N., Zige, D.V. and Izah, S.C., 2015a.Microbial load and heavy metals properties of leachates from solid wastes dumpsites in the Niger Delta, Nigeria. Journal of Environmental Treatment Techniques, 3(3), 175 – 180.

[6] Angaye, T.C.N., Cosboy, M.E., Zige, D.V., Angaye, S.S. and Izah, S.C., 2015b. Assessment of Untreated groundwater against some common fresh water Fish in Bayelsa State, Nigeria. Point Journal of Agriculture and Biotechnology Research 1(2), 30 - 36.

[7] Azizullah, A., Khattak, M.N.K., Richter, P. and Häder, D-P., 2011. Water pollution in Pakistan and its impact on public health — A review. Environ Intern 37, 479–497

[8] Ben-Eledo, V.N., Kigigha, L.T., Izah, S.C. and Eledo, B.O., 2017a. Bacteriological Quality Assessment of Epie Creek, Niger Delta Region of Nigeria. International Journal of Ecotoxicology and Ecobiology, 2(3), 102-108

[9] Ben-Eledo, V.N., Kigigha, L.T., Izah, S.C. and Eledo, B.O.,2017b. Water quality assessment of Epie creek in Yenagoa metropolis, Bayelsa state, Nigeria. Archives of Current Research International, 8(2), 1 – 24.

[10] Butu, A. W., and Iguisi, E. O., 2013. Concentration of heavy metals in sediment of river Kubanni, Zaria, Nigeria. *Comprehensive J Environ Earth Sci., 2*(1), 10 – 17.

[11] Daka, E.R., Amakiri-Whyte, B. and Inyang, I.R., 2014. Surface and groundwater in some oil field communities in the Niger Delta: implications for domestic use and building construction. Research

Journal of Environmental and Earth Sciences, 6(2), 78 – 84.

[12] Emoyan, O.O., Ogban, F.E. and Akarah, E., 2016. Evaluation of Heavy Metals Loading of River Ijana in Ekpan – Warri, Nigeria. J. Appl. Sci. Environ. Mgt. 10 (2), 121 - 127

[13] Eneji, I.S., Sha.Ato, R. and Annune, P.A., 2011. Bioaccumulation of Heavy Metals in Fish (*Tilapia Zilli* and *Clarias Gariepinus)* Organs from River Benue, North Central Nigeria. Pakistan Journal of Analytical and Environmental Chemistry 12(1 & 2), 25-31

[14] Ezemonye, L., Ikpetsu, T. and Tongo, I., 2009. Distribution of Propoxur in water, sediment and fish from Warri River Niger Delta, Nigeria. Turkish Journal of Biochemistry–34(3), 121 – 127.

[15] Fu, F. and Wang, Q., 2011. Removal of heavy metal ions from wastewaters: A review. J Environ Manage 92, 407-418.

[16] Idris, M.A., Kolo, B.G., Garba, S.T. and Waziri, I., 2013. Pharmaceutical Industrial Effluent: Heavy Metal Contamination of Surface water in Minna, Niger State, Nigeria. Bull Env Pharmacol Life Sci 2 (3), 40-44.

[17] Inengite, A.K., Oforka, N.C. and Osuji, L.C., 2010. Survey of heavy metals in sediments of Kolo creek in the Niger Delta, Nigeria. African Journal of Environmental Science and Technology, 4(9), 558-566.

[18] Ineyougha, E.R., Orutugu, L.A. and Izah, S.C., 2015. Assessment of Microbial Quality of Smoked *Trachurus trachurus* sold in some Markets of Three South-South States of Nigeria. International Journal of Food Research, 2, 16 – 23.

[19] Izah, S.C., Inyang, I.R., Angaye, T.C.N. and Okowa, I.P., 2017. A review of heavy metal concentration and potential health implications in beverages consumed in Nigeria. Toxics, 5 (1), 1-15. doi: 10.3390/ toxics 5010001.

[20] Izah, S.C., Chakrabarty, N. and Srivastav, A.L., 2016. A Review on Heavy Metal Concentration in Potable Water Sources in Nigeria: Human Health Effects and Mitigating Measures. Exposure and Health 8, 285–304.

[21] Izah, S.C. and Angaye, T.C.N., 2016. Heavy metal concentration in fishes from surface water in Nigeria: Potential sources of pollutants and mitigation measures. Sky Journal of Biochemistry Research,5(4), 31-47.

[22] Izah, S.C. and Angaye, T.C.N.,2015. Ecological perception of fish farmers in Yenagoa Metropolis, Nigeria. Bulletin of Advanced Scientific Research 1(1), 26 – 28.

[23] Izah, S.C. and Ineyougha, E.R., 2015. A review of the microbial quality of potable water sources in Nigeria. Journal of Advances in Biological and Basic Research, 1(1), 12 – 19

[24] Izah, S.C. and Srivastav, A.L., 2015. Level of arsenic in potable water sources in Nigeria and their potential health impacts: A review. Journal of Environmental Treatment Techniques, 3(1), 15 – 24.

[25] Izonfuo, L.W.A. and Bariweni, A. P., 2001. The effect of urban runoff water and human activities on some physico-chemical parameters of the Epie Creek in the Niger Delta. Journal of Applied Sciences and Environmental Management, 5(1), 47-55.

[26] Kigigha, L.T., Seiyaboh, E.I., Obua, V.J. and Izah, S.C.,2018. Contamination of River Nun at Amassoma, Bayelsa State, Nigeria Due to Microbial Diversity in Sediments. Environmental Toxicology Studies Journal, 2 (1):2

[27] Lenntech (2014). EU's drinking water standards. Council Directive 98/83/EC on the quality of water intented for human consumption. Adopted by the Council, on 3 November 1998: http://www.lenntech.com/periodic/elements/. Accessed July 14th 2014.

[28] Muhammad, I., Ashiru, S., Ibrahim, I.D., Salawu, K., Muhammad, D.T. and Muhammad, N.A., 2014. Determination of some heavy metals in wastewater and sediment of artisanal gold local mining site of Abare Area in Nigeria. J Environ Treatment Techniq 1(3), 174-182.

[29] Nyananyo, B. L., Gijo, A. H., and Ogamba, E. N., 2007. The physico-chemistry and distribution of water hyacinth (*Eichhornia crassipes*) on the river Nun in the Niger Delta. J. Appl. Sci. Environ. Manage.,*11*, 133-137.

[30] Ogamba, E.N., Izah, S.C. and Oribu, T., 2015a. Water quality and proximate analysis of *Eichhornia crassipes* from River Nun, Amassoma Axis, Nigeria. Research Journal of Phytomedicine, 1(1): 43 – 48.

[31] Ogamba, E.N., Izah, S.C. and Toikumo, B.P., 2015b. Water quality and levels of lead and mercury in Eichhornia crassipes from a tidal creek receiving abattoir effluent, in the Niger Delta, Nigeria. Continental Journal of Environmental Science, 9(1), 13 – 25.

[32] Ogamba, E.N., Seiyaboh, E.I., Izah, S.C., Ogbugo, I. and Demedongha, F.K., 2015c.Water quality, phytochemistry and proximate constituents of *Eichhornia crassipes* from Kolo creek, Niger Delta, Nigeria. International Journal of Applied Research and Technology, 4(9): 77 – 84.

[33] Ogamba, E.N., Izah, S.C. and Ebiowe, R.G.,2015d. Bio concentration of Mercury, Lead and Cadmium in the bones and muscles of *Citharinus citharus* and *Synodontis clarias* from the Amassoma Axis of River Nun, Niger Delta,

Nigeria. Research Journal of Pharmacology and Toxicology 1(1), 21-23

[34] Ogamba, E.N., Izah, S.C. and Ofoni-Ofoni, A.S.,2016a. Bioaccumulation of Chromium, Lead and Cadmium in the bones and tissues of Oreochromis niloticus and Clarias camerunensis from Ikoli creek, Niger Delta, Nigeria. Advanced Science Journal of Zoology, 1(1), 13 – 16.

[35] Ogamba, E.N., Izah, S.C. and Isimayemiema, F., 2016b. Bioaccumulation of heavy metals in the gill and liver of a common Niger Delta wetland fish, *Clarias garepinus*. British Journal of Applied Research 1(1), 17 – 20.

[36] Ogamba, E.N., Ebere, N. and Izah, S.C., 2017a. Levels of lead and cadmium in the bone and muscle tissues of Oreochromis niloticus and Clarias camerunensis. EC Nutrition, 7(3), 117 – 123.

[37] Ogamba, E.N., Ebere, N. and Izah, S.C., 2017b. Heavy Metal Concentration in Water, Sediment and Tissues of Eichhornia crassipes from Kolo Creek, Niger Delta. Greener Journal of Environment Management and Public Safety, 6 (1), 001-005.

[38] Ohimain, E.I., Jonathan, G. and Abah, S.O., 2008. Variations in Heavy Metal Concentrations Following the Dredging of an Oil Well Access Canal in the Niger Delta. Advances in Biological Research,2 (5-6), 97-103.

[39] Perera, P.A.C.T., Suranga, P.A.C.T., Kodithuwakku, P.**,** Sundarabarathy, T.V. and Edirisinghe, U., 2015. Bioaccumulation of Cadmium in Freshwater Fish: An Environmental Perspective. Insight Ecology 4, 1-12**.**

[40] Seiyaboh, E.I., Inyang, I.R. and Izah, S.C., 2016a. Spatial Variation in Physico-chemical Characteristics of Sediment from Epie Creek, Bayelsa State, Nigeria. Greener Journal of Environment Management and Public Safety, 5(5): 100 – 105.

[41] Seiyaboh, E.I., Inyang, I.R. and Izah, S.C., 2016b. Seasonal Variation of Physico-Chemical Quality of Sediment from Ikoli Creek, Niger Delta. International Journal of Innovative Environmental Studies Research, 4(4), 29-34.

[42] Seiyaboh, E.I., Izah, S.C. and Oweibi, S., 2017a. Assessment of Water quality from Sagbama Creek, Niger Delta, Nigeria. Biotechnological Research, 3(1), 20-24.

[43] Seiyaboh, E.I., Izah, S.C. and Oweibi, S., 2017b. Physico-chemical Characteristics of Sediment from Sagbama Creek, Nigeria. Biotechnological Research, 3(1), 25-28

[44] Seiyaboh, E.I., Izah, S.C. and Bokolo, J.E., 2017c. Bacteriological quality of water from river nun at Amassoma Axises, Niger Delta, Nigeria. ASIO Journal of Microbiology, Food Science & Biotechnological Innovations, 3(1), 22 – 26.

[45] Seiyaboh, E.I. and Jackson, F.,2017. Level and impact of hydrocarbon in sediment characteristics of Imiringi oil and gas field facilities in the Niger Delta. Proceedings of the 15th International Conference on Environmental Science and Technology Rhodes, Greece, 31 August to 2 September 2017

[46] Seiyaboh, E.I. andIzah, S.C.,2017a. Review of Impact of Anthropogenic Activities in Surface Water Resources in the Niger Delta region of Nigeria: A case of Bayelsa state. International Journal of Ecotoxicology and Ecobiology. 2(2), 61 – 73.

[47] Seiyaboh, E.I. and Izah, S.C., 2017b. Bacteriological assessment of a tidal creek receiving slaughterhouse wastes in Bayelsa state, Nigeria. Journal of Advances in Biology and Biotechnology, 14(1): 1 -7.

[48] Standard organization of Nigeria (SON)., 2007. Nigerian Standard for Drinking Water Quality. Nigerian industrial standard, Nigeria

[49] World Health Organization (WHO)., 2011. *Guideline for drinking water quality.* 4th Edition.