African Journal of Environment and Natural Science Research
ISSN: 2689-9434
Volume 8, Issue 2, 2025 (pp. 102-115)
www.abjournals.org

RISKS ASSESSMENT OF HEAVY METALS IN *GONIOPSIS CRUENTATA* FROM K- DERE CREEK, RIVERS STATE, NIGERIA

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Cite this article:

Karikpo, L. P., Ekweozor, I. K. E., Daka, E. R., Boisa, N., Anaero-Nweke, G. N., Awanen, A. V. (2025), Risks Assessment of Heavy Metals in Goniopsis Cruentata from K-Dere Creek, Rivers State, Nigeria. African Journal of Environment and Natural Science Research 8(2), 102-115. DOI: 10.52589/AJENSR-MGB2MA50

Manuscript History

Received: 8 Mar 2025

Accepted: 10 Apr 2025

Published: 27 Aug 2025

ABSTRACT: *The growth in population and industrialisation have contributed to the exponential increase in pollution in the Niger Delta ecosystem. Aquatic organisms have the ability to accumulate metals. This study is aimed at evaluating the levels and health risk assessment of metals (Cd, Cr, Pb and Fe) in Goniopsis cruentata from K-Dere Creek. Six sampling locations were mapped out with GPS and biological samples were collected and transported to the laboratory. Atomic Absorption Spectrophotometer was used for metals analysis using standard methods. Data obtained were statistically analysed using SPSS version 23. The mean concentrations of metals in biota across the six stations were greater than the recommended limit by the Federal Ministry of Environment in 2021. Mean and standard deviation concentration Cd, Pb, and Fe showed no significant difference but Cr showed significant differences at p>0.05 across the stations. Metal concentrations decrease across the stations as follows; station1(Fe>Cd>Pb>Cr), station2(Fe>Cd>Pb>Cr), station 3(Fe>Cr>Cd> Pb), station4(Fe>Cr>Cd>Pb), station 5(Fe>Cr>Cd> Pb) and station6 (Fe>Cr>Cd>Pb). There was no significant difference in the mean concentration of metals across the months of sampling. Exposure assessment was evaluated in terms of estimated daily intake which from 3.34E-05 – 0.06 in station 1, 9.95E-06 – 0.05 in station 2, 7.99E-06 – 0.06 in station 3, 7.99E-06 – 0.06 in station 4, 7.99E-06 – 0.05 in station 5 and 9.59E-06 – 0.06 in station 6 between Pb and Fe respectively. Risk assessment for non-carcinogenic elements through Hazard Quotient showed no significant health risk for Cr, Pb and Fe but Cr showed significant health risk across the stations. Hazard Indexes were greater than 1 across the six stations. Cd showed a significant cancer risk while Cr showed no significant cancer risk across the stations respectively.*

KEYWORDS: Heavy-metals, Accumulation, Risk assessment, Hazard quotient, Hazard index.

Article DOI: 10.52589/AJENSR-MGB2MA50
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INTRODUCTION

The increased pollution in rivers and streams in Niger Delta have been traced to the exponential rate of urbanization, industrialization and high population growth. Oil and gas activities from petroleum companies are the major source of pollution of rivers and streams. The oil and gas activities include drilling, refining of crude oil, flaring and the production of petrochemicals (Egborge, 1994). Furthermore, the petroleum industry is a primary source of pollutants in the Niger Delta due to the aforementioned activities. Other pollutants from petroleum industrial sources include carbon black, wastes from mechanic workshops and welding industries, utilization and disposal of spent petroleum products and the incidence of major tars from road construction and oil spills and repair of ships. As a result, all these have significant heavy metals categorized among their components (Egborge, 1994). Through both natural and anthropogenic sources, heavy metals could enter the aquatic environment. According to Agbozu and Ekweozor (2001), anthropogenic inputs are mainly from industrial effluents, domestic effluents, rural and urban storm water runoff and spoil heaps.

High concentrations of heavy metals in the catfish S*ynodontis clarias* reported from Tylor creek was a good indication of pollution of an aquatic ecosystem due to anthropogenic influence. The concentrations of Zn, Cd, Pb, Mn and Ni were recorded in measurable quantities signifying their bioavailability (Agbozu *et al.,* 2007). Osakwe and Peretiemo (2008) stated that aquatic bodies have been seriously polluted due to the periodic occurrence of oil spillage. Most micro populations and invertebrates are eliminated following large-scale spillages, while sublethal levels of oil following small scale spillages have normal constituents of crude oil, such as Ni, V, Cu, Cd, and Pb, recorded in the Ebocha-8 oil-spill-polluted site in Rivers State were high when determined as reported by Osuji and Onojake (2004).

The organic and physicochemical levels of rivers and sediments have badly been affected from major crude oil spillages in Ogoni land including the Niger Delta area with obviously higher levels of heavy metals (Pb, Cd and Ni). This spillage impacted the entire area consequently, polluting it with inorganic ions (Onyeike *et al.,* 2002). Obiajunwa *et al.* (2002) reported the differences in heavy metal levels following the dredging of an oil well access canal in the Niger Delta. Ohimain *et al.* (2008) recognized that the rise of heavy metals in Warri Rivers is caused by the scouring of an oil well entrance canal.

A study of heavy metals concentration in water, sediment and periwinkle in Elechi Creek, Niger Delta, was conducted. The biological accumulation factor (BAF) of metals in periwinkles, were high concentration in tandem with their sizes (Davies *et al.,* 2006). Metals are introduced into the aquatic ecosystem from two sources they are; natural and anthropogenic sources. This could be a direct discharge or through indirect routes such as dry and wet deposition and water runoff from the land. Importantly, natural sources include volcanic activity, continental weathering and forest fire (Aremu *et al.,* 2007). In Nigeria, the anthropogenic sources include: effluent from industries and homes, urban storm-water runoff, leaching of metals from waste management sites. Also, metals contained in pesticides, atmospheric sources, e.g. burning of fossil fuels, incineration of waste and Industrial emissions petroleum industry activities (Agbozu & Ekweozor, 2001; Adeyemo, 2003; Akpan, 2003).

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MATERIALS AND METHOD

Study Area and Sample Collection

K-Dere creek is an inter-tidal brackish water environment, which has boundaries with B. Dere, Kpor, Bodo and Ogu/Gbolo all in Rivers State. The study area is characterised by a devastated mangrove platform from artisan oil refinery activities which leads to loss of biodiversity. Also, the K-Dere community has recorded many oil spillages from equipment failure and vandalism respectively.

Crabs (samples) were collected from skilled fishermen that used traps to catch them from the various sampling stations and transferred into a labelled bag before being transported to the laboratory for chemical analysis.

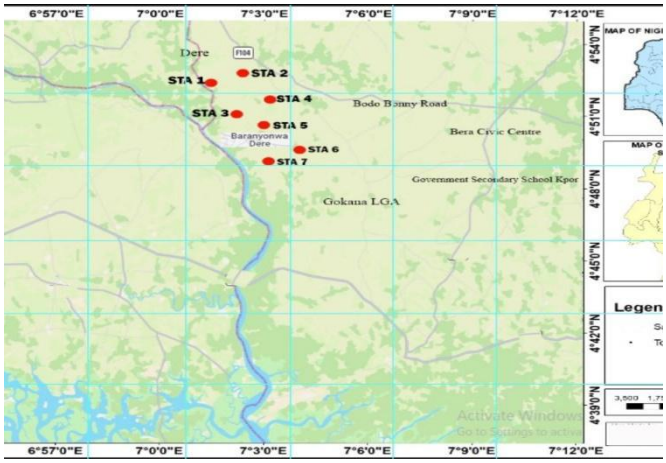

Plate 1 Map of sampling stations across K-Dere Creek

Plate *2 Goniopsis cruentata*

Determination of Heavy Metals in biota

The Carapace of the crab was removed and all the tissues dried properly in the oven at 45^{o}C. The dried samples were then ground into a fine powder from where 0.5g each of the sample was weighed into a borosilicate beaker. Twenty-five millimetres of freshly prepared aqua-regia (HCl: HNO_3) was added. This was then heated to near dryness, then heating was removed and allowed to cool. Twenty millimetres distilled water was then added and heated again for about 3-5 minutes. This was then allowed to cool and filtered. The filtrate was made up to mark in a 25 ml round bottom flask and kept refrigerated pending metal determination by AAS.

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Estimated Daily Intake

Estimated daily intake was calculated using following the generic equation as proposed by (USEPA, 1993):

"$EDI = E_F \times E_D \times F_{IR} \times 10^{-3} \times C_F \times C_M / W_{AB} \times T_A$"…….(5)

Where,

EDI = Estimated daily intake

E_F = Exposure frequency (365 days/year or days of exposure / week per 52 weeks / year)

E_D = Exposure duration (average life expectancy of 54 years by World Bank, 2017)

F_{IR} = Fish ingestion rate (person/day) was considered 40g/day (and converted to be 0.04mg/day for a healthy adult in Niger Delta Region of Nigeria (Maximilian *et al*., 2015)**.**

C_F = Conversion factor from dry fish weight to fresh fish weight (1-moisture content) (Rattan *et al*., 2005; USDA, 2007)

C_M = Heavy metal concentration in biota studied (mg/kg)

W_{AB} = Average body weight (70kg) (IRIS, 2013).

T_A = Average exposure time for non-carcinogens (E_F X E_D) (Wang *et al.*, 2012; World Bank, 2017).

Hazard Quotient (HQ)

Potential risk assessment of the toxicant was interpreted based on the values of Hazard Quotient (HQ) being the exposure dose divided by the Reference dose.

$HQ = EDI / R_{fdo}$ ……(6)

Where;

HQ = Hazard Quotient

EDI = Exposure Dose

R_{fDO} = Reference dose (Pb = 004, Mn = , Cr = , Ni = , Fe = 0.7 , Zn = and Cd = 0-001) (IRIS, 2013; USEPA, 2012).

And Total Hazard Index (THI) being the sum of HQ of the respective toxicants (Wang *et al.*, 2012, Olu *et al*., 2019)

$THI = HQ_{Mn} + HQ_{Fe} + HQ_{Cd} + HQ_{Ni} + HQ_{Cu} + HQ_{Zn}$ ……(7)

Where;

THI = Total Hazard Index. HQpb = Hazard Quotient of Lead. HQ_{Mn}= Hazard Quotient of Manganese. HQ_{Cr} = Hazard Quotient of Chromium. HQ_{Ni} = Hazard Quotient of Nickel. HQ_{Fe} =

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Hazard Quotient of Iron. HQ_{zn} = Hazard Quotient of Zinc. HQ_{Cd} = Hazard Quotient of Cadmium. Any THI above 1 .0 is indicative of potential health risk.

Cancer Risk (CR)

Cancer Risk was estimated based on USEPA (2011) and Liang *et al*., (2011) using the following equation;

$$\mathbf{CR=M_c \times x\ F_{IR} \times 10^{-3} \times CPS_0 \times E_F \times E_D /BW \times ATc} \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(8)}$$

CR = Cancer risk

E_F = Exposure frequency (365 days /year of exposure /week per 52 weeks /year)

E_D = Exposure duration (average life Expectancy of 54 years by World Bank, 2017)

F_{IR} = Fish ingestion rate (person/day) considered to be 40g/day (was converted to 0.04mg/day for a healthy adult in the Niger Delta region of Nigeria) (Maximilian *et al*., 2015).

CPS_0 = Cancer Slope Factor which is the risk produced by lifetime average dose of

1 mg/kg^{-1} $BWday^{-1}$ (Cd =0.38mg/kg, Pb=0-0085 mg/kg) Nkpaa *et al*., 2015)

M_c = Heavy metal concentration in food stuff (Biota studied (mg/kg)

BW = Average body weight (70kg) IRIS, 2005)

ATc = Average Exposure time for non-carcinogens (Wang *et al.*, 2012; World Bank, 2017).

Data Analysis

Descriptive statistics and one-way anova were used for measurement of central tendencies. Duncan was used for means' separations. Pearson correlation was used to determine the correlation coefficient between variables. All at 95% confidence interval with SPSS version 23.

RESULTS AND DISCUSSION

Concentration of Metals in Biota

There was a slight variation in the mean concentration of Cr across the stations, but there was a significant difference in the concentrations of Cr across the stations. Station 4 was significantly different from station 6 at $p<0.05$. The concentrations of Cr in biota declined as follows across the station 1 = station 2 > station 3 > station 6> station 5 = station 4 as illustrated in table 1. Cr was assessed in biota for six months for one-year duration. The mean and standard deviation concentrations of Cr in biota across the months of sampling showed significant differences at 95% confidence interval among the months of sampling, as illustrated in table 2. Fig. 1 represents the mean concentration of mean concentration of Cr across the stations by months for the sampling period.

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There was a little deviation in the mean concentration of Cd across the stations. There was no significant difference in mean concentrations of Cd in biota across the stations. The concentrations of Cd in sediment decreased as follows across the stations; station 4 > station 2 > station 6 >station 3 > station >1 > station 5 as shown in table 1.

Cd was examined for six months within a period of one year. The mean and standard deviation concentrations of Cd in biota across the months of sampling showed no significant differences at $p < 0.05$. The mean concentration of Cd decreased across the months of sampling as follows; September > January > March > November > May > July, as illustrated in table 2.

Fig. 2 illustrated the mean concentration of Cd across the stations by months of sampling. There was a little variation in the mean concentration of Pb across the stations. There was no significant difference in the mean concentrations of Pb across the stations at $p<0.05$. The concentrations of Pb in biota declined as follows across the stations; station 1 > station 2 = station 6> station 3 =station 4 = station 5 as illustrated in table 1. Pb was evaluated in biota for six months within a one-year duration. The mean and standard deviation concentrations of Pb in biota across the months of sampling showed no significant differences at 95% confidence interval. The mean concentrations of Pb descended across the sampling period as follows; March > January = May > November > July = September as shown in table 2. Fig. 3 showed the mean concentration of Pb in biota by station and by months of sampling.

There was a slight variation in the mean concentrations of Fe across the stations. There was no significant difference in the mean concentrations of Fe across the stations. The mean and standard deviation concentrations of Fe in biota decreased as follows; across the stations; station 6 > station 1 > station 4>station 3 >station 5 > station 2 as shown in table1. Fe was examined in biota for six months within a one-year period. The mean and standard deviation concentrations of Fe in sediment across the months of sampling showed no significant difference at 95% confidence interval. The mean concentration of Fe decreased across the months of sampling as follows; May > November > July > May> September > January> March as shown in table 2. Fig. 4 showed mean concentration of Fe in biota by stations across the months of sampling.

Table 1: Mean (±SD) Concentration of Metals in Biota by Stations

Station	Concentration (mg/kg)			
	Cr	**Cd**	**Pb**	**Fe**
Station 1	0.49 ± 0.14 [ab]	2.33 ± 0.62	1.90 ± 0.22	1552.00 ± 83.14
Station 2	0.16 ± 0.14[ab]	2.33 ± 0.11	2.00 ± 0.19	1586.42 ± 88.13
Station 3	3.01 ± 0.20 [ab]	2.35 ± 0.90	2.00 ± 0.12	1530.75 ± 81.90
Station 4	3.00 ± 0.34 [a]	2.29 ± 0.90	2.05 ± 0.14	1571.67 ± 56.65
Station 5	3.16 ± 0.16 [ab]	2.31 ± 0.11	1.94 ± 0.18	1562.75 ± 79.29
Station 6	3.06 ± 0.23 [b]	2.38 ± 012	1.92 ± 0.19	1556.17 ± 64.61
P value	0.888	0.056	0.522	0.100
Standard (FMEnv., 2021)	0.003	0.5		0.5

Alphabets with different superscripts are with significant difference at $p>0.05$

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Table 2: The Mean ± SD of Metals Concentrations in Biota by Months

Station	Concentration (mg/kg)			
	Cr	Cd	Pb	Fe
November	0.49±0.19[ab]	0.47±0.11	0.04±0.01	109.12± 23.50
January	0.63±0.17[bc]	0.55±0.20	0.06±0.02	63.00±18.19
March	0.67±0.21[c]	0.62±0.19	0.23±0.56	74.37±21.47
May	0.44±0.18 [a]	0.55±0.22	0.06±0.03	71.62±20.67
July	0.58±0.17[ab]	0.58±0.22	0.04±0.02	51.12±14.74
September	0.49±0.21[ab]	0.56±0.14	0.05±0.02	53.70±15.50
P value	0.034	0.565	0.33	0.253

superscripts with different letters are significantly different at p>0.05

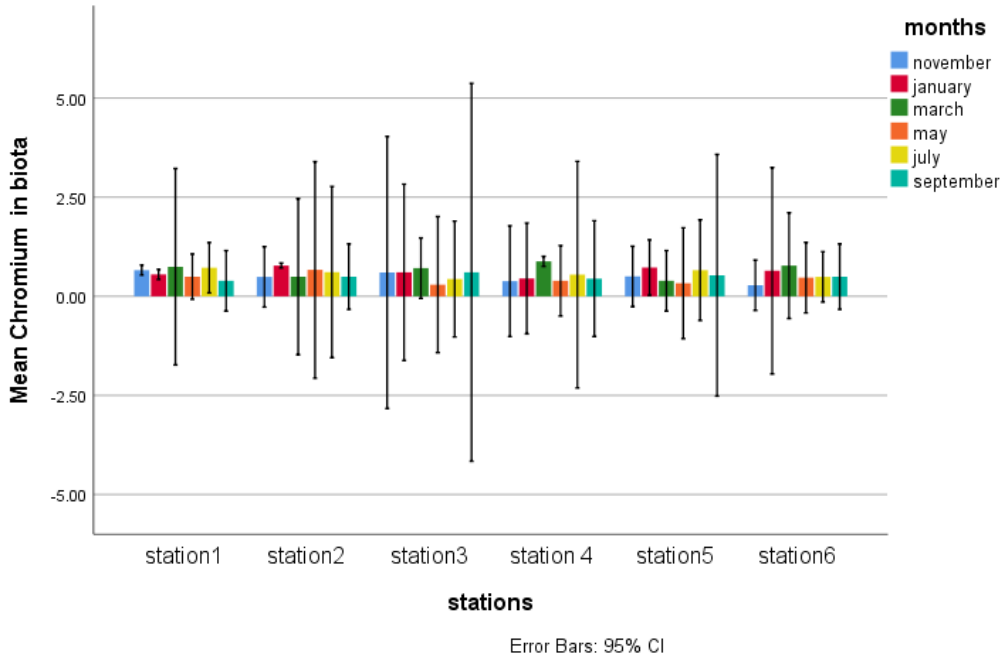

Fig. 1: Mean concentration Cr in biota by stations across months of sampling

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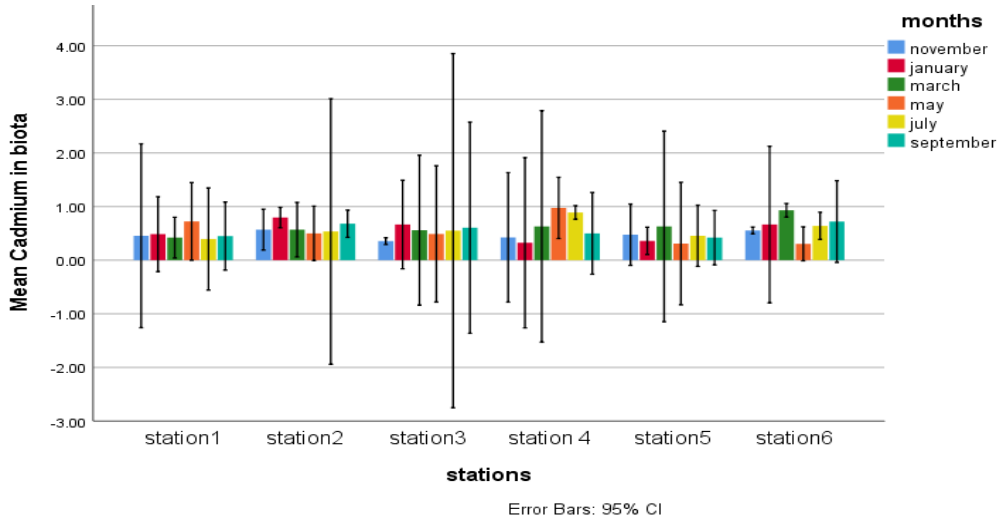

Fig. 2: Mean concentration Cd in biota by stations across months of sampling

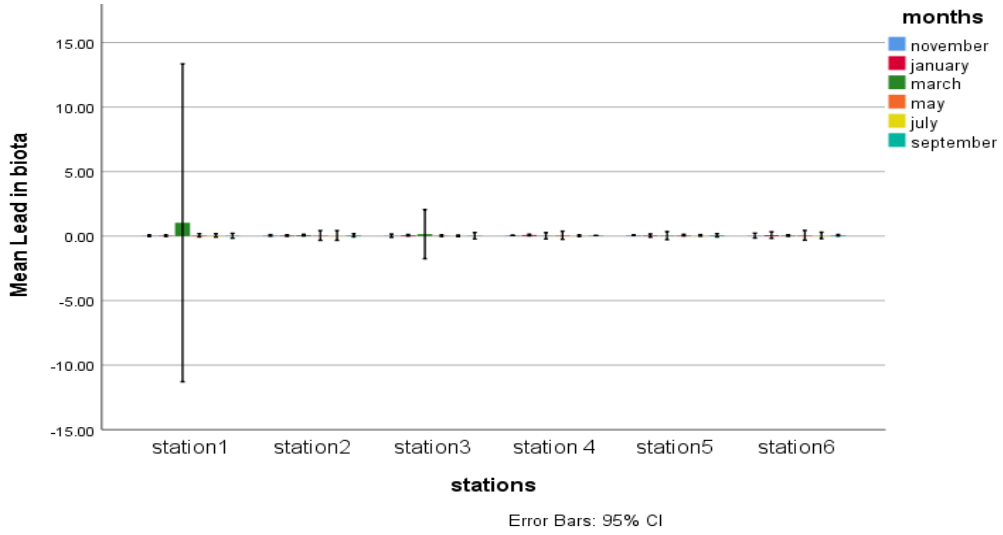

Fig. 3: Mean concentration Pb in biota by stations across months of sampling

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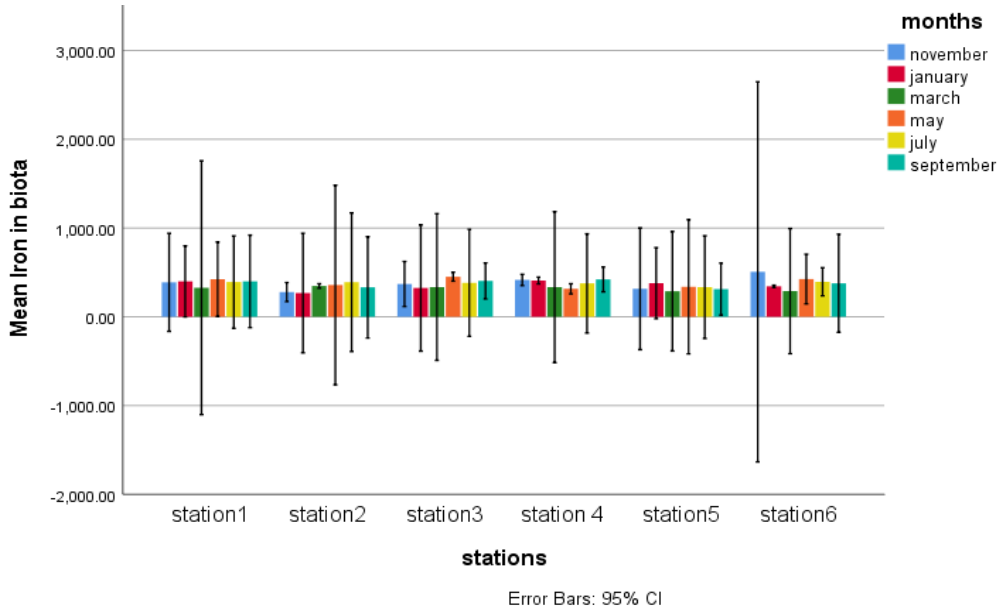

Fig. 4: Mean concentration Fe in biota by stations across months of sampling

Exposure Assessment

The exposure assessment of metals was evaluated in terms of Estimated Daily Intake (Average Daily Dose). The average daily dose of metals consumption through sampled biota was calculated for adults. The result of this is illustrated in table 3.

Non-Carcinogenic Risk

The non-carcinogenic risk of metals was expressed in terms of Hazard Quotient (HQ) and Hazard Index (HI). The Hazard Quotient was calculated for adults through metal consumption of biota across the sampling stations. Cd was >1, across the six stations. Cr, Pb and Fe were <1 across the stations. This is illustrated in table 4. The Hazard Index (HI) is the cumulative results of all the hazard quotients of each metal obtained across the stations. This indicates the risk of all the elements simultaneously. This is shown in table 5.

Carcinogenic Risk

The carcinogenic risk of metals was determined in terms of Cancer Risk. Cancer risk was calculated for Cr and Cd across the six sampling stations. This is shown in table 6**.**

Table 3: Average Daily Dose

Station	**Concentration (mg/day/bw)**			
	Cr	**Cd**	**Pb**	**Fe**
Station 1	9.4E-05	7.83E-05	3.34E-05	0.06
Station 2	9.4E-05	9.75E-05	9.59E-06	0.05
Station 3	8.63E-05	8.63E-05	7.99E-06	0.06

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Station 4	8.31E-05	9.90E-05	7.99E-06	0.06
Station 5	8.31E-05	7.03E-05	7.99E-06	0.05
Station 6	8.45E-05	8.95E-05	9.59E-06	0.06
Standard				

Table 4: Hazard Quotient

Station	Concentration			
	Cr	Cd	Pb	Fe
Station 1	3.13E-02	1.56	0.95E-02	0.08
Station 2	3.13E-02	1.95	2.74E-02	0.07
Station 3	2.88E-02	1.72	2.28E-02	0.08
Station 4	2.77E-02	1.98	2.28E-02	0.08
Station 5	2.77E-02	1.46	2.28E-02	0.08
Station 6	2.82E-02	1.75	2.74E-02	0.09
Standard	1	1	1	1

Table 5: Hazard Index

Station	**Concentration**				
	Cr	Cd	Pb	Fe	**Hazard Index**
Station 1	3.13E-02	1.56	0.95E-02	0.08	**1.73**
Station 2	3.13E-02	1.95	2.74E-02	0.07	**2.05**
Station 3	2.88E-02	1.72	2.28E-02	0.08	**1.83**
Station 4	2.77E-02	1.98	2.28E-02	0.08	**2.04**
Station 5	2.77E-02	1.46	2.28E-02	0.08	**1.59**
Station 6	2.82E-02	1.75	2.74E-02	0.09	**1.87**

Table 6: Cancer Risk

Stations	Concentration	
	Cr	Cd
Station 1	3.85E-03	2.9E-05
Station 2	3.85E-03	3.7E-05
Station 3	3.50E-03	3.3E-05
Station 4	3.40E-03	3.76E-05
Station 5	3.40E-03	2.67E-05
Station 6	3.50E-03	3.40E-05
Standard	10E-05 - 10E-08	

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Metals in Biota

In this present study *Goniopsis cruentata* was used as a sampled organism. Crab has been reported to have great bioaccumulation potentials. Several literatures have reported the accumulation of heavy metals and other persistent organic components in crab. This may be through ingestion of food particles or absorption through the physical principles of diffusion and osmosis. The source of food for aquatic organisms comes from their immediate aquatic ecosystem. Therefore, evaluating metals' levels in sampled organisms illustrates the presence and levels of metals within the environment.

The mean concentration result obtained in this study was 0.56mg/kg and there was no significant difference in the mean concentrations across the stations and months of sampling at $p<0.05$. The concentration of Cr in this study was higher than the concentration of Cr reported by Moslen *et. al.* (2017) in *T. fuscatus* from Upper Reaches of the Bonny Estuary, Nigeria. Ijeoma (2015) reported a mean concentration of 0.004mg/kg for Cr in T. *fuscatus* from an oil polluted site. Ogbona and Origbe reported a lower concentration of Cr across the sampling stations in Bodo Creek than obtained in this present study.

Javed and Nazura (2014) reported an average concentration of 23.03mg/kg in fish (*Channa punctatus*), a higher concentration than the concentration of Cr recorded in this present study. The concentration of Cr in this study was within the recommended standard of 0.13mg/kg by FEPA (2003) permissible limit in fish/food. The concentration of Cd in biota in this present study was 0.56mg/kg. The result obtained in this present study was higher than the concentration reported by Otitoju and Otitoju (2013) that stated concentrations of 0.11mg/kg and 0.27mg/kg in the same organism in Abuloma and Oron Rivers respectively. Also, Ogbona *et al.* (2021) reported a lower concentration of Cd in biota across the sampling stations in Otamiri and Imo River, Nigeria.

Moslen and Miebaka (2017) reported high concentration of Cd (0.73±0.14) in *Callinectis amnicola* from Estuarine Creek in the Niger Delta, Nigeria, higher than the mean of Cd obtained in the present study. However, the concentration of Cd in biota was above the permissible limit of FOA/WHO (2013) MPL of 0.05mg/kg. Cd had no significant differences across the stations and months of sampling at 95% confidence interval. But slight differences in mean concentration. The difference in concentration of metals in biota may be linked to the physiological attributes of the biotas and their feeding patterns (Daka *et al.*, 2006).

Pb had a mean concentration of 0.08mg/kg in biota. And, there were no significant differences in the element concentrations across the six sampling stations and across the months of sampling at 95% confidence interval. However, Ijeomah (2015) recorded mean values of 0.72, 0.74, and 0.63mg/kg in water-snail at Burutu, Bomadi and Warri Southwest and also reported 0.63, 0.73 and 0.63mg/kg in periwinkle at the same studied areas. The result of metal concentration in biota obtained in this study was higher than the results obtained by Ogbona et al. (2021). They reported a lower concentration of Pb across the sampling station in biota at Otamiri and Imo River, Rivers State.

Similar results obtained in this study were obtained by Anyimamuka-chinedu (2019), in the concentration of Pb in gills, liver and muscle in P. *papillo* from Elechi Creek, Port Harcourt. Also, Jumbo (2015) reported lower Pb in Fish from Kaa and Bodo Rivers in Rivers State. Iron is a trace element and is needed in the body for metabolic and biochemical processes. However, in this study, the mean amount of Fe in biota was 365.07mg/kg in biota. There was no

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significant difference in the mean concentration of Fe across the station and months of sampling at $p<0.05$.

Moreover, excessive consumption, Fe can bring about skin discolorations, increase the risk of liver cancer, development of diabetes, liver damage and colorectal cancer. According to USEPA (2011), human health risk is the description of the possible adverse health effects on humans resulting from the introduction of environmental risks. The high and frequent consumption proportion of seafood in the Niger Delta Region of Nigeria had deemed it necessary to use Estimated Daily Intake or Average Daily Dose to assess health risk associated with the consumption of aquatic organisms.

Exposure Assessment

Health metals are considerably a major source of pollutants in food contamination from the immediate environment regarding its potentials to bioaccumulate, persist and toxic levels to living organisms. The toxicity of heavy metals to humans is a function of their direct intake of metals The estimated daily intake of the metals in study context were compared with the Tolerable Daily Intake (TDI) and the upper tolerable daily intake (UTDI) recommended by the Institute of Medicine for adult population of 19-79 years (FDA, 2021; Garcia-Rico, 2007).

EDI values for Pb, Cr and Cd in biota are lower than their reference doses indicating no potential health risk, this was in tandem with the findings of Etuk *et al*. (2020) and Udousoro *et al*. (2018) on *Tympanostus fuscatus* and *Pachymelenia fusca* from two coastal areas of Akwa Ibom State, Nigeria. However, Markmanuel *et al*. (2016) recorded higher EDI values in periwinkle than their reference doses indicating potential non carcinogenic health risk of metals from exposure to biota from the studied area.

Non-Carcinogenic Risk

The Hazard Quotient values for metals in biota across the stations were less than 1 for Cr and Pb and Fe. This signifies no potential non carcinogenic health of metals from consumption of biota across the stations. However, The Hazard Quotient of Cd was above 1 across the sampling stations indicating significant non carcinogenic health risk for these heavy metals over lifetime exposure from the studied area.

The hazard index (HI) of metals across the six sampling stations in this study HI was (1.73, 2.05, 1.82, 2.09, 1.57, 1.87) for station 1 to station 6 respectively. HQ is the summation of all the metals analysed. In this present study, HI was higher than 1 which indicates a high potential non cancer risk for individuals who consume biota contaminated with all the metals.

Cancer Risk (CR)

Cancer risk for metals in biota were less than the standard limit which signifies no potential cancer risk for people who consume the biota from the study area on. The cancer risk for metal in biota from this study Cr and Cd were less than the recommended cancer limit of 10^{-6} indicating that there is no significant cancer risk for people living around the study area who consume fish.

Article DOI: 10.52589/AJENSR-MGB2MA50
DOI URL: https://doi.org/10.52589/AJENSR-MGB2MA50

CONCLUSION

Metals concentration in sediment showed a significant difference in mean concentration of Cr between station 4 and station 6, but in biota, there was no significant difference in the mean concentration of metals across the stations. Metals concentration in sediment and biota were within the recommended standard by former NUPRC (former DPR), 2012 regulatory provisions. However, Cd concentration was significantly enriched across the six sampling stations. This is an indication that the significant increase of metals level within the studied areas were from anthropogenic sources. The estimated daily intake of biota was within the recommended standard of reference oral dose for metals.

However, Hazard Quotient and Hazard Index showed a potential health risk of non-carcinogenic elements of Cd which makes the consistent exposure to biota very dangerous to human health. The human health effects due to the consumption of metal via crabs identified could pose a serious public health crisis in the area.

Cancer risk for carcinogenic elements showed a potential health risk for Cr across the sampled stations, which reveal a threat to the health of the locals on exposure to the studied biota. It is, therefore, necessary that environmental monitoring in the coastal regions of Nigeria be more stringent; it should go beyond the monitoring of the effect of oil and gas activities to the effect of day-to-day anthropogenic activities. Environmental regulatory agencies and policymakers should expand on monitoring protocols and policies.

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