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Hazard Indices and Human Health Risks Associated with Toxic Element Contaminants in Bivalve Shellfish from Niger Delta, Nigeria

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Abstract

The quality of coastal waters in Niger delta have increasingly and adversely impacted by varieties of contaminants occasioned by environmental degradation and aquatic perturbation posed by petroleum exploration activities. This tends to undermine nutritional and health benefits derived from consumption of shellfish harvested from these waters. This study investigated tissue burden, hazard indices and human health risks associated with toxic element contaminants in bivalve shellfish harvested from coastal waters of Niger delta. Four species of bivalve shellfish; bloody cockle (*Anadara senilis*), donax clam (*Donax rugosus*), knife clam (*Tagelus adansonaii*) and mangrove oyster (*Crassosstra gasar*) collected from four locations were assessed for levels of toxic element contaminants as well as hazard indices and human health risk associated with their consumption. The tissue burden of toxic element contaminants was determined using atomic absorption spectrometer while United State Environmental Protection Agency (US EPA) method was employed to estimate hazard indices and human health risk. Results indicated lead concentrations were within the 1.5mg/kg acceptable limits while levels of cadmium, arsenic and mercury were higher than FAO limits of 0.5, 0, 0.5 mg/kg respectively. The estimated human health risk indicated non-carcinogenic values and hazard indices higher than threshold value of one for cadmium, total arsenic and methyl mercury while values for inorganic arsenic at some locations were higher than stipulated one in one million ($1.0x10^{-6}$) chances. This implies that toxic elements apart from lead in bivalves shellfish from these locations can induce potential deleterious health effects at consumption of 48g/day of bivalve shellfish.

1. Introduction

Food contamination by chemical contaminants have continued to be a subject of serious concern to researchers globally particularly due to their harmful effects on human body. Among the chemical contaminants are toxic elements which constitutes food safety risk because of their poor rate of metabolism, potential to bioaccumulate in aquatic ecosystems resulting from their non-biodegradable nature and long biological half-lives **(Censi *et al.*, 2006)**. Although some toxic elements occur naturally in the environment, anthropogenic inputs which originate from various human activities have continued to increase their concentrations **(Sarkar *et al.*, 2008; Giri *et al.*, 2015)**. Also, increased coastal population, rapid urbanization, oil and gas production, artisanal petroleum refining, oil spillage, tourism development, heavy rainfall throughout, and other economic activities have created numerous environmental and ecological problems in the Niger delta coastal areas **(Ukwo *et al.*, 2019)**.

Marine bivalve shellfish such as clams, mangrove oyster, cockles and other benthic filter feeders organisms are found on the mangrove mudflats, intertidal sandy beaches and the estuarine waters of the Niger delta. Bivalve shellfish are usually exploited by adult female and youth of these coastal communities **(Udotong *et al.*, 2017)**. Bivalve shellfish and other seafood products are currently the cheapest source of animal protein consumed by the average Niger delta and it accounted for about 50% of the total protein intake. Bivalve shellfish are also economically and nutritionally very important for human consumption, and particularly playing a central role in the Niger delta gastronomy. Apart from forming greater part of diet to the coastal population, bivalve shellfish constitute both traditional and primary source of enterprise and livelihood to most population of these communities **(Ukwo *et al.*, 2019)**. Seafood including bivalve shellfish have always contained certain amounts of toxic elements as a consequence of their habitat. In open seas, unaffected by pollution, bivalves mostly carries just the natural burden of toxic elements content. However, in polluted areas which have no sufficient exchange with the world oceans, in estuaries, in rivers and especially in places which are close to sites of industrial activities, the concentrations of toxic elements usually exceed the natural load **(Oehlenschläger, 2002)**. Most species of bivalve shellfish consumed in Nigeria are harvested from the brackish water that is exposed to varying amounts of chemical and environmental contaminants such as industrial chemicals, toxic residues from various anthropogenic

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activities. In the Niger delta region of Nigeria, pollution of the coastal waters has continued to attract greater attention. This is due to the high level of environmental degradation posed by petroleum production and exploitation along the coastline **(Wala *et al.*, 2016; Zabbey and Babantunde, 2015)**. Petroleum hydrocarbon from oils spills and human-mediated activities are usually incorporated into sediments where they can persist for years gradually releasing toxic substances into the immediate and remote environments **(Zabbey and Babatunde, 2015)**.

According to **Amnesty International (2018)** reports, Niger Delta region is the most recognized oil-producing region in Africa. It is also known to be the most polluted area on earth. The prevailing widespread pollution has severally impacted negatively on the food product especially seafood obtained from the coastal waters of this area. Also, the filtration nature of bivalves has led to accumulation of high amounts of some toxic elements, usually at higher concentrations than in what is obtained in the sediment making a bivalve a better indicator and thus, easily reaching toxic concentrations to themselves and their consumers **(Figueira *et al.*, 2011)**. Because the above stated reasons, levels of toxic elements in bivalve shellfish are of serious public health concerns, therefore the European Commission and other regulated bodies have set Maximum Permissible Limits (MPLs) for toxic elements in edible tissues of bivalve molluscs **(EC, 2006)**.

Some of the deleterious effects associated with dietary intake of these contaminants include diarrhea and gastrointestinal disorders, immune suppression, neurological disorder, reproductive impairment, developmental retardation, cardiovascular disorder, liver disease, infertility and miscarriage **(ASTDR, 2002; Ukwo *et al.*, 2019)**. The groups most vulnerable to dietary exposure of the contaminants are child-bearing women, children below twelve years, and subsistence fish farmers **(FAO/WHO, 2011)**.

For better understanding and characterization of the risk presented by chemical toxins in the environment to human and ecological receptors, most researchers used benthic organisms such as bivalve shellfish as bio monitors of the levels and long-term influences of chemical toxins within the ecosystem These circumstances make them important sources of food borne diseases which represent a significant health risk to consumers **(Sarkar *et al.*, 2008)**. The objectives of the present study are to determine the levels of toxic elements accumulated by bivalve shellfish harvested from the coastal waters of the Niger delta as well as estimate hazard indices and human health risk associated with toxic element contaminants in bivalve shellfish consumed in Niger delta. This study will assess their suitability for human consumption and provide baseline information on the quality and safety of fresh bivalve shellfish obtained from these coastal locations. The study will also quantify the potential human risk associated with bivalve shellfish consumption in the Niger delta.

2. Material and methods

2.1 Study Location

The location is a stretch of Atlantic coastline in the Niger Delta region of Nigeria. The Niger Delta sustains Africa's largest, and the world's third mangrove forest, bearing not only Nigeria's most abundant petroleum resources, but also diversified ecosystems, with numerous aquatic and terrestrial organisms **(Okonkwo *et al.*, 2015)**. Four locations along the Atlantic coastline of Niger Delta were chosen for this study: Andoni ($4^{0}28'$ - $4^{0}45'$ and $7^{0}22'$-$7^{0}23$), Bonny ($4^{o}23$`- $4^{o}25$` and $7^{0}05'$-$7^{0}15'$), Ibeno ($4^{o}56'$ -$4^{o}57$` and 8^{o} 07' - $8^{o}15'$) and Iko Town ($4^{o}20'$ – $4^{o}35'$ and $7^{o}40'$ - $7^{o}50'$). Bonny and Andoni are located in Rivers State while Iko Town and Ibeno are located in Akwa Ibom State both in the Niger Delta region of Nigeria (Fig 1). The locations were chosen because of their accessibility and availability of the four (4) species of bivalve molluscs and also the fact that they served as important delicacy and food for indigenous people. They also served as an important source of income and employment for the people in these communities. The locations are essentially estuarine in nature with brackish water characterized by fine sandy beaches surrounded with mangrove swamp and intertidal mudflat in which Nypa vegetation dominate. The area is also naturally endowed with abundance of rivers, creeks and streams which received water and waste from the interland into the Atlantic Ocean. Also, this coastal environment has continued to suffer from environmental degradation occasioned by exploration and production of petroleum, liquefied natural gas production and spillage of petroleum products.

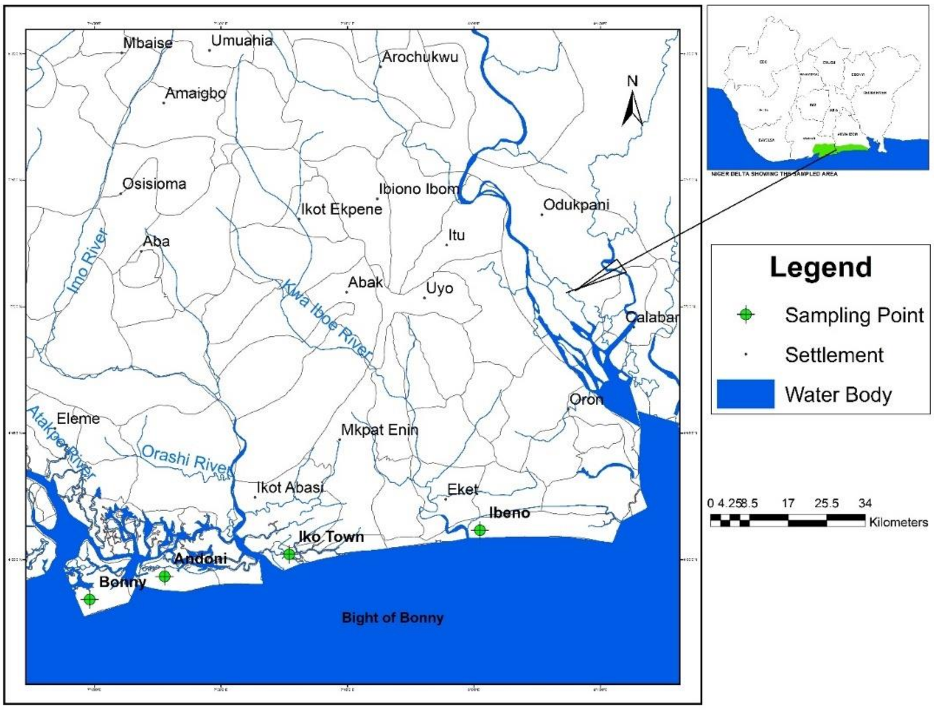

Figure 1. Section of Niger Delta coastal area showing the sampling locations along the Atlantic coastline. Insert Map: of the Niger Delta showing the study location

2.2 Sample Collection and Treatment

Fresh bivalve specimens mostly consumed in these localities were harvested manually by fishermen during low tide from intertidal estuarine mudflats of the different study locations. The bivalve specimens collected were, Bloody cockle (*Anadara senilis*), Donax clam (*Donax rugosus*), Knife or Razor clam (*Tagelus adansonii*) and Mangrove oyster (*Crassosstrea gasar*). They were identified at the Department of Fisheries and Aquatic Environmental Management, University of Uyo. At each sampling site, twenty (20) species of each bivalve specimens were collected and transferred to the laboratory within 24 hours of collection in plastic containers washed with 5% nitric acid and rinsed with distilled water before use. The traditional method of preparing bivalve for consumption was used in this study. At the laboratory, the bivalves were promptly cleaned of incrustations, washed in distilled water to remove all dirt, put into a stainless pot, and blanched for 5 minutes at 100°C. After blanching, the samples were poured into a perforated basket to drain and allowed to cool at room temperature (28±2°C). Samples were then shucked with sterile scalpel to extract the flesh into a sterile container. The extracted tissues were homogenized for 60s in a stomacher (Seward Laboratory Stomacher 400, England) and stored at -20°C in a scanfrost deep freezer for various experimental assays.

2.3 Analysis for Toxic Element Contaminants of Bivalve Shellfish

The levels of toxic element present in the bivalve samples were determined using a perkin – Elmer model 3030 Atomic Absorption spectrophotometer (AAS) at their respective lamp and wavelength. Standard stock solution of the element to be analysed were prepared, diluted to the corresponding working standard solution for recovery experiment according to the methods as outlined by **Onwuka (2018)**. The wet ashing method as outlined by **Onwuka (2018)** was used to determine the concentration of toxic element in the bivalve samples. The method of preparation and digestion procedure as outlined by **AOAC (2010)** for biological sample was also employed.

2.4 Human Health Risk Assessment Procedure

Assessment of human health risk for ingesting bivalve shellfish with toxic elements contaminants were determined based on methods outlined by **US EPA (2000)**. The non-carcinogenic risk due to consumption of chemical contaminants were determined using target hazard quotient (THQ) values as shown in the equation below:
Firstly, the level of exposure resulting from consumption of toxic element contaminants in bivalve samples can be expressed by estimating the daily intake levels.

$$EDI = \frac{C\ x\ IR\ x\ EF\ x\ ED}{BW\ x\ AT.}$$

Where
EDI = Estimated Daily Intake (mg/kg – day)
IR = Ingestion rate of Bivalve (kg/day)
C = Concentration of chemical contaminant in bivalve tissue (mg/kg)
EF = Exposure Frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Average time (days)

Risk for both carcinogenic and non-carcinogenic chemicals were calculated in this study and the above equation was used as the intake equation. The non-carcinogenic risk due to consumption of toxic element contaminants were then determined using target hazard quotient values (THQ).

$$THQ = \frac{EDI}{RfD}$$

Where:
THQ = Non-carcinogenic risk value of chemicals contaminants.
EDI = Estimated daily Intake or exposure rate (mg/kg –day)
RfD = Reference dose of chemical (mg/kg – day)

Secondly, Carcinogenic risk is express as a product of EDI and cancer potency value or cancer slope factor (CSf) and the following equation was used to estimate lifetime risk of cancer.

Risk = EDI* CSf

Where: Risk = Lifetime cancer risk
EDI = Estimated Daily Intake mg/kg-day
CSf = cancer slope factor mg/kg-day

The calculations were made using the standard assumptions for an integrated USEPA risk analysis **(US EPA 2009)**. For the purpose of this study, the intake rate of fish (IR) was assumed to be 48g/person per day (FAO 2017), average body weight of exposed individual (70kg), exposure frequency(365day/year) while duration of exposure was taken to be an average life expectancy of a Nigerian (55.20years) as reported by **WHO, (2018)**. The length of time for average does was calculated as 365days x 55.20 years. It was also assumed that ingested doses were equal to absorbed contaminants doses. For calculation of Target Hazard Quotient (THQ) for toxic elements, the following reference dose (RfD) as listed by **US EPA (2009)** were used for the respective elements; Pb = $3.6x10^{-3}$mg/kg-day, Cd = 1.0×10^{-3}mg/kg-day, total arsenic = 3.0×10^{-4}mg/kg-day and Hg = 1.0×10^{-4} mg/kg-day as methyl mercury (meHg). The hazard index (HI) is the sum of total hazard quotients; (HI = ΣTHQ). Carcinogenic risk is express as a product of EDI and cancer potency value or cancer slope factor (CSf) and the following equation was used to estimate life time risk of cancer. The carcinogenic risk value for inorganic arsenic was determined using the cancer slope factor (CSf) of 1.5mg/kg-day

2.5 Data Analysis

All the analyses were carried out in triplicate and data obtained from laboratory analyses were subjected to two-way analysis of Variance (ANOVA) to evaluate the effect of location and species on bivalve molluscs. Level of significance was set at $P<0.05$. Means with significantly difference were separated using Ducan-multiple Range Test. All experiments were conducted in triplicate and data were analysed using XLSTAT – Pro software program, Addinsoft, Boston (USA) Version 2018.7.

3. Results and Discussion

3.1 Toxic elements

The toxic elements content of bivalve shellfish species is presented in Table 1 and Figure 2. Results indicated significant differences ($p< 0.05$) in lead, cadmium, arsenic and mercury content across species and locations. The highest lead concentration of 1.68 mg/kg was recorded at Bonny location while the lowest value of 0.25 mg/kg was recorded at Iko Town in mangrove oyster. Analysis for cadmium indicated a concentration of 4.24 mg/kg in mangrove oyster at Iko Town was the highest and was closely followed by knife clam with 3.74 mg/kg at Ibeno location. The highest concentrations of arsenic and mercury were recorded at Bonny location with 2.05mg/kg for arsenic while 1.34 mg/kg of mercury in knife clam at the same location. The total concentrations of toxic elements accumulated by bivalve shellfish in each sampling location are shown in Fig. 2. It indicated that bivalve shellfish samples from Bonny location had the highest toxic element accumulation and was closely followed by samples from Ibeno while samples from Andoni and Iko Town had relatively lower toxic element concentrations. The concentrations and levels of accumulation of toxic elements by bivalve samples in this study clearly revealed that bivalve shellfish are differentially selective for a range of toxic element and these variations might be influenced by a number of intrinsic (e.g. size, age, and sex) and extrinsic factors (e.g. metal speciation, Temperature and salinity). Also, the concentration of toxic elements in the tissue of marine invertebrates depends on the accumulation strategy adopted by each bivalve shellfish for each element **(Sarkar *et al.*, 2008)**. This strategy results from net differences between rate of absorption and excretion of elements, the permeability of the body surface, and the nature of the food and the efficiency of the osmo regulatory system present **(Benson *et al.,* 2017)**.

Table 1. Effect of location and species on Toxic metal content of bivalve (mg/kg)

Location	Species	Lead (Pb)	Cadmium (Cd)	Arsenic (As)	Mercury (Hg)
Andoni	Cockle	1.43±0.05^{bc}	1.40±0.47^{f}	0.85±0.12^{d}	0.61±0.10^{b}
	Donax clam	1.25±0.04^{d}	1.68±0.07^{ef}	0.40±0.02^{f}	0.53±0.03^{bc}
	Knife clam	0.63±0.09^{f}	2.04±0.16^{de}	0.12±0.05^{g}	1.19±0.02^{a}
	Oyster	1.04±0.15^{e}	0.78±0.08^{g}	0.82±0.02^{d}	0.58±0.06^{b}
Bonny	Cockle	1.54±0.07^{ab}	2.48±0.02^{c}	1.41±0.11^{c}	0.66±0.12^{b}
	Donax clam	1.63±0.06^{a}	1.37±0.05^{f}	2.05±0.09^{a}	0.52±0.02^{bc}
	Knife clam	0.98±0.05^{e}	2.25±0.07^{cd}	1.63±0.05^{b}	1.33±0.07^{a}
	Oyster	1.68±0.13^{a}	1.78±0.09^{ef}	1.56±0.03^{b}	1.34±0.02^{a}
Ibeno	Cockle	1.33±0.04^{cd}	0.60±0.22^{g}	1.40±0.02^{c}	0.11±0.10^{d}
	Donax clam	0.99±0.10^{e}	2.60±0.41^{c}	0.83±0.09^{d}	0.59±0.08^{b}
	Knife clam	1.24±0.04^{d}	3.74±0.38^{b}	0.66±0.17^{e}	0.66±0.36^{b}
	Oyster	0.45±0.08g	3.50±0.33^{b}	0.83±0.08d	0.38±0.12^{c}
Iko Town	Cockle	0.18±0.03^{h}	0.80±0.09^{g}	0.05±0.01^{g}	0.00±0.00^{d}
	Donax clam	0.94±0.02^{e}	1.75±0.07^{ef}	0.01±0.00^{g}	0.01±0.00^{d}
	Knife clam	0.51±0.08^{fg}	2.53±0.15^{c}	0.07±0.01^{g}	0.13±0.01^{d}
	Oyster	0.25±0.07^{h}	4.24±0.15^{a}	0.01±0.01^{g}	0.07±0.01^{d}

Means with different superscripts along the same column are significantly different (Duncan's test) p<0.05
Values are means ± standard deviation of triplicate samples

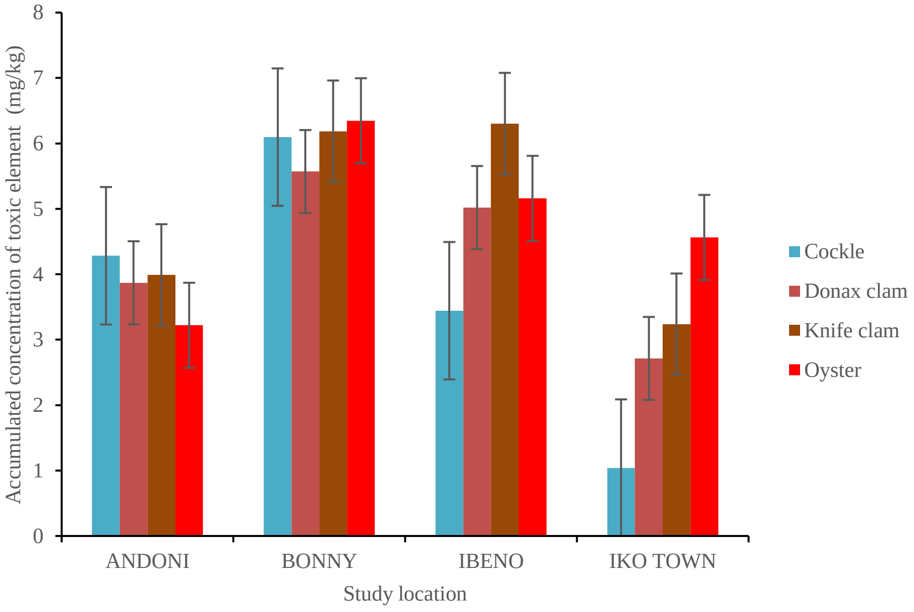

Figure 2. Accumulated toxic element concentrations in bivalve species from study locations

Bivalve molluscs have been extensively used as a model organism in environmental studies of water quality and biomonitoring agent hence the results from this study reflects the level of contamination of the Niger Delta environment as well as the safety of bivalve molluscs consumed in this area. According to **FAO (2003)**, and **EC (2008)**, regulations, lead concentration above acceptable limits 1.5mg/kg in bivalve tissue is unacceptable and can pose health risk to the consumers. Cadmium concentration above legal limits of 1.0 mg/kg and mercury above 0.5 mg/kg as well as the present of arsenic in the tissue of bivalve shellfish is dangerous to the health of the consumers. Therefore, the consumption of bivalve shellfish from the some of these locations would constitute a health risk because the concentrations of cadmium, arsenic and mercury above their safety limits. The concentration of toxic elements in the tissue of bivalve molluscs from this study were higher when compared to values reported by **Onwuteaka *et al.,* (2015)** at B/Dere in Ogoni land but lower than values reported by **Benson *et al.,* (2017)** at Qua Iboe estuary both in the Niger Delta region of Nigeria. The values are also lower when compared with the values reported by **Sarkar *et al.,* (2008)**, in bivalve shellfish at Sunderban mangrove Wetland at Bay of Bengal in India. Toxic elements are assimilated, stored, and concentrated by living organisms through food chain causing serious toxic effect to humans **(Giri and Singh, 2015)**. The toxicity of those elements is due to their ability to replace other metals in the active sites of enzymes, form complexes and precipitates with enzyme metals or other groups involve in metabolism, catalyzes the breakdown of essential metabolites as well as combined with membranes, thereby altering their permeability and hindering other elements in their electrochemical functions **(Burger and Gochfield, 2005, Oehlenschlager, 2002 and FAO, 2003)**.

For instance, lead and cadmium interact with essential elements such as zinc, iron, calcium and copper exerting an inhibitory effect on the activity of enzymes containing these mineral elements. This results in growth failure, improved nutrients tolerance, poor metabolism and absorption of these elements, reduction in plasma ceruloplasmic concentration among others **(Goyer and Clarkson, 2001 and Carvalho *et al*., 2005)**. Considering the study locations, samples from Bonny and Ibeno recorded higher accumulation of toxic elements (Fig. 2). This could be attributed the high population and industrial activities in these areas. Bonny hosts the Liquefied Natural Gas (LNG) Company, and Forcados terminal of Shell petroleum Development Company while Ibeno is a home to Mobile producing Nigeria Unlimited and other subsidiary companies. The discharged effluents alongside the activities such as artisanal refining of petroleum product and pipeline vandalization has negatively affected the environment resulting in elevated toxic element concentrations in seafood harvested from these locations raising serious concern about their safety for human consumption.

3.2 Non-Carcinogenic Risk of toxic elements

The estimated non-carcinogenic risk value or target hazard quotient (THQ) and hazard index (HI) are presented in Table 2 and Fig. 3. respectively. The non-carcinogenic risk values for lead indicated values ranging from 0.03 – 0.32. The values of THQ obtained for lead were less than the threshold limit of one. The non-carcinogenic risk values for cadmium ranged from 0.55-2.91, total arsenic ranged from 0.02-4.68 and methyl mercury ranged from 0.01-9.17. The non-carcinogenic values for total arsenic and methyl mercury at Iko Town were below the threshold limit of one while the non-carcinogenic values for cadmium, total arsenic and methyl mercury at Ibeno, Bonny and Andoni were above the threshold limit of one. Hazard index for toxic elements as shown in Fig. 3 were higher than the threshold limit of one except for bloody cockle harvested from Iko town. Also values for hazard index were highest in knife clam and mangrove oyster harvested from Bonny location.

The estimated non carcinogenic risk values were determined on the basis of the reference dose (RfD) for toxic elements as proposed by **US EPA (2009)**. According to **Saha and Zaman (2013)**, the RfD values represent the estimated daily exposure to which human population may continually be exposed over a life time without any appreciable health risk. The results for lead as obtained in this study is in agreement with reports of **Markmanuel and Horsfall (2015)**, **Archibong *et al* (2017)**, and **Udousoro *et al.,* (2018)**. According to **Uche *et al* (2017)**, whenever the non-carcinogenic risk value exceeded one, the estimated daily intake is relatively higher or more than the RfD. The estimated risk value for lead in this study is an indication that consumption of bivalve shellfish from the studied location would not likely increased health risk unrelated to cancer. However, excess consumption above 48g/day may likely result in eventual bioaccumulation and bioconcentration of lead which may result in serious deleterious health effects. The estimated non carcinogenic risk values for lead were less than the threshold limit of one indicating that consumers are unlikely to experience any significant health risk from lead through consumption of bivalve shellfish contaminated with lead in the Niger delta. The non-carcinogenic risk values for cadmium ranged from 0.55-2.91, total arsenic ranged from 0.02-4.68 and methyl mercury ranged from 0.01-9.17. The non-carcinogenic values for total arsenic and methyl mercury at Iko Town were below the threshold limit of one while the non-carcinogenic values for cadmium, total arsenic and methyl mercury at Ibeno, Bonny and Andoni were above the threshold limit of one which is similar to values reported by **Udousoro *et al.,* (2018)** in Periwinkle species from Ishiet and Ibeno coastal waters in Akwa Ibom State, Nigeria. Also, the non-carcinogenic values for methyl mercury and total arsenic were similar to values reported by **Archibong *et al* (2017)** on different fish species from Choba, Rivers state in the Niger Delta and **Lushenko (2010)** at the Imperial Beach, California. When the non-carcinogenic value is above the threshold value of one, there is likelihood of adverse health effects developing due to exposure to cadmium, total arsenic and methyl mercury at the oral ingestion of 48g/day of bivalve samples. According to **Khoshnood *et al.,* (2014)**, the higher the non-carcinogenic risk value the higher the probability of risk on human body would be. Therefore, with the risk value of total arsenic and methyl mercury above 4 and 9 respectively is an indication that there is a greater risk for non-carcinogenic health effects for consumers of bivalve shellfish from the studied locations and this is a called for serious concern. A hazard index (HI) is the total chronic hazard attributable to exposure to all non-carcinogenic contaminants through the consumption of bivalve shellfish from the studied locations. It is calculated by summation of non-carcinogenic risk value for each species. There is no doubt that toxic elements such as Pb, Cd, As and Hg are present throughout the environment whether through natural or anthropogenic means and as long as the levels of these elements are continually increased due to pollution in the Niger Delta, and with the consumption of bivalve shellfish and other available exposure route in these coastal locations continuing unabated there is a likelihood of an adverse health effects considering values from the estimated non-carcinogenic values and hazard index calculated for toxic elements in this study. The higher levels of hazard indices for some element especially As and Hg could be attributed to various forms of anthropogenic activities such as environmental pollution occasioned by oil and gas exploitation, oil spillage and artisanal refining of petroleum product in these locations.

Table 2. Non-carcinogenic risk value of toxic elements in bivalves species

Location	**Species**	**Lead (Pb)**	**Cadmium (Cd)**	**Total arsenic (As)**	**Methylmercury (MeHg)**
Andoni	Bloody Cockle	0.27	1.00	1.94	4.21
	Donax clam	0.24	1.15	0.92	3.63
	Knife clam	0.12	1.40	0.28	8.18
	Mangrove oyster	0.20	1.01	1.87	3.98
Bonny	Bloody Cockle	0.29	1.70	3.23	4.50
	Donax clam	0.31	1.00	4.68	3.57
	Knife clam	0.19	1.54	3.73	9.10
	Mangrove oyster	0.32	1.22	3.56	9.17
Ibeno	Bloody Cockle	0.25	0.41	3.19	0.75
	Donax clam	0.19	1.78	1.90	4.07
	Knife clam	0.24	2.56	1.52	4.50
	Mangrove oyster	0.09	2.40	1.89	2.61
Iko Town	Bloody Cockle	0.03	0.55	0.11	0.01
	Donax clam	0.18	1.20	0.02	0.07
	Knife clam	0.10	1.73	0.17	0.89
	Mangrove oyster	0.05	2.91	0.02	0.46

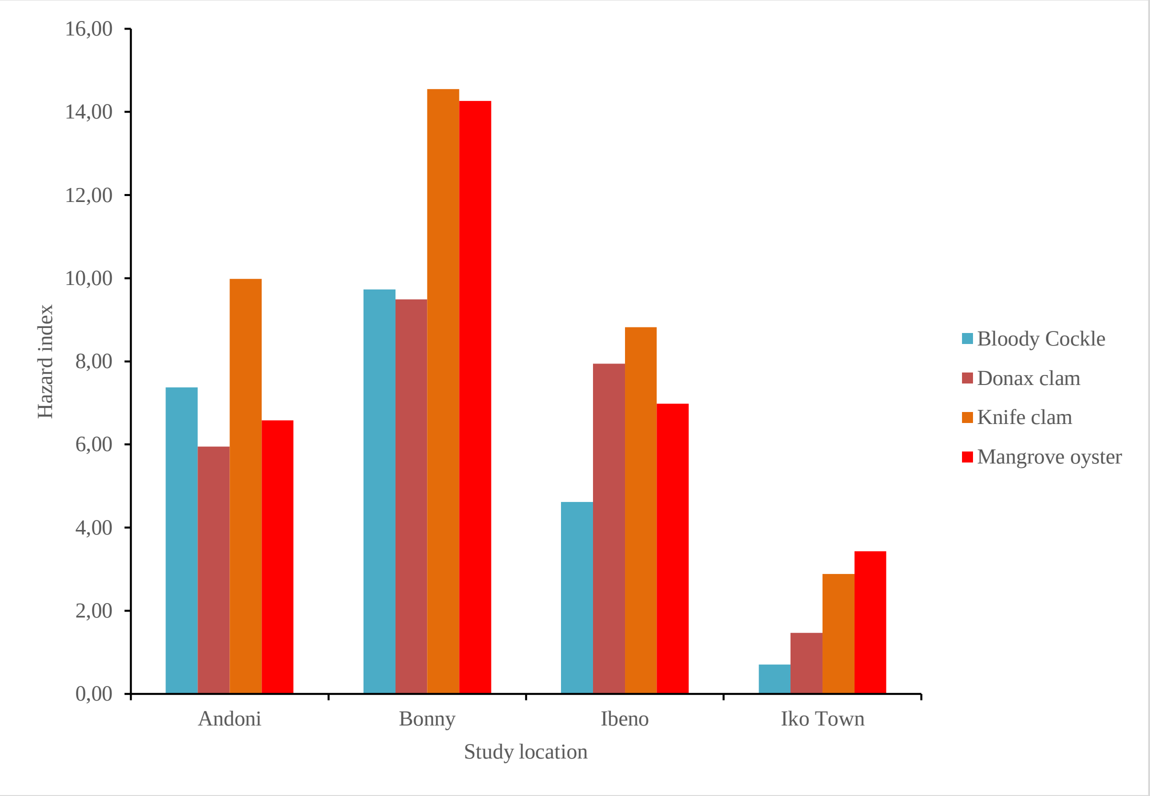

Figure 3. Hazard index of toxic elements in bivalve shellfish species

3.3 Carcinogenic Risk of toxic elements

The carcinogenic risk value or lifetime cancer risk for inorganic arsenic as presented in Table 3. indicated a cancer risk index higher than the acceptable limit of 1.0×10^{-6} in Andoni, Bonny and Ibeno when exposed to 48g/day of bivalve. Results showed that bivalve consumers from Bonny had the highest risk to the extent that 1 to 2 consumers in every 10,000 were likely to experience cancer related health conditions as a result of exposure to inorganic arsenic during their lifetime while consuming bivalve shellfish. Particularly, consumers from Andoni and Ibeno were also at a higher lifetime cancer risk ranging from 1 to 8 in every 100,000 people consuming bivalve shellfish due to their exposure to inorganic arsenic through consumption of contaminated bivalve shellfish. The carcinogenic risk index for bivalve consumers in Iko Town were within the expected limit.

Bonny, Andoni and Ibeno locations are host to multinational oil and gas industries which engaged in several forms of oil and gas explorations. These locations also experienced oil spillage and gas flaring which continually exposed these estuaries and coastal waters to various form of pollutions which may account for the results obtained in this study

Table 3. Carcinogenic risk value for toxic elements during bivalve consumption

Location	Species	Inorganic Arsenic	Risk Value
Andoni	Bloody Cockle	8.47E-02	8.71E-05
	Donax clam	4.03E-02	4.15E-05
	Knife clam	1.23E-02	1.27E-05
	Mangrove oyster	8.20E-02	8.43E-05
Bonny	Bloody Cockle	1.41E-01	1.45E-04
	Donax clam	2.05E-01	2.11E-04
	Knife clam	1.63E-01	1.68E-04
	Mangrove oyster	1.56E-01	1.60E-04
Ibeno	Bloody Cockle	1.40E-01	1.44E-04
	Donax clam	8.33E-02	8.57E-05
	Knife clam	6.63E-02	6.82E-05
	Mangrove oyster	8.27E-02	8.50E-05
Iko Town	Bloody Cockle	5.00E-03	5.14E-06
	Donax clam	1.00E-03	1.03E-06
	Knife clam	7.33E-03	7.54E-06
	Mangrove oyster	1.00E-03	1.03E-06

4. Conclusion

The present study confirms the occurrence and variability in the levels of toxic elements contaminants in the bivalve shellfish consumed by the coastal populations of the Niger Delta, Nigeria. Results provided qualitative information on the pollution status of lead (Pb), cadmium (Cd), arsenic (As) and mercury (Hg) in the coastal waters of the study locations. Available assessments indicated that anthropogenic activities such as petrochemical operations, fuel combustion, oil spillage, and artisanal crude oil refining are very likely sources of toxic elements burden in the bivalve shellfish. Results from analysis of bivalve shellfish for toxic element concentrations and level of accumulation by bivalve shellfish revealed that bivalve shellfish are differentially selective for a range of toxic element and their concentration depends on the accumulation strategy adopted by each species for a particular element. Lead concentration was within the acceptable FAO limit of 1.5mg/kg while cadmium, arsenic and mercury were above their acceptable standards in shellfish which are likely to pose potential health risk to consumers. The estimated values for hazard indices and human health revealed a non-carcinogenic value and hazard index of less than one for lead while values for cadmium, total arsenic methyl mercury in Andoni, Bonny and Ibeno were higher than the threshold value of one indicating that consumers are not likely to experience any significant health risk through the consumption of 48g/day of bivalve samples. However, risk value for carcinogenic inorganic arsenic some study locations were higher than the stipulated one in one million ($1.0x10^{-6}$) chances which implies that carcinogenic effects were more likely due to consumption of 48g/day of bivalve shellfish with this contaminant. There is need for adequate strategies are to be adopted in order to control their presence of these toxic elements so that the possible health hazards to different life forms including man can be prevented also further studies on food safety risk assessment should be extended to more food matrices such as other benthic macrofauna, shrimps, crabs, catfish, sea snails and other important consumable seafood. This will help to generate enough evidence for regulatory and advisory purposes.

Declaration of interest

The authors report no conflicts of interest.

References

1. Amnesty International. (2018). ‘Negligence in the Niger Delta: Decoding SHELL and ENI’s Poor Record on Oil Spills’ (2018), online: https://www.amnesty.ch/de/themen/wirtschaft-und-menschenrechte/fallbeispiele/nigeria/dok/2018/nigeria-fahrlaessigkeit-von-shell-eni/negligence-in-the-niger-delta.pdf
2. AOAC. (2010). Official methods of analysis of Association of Official Analytical Chemist. Washington DC. USA.
3. Archibong, I. E., Okonkwo, C. J., Wegwu, M. O., & Okonkwo, C. J. (2017). Distribution and health risk assessment of selected endocrine disrupting chemicals in two fish species obtained from Choba River in Rivers State, Nigeria. *Bioengineering and Bioscience*, *5*(4), 65-73. https://doi.org/10.13189/bb.2017.050402
4. ASTDR (2002). Agency for Toxic Substances and Disease Registry. Toxicological profile for DDT, DDE, and DDD. Department of Health and Human Services. Atlanta, Georgia, USA. pp. 1-497.
5. Benson, N. U., Anake, W. U., Essien, J. P., Enyong, P., & Olajire, A. A. (2017). Distribution and risk assessment of trace metals in Leptodius exarata, surface water and sediments from Douglas Creek in the Qua Iboe Estuary. *Journal of Taibah University for Science*, *11*(3), 434-449. https://doi.org/10.1016/j.jtusci.2016.08.004
6. Burger, J., & Gochfeld, M. (2005). Heavy metals in commercial fish in New Jersey. *Environmental Research*, *99*(3), 403-412. https://doi.org/10.1016/j.envres.2005.02.001
7. Carvalho, M. L., Santiago, S., & Nunes, M. L. (2005). Assessment of the essential element and heavy metal content of edible fish muscle. *Analytical and Bioanalytical Chemistry*, *382*(2), 426-432. https://doi.org/10.1007/s00216-004-3005-3
8. Censi, P., Spoto, S. E., Saiano, F., Sprovieri, M., Mazzola, S., Nardone, G., Geronimo, S. I. Di., Punturo, R., & Ottonello, D. (2006). Heavy metals in coastal water systems. A case study from the northwestern Gulf of Thailand. *Chemosphere*, *64*(7), 1167-1176. https://doi.org/10.1016/j.chemosphere.2005.11.008
9. EU European Commission. (2006). Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs (consolidated version from 12/12/2014). Off J Eur Union, p. *Off J Eur Union*, L364.
10. EU European Commission. (2008). Commission Regulation (EC) No 629/2008 of 2 July 2008 amending Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs. *JO* L173, pp. 6-9.
11. FAO, (2003). Review of the State of World Aquaculture. Inland Water Resources and Aquaculture Services. FAO Fisheries Circular, 886(Rev2):1-95.
12. FAO/WHO (2011). Food and Agriculture Organization of the United Nations. Report of the Joint FAO/WHO Expert Consultation on the Risk and Benefit of fish consumption. FAO Fisheries and Aquaculture Report No. 978 Rome. 1-63.
13. Figueira, E., Lima, A., Branco, D., Quintino, V., Rodrigues, A. M., & Freitas, R. (2011). Health concerns of consuming cockles (Cerastoderma edule L.) from a low contaminated coastal system. Environment international, 37(5), 965-972. https://doi.org/10.1016/j.envint.2011.03.018
14. Giri, S., & Singh, A. K. (2015). Human health risk and ecological risk assessment of metals in fishes, shrimps and sediment from a tropical river. *International Journal of Environmental Science and Technology*, *12*(7), 2349-2362. https://doi.org/10.1007/s13762-014-0600-5
15. Goyer, R. A., Clarkson, T. W., (2001). Toxic effects of metals. *In*: Casarett and Doull´s Toxicology: The basic science of poisons, C. D.

Klaassen (Ed.), McGraw-Hill, NY USA, pp. 811-867. *JO* L364, pp. 5-24.

16. Khoshnood, R., Jaafarzadeh, N., Khoshnood, Z., Ahmadi, M., & Teymouri, P. (2014). Estimation of target hazard quotients for metals by consumption of fish in the North Coast of the Persian Gulf, Iran. *Journal of advances in environmental health research*, *2*(4), 263-272. https://doi.org/10.22102/JAEHR.2014.40177
17. Lushenko, M. A. (2010). *A Risk Assessment for Ingestion of Toxic Chemicals in Fish from IMPERIAL Beach, California* (Doctoral dissertation, San Diego State University).
18. Markmanuel, D. P., & Horsfall, M. Jnr. (2015). Assessment of Non-carcinogenic Human Health Risk of some Heavy Metals in Land Snails commonly consumed in Bayelsa State, Nigeria. *Research Journal of Chemical Sciences*, *5*(10), 61-66.
19. Oehlenschläger, J., (2002). Identifying heavy metals in fish. In: Safety and quality issues in fish processing H. A. Bremer (Ed.), Woodhead Publishing. Limited, Cambridge, pp. 95-113.
20. Okonkwo, C. N. P., Kumar, L., & Taylor, S. (2015). The Niger Delta wetland ecosystem: What threatens it and why should we protect it?. *African Journal of Environmental Science and Technology*, *9*(5), 451-463. https://doi.org/10.5897/AJEST2014.1841
21. Onwuka, G. I. (2018). *Food Analysis and Instrumentation:Theory and Practice*.2nd Edition. Naphtali Prints, Somolu Lagos, Nigeria. pp 1-100.
22. Onwuteaka, J., Edoghotu, A. J., Friday, U., Wokoma, A. O. F., Bob-Manuel, F. G. (2015). Heavy metals contamination of the sessile bivalve, *Crassostrea gasar* (mangrove oyster) in A^{i} post oil spilled brackish water creek of the Niger Delta, Nigeria. *Annals of Biological Research, 6*(11), 72-77.
23. Saha, N., & Zaman, M. R. (2013). Evaluation of possible health risks of heavy metals by consumption of foodstuffs available in the central market of Rajshahi City, Bangladesh. *Environmental monitoring and assessment*, *185*(5), 3867-3878. https://doi.org/10.1007/s10661-012-2835-2
24. Sarkar, S. K., Cabral, H., Chatterjee, M., Cardoso, I., Bhattacharya, A. K., Satpathy, K. K., & Alam, M. A. (2008). Biomonitoring of heavy metals using the bivalve molluscs in Sunderban mangrove wetland, northeast coast of Bay of Bengal (India): possible risks to human health. *CLEAN–Soil, Air, Water*, *36*(2), 187-194. https://doi.org/10.1002/clen.200700027
25. Uche, A. O., Sikoki, F. D., Babatunde, B. B., Konya, R. S., & Ifeh, M. O. (2017). Assessing Carcinogenic and other Health Risks Associated with Consuming a Food Fish,(Labeo pseudocoubie), from the Niger-Benue/Imo River Systems, Nigeria. *Journal of Fisheries and Livestock Production*, *5*(216). https://doi.org/10.4172/2332-2608.1000216
26. Udotong, J. I. R., Udoudo, U. P., & Udotong, I. R. (2017). Effects of oil and gas exploration and production activities on production and management of seafood in Akwa Ibom State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology*, *9*(3), 20-42. https://doi.org/10.5897/JECE2017.0405
27. Udousoro, I. I., Offiong, N. A. O., & Abraham, E. M. (2018). Bioaccumulation and health risk of trace elements in shellfish and their leachates from two coastal areas of Nigeria. *International Journal of Development and Sustainability, 7(4),* 1474-1494.
28. Ukwo, S. P., Ezeama, C. F., & Obot, O. I. (2019). Microbiological safety and toxic element contaminants in bivalve shellfish from intertidal mudflats of IKO estuary, Niger delta, Nigeria. *South Asian Journal of Food Technology and Environment,* 5(2): 846-854.
29. US EPA (2000). United States Environmental Protection Agency, *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories*. Volume 2 Risk Assessment and Fish Consumption Limits, *2*,1–383. Washington DC USA. pp1-67.
30. US EPA (2009). United State Environmental Protection Agency. *Integrated risk information system* (IRIS) (on-line database). Washington, DC: Office of Health and Environmental
31. Wala, C., Hart, A. I., Babatunde, B. B., & Zabbey, N. (2016). Assessment of Human Health Risk from Heavy Metal Loads in Freshwater Clam (Ergeria radiate) from the Nun River, Niger Delta, Nigeria. *Journal of Environment and Earth Science*, *6*(9), 10-20.
32. WHO (2018). World Health Rankings: World Life Expectancy. World Health Organisation (WHO). Geneva, Switzerland
33. Zabbey, N., & Babatunde, B. B. (2015). Trace metals in intertidal sediment of mangrove-sheltered creeks in Niger Delta, Nigeria: Variability before and after crude oil spillage. *African Journal of Environmental Science and Technology*, *9*(4), 371-378. https://doi.org/10.5897/AJEST2015.1875