Health risk assessment of consuming heavy metal contaminated benthic seafood, *Anadara (Senilia) senilis* in the southern region of Nigeria.

1Miebaka Moslen*, 2Calista. Adamma Miebaka, 3Ruth Braide
1,3Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Nigeria
2Institute of Pollution Studies, Rivers State University, Port Harcourt, Nigeria.

This study evaluated health risks associated with the consumption of a seafood (bivalve - *Anadara (Senilia) senilis*) contaminated with some heavy metals in southern Nigeria. Atomic absorption spectrophotometry was used for metal analysis. Mean metal concentrations (µg g⁻¹) was in the order of Zn(12.96±1.0)> Pb(4.69±0.6)> Cr(2.91±0.7)> Ni(2.47±0.2)> Cu(2.03±0.3)> Cd(1.68±0.2). Mean concentrations of Cr, Cu and Zn were below their respective FAO/WHO recommended limits while those of Ni, Cd and Pb exceeded. The Estimated daily intake-EDI values of all metals were less than their respective reference oral doses-RFD implying minimal health risk. The target hazard quotient (non-carcinogenic) and hazard index-HI had values <1 suggesting minimal health risk of non-carcinogenic origin but HI value showed potency of increase. The value of Incremental Lifetime Cancer Risk-ILCR ranged from 10⁻⁵-10⁻² with Ni and Cd within the acceptable range of 10⁻⁴-10⁻⁶ while Cr and Pb exceeded the limit. The target cancer risk-TR had values of 10⁻³ indicating moderate to high risk according to the New York State Department of Health classification. The study concluded the presence of moderate to high carcinogenic risk due to Cr and Pb for consumers of heavy metal contaminated seafood (bivalves) in southern Nigeria. Minimal consumption and further action are advised with regular monitoring to detect changes.

Keyword: Health Risk; Heavy metals; Bioaccumulation; Bivalve-Anadara; Nigeria.

INTRODUCTION

The toxic effect of heavy metals in the environment via food and water contamination remains a global concern. Monitoring programs and researches on heavy metals in samples from the aquatic environment have become widely important due to concerns over accumulation and toxic effects in aquatic organisms and to humans through the food chain (Otchere, 2003). Several studies have attributed the increased presence of heavy metals in the aquatic environment to rapid urbanization and population increase, exploration and exploitation of natural resources, agricultural practices, rapid industrialization and other anthropogenic activities in the ecosystem (Moslen and Aigberua 2018; Moslen and Ameki 2018; Moslen et al. 2018). Heavy metals may occur in aquatic environments from natural processes and discharges or leachates from several anthropogenic activities (Franca et al. 2005). The contamination of natural waters by heavy metals negatively affect aquatic biota and pose considerable environmental risk and concerns (Ravera 2004).

*Corresponding Author: Miebaka Moslen, Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Nigeria E-mail & ORCID: moslen4c@yahoo.com (moslen.miebaka@ust.edu.ng), https://orcid.org/0000-0002-1658-5977
Because of the fact that sediments are an important sink of different pollutants, including heavy metals, it also serves as an enriched source of contaminants for benthic organisms particularly in estuarine ecosystems that provide habitats for bivalves such as *Anadara (Senilia) senilis*. (Wang et al. 2002). *Anadara (Senilia) senilis* is a filter-feeding mollusc of the order Arcoidae in the family Arcidae. This bivalve satisfies basic biomonitoring conditions due to wide distribution along with coastal areas, sessile lifestyle, easy to handle and a filter feeder with the ability to accumulate heavy metals and contaminants without appreciable metabolism (Olivier et al. 2002). However, Philip and Rainbow (1998) stated that several biotic and abiotic factors could influence the accumulation of heavy metals in bivalves.

Metal toxicity depends upon the absorbed dose, the route of exposure and duration of exposure (acute or chronic (Moslen and Miebaka 2016). Jaishankar (2014) reported that metal toxicity can lead to different disorders in addition to excessive damage due to oxidative stress induced by free radical formation. Heavy metals bind to protein substances and obstruct normal metabolic activities, reactions and cycles in the body with some target organs including skin, lung, liver, kidney bladder and others but this depends on exposure and type of metal. Arsenic exposure is linked to cancer of skin, lung, bladder, liver and kidney in human (Singh et al. 2007) and exerts some of its effects through interaction with glutathione - GST (Yoon et al. 2008) while Cd affects the transcription of genes and induces human genes which perform protective functions (Koizumi 1997). Mercury can form several stable organic mercury compounds by attaching to one or two carbon compounds e.g. methyl mercury (CH$_3$Hg$^+$). Yoon et al. (2008) which can undergo biotransformation to divalent mercury compounds in tissues by cleavage of the carbon mercury bond. Yoon et al. (2008) also stated that mercury may bind to various enzyme systems like those of microsomes and mitochondria leading to nonspecific cell injury and cell death. Major toxic effects of Cr in human is related to Cr (III) complexes with intracellular macromolecules (Yoon et al. 2008). The mechanism of toxicity of Cr at the biochemical level, cellular level –cell cycle arrest and genomic level had also been reported (Kaltreider et al. 1999; Solis-Heredia et al. 2000). The Mechanisms of lead toxicity include the destruction of membranes, obstruction in metabolism and direct interference with the synthesis of neurotransmitter (Yoon et al. 2008). Molecular mechanisms of toxicity of copper leading to Wilson disease had also been reported by Bull et al. (1993).

Health risk assessments have been conducted on bivalves due to its high adaptability to various levels of contaminations (Moslen et al. 2019). *Anadara (Senilia) senilis* was chosen for this research because it satisfies most of the characteristics of bivalves as biomonitors and it is a commercially important species exploited for its great food value in the south coast of Nigeria (Moslen et al. 2019). Accumulations of heavy metals in filter-feeding organisms pose health risk concern to consumers of these sea foods. It is therefore, imperative to assess the health risk associated with such populations consuming contaminated sea foods such as bivalves, in order to provide missing data and information for further studies and policy/decision-makers in the study region. Data and health risk information due to the consumption of bivalves *Anadara (Senilia) senilis* in the southern region of Nigeria is quite poor. This study therefore, seeks to examine health risk due to consumption of bivalves (*Anadara Senilia senilis*) in relation to bioaccumulation of heavy metals contamination in southern Nigeria.

**MATERIALS AND METHODS**

**Sample collection**

Bivalve (*Anadara Senilia senilis*) samples were obtained from two regional markets in southern Nigeria. The regional markets in Port Harcourt (4°45′29.64″N 7°1′25.30″E) and Eket - Kwa Ibo (4°32′47.93″N 7°59′25.85″E) (Fig.1) are major landing areas for variety of see-foods from the south coast of Nigeria. Freshly collected samples of bivalves (*Anadara Senilia senilis*) were wrapped in aluminum foil, properly labeled, put in ice-chest coolers and immediately taken to the laboratory for analysis. Fifty samples were collected monthly for eighteen months (October 2017 to March 2019). Sample collection was done to satisfy incremental sampling to give aggregate samples representative of lots or sub-lots for laboratory analysis (FSAI, 2015).
Extraction and Analysis

Bivalve samples were extracted from the shell, oven-dried and properly homogenized. The homogenized sample was digested according to the method described by the Association of Official Analytical Chemists (AOAC, 2006). Two grams of the homogenized tissues were 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% HNO₃, 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 a 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 µgg⁻¹). The concentrations were blank-corrected and expressed as µg g⁻¹ dry weight of the sample analyzed.

Human Health Risk Assessment

Health risk on humans was evaluated in order to determine possible adverse health effects due to the consumption of bivalves (Anadara (Senilia) senilis) contaminated with heavy metals. Standard and acceptable indices were used for the health risk assessment. The indices/parameters used for the various calculations are presented in Table 1.

Table 1: Parameters used for estimating exposure assessment through fish consumption

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Value</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean concentration of heavy metals in bivalve (µgg⁻¹)</td>
<td>µgg⁻¹</td>
<td>Table 2</td>
<td>Table 2</td>
</tr>
<tr>
<td>Reference Dose (RfD)</td>
<td>mg/kg/day</td>
<td>(USEPA 2009, 2011)</td>
<td>(USEPA 2009, 2011)</td>
</tr>
<tr>
<td>Fish ingestion rate (FIR)</td>
<td>Kg/capita/day</td>
<td>0.0548 (54.8g)</td>
<td>(FAO 2014)</td>
</tr>
<tr>
<td>Exposure Duration (ED)</td>
<td>years</td>
<td>70</td>
<td>(Qu et al. 2015)</td>
</tr>
<tr>
<td>Exposure Frequency (EF)</td>
<td>Days/year</td>
<td>365</td>
<td>(Qu et al. 2015; Moslen and Miebaka 2017a)</td>
</tr>
<tr>
<td>Adult body weight (BW)</td>
<td>kg</td>
<td>70</td>
<td>(Tongo et al. 2017a; Moslen et al. 2019)</td>
</tr>
<tr>
<td>Average life span (ATn)</td>
<td>days</td>
<td>25550</td>
<td>(USEPA, 2011)</td>
</tr>
<tr>
<td>Oral Slope Factor (SF)</td>
<td>mg/kg/day</td>
<td></td>
<td>(USEPA, 2011; Nkpa et al. 2017)</td>
</tr>
<tr>
<td>Conversion factor</td>
<td>dimensionless</td>
<td>0.208</td>
<td>(Wang et al. 2005; Moslen and Miebaka, 2017a)</td>
</tr>
</tbody>
</table>
Exposure assessment (Estimated Daily Intake (EDI))

The Estimated Daily Intake (EDI) via consumption of heavy metal contaminated seafood (bivalves - *Anadara (Senilia) senilis*) was evaluated using equation 1.

\[
\text{Estimated Daily Intake (EDI)} = \frac{EF \times ED \times FIR \times CF \times Cm}{BW \times TA \times EF \times ED}
\]

(Akoto et al. 2014).

Where: 
- EF = Exposure frequency
- ED = Exposure duration
- FIR = Fish ingestion rate
- CF = conversion factor
- Cm = heavy metal concentration in bivalve (μg/g d-w),
- BW = Adult body weight 70 kg (Tongo et al. 2017b)
- TA (EF × ED) = average exposure time (Moslen and Miebaka 2017a).

Assessment of non-carcinogenic health risks

The hazard quotient (HQ) was used to evaluate the non-carcinogenic health risks associated with consumption of bivalve contaminated with heavy metals. This is expressed as Target hazard Quotient (THQ) in equation 2.

Target hazard Quotient (THQ) = \( EDI \), equation 2. (Akoto et al. 2014; Moslen and Miebaka 2017a)

Where EDI = Estimated Daily Intake

RFD = Reference Oral Dose of metal

Assessment of Carcinogenic health risks

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

Hazard quotient (carcinogenic)

Incremental Lifetime Cancer Risk (ILCR) = CDI X SF eqn (3) (Sultana et al. 2017)

Where CDI = Chronic daily intake (CDI) = \( \frac{EDI \times EF \times ED}{ATn} \) eqn. 4

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

Hazard index (HI)

In view of the fact that contaminants do not act in isolation in the environment, the HI was used to evaluate the total risk from various contaminant pathways. This is the sum of the hazard quotients for all heavy metals, which was calculated using equation 5 (Guerra et al., 2010; Moslen and Miebaka 2017a). HQ and HI values less than 1 were considered safe (Tongo and Ezemonye 2019).

\[
HI = \sum HQ = HQ_{Ni} + HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Pb} + HQ_{Zn}
\]

Target cancer risk (TR)

The TR was determined based on (USEPA, 2011) using equation 6.

Target cancer risk (TR) = \( \frac{Mc \times X IR \times 10^{-3} \times CPSo \times X EF \times ED}{BW \times ATn} \) eqn. 5

where
- Mc = metal concentration,
- IR = ingestion rate,
- EF = exposure frequency,
- ED = exposure duration,
- BW = body weight,
- CPSo = carcinogenic potency slope, oral.
- ATn = averaging time for carcinogens.

Data Analysis

Significant difference in metal concentrations between periods (months) was tested with ANOVA (General Linear Model) using the software Minitab 16.

RESULT AND DISCUSSION

Concentration of heavy metals in tissues of bivalves

Heavy metal toxicity could predispose humans to health risk via consumption of contaminated sea-food hence its necessity for evaluation. The mean concentrations of heavy metals (Ni, Cd, Cr, Cu, Pb and Zn), F-values of ANOVA and recommended limits are presented in Table 2. Mean metal concentrations (µg g\(^{-1}\)) in the soft tissues of bivalves (*Anadara (Senilia) senilis*) examined was in the order of Zn (12.96 ± 1.0) > Pb (4.69 ± 0.6) > Cr (2.91 ± 0.7) > Ni (2.47 ± 0.2) > Cu (2.03 ± 0.3) > Cd (1.68 ± 0.2). Metal concentrations between study periods did not differ significantly (p>0.05) for Zn and Pb but Ni (p<0.001), Cd (p<0.01), Cr (p<0.001) and Cu (p<0.05) had significant differences. Mean values of Cr, Cu and Zn observed in this study were below their respective recommended limits of 12–13 (USFDA, 1993; FAO/WHO, 1983), and 30 (FAO/WHO, 2005) while mean values of Ni, Cd and Pb exceeded their recommended limits of 0.2 (WHO, 2005), 0.1 (FAO, 2003) and 0.5 (FAO/WHO, 1989).
Table 3: Comparison of results of this study with other findings

<table>
<thead>
<tr>
<th>Location</th>
<th>Organism</th>
<th>Ni</th>
<th>Cd</th>
<th>Cr</th>
<th>Cu</th>
<th>Pb</th>
<th>Zn</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korean Coastal</td>
<td>Gastropod</td>
<td>0.746 mg/g</td>
<td>(0.050 mg/g)</td>
<td>0.076 mg/g</td>
<td>6.658 mg/g</td>
<td>0.003 mg/g</td>
<td>35.06 mg/g</td>
<td>(Mok et al. 2014)</td>
</tr>
<tr>
<td>Kenyan Coastal</td>
<td>Bivalve</td>
<td>0.12 ± 0.04</td>
<td>0.60 ± 0.15</td>
<td>0.26 ± 0.09</td>
<td>34.45 ± 12.4</td>
<td>0.117 ± 0.06</td>
<td>108.29 ± 60.82</td>
<td>(Mok et al. 2014)</td>
</tr>
<tr>
<td>Kenyan Coast</td>
<td>Bivalve</td>
<td>Nd to 7.15 ± 1.4 µg/g</td>
<td>Nd to 98.24 ± 19.73 µg/g</td>
<td>2.90 ± 0.48 µg/g to 254.98 ± 9.50 µg/g</td>
<td>Nd 70.35 to 2.47 µg/g</td>
<td>2504.92 ± 96 µg/g</td>
<td>(Swaleh et al. 2016).</td>
<td></td>
</tr>
<tr>
<td>Niger Delta</td>
<td>Bivalve</td>
<td>1.17 ± 0.05</td>
<td>0.06 ± 0.01</td>
<td>2.44 ± 0.01</td>
<td>0.29 ± 0.06</td>
<td>5.57 ± 0.61</td>
<td>164.102</td>
<td>Akinrotimi et al. 2019</td>
</tr>
<tr>
<td>Niger Delta</td>
<td>Bivalve</td>
<td>0.658 mg/kg</td>
<td>0.6134 mg/kg</td>
<td>0.068</td>
<td>164.102</td>
<td>58.3 ± 1.2</td>
<td>(Vargas et al. 2015)</td>
<td></td>
</tr>
<tr>
<td>Costa Rica</td>
<td>Bivalve</td>
<td>1.30 ± 0.05 (µg/g dw)</td>
<td>6.03 ± 0.49</td>
<td>58.3 ± 1.2</td>
<td>23.0 ± 2.1</td>
<td>76.6 ± 1.6</td>
<td>(Vargas et al. 2015)</td>
<td></td>
</tr>
<tr>
<td>Malasia</td>
<td>Bivalve</td>
<td>1.09 - 1.98 (µg/g )</td>
<td>0.61 - 2.86</td>
<td>12.52 - 24.93</td>
<td>0.8 - 1.9</td>
<td>84.16 - 105.63</td>
<td>(Yunus et al. 2014)</td>
<td></td>
</tr>
<tr>
<td>Niger Delta</td>
<td>Bivalve</td>
<td>0.01 - 0.04 µg/g</td>
<td>24.8 - 30.0</td>
<td>0.02 - 0.05</td>
<td>23.5 - 42.1</td>
<td>135.5 ± 53.6</td>
<td>(Denil et al. 2017)</td>
<td></td>
</tr>
<tr>
<td>Malasia</td>
<td>Bivalve</td>
<td>2.58 ± 3.41</td>
<td>0.24 ± 0.13</td>
<td>6.42 ± 1.68</td>
<td>0.95 ± 0.30</td>
<td>135.5 ± 53.6</td>
<td>(Denil et al. 2017)</td>
<td></td>
</tr>
<tr>
<td>Niger Delta</td>
<td>Gastropod</td>
<td>0.02</td>
<td>1.57</td>
<td>0.01</td>
<td>24.42</td>
<td>(Moslen et al. 2017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>This Study</td>
<td>Bivalve</td>
<td>2.47 ± 0.2</td>
<td>1.68 ± 0.2</td>
<td>2.91 ± 0.7</td>
<td>2.03 ± 0.3</td>
<td>4.69 ± 0.6</td>
<td>12.96 ± 1.0</td>
<td>(Moslen et al. 2017)</td>
</tr>
</tbody>
</table>

The result of this research was compared with the findings of other researchers (Table 3). The concentration of Ni in this study compares with those of other researchers (Table 3). The same applies to the concentration (1.68 ± 0.2) of Cd of this study but was found to be less than the maximum concentration (7.15±1.14) reported in a study in Kenya. Table 3 showed regional variations in metal concentrations but values of this study were far below maximum metal concentrations observed in neighboring east Africa as reported by (Swaleh et al. 2016). It is important to state that legal limits of some countries or regions may differ even, from those of international organization. For example, Cd concentration of this study fell within the lowest safety limits (1.01–2.00 µg/g) set by Malaysian Food Act 1983 and Regulation 1985 (Yunus et al. 2014) which could be at variance with limits set by other countries or regions.
Exposure assessment (Estimated Daily Intake (EDI))

Consumption of contaminated fish is a key exposure route for human health risk. Estimated daily intake (EDI) was used for exposure assessment via the consumption of contaminated bivalves. EDI values (µg/kg) of this study ranged from 0.26 (Cd) - 2.03 (Zn) (Table 4). Variations in EDI values have been reported by different researchers. Tong and Ezemonye (2018), had reported EDI values of 0.138 - 0.200 mg/kg/bw/d in fish from the Niger Delta region while (Copat et al. 2012) reported EDI ranges of 0.007 - 0.503 µg/kg/d in Sicily. The findings of the present study also showed slightly higher EDI compared to those (Cu: 0.54, Pb: 0.01; Zn: 2.14, Cd: 0.01, Cr: 0.04) reported by (Feng et al., 2020) in bivalves, (Zhao et al. 2013) however, reported higher EDI of 15.0–255.1 times lower than the RFD values in bivalves when compared to the present study. Such variations could be attributed to the consumption rate of fish, body weight and accumulation level of the contaminants in the fish (Tongo and Ezemonye 2018). The EDI values of this study is also comparable to those reported by (Yap 2018) in Anadara granosa (Cd: 0.11 - 0.16, Cu: 0.08 - 0.12) but lower than that reported for Zn (4.47 - 5.20). 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 the consumption of contaminated bivalves from southern Nigeria. However, Akoto et al. (2014) 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 (EC, 2001; FDA, 2001). Lead (Pb) is one of the highly-rated toxic metals after arsenic (As). Massadeh et al., (2004) had reported organs such as bones, brain, blood, kidneys, reproductive and cardiovascular systems, and thyroid gland as targets of Pb. The NAS–NRC (1982) reported the threshold for acute cadmium toxicity could be total ingestion of 3–15 mg while severe toxic symptoms were reported to occur with ingestions of 10–326 mg. Fatal ingestions of Cd, producing shock and acute renal failure, occur by ingestions exceeding 350 mg. Mean concentrations and EDI values obtained in this study were below these limits but caution should be taken because accumulation and magnification are possible along the food chain. Overexposure to Ni as a carcinogenic metal could lead to decreased bodyweight, heart and liver damage and skin irritation (Homady et al. 2002). Though Cr is listed among hazardous metals (USFDA, 1993) estimated average daily human need of chromium to be 1 g. According to Calabrese et al. (1985) deficiency of chromium could lead to impaired growth and disturbances in glucose, lipid, and protein metabolism.

<table>
<thead>
<tr>
<th>Heavy Metals (µg/g)</th>
<th>EDI (X10⁻³) (µg/kg-bw-d)</th>
<th>THQ (Non-Carcinogenic)</th>
<th>Hazard Index (HI)</th>
<th>% of each Metal in HI</th>
<th>ILCR (Carcinogenic)</th>
<th>Target Cancer Risk (TR X10⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>0.38</td>
<td>0.019</td>
<td>0.86</td>
<td>2.2</td>
<td>0.00065</td>
<td>1.58</td>
</tr>
<tr>
<td>Cd</td>
<td>0.26</td>
<td>0.25</td>
<td></td>
<td>30.2</td>
<td>0.00098</td>
<td>0.24</td>
</tr>
<tr>
<td>Cr</td>
<td>0.46</td>
<td>0.31</td>
<td></td>
<td>36.1</td>
<td>0.23</td>
<td>0.54</td>
</tr>
<tr>
<td>Cu</td>
<td>0.32</td>
<td>0.008</td>
<td></td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb</td>
<td>0.74</td>
<td>0.21</td>
<td></td>
<td>24.4</td>
<td>0.0063</td>
<td>0.015</td>
</tr>
<tr>
<td>Zn</td>
<td>2.03</td>
<td>0.05</td>
<td></td>
<td>5.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Human Health Risk Assessment

Assessment of risk is very important because it has to do with the 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 (Wongsasuluk et al. 2014). The target hazard quotient was used to assess the non-carcinogenic risk while the Incremental Lifetime Cancer Risk (ILCR) was used to evaluate the carcinogenic risk. In the present study, THQ (non-carcinogenic) values ranged from 0.05 (Zn) - 0.31 (Cr). The values of THQ (non-carcinogenic) in the present study were all <1 suggesting low risk of exposure for consumers of bivalves. Researchers have reported that THQ >1 potent risk of non-carcinogenic effect to consumers of such sea-foods (Abdou and Hassan 2014; Moslen and Miebaka 2018). However, Khan et al. (2009) stated that THQ builds some degree of alarm for carelessness but does not assess risk regarding exposure to contaminants. Denil et al. (2017) had reported THQ values comparable to that of the present study in various clams: Cd: 0.04 - 0.44; Cu: 0.03 - 0.05; Ni: 0.02 -0.05; Pb: 

Health risk assessment of consuming heavy metal contaminated benthic seafood, Anadara (Senilia) senilis in the southern region of Nigeria.
0.03 - 0.13; Zn: 0.02 - 0.51. Yap et al. (2018) also reported similar THQ values in Anadara granosa as follows Cu (0.002 - 3.53), Cd (0.0 - 0.96), Zn (0.002 - 0.075). Dee et al. (2019) also found THQ for Cd, Cu, Mn, Pb, and Zn as 0.12, 0.06, 0.04, 0.41, and 0.03, respectively.

The ILCR (hazard quotient carcinogenic) of this study had values in the range of 10^{-5}-10^{-2}. The ILCR is defined as the incremental probability of a person developing any type of cancer over a lifetime as a result of twenty-four hours per day exposure to a given daily amount of a carcinogenic element for seventy years (Grzetic and Ghariani 2008). The ILCR values of Ni and Cd in this study were within acceptable limits of 10^{-4} and 10^{-6} but those of Cr (10^{1}) and Pb (10^{3}) exceeded the safe limits and calls for concerns of health risk for consumers of bivalve in southern Nigeria. The permissible limits are considered to be 10^{0} and <10^{-4} for a single carcinogenic element and multi-element carcinogens (Teplanosyan et al. 2017). This however varies from region to region. Excess lifetime cancer risk of ≥10^{-6} has been consistently considered insignificant and ≥10^{-4} as significant, where actions are usually taken in order to reduce risk when cancer risk falls within the latter group (Mana et al. 2013). The hazard quotient (carcinogenic) of the present study is above that (2.24x10^{-7}) observed by (Tongo and Ezemonye, 2018) for seven different metals in fish from the Niger Delta Region of Nigeria.

Metals in the environment may not act in isolation. The sum of the THQ (hazard index - HI) was calculated to indicate the total potential non-carcinogenic health impacts that could result from exposure to a mixture of heavy metals in bivalves consumed, following EPA guidelines for health risk assessment (Huang et al. 2008; Bamuwamye et al. 2015). The HI value (0.86) of the present study was <1 depicting low risk but caution and action is advised to reduce risk of exposure for consumers of bivalves due to the possibility or potency of increase in HI value. The HI value of the present study is less than that (1.60 - 5.06) reported by (Denil et al. 2017) for four different clams but agrees with that (0.64) in fish and shrimp (0.52) found in the Niger Delta region (Moslen and Miebaka 2017b). Tongo and Ezemonye (2018) reported HI value (1.6) above that of the present study but Dee et al. (2019) reported HI value of 0.61 which is less than 1 and considered it as a safe consumption level, which also agrees with the finding of the present study. The percentage make-up of the HI was in the order Cr>Cd>Pb>Zn>Ni>Cu indicating the elevated input of Cr, Cd and Pb concentrations in the bivalves examined.

According to the USEPA’s screening level of chemical pollutants, oral exposure to Pb, Cr, As and Cd through consumption of certain seafood may raise the carcinogenic risk (Yuana et al. 2019). The target cancer risk (TR) values of this study ranged from 0.015 x10^{-3} - 1.58 x10^{-3} (10^{-3}) indicating moderate to high values. This is comparable to carcinogenic risk (CR) values of Cr (5.74x10^{-5} - 1.73x10^{-3}) and As (1.65x10^{-4} - 1.45x10^{-3}) but higher than that Cd (1.33x10^{-5} - 8.38x10^{-6}) reported by Yuana et al. (2019). The TR value of this study also compares with that (2.63 x 10^{-3}) reported in Ni by Moslen and Miebaka (2017b) which indicated moderate to high condition compared to the range issued by NYSDOH (2007). According to NYSDOH (2007), the TR categories are described as, if TR ≤ 10^{-6} = Low; 10^{-4} to 10^{-3} = moderate; 10^{-3} to 10^{-1} = high; ≥10^{-1} = very high. This is not an absolute value but suggests an upper limit of likelihood in which exposure may predispose consumers to cancer once in a lifetime. Markmanuela and Horsefall Jrn (2016) reported average values of target cancer risk (TR) for Cd and Ni as is 2.9 x 10^{-3} and 1.2 x 10^{-2} and stated that these values were higher than the acceptable limits of 10^{-4} – 10^{-4}. (USEPA, 2011)

CONCLUSION

The contamination, accumulation and toxicity of heavy metals in the environment remains a major global health risk of concern and require regular observations. This study was conducted to examine health risk exposure to heavy metals by consumers of bivalves (Anadara Senilia senilis) in southern Nigeria. The findings further consolidate known health risks of metals like Ni and Cd particularly for ecological exposure pathways but most importantly fill data and information gap for further research and policy decision making. Assessment of bioaccumulation gave values below and above respective recommended limits for metals examined. Dietary intakes (EDI) were below reference oral doses (RFD) while the target hazard quotient (non-carcinogenic) was also below the reference value of one (1) but hazard index implicated the heavy metals via synergistic/antagonistic reactions. Evaluation of carcinogenic health risk further implicated Cr and Pb in the samples examined with respect to consumption. The study, therefore concluded that consumers of bivalves contaminated with heavy metals within southern Nigeria are exposed to moderate to high health risk. Caution on consumption and action is advised but regular monitoring is necessary to continue to observe fluctuations.

ACKNOWLEDGEMENT

We wish to acknowledge the effort of Mr. G. Ogbe for sample map production and Dr. A Aigberua during sample analysis

Compliance with Ethical Standards and Declarations

Funding: Not applicable. No funding or grant was received for this work. It was solely funded by authors
Conflict of Interest: The following authors of this manuscript; Dr. M. MOSLEN, Dr (Mrs) C. A. MIEBAKA and Ms R. BRAIDE hereby declare that there is NO CONFLICT OF INTEREST concerning this manuscript.

Ethical approval: This research was approved by the academic board of the Department of Animal and Environmental Biology, Rivers State University, Port Harcourt, Nigeria.

Informed Consent: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors therefore, give their total/informed consent for the publication of this manuscript.

REFERENCE


arsenic (III) and chromium (VI) on nuclear transcription factor binding. *Molecular Carcinogenesis*, 25, 219-229.


Yuana, Y., Suna, T., Wang, H., Liua, Y., Pana, Y., Xiea, Y., Huang, H., & Fana, Z. (2019). Bioaccumulation and health risk assessment of heavy metals to bivalve species in Daya Bay (South China Sea): Consumption...


Accepted 30 September 2020


Copyright: © 2020 Miebaka et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are cited.