Chapter

Consumption Safety in Relation to Bioaccumulation of Heavy Metals in Periwinkles (*Tympanotonus fuscatus*) Obtained from Ogbia in the Niger Delta Region of Nigeria

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Abstract

The study assessed human health risk and accumulation of heavy metals (Cd, Cu, Pb, Ni, Cr and Zn) in periwinkles (*Tympanotonus fuscatus*) obtained from the Niger Delta region of Nigeria. Samples were collected for six months on a monthly basis. The samples were digested according to the method described by Association of official analytical chemists and analyzed using atomic absorption spectrophotometer (AAS). Temporal variations in metal concentrations were observed with values ($mgkg^{-1}$) ranging as follows Pb (2.34–6.7), Ni (0.55–2.28), Zn (0.55–11.66), Cr (0.74–3.65), Cu (1.15–3.91) and Cd (0.22–1.06). Variation in metal concentration was significantly different ($p < 0.05$) with metals such as Pb, Ni and Cd found to be above their respective FAO/WHO permissible limits. The estimated daily intake (EDI) of all metals examined was less than their respective reference oral doses (RFD). The target hazard quotient (THQ) non-carcinogenic and the hazard index (HI) of metals were < 1 while the hazard quotient carcinogenic (HQ) ranged between $10^{-6} – 10^{-4}$. The study therefore concluded gradual accumulation of metals and minimal health risk due to consumption of contaminated periwinkles in the study area.

Keywords: heavy metals, bioaccumulation, health risk, periwinkles, Niger delta

1. Introduction

Heavy metal pollution is one of the challenges of coastal waters due to human activities such as oil exploration and exploitation, construction and fabrication of marine boats, disposal of industrial and domestic wastes, sailing and illegal bunkering activities [1]. Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms [2]. Nagajyoti et al. [3] and [4]; stated that metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons. Heavy metal contamination in the aquatic environment is a major challenge with regards to industrialization in view of the fact that industrial and domestic wastes

containing such pollutants are regularly channeled into nearby water bodies [1]. Increase in population has induced urbanization and industrialization with corresponding discharge of wastes such as heavy metals into the environment [5, 6] but Dural et al. [7] stated that heavy metals occur naturally in aquatic ecosystem but deposits of anthropogenic origin increase their levels and create environmental problems in coastal zones and rivers. Aquatic organisms like periwinkles have the ability to accumulate and bio-magnify contaminants like heavy metals, polycyclic aromatic hydrocarbons and PCB in the environment [8]. Researchers had stated that ideal bio-indicators (biomonitors) should satisfy certain conditions such as ability to accumulate pollutants without being killed by the levels encountered in the environment; sedentary in order to be representative of the study area, sufficiently long lived to allow the sampling of more than one year-class, if desired: be of reasonable size, giving adequate tissue for analysis [9, 10]. Mollusks such as *Tympanotonus fuscatus*, a deposit feeder common along the mangrove intertidal coast and estuarine swamps of the Niger Delta also satisfy most these conditions due to wide usage in biomonitoring studies [11]. Moslen [11] reported gradual bioaccumulation of heavy metals in fish (biota) with attendant minimal to moderate health risk concern but recommended regular monitoring in order to detect changes over time. *Tympanotonus fuscatus* is a mollusk (Gastropods) of high commercial and economic value in the Niger Delta region of Nigeria [11]. This study therefore, aim to evaluate consumption safety and heavy metal bioaccumulation in periwinkles (*Tympanotonus fuscatus*) obtained from Ogbia in Niger Delta, Nigeria.

2. Materials and methods

2.1 Sample collection and preparation

Periwinkle (*Tympanotonus fuscatus)* samples were obtained from landings of artisanal fishermen in Ogbia, Niger Delta, Nigeria (**Figure 1**). Samples were collected monthly for six months (February to July 2018). The samples were placed in labeled container, preserved in ice-packs and immediately taken to the laboratory for further analysis. The samples (tissue) were removed from the shell and oven

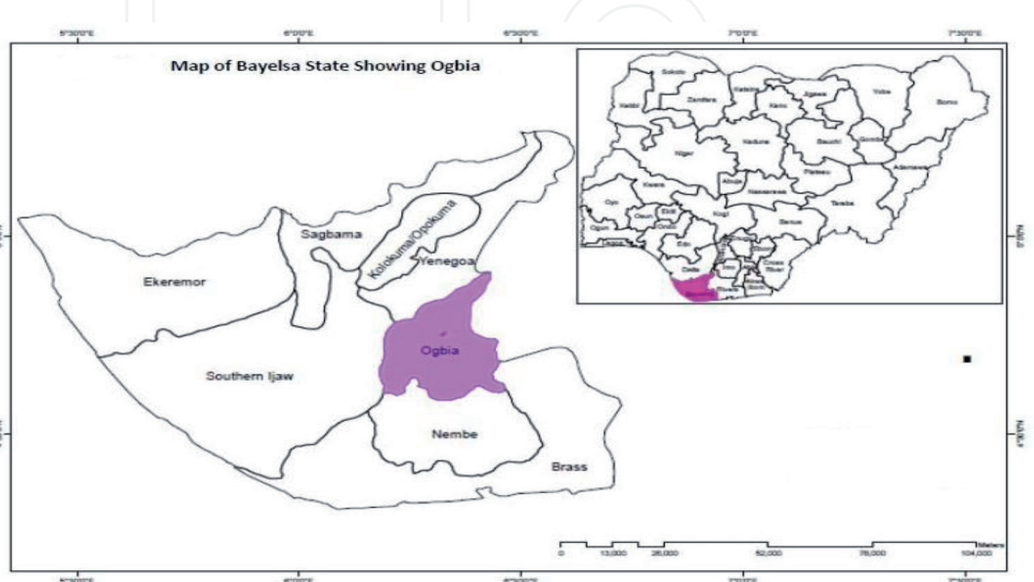

Figure 1.
Map of study area (Ogbia) with an inset map of Nigeria.

dried at 80°C for 24 hours after which, the sample was ground to powder using ceramic mortar and pestle.

2.2 Sample digestion

The homogenized sample was digested according to the method described by the Association of official Analytical Chemists [12]. Two (2 g) of the homogenized tissues was weighed into bottles and transferred into labeled boiling tube in a fume cupboard, 5 ml of 10% HCl acid was added to the sample and stirred. It was then treated with 5 ml of 10% HNO_3, and warmed on a water bath to dissolve. The digested sample was allowed to cool at room temperature and then filtered through 0.45 μm into volumetric flask. The concentrations of heavy metals in the samples were determined with an Atomic Absorption Spectrophotometer (GB Avanta PM AAS, S/N A6600 with detection limit for individual metals of study in the range of 0.001–0.02 $mgkg^{-1}$). The concentrations were blank-corrected and expressed as μgg^{-1} dry weight of sample analyzed.

2.3 Human health risk assessment

Health risk on humans was evaluated to determine possible adverse health effects due to consumption of periwinkles *(Tympanotonus fuscatus)* contaminated with heavy metals. Standard and acceptable indices were used for health risk assessment.

2.4 Exposure assessment (Estimated Daily Intake (EDI))

The Estimated Daily Intake (EDI) via consumption of heavy metal contaminated periwinkle was evaluated using Eq. 1 [13].

$$\text{Estimated Daily Intake}\left(EDI\right)=\frac{EFXEDXFIRXCfXCm}{BWXTA\left(EFXED\right)} \tag{1}$$

where EF = Exposure frequency
ED = Exposure duration
FIR = Fish ingestion rate
CF = conversion factor
Cm = heavy metal concentration in periwinkle (μg/g d-w),
BW = Adult body weight 70 kg [14, 15].
TA (EF × ED) = average exposure time [5, 6].

2.5 Assessment of non-carcinogenic health risks

The target hazard quotient (THQ) was used to evaluate the non-carcinogenic health risks associated with consumption of periwinkles contaminated with heavy metals. THQ was expressed in Eq. 2 [5, 6, 13].

$$\text{Target hazard Quotient}\left(THQ\right)=\frac{EDI}{RFD} \tag{2}$$

where EDI = Estimated Daily Intake.
RFD = Reference Oral Dose of metal.

2.6 Assessment of carcinogenic health risks

Assessment of Carcinogenic health risks with hazard quotient was done using Eq. 3.

Hazard quotient (carcinogenic) [16].

$$\text{Incremental Lifetime Cancer Risk}\left(\text{ILCR}\right) = CDI \text{ X } SF \tag{3}$$

where CDI = Chronic daily intake (CDI) = $\dfrac{EDIXEFXED}{ATn}$ (4)

SF = slope factor
EDI = Estimated Daily Intake
EF = Exposure frequency
ED = Exposure duration
ATn = Average life span.

2.7 Hazard index (HI)

In view of the fact that contaminants do not act in seclusion in the environment, the HI was used to assess the total risk from various contaminant pathways. This is the sum of the target hazard quotients for all heavy metals, calculated using Eq. 5 [5, 6, 17]. HQ and HI values less than 1 were considered safe [18].

$$HI = \sum HQ = HQ_{Ni} + HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Pb} + HQ_{Zn} \tag{5}$$

2.8 Data analysis

Significant difference in metal concentrations between periods (months) was tested with ANOVA (General Linear Model) using the software Minitab 16. The standard deviation was calculated as the positive square root of the sample variance with number of observations as six (6) and expressed in the Eq. 6 as.

$$S_X = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1}} \tag{6}$$

3. Result and discussion

3.1 Concentration of heavy metals in tissues of bivalves

The concentration of heavy metals in tissues of *Tympanotonus fuscatus* is presented in **Figure 2a–f** while **Table 1** compared the metal concentrations with permissible limits. Heavy metal toxicity is a major global concern due to human health risk associated with consumption of contaminated sea food, hence the need for evaluation. Mean metal concentrations ($mgkg^{-1}$) in the soft tissues of

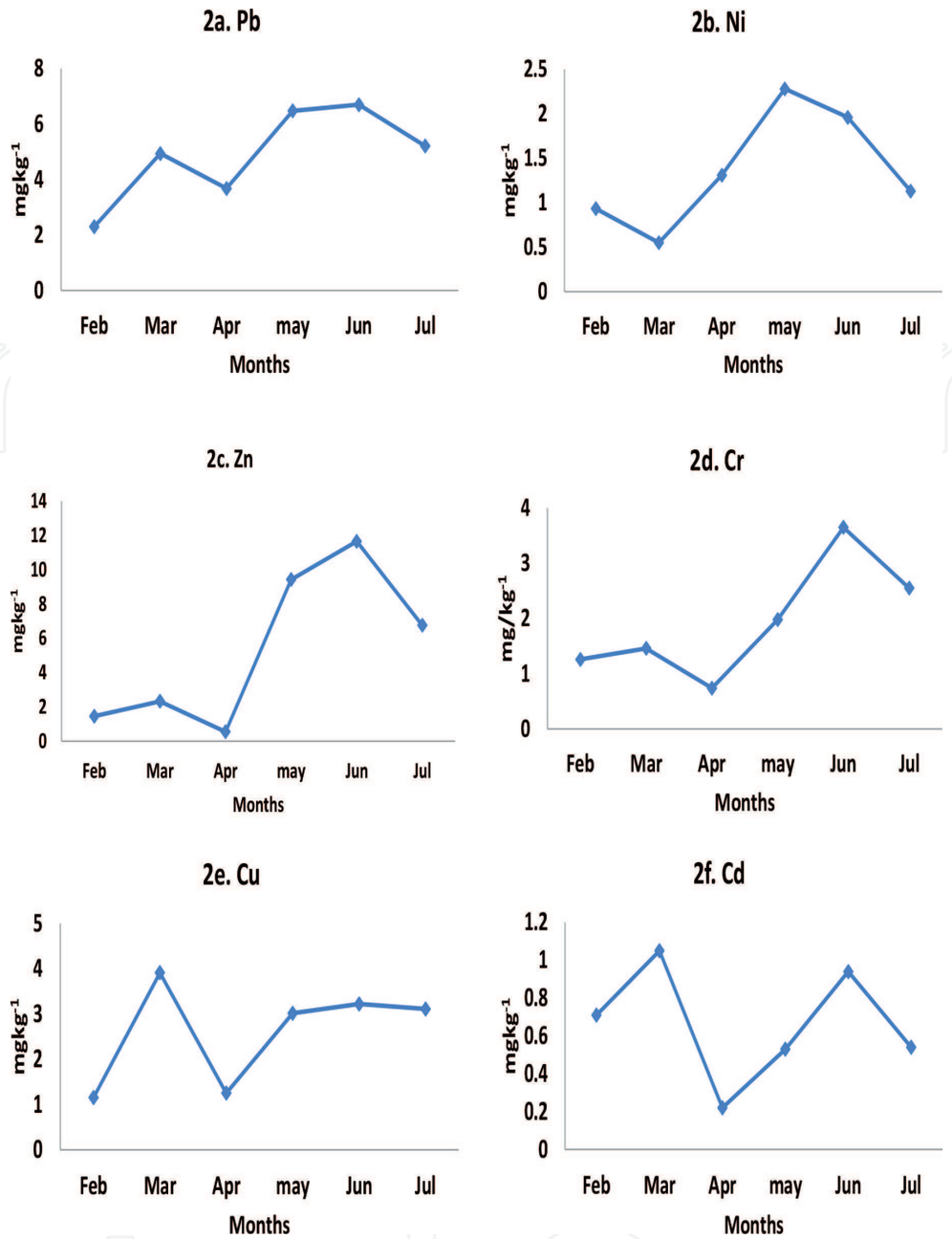

Figure 2.
(a–f) Temporal variations of heavy metal concentrations in the study area.

Heavy metals	Mean ± STDEV	Recommended limits (ppm)
Pb	4.88 ± 1.67	0.5 [19]
Ni	1.36 ± 0.64	0.2 [20]
Zn	5.36 ± 4.5	30
Cr	1.94 ± 1.04	12–13 [21]
Cu	2.61 ± 1.13	30 [22]
Cd	0.66 ± 0.3	0.1 [23]

Table 1.
Heavy metal concentrations and permissible limits.

periwinkles (*Tympanotonus fuscatus*) examined was in the order of Zn (5.36 ± 4.5) > Pb (4.88 ± 1.67) > Cu (2.61 ± 1.13) > Cr (1.94 ± 1.04) > Ni (1.36 ± 0.64) > Cd (0.66 ± 0.3). Variation in metal concentrations was significantly different ($p < 0.05$). This implies differential bioaccumulation in the concentrations of the heavy metals in gastropod tissues with respect to time, particularly those metals with elevated concentrations above regulatory limits. Consumers of periwinkle from the study area are therefore, exposed to significantly higher concentrations of heavy metals. Moslen and Miebaka [1] had reported that fish could accumulate elevated levels of heavy metals in their tissues over time without physical signs of distress but this may constitute potential health harm to consumers of such fish from presumed polluted areas. Mean values of Cr, Cu and Zn observed in this study were below their respective recommended limits of 12–13 [21, 22] , and 30 (FAO/[20]) while mean values of Ni, Cd and Pb exceeded their recommended limits of 0.2 [20], 0.1 [23] and 0.5 [19]. In other studies, Akinrotimi et al. [24] reported heavy metal concentrations ($mgkg^{-1}$) as follows Ni (1.17 ± 0.05), Cd (0.06 ± 0.01), Cr (2.44 ± 0.01), Pb (0.29 ± 0.06), Zn (5.57 ± 0.61) in bivalve Mollusks while Moslen et al. [11] reported thus Cd (0.02), Cr (1.57), Pb (0.01) and Zn (24.42) in gastropod Mollucs.

3.2 Health Risk assessment

3.2.1 Exposure assessment (Estimated Daily Intake (EDI))

Consumption of contaminated periwinkles (*Tympanotonus fuscatus*) is a key exposure route for human health risk. Estimated daily intake (EDI) was used for exposure assessment via consumption of contaminated periwinkles. EDI values ($mgkg^{-1}$) of this study ranged from 0.1×10^{-3} (Cd) – 0.84×10^{-3} (Zn) (**Figure 3**). Different researchers have reported variations in EDI values. Anaero-Nweke et al. [25] in a study of bioaccumulation of heavy metals in tissues of *Tympanotonus fuscatus* had reported EDI range of 6.57–8.81 $mgkg^{-1}$ above FAO/WHO [26] permission tolerable daily intake of 0.25 $mgkg^{-1}$ for Pb and EDI values of 0.01–0.07 $mgkg^{-1}$ within FAO/WHO [26] permissible tolerable daily intake of 0.07 $mgkg^{-1}$ for Cd. Tongo and Ezemonye [18], had reported EDI values of 0.138–0.200 $mgkg^{-1}$ in fish from the Niger Delta region while Moslen [11] also reported EDI values of fish

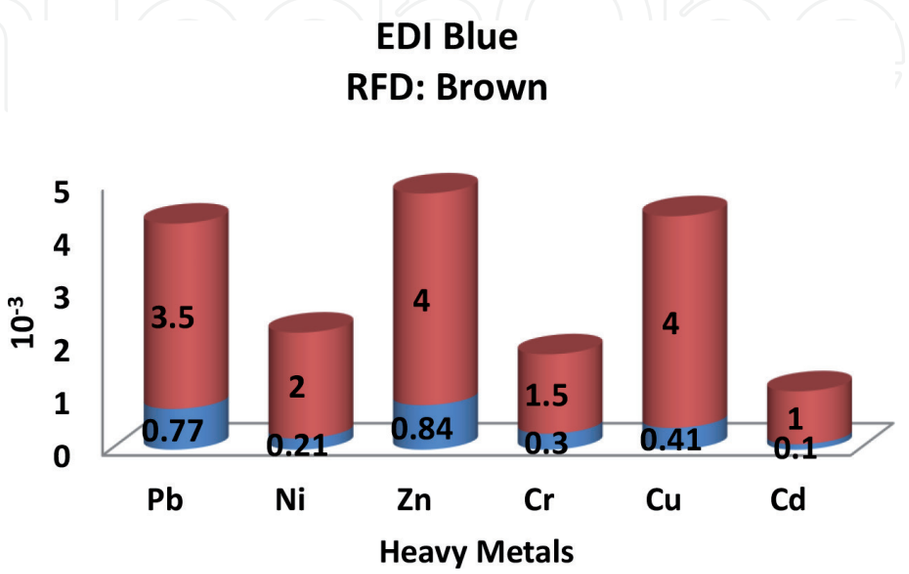

Figure 3.
Estimated daily intake of the periwinkles is presented in the study area.

tissue as follows: Cd (5.5×10^{-5}), Cu (6.9×10^{-4}), Ni (3.0×10^{-4}), Pb (4.5×10^{-4}) and Ag (1.9×10^{-4}). The EDI values of all metals examined in the present study were less than their respective reference oral doses (RFD) implying minimal health risk due to consumption of contaminated periwinkles in the study area. However, [13] stated that RfD represents an estimation of the daily exposure of a contaminant to which the human population may be continually exposed over a lifetime without an appreciable risk of harmful effects. It is important to mention that among the different metals examined Pb, Cd, Cr and Ni are classified as chemical hazards [27, 28] meaning they could impair body functions at certain concentrations.

3.3 Target Hazard Quotient

Assessment of risk is very important because it has to do with evaluation of the amount of a substance that could lead to negative health impact for exposed persons over a particular duration. The health risk assessment of each contaminant is often based on the evaluation of the risk level and is classified as carcinogenic or non-carcinogenic health hazards [29]. The target hazard quotient was used to assess the non-carcinogenic risk. In the present study, THQ (non-carcinogenic) values ranged from 0.01 (Cu) - 0.22 (Pb) (**Figure 4**). The values of THQ (non-carcinogenic) in the present study were all <1suggeting low risk of exposure for consumers of periwinkles. Researchers have reported that THQ >1 potent risk of non-carcinogenic effect to consumers of such sea foods [5, 6, 30]. However, Khan et al. [31] stated that THQ builds some degree of alarm for carefulness but does not assess risk regarding exposure to contaminants. The THQ of the present study were also in tandem with values reported by Moslen and Miebaka [32]. Dee et al. [33] also found THQ for Cd, Cu, Mn, Pb, and Zn as 0.12, 0.06, 0.04, 0.41, and 0.03, respectively. The values of hazard quotient carcinogenic (HQ) of the present study ranged from $10^{-6} – 10^{-4}$ (**Figure 5**). Such values indicated low to moderate values of carcinogenic risk [34].

Metals in the environment may not act singly. The sum of the THQ (hazard index - HI) was calculated to give an indication of the total potential non-carcinogenic health impacts that could result from exposure to a mixture of heavy metals in periwinkles consumed, following EPA guidelines for health risk assessment [35, 36]. The HI value (0.56) of the present study was <1 depicting low risk of exposure for consumers of periwinkles. The HI value of the present study is less than that

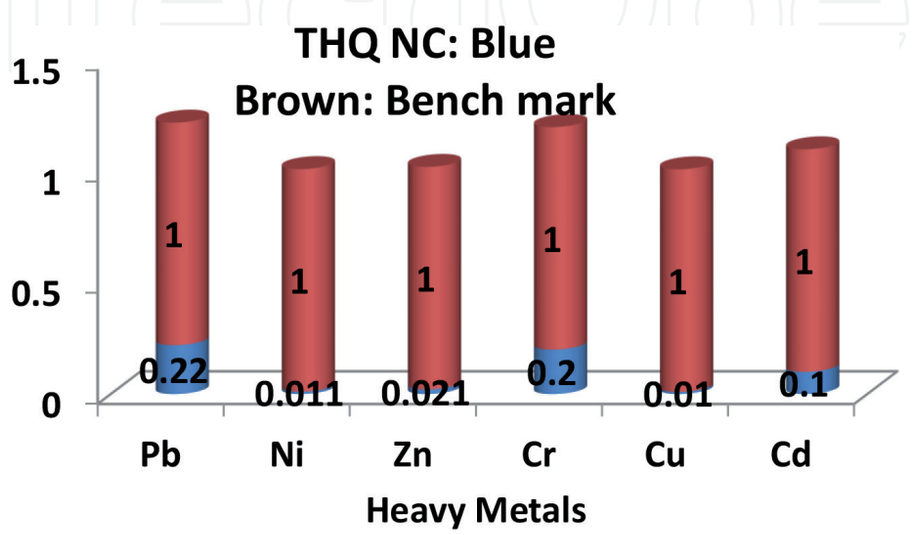

Figure 4.
The target hazard quotient non-carcinogenic of heavy metals.

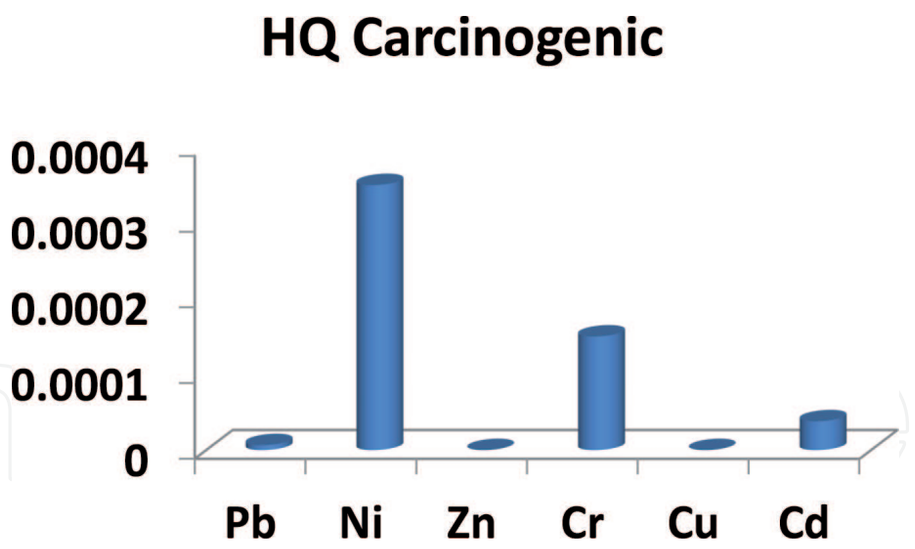

Figure 5.
The hazard quotient (carcinogenic) of heavy metals.

(1.60–5.06) reported by Denil et al. [37] for four different clams but agrees with that (0.45) in fish reported in the Niger Delta region [38]. The percentage make-up of the HI was in the order Pb > Cr > Cd> > Zn > Ni > Cu indicating the elevated input of Pb, Cr and Cd concentrations in the periwinkles examined.

4. Conclusion

The study therefore, concluded gradual bioconcentration of some heavy metals in tissues of periwinkles obtained from the study area. Both carcinogenic and non-carcinogenic indices indicated safe levels for health risk. Therefore, consumers of periwinkles in the study area have low to moderate risk of exposure for health concerns. It is import to continue monitoring to observe changes in bioaccumulation.

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