ORIGINAL ARTICLE

Heavy metals level in water, sediments and health risks assessment of Ikoli Creek, Bayelsa State, Nigeria

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Water and sediments sample from Ikoli Creek, Bayelsa state were analyzed for levels of Heavy Metals (Cd, Cr, Pb Zn and Fe) using atomic absorption spectrometer (GBC Avanta PM AAS, SNA6600) under standard operating conditions and was compared with permissible limits set by World Health Organization (WHO). The mean concentration of different metals in water followed this order: Fe>Cd>Cr>Pb>Zn. Sediments Fe>Zn>Cd>CD>Pb. The health risk assessment of the various heavy metals were calculated. The values for Chronic Daily Intake (CDI) for heavy metals (Cd, Cr, Pb and Zn) were found not detectable except for Iron (Fe) having a high value which was ascribed to the soil composition of the area. Hazard Indices were below 1 for the heavy metals in drinking water samples and the Life Cancer Risk (LCR) indicated no health risk when compared with USEPA recommended standard limits. This study recommended that continuous monitoring of (Cd, Cr, Pb Zn and Fe) in water and sediments of Ikoli Creek should be done to assess the risk of these metals in this creek.

Key Words: Health risk; Ikoli Creek; Heavy metal; Geology; Sediments

INTRODUCTION

Many of the challenge that mankind is facing in the modern world today are related to the quality of water consumed [1,2]. Ikoli creek is one of the numerous creek in Bayelsa state, Nigeria facing pollution problems and it is also a major transportation route to many communities in Bayelsa State, Nigeria [3]. These problems are aggravated by the release of inorganic pollutants to the environment. The sources of inorganic pollutants in freshwater are diverse. About 40% of the globally accessible renewable freshwater is used by industry and consumed by humans [4], generating together a vast amount of wastewaters containing several toxic chemicals in unstable concentrations. These inorganic pollutants are persistent in small amount in the environment [5] and manifest itself in the form of heavy metals in freshwater resulting to health risk in humans [6] and are further deposited in the sediments. This problem is receiving a global attention all over the world and in developing countries in particular as a result human anthropogenic activities. The level of contamination by heavy metals to water in the environment internationally is very high thereby affecting the biosphere including aquatic lives present in the freshwater habitat [3,7-10]. More attention should be given to toxic heavy elements because of bioaccumulation and biomagnification potential, and their persistence in the environment [11-13].

The investigation of metals with relatively high density compared to water and sediments could be used to assess the anthropogenic and health risks posed by toxic chemicals discharges on the riverine ecosystems [15-17]. Therefore, it is imperative to assess the concentrations of heavy metals in water and sediments of any contaminated riverine ecosystem. The objective of this study are to determine the concentration of heavy metals in Ikoli creek and sediment; to assess the carcinogenic and non-carcinogenic systemic health risks that the estimated concentrations would pose on the inhabitants who consume the water for drinking.

MATERIALS AND METHODS

Study area

lkoli creek is located in Yenagoa, the Bayelsa state capital linking Agbura community. it is located in between Longitude 5°00 and 6°.45' East and Latitude 5°00 and 6°.30' North Surrounded by vegetation. The natives of Agbura community major occupation is farming and fishing.

Sample collection and preparation

The representative water samples (250 ml each) were therefore collected from Ikoli creek (15 samples in triplicate) including a control sample from Swali River in Yenagoa Bayelsa State. Triplicate samples of the sediment were also collected using Eckman sediment grab from 5 locations along Ikoli creek including Swali river. The samples were wrapped with aluminum fossil and transported to the laboratory in an ice pack. At the laboratory, the samples were air-dried and sieved using mesh. From each sampling point, the water samples were collected using amber bottles pre-washed with 10% nitric acid (HNO_3) and double distilled water. Water sample was transported to the laboratory, for heavy metal analysis, all the samples were stored in a refrigerator at 5°C.

Chemical analysis

All filtered and acidified water samples and sediment were analyzed for Heavy Metals (Cd, Cr, Pb, Zn and Fe) by using atomic absorption spectrometer (GBC Avanta PM AAS, SN A6600) under standard operating conditions. In order to provide greater data confidence from the analytical procedure regarding bias and variability, appropriate quality assurance and quality control (QA/QC) on water and sediment samples were ensured.

Analytical technique and accuracy check

In view of data quality assurance, each sample was analyzed in triplicate and after every 5 samples two standard; one blank and another of 2.5 µg/L of respective metal were analyzed on atomic absorption spectrophotometer. The reproducibility was found to be at 95% confidence level. Therefore, the average value of each water sample was used for further interpretation. Standard solutions of all five elements were prepared by dilution of 1000 mg/L certified standard solutions from Sigma-Aldrich Fluka, Switzerland of corresponding metal ions with distilled water. All the acids and reagents used were of high analytical grade. Performance of the instrument was checked by analyzing the

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standard reference material solutions concurrently to check the precision of the instrument. Blanks and Standard Reference Materials were included in the analysis as part of the quality assurance and quality control (QA/QC).

Water quality parameters

Physico-chemical parameters like temperature, pH and dissolved oxygen (DO) of the Ikoli creek river water were measured. Water samples were collected on spot using water sampler for the detection of physicochemical parameters. EXTECH Multi-probe DO700 kit was used to determine pH, Total Dissolve Solid (TDS), Temperature, Conductivity, Dissolved oxygen and Salinity. Hach's 2100P turbidimeter was used to determine the turbidity of the water. Winkler Method was used to measure dissolved oxygen in freshwater systems.

Assessment of heavy metal analysis in sediment

The concentration of heavy metals in sediment was analyzed using standard analytical procedure. The elements determination was performed by means of GBC Avanta PM AAS, SN A6600 (Atomic Absorption Spectrophotometer (AAS) for Cd, Cr, Pb, Zn and Fe.

Statistical analysis

The statistical analysis used is version 20 of SPSS Statistical package. Data were expressed as mean ± standard deviation using one way analysis of variance (ANOVA), While Duncan multiple range test statistics was used to determine the source of observed difference at P<0.05.

Data analysis

Human Health Risks Assessment (HHRA) of the water was also carried out using toxicological indices to calculate the non-carcinogenic health risk effects and carcinogenic health risk effects. The risk values are presented in Table 1.

Table 1: Water quality parameters, abbreviation and analytical methods.

Parameters	Abbreviation	Unit	Analytical techniques
Temperature	Temp	℃	Handheld EXTECH Multi-probe DO700
pH	pH		Handheld EXTECH Multi-probe DO700
Conductivity	Cond	µS/cm	Handheld EXTECH Multi-probe DO700
Total Dissolved Solid	TDS	mg/L	Filtration and gravimetric
Salinity	Sal	mg/L	Handheld EXTECH Multi-probe DO700
Turbidity	Tur	NTU	Handheld Hach's 2100P turbidimeter
DO	DO	mg/L	EXTECH Multi-probe DO700
BOD^5	BOD^5	mg/L	5-day incubation at 20°C
COD	COD	mg/L	Potassium dichromate oxidation reflux
Lead	Pb	mg/L	Instrumental, digestion (GBC Avanta PM AAS, SN A6600)
Chromium	Cr	mg/L	Instrumental, digestion (GBC Avanta PM AAS, SN A6600)
Cadmium	Cd	mg/L	Instrumental, digestion (GBC Avanta PM AAS, SN A6600)
Zinc	Zn	mg/L	Instrumental, digestion (GBC Avanta PM AAS, SN A6600)
Iron	Fe	mg/L	Instrumental, digestion (GBC Avanta PM AAS, SN A6600)

Non-carcinogenic water ingestion equation

$$CDI(nc) = \frac{C \times EF \times ED \times IR \times (kg/1000g)}{(365 \ days/year) \times LT \times BW}$$

where the toxicant Chronic Daily Intake (CDI), heavy metal concentration in fish (C), the total body weight (BW) for an adult of 70 kg having the unit's mg/kg-day, duration of exposure (ED), frequency of exposure (EF), the average life time is given as (LT), the rate of ingestion in fish (IRF). Fish consumption=102.74 g/day [3].

Non-carcinogenic health risk

The equation for calculating this is given as:

Target Hazard Quotient $(THQ) = \frac{CDI}{RfD}$

Where the toxicant Chronic Daily Intake is given as CDI; the reference dose is given as RfD all expressed in milligrams per kilogram.

Hazard index

For the risk assessment of multiple heavy metals contained in water, hazard index (HI) was employed by summing all the calculated THQ values for the determined metals [18].

HI=THQ (Pb)+THQ (Cr) THQ (Cd)+……

Where THQ is the target hazard quotient of an individual metal in the present study is five (5) metals (Cd, Zn, Fe, Pb, and Cr).

The exposed population is assumed to be safe when HQ<1 [14].

Carcinogenic health effects

The oral slope factor estimates the chance of an individual developing cancer through oral means by exposure to pollutant levels over time. The equation for calculating excess Lifetime Cancer risk is presented below:

Carcinogenic risks=CDI × SF

Where risk is the likelihood of an individual developing cancer over time; Chronic Daily Intake dose (CDI) and slope factor (SF) units are in [(mg/kg-day)$^{-1}$]. In this study, the amount of estimated excess cancer risk was compared with the acceptable maximum risk suggested by the USEPA which is $\leq 1 \times 10^{-6}$ [18].

Where, according to USEPA database the oral toxicity reference dose values (RfD) are 5.0E-04, 1.5, 3.6E-02, 3.0E-01, 7.0E-01 mg/kg-day for Cd, Cr, Pb, Zn and Fe respectively [19].

RESULTS AND DISCUSSION

Water quality parameters

The physico-chemical parameters of the water column such as pH, temp, salinity, dissolved oxygen (DO), etc. are presented in Table 1. The physicochemical parameters are very important because they have a significant effect on the water quality. It is obviously clear that water is one of most important elements responsible for life on earth. Unfortunately, human activity and Industrial activity have degraded the quality of water [20]. The values of temperature were ranged from 28.95-30.33 ℃ and the control 31.12 ± 0.09 respectively. The mean value of water temperature was found within the permissible limits set by WHO [21], which was between 25 and 30 ℃. The pH of the water samples analyzed were found to be slightly acidic having a mean concentration value ranging from 6.61-6.93 mg/L including the control 6.93 respectively (Table 2). The pH value was within the acceptable limit of 6.5-8.5, the pH affects chemical and biological processes and temperature affects the availability of oxygen concentration in the water [22].

Table 2: Water quality parameters of Ikoli creek, Bayelsa state, Nigeria. AGAQ - Sampling points, NG - No Guideline, AGAQX - Control, Data is expressed as Mean ± Standard Deviation in the same column with different alphabet is significantly different (p<0.05) while Mean ± Standard Deviation in the same column with the same alphabet is not significantly different.

	Temperature (°C)	pH (mg/L)	Conductivity (µS/cm)	TDS (mg/l)	Salinity (mg/L)	Turbidity (NTU)	DO (mg/L)	BOD5 (mg/L)	COD (mg/l)
AGSW1	30.22 ± 0.02e	6.66 ± 0.01b	70.56 ± 0.03a	52.53 ± 0.13c	37.44 ± 0.06c	10.07 ± 0.03d	4.14 ± 0.04a	6.37 ± 0.10f	9.74 ± 0.04c
AGSW2	29.17 ± 0.02d	6.61 ± 0.01a	72.36 ± 0.05d	50.43 ± 0.02b	36.35 ± 0.04bc	8.15 ± 0.04b	4.63 ± 0.03d	6.02 ± 0.01a	8.77 ± 0.02a
AGSW3	28.90 ± 0.02b	6.61 ± 0.03a	71.81 ± 0.03b	50.20 ± 0.03a	35.50 ± 0.02a	7.97 ± 0.01a	4.34 ± 0.03c	6.13 ± 0.02b	9.08 ± 0.03b
AGSW4	29.12 ± 0.00c	6.63 ± 0.02ab	77.05 ± 0.04c	55.15 ± 0.02d	39.50 ± 0.05d	9.17 ± 0.03c	4.31 ± 0.01c	6.23 ± 0.04cd	9.72 ± 0.02c
AGSW5	30.33 ± 0.02f	6.62 ± 0.02ab	71.05 ± 0.04b	52.50 ± 0.02ce	35.07 ± 0.05bc	10.41 ± 0.02e	4.24 ± 0.02b	6.20 ± 0.02bc	9.72 ± 0.01c
AGSWX	28.39 ± 0.02a	6.93 ± 0.02c	92.31 ± 0.01e	62.34 ± 0.03	41.22 ± 0.02e	16.33 ± 0.02f	4.30 ± 0.02c	6.30 ± 0.20ef	10.08 ± 0.03d
WHO		NG	250	NG	NG	5	NG	NG	NG

The mean concentration value of water conductivity ranged from 70.56-77.05 µS/cm and the control was higher with a mean concentration of 92.31 µS/cm. Total Dissolved Solids (TDS) is a measure of the amount total ions present in the solution. This dissolved solid includes minerals, salt, metals. It can be comparable to conductivity. The mean concentration value of total dissolved solid ranged from 50.20-55.15 mg/L. It was found that the control 62.34 mg/L has higher mean concentration value as a result of anthropogenic activity in that location (swali river). The U.S Environmental Protection Agency (EPA) advises against consuming water containing more than 500 mg/liter of TDS. Salinity is a measure of the salt content of the water. The salinity of freshwater is always less than 0.5%. The mean concentration values of salinity ranged from 35.50-37.44 mg/L but the control 41.22 mg/L was higher when compared.

In the present study, the mean concentration value of water turbidity ranged from 7.97-10.41 NTU in the various sampling point compared with the control 16.33 NTU. The control sample was the highest after analysis as a result of ongoing human activity there. The mean value of water turbidity was above W.H.O permissible limit [21].

The DO mean concentration value ranged from 4.14-4.63 mg/L compared with the control 4.30 mg/L. The dissolve oxygen in the study area was reduced as a result of the presence of oil sheen on the surface of the water. In this study, the concentration of DO is within the WHO acceptable limit of 4-10 mg/L [23].

BOD and COD water sampled ranged from 6.02-6.37 mg/L compared with the control 6.20 mg/L, and from 8.77-9.74 mg/L compared to the control 10.08 mg/L respectively.

BOD and COD concentrations in all the sampling points show that mean value is within the acceptable limit of 8 mg/L according to United Nations World Water Development Reports 2016 by Connor Richard. BOD is the measure of dissolved oxygen needed for the biochemical breakdown of organic compounds and the loss of oxygen of certain inorganic materials (e.g., iron, sulfites). unpolluted natural water has a BOD value of <5 mg/L. The presence of organic compound in water under normal conditions supports the growth of bacteria and other microorganisms, which may enhance the concentration of BOD5 and COD [23,24].

Metal ion concentration in water

The results of heavy metal concentrations (Zn, Pb, Cr, Cd Fe and Cr) in Ikoli creek are presented in Table 3. The concentration of studied metals in Ikoli creek followed the ranged order of: Fe>Zn>Pb>Cr>Cd. The mean concentration of Zn, Pb, Cr, and Cd in the samples was Not Detected, However only Fe was detected in all the sampling point including the control sample and was above WHO/FAO Permissible limit of 0.3 mg/L for drinking water (Table 3) when compared with lake Asejire, a non-natural lake constructed on River Oshun, located in Egbeda Local Government Area of Oyo State, Southwestern Nigeria facing pollution problems as a result of anthropogenic activities, heavy metals present (Fe and Pb) in the water were in small amount while Cr and Cd were not detected [25,26].

Heavy metal Pollution affect the physio-chemical quality of water [3,13]. These heavy metals have the ability to built up or bioaccumulates overtime in the aquatic ecosystems [28,29]. Some metals are considered in the environment as indicators are as a result of human activities example of such are arsenic, cadmium, chromium, mercury, nickel, and lead. These metals are dangerous when present in the natural environment in high amount [29,30].

Table 3: Heavy Metals in River Water (Ikoli Creek Bayelsa State). AGAQ - Sampling points, AGAQX - Control, Data is expressed as Mean ± Standard Deviation in the same column with different alphabet is significantly different ($p<0.05$) While Mean ± Standard Deviation in the same column with the same alphabet is not significantly different.

	Zinc (mg/L)	Chromium (mg/L)	Lead (mg/L)	Cadmium (mg/L)	Iron (mg/L)
AGW 1	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	1.136 ± 0.03c
AGW 2	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	2.107 ± 0.04e
AGW 3	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	2.216 ± 0.02f
AGW 4	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.958 ± 0.06b
AGW 5	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.426 ± 0.02a
AGSWX	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	1.413 ± 0.08d
WHO/FAO	3	0.05	0.01	0.003	0.3

Metal concentration in sediment

Heavy metal concentrations of sediments are presented in Table 4. Fe was found to be abundant. The mean concentration value ranged from 266.46-2143.23 mg kg^{-1}, while Zn mean concentration values ranged from 0.08-3.13 mg kg^{-1} and the other heavy metals were found to below detection limits as presented in Table 4. However, the control sample (swali river sediment) were shown to have some level of Zn (3.13 mg kg^{-1}), Cr (2.32 mg kg^{-1}) and Fe (920.64 mg kg^{-1}) present respectively. However when compared with Karnaphuli river in Bangladesh, Chromium concentration in sediment was higher than other metals as a consequence of direct discharging untreated wastes from petroleum, fertilizers and textile industries [7,8]. Also, when compared with lake Asejire, in Oyo State, Southwestern Nigeria, heavy metals (Fe, Pb, Cr and Cd) in the sediment were found in quantities less than 1 mg kg^{-1}, except iron which showed a notably high concentration (2.392 mg kg^{-1}) [25]. Epe and Badagry lagoon [31], Kolo Creek Niger Delta [32].

Table 4: Heavy Metals in Sediment (Ikoli Creek Bayelsa State). AGAQ - Sampling points, AGAQX - Control, Data is expressed as Mean ± Standard Deviation in the same column with different alphabet is significantly different ($p<0.05$) While Mean ± Standard Deviation in the same column with the same alphabet is not significantly different.

	Zinc (mg kg^{-1})	Chromium (mg kg^{-1})	Lead (mg kg^{-1})	Cadmium (mg kg^{-1})	Iron (mg kg^{-1})
AGSW1	1.26 ± 0.041c	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	920.61 ± 0.30c
AGSW2	0.08 ± 0.011a	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	368.77 ± 0.17b
AGSW3	1.33 ± 0.020d	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	266.46 ± 0.43a
AGSW4	1.33 ± 0.041d	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	1043.81 ± 0.23d
AGSW5	0.70 ± 0.017b	0.001 ± 0.00a	0.001 ± 0.00a	0.001 ± 0.00a	2143.23 ± 0.21e
AGSWX	3.13 ± 0.047	2.320 ± 0.08b	0.001 ± 0.00a	0.001 ± 0.00a	920.64 ± 0.28c

Human health risk assessment

The residents inhabiting the study area were interviewed for basic information about Ikoli creek about possible health problems after consumption of the water in the study area. It was noted during interview that residents were generally using river water (Ikoli creek) for drinking and other domestic purposes. Therefore, the river that were used for drinking purposes were also selected for Health risk assessment like CDI and HQ indices.

Chronic Daily Intake (CDI) indices

Table 5 summarizes the calculated Chronic Daily Intake (CDI) values for consumption of drinking water in Ikoli creek. The results indicated that heavy metals were not detected in Ikoli creek, but only Fe was present in a considerable amount. The CDI values for Fe ranged from 1.34E-02, 3.24E-03 to 6.62E-02, 1.60E-02 for adult and child. Therefore, CDI indices for heavy metal in the study area were found in the order of Fe>Zn>Cr>Cd>Pb. However, the Chronic Daily Intake (CDI) for heavy metals in water for adult and child were not detected for Zn, Cr, Pb and Cd and were found to be below US EPA Standard limit. US EPA [33] only Fe level was found in Ikoli Creek as a result of the geology of the area.

A recent study of a Chinese population exposed to Cr^{+6} in drinking water provided evidence of an increased risk of stomach cancer [34]. Chronic ingestion of water contaminated with cadmium above 0.005 mg/L^{-1} may cause renal failure and skeletal system damage [35]. Cadmium poisoning can result into itai-itai disease by drinking cadmium contaminated water [36].

Table 5: Chronic Daily Intake (Cdi) For Water. (–) Not Detected.

	Pb		Cd		Cr		Zn		Fe	
Samples	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
AGW 1	-	-	-	-	-	-	-	-	3.57E-02	8.63E-03
AGW 2	-	-	-	-	-	-	-	-	6.62E-02	1.60E-02
AGW 3	-	-	-	-	-	-	-	-	6.96E-02	1.68E-02
AGW 4	-	-	-	-	-	-	-	-	3.01E-02	7.28E-03
AGW 5	-	-	-	-	-	-	-	-	1.34E-02	3.24E-03

Target Hazard Quotient (THQ) indices

Table 6 summarizes the Target Hazard Quotient (THQ) indices of heavy metals through consumption of drinking water in the study area (Agbura Community), the mean THQ index values for Cd, Cr, Pb and Zn for Ikoli creek (river water) were not detected except Iron (Fe) having a ranging from 7.60E-01, 1.84E-01 to 1.48E+00, 3.58E-01 for adult and child.

Table 6: Target Hazard Quotient For Water. USEPA [17], THQ: 1,HI: 1.

	Pb		Cd		Cr		Zn		Fe	
Samples	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
AGW 1	-	-	-	-	-	-	-	-	7.60E-01	1.84E-01
AGW 2	-	-	-	-	-	-	-	-	1.41E+00	3.41E-01
AGW 3	-	-	-	-	-	-	-	-	1.48E+00	3.58E-01
AGW 4	-	-	-	-	-	-	-	-	6.41E-01	1.55E-01
AGW 5	-	-	-	-	-	-	-	-	2.85E-01	6.89E-02

Hazard indices

Table 7 summarizes the HI through consumption of the water in the study area. The HI values for other heavy metals were not detected with exception of Fe having a value slightly above 1.

Table 7: Hazard Indices of Water. USEPA [18], Maximum Permissible Limit, LCR: 1×10^{-6} to 1×10^{-4}, HI: 1.

	HI	
Samples	Adult	Child
AGW 1	7.60E-01	1.84E-01
AGW 2	1.41E+00	3.41E-01
AGW 3	1.48E+00	3.58E-01
AGW 4	6.41E-01	1.55E-01
AGW 5	2.85E-01	6.89E-02

CONCLUSION

Water quality can be affected by heavy metal pollution. It is apparent from this study that most of the heavy metal were below detectable limit with exception of Fe having high level, which was ascribed to the soil composition of the area. Carcinogenic and non-carcinogenic risk of water for the heavy metals Cd, Cr, Pb, and Zn were below detectable limits. Consumption of water from Ikoli creek can be affect humans as a result of bioaccumulation of high level of Iron present. However the exposed population in the study area is assumed to be safe from carcinogenic and non-carcinogenic risk condition.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

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