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Probabilistic Risk Assessment of Heavy metals in Shellfish from an Artisanal Refining Site, K-Dere, South-South Nigeria

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Abstract: *Bioaccumulation of Heavy metals (Fe, Pb, Cd, Cr, Zn, Ni, As and V) were evaluated in the tissues of three shellfish commonly ingested by the people of Ogoni. The shellfish studied were land crab (Cardisomaarmatum), purple-mangrove crab (Goiniopsispelii) and swimming crab (Callinectesamnicola) using Atomic Absorption Spectrophotometer in accordance to the relevant US EPA sample digestion and analytical standards.Fe showed the highest concentration among all studied metals in the order of Goiniopsispelii(80.43±3.46)>Callinectesamnicola (73.08±11.59)>Cardisomaarmatum(63.46±10.18). The concentrations of heavy metals varied significantly ($P<0.05$) between the two study areas.Non-carcinogenic health-risk and Carcinogenic health-risk were evaluated using Estimated Daily Intake (EDI) and Chronic Daily Intake (CDI) to determine HQ and ILCR respectively. Hazard quotients of Cd in all shellfish at the artisanal refining site were greater than 1 but less than 1 for other metals.Cardisomaarmatum showed Cd with HQ>1 at the control site. The probability of an individual to develop cancer exceeded the US EPA threshold limit of 1.0×10^{-4} for Cd, Cr, and Ni while ILCR for Pb was within the safe limit (1.0×10^{-6}). Furthermore, the cumulative lifetime cancer risk (∑ILCR)for all shellfish studiedviolated the moderate risk level of 1.0×10^{-3}. Therefore, there is high probability of human consumers of shellfish to develop cancer due to combined effects of carcinogenic heavy metals intake.*

Keywords:*Shellfish, non-cancer health-risk; hazard quotients (HQ); carcinogenic health risk, cumulative individual lifetime cancer risk (∑ILCR)*

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I. Introduction

Environmental degradation arising from the activities of illegal petroleum refining is a growing menace in K-Dere, Ogoniland and the Niger Delta at large. Artisanal refining refers to an illegitimate practice of distilling crude oil in locally constructed stills into sub-standard petroleum products. The crude oil used in the process is stolen from pipelinesor traded illegimately and eventually transported to the coastal regions where they are refined. The entire process is highly inefficient and deleterious. According to Attah (2012), the inefficiency of the process is so high such that it is most likely that up to 80% of the bottom fractions of the crude oil cannot be refined and are commonly discharged into the environment[14]. These are eventually washed into creeks at high tide and are deposited at the foreshore and seabed thereby increases the exposure to aquatic organisms. The intertidal zones of the tidal brackish and tidal freshwater are noted for macrofauna (mostly shellfish) that depend on the daily tidal cycle[8].

Hydrocarbons are constantly disposed into the environment during the bunkering operation and the distillation process. Heavy metals are natural constituent the earth's crust and are commonly incorporated into crude oil from reservoir rocks.Their levels are usually low in the environment[15]. However, anthropogenic activities such have increased the levels of heavy metals entering into the environment. These metals stay permanently because they cannot be degraded in the environment. They enter into the food material and from there they ultimately make their passage into the tissue [9]. They are ingested by shellfish via the food chain and bioconcentrated in their tissues. Shellfish are predominantly consumed by the people of K-Dereand may pose serious health hazards to the people of K-Dere and her environs that depend on fishes and crabs caught from these rivers for protein.

WHO (2000) has defined heavy metals as metallic element with high atomic weight (e.g., mercury, chromium, cadmium, arsenic, and lead); which can damage living things at low concentrations and tend to accumulate in the food chain[40].Some 'trace elements' are also known as heavy metals such as copper (Cu), selenium (Se) and zinc (Zn). They are essential to maintain the body metabolism, but they are toxic at higher concentrations. Humans can be exposed to heavy metals via food, drinking water and air.Although toxicity and the resulting threat to human health of any contaminant are a function of concentration, it is well-known that chronic exposure to heavy metals and metalloids at relatively low levels can cause adverse effects [14], [18].

II. Material And Methods

Study Area:

Bon-Ngyia is located within Bomu oilfield (Figure 1) in Kegbara Dere (N04^{o}38`21.7" and E007$^{o}$14`30.4), one of the largest and populous communities in Gokana Local Government Area of Ogoniland. Ogoniland is situated in South-Eastern region of Rivers State, South-South of Nigeria (Figure 1). Ogoniland covers an estimated 1,000km^2 of the Niger Delta basin [34]. According to the 2006 census, the population of the Ogonis was about 832,000 people and maybe over a million and a half presently. While in operation in Ogoniland, SPDC built 12 oilfields and drilled 116 oil wells of which about 52 is in Bomu Oilfield (K-Dere) networked to 2 flow stations (UNEP, 2011). Although oil production ceased in Ogoni in 1993, there are numerous pipelines still carrying crude across the rivers and lands of K-Dere which serve as a source of oil for artisanal refining. Hence, refinery sites are commonly located at the riverbanks, wetlands, coasts and in the mangrove zones bordering the river and creeks in the area to enable easy access to crude oil from pipelines, wellheads and well as to aid the transportation of both raw crude and refined fractions. Bon-Ngyia serves as one of the numerous local seaports for fishermen and other sea businesses in K-Dere. Several artisanal refineries are located within the coasts of Bon-Ngyia and their potential impacts on the environment are cumulative.

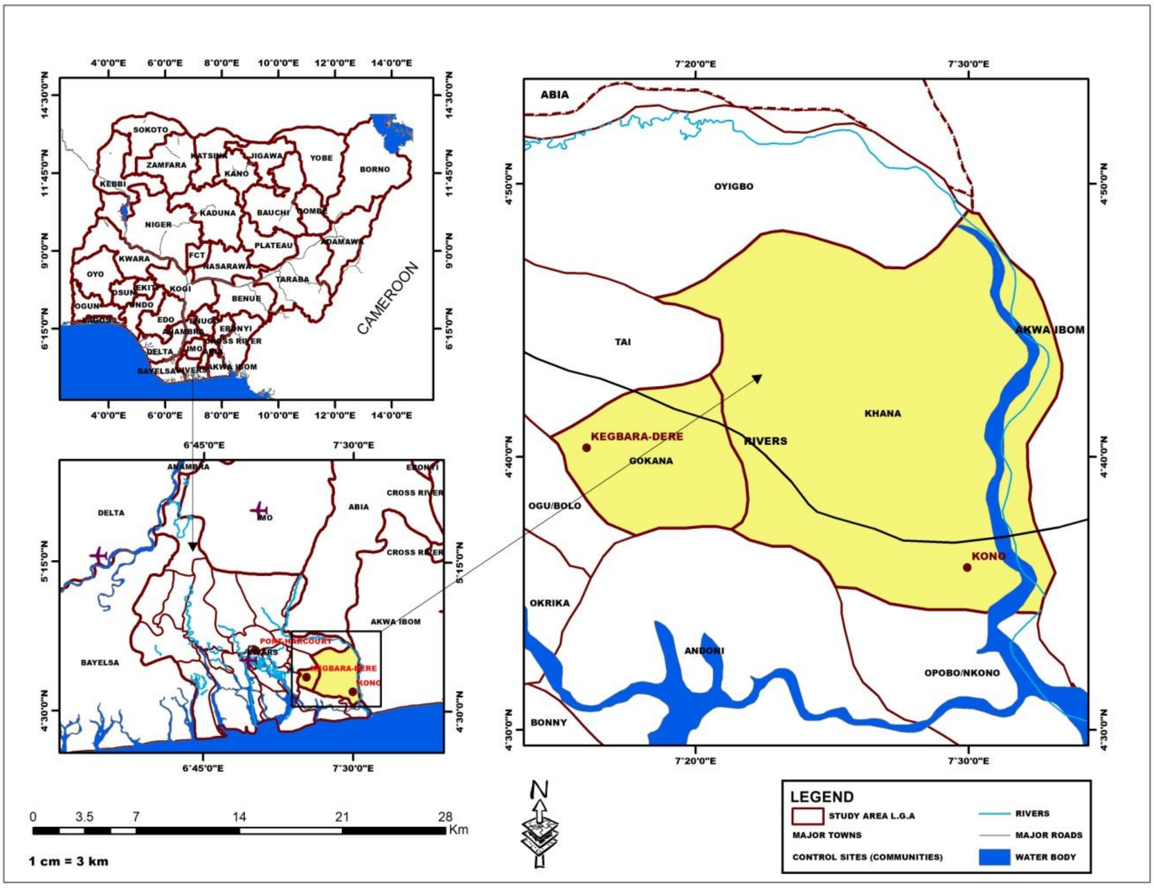


Figure1: Map of Ogoni showingK-Dere and Kono in Ogoni Rivers State, Nigeria

Field Study

Samples were collected from the intertidal zone and creeks of Bon- Ngyiaartisanal refining site in K-Dere coastal region (N04^{o}38`21.7" and E007$^{o}$14`30.4) and Nwinua Protected Mangrove Forest in Kono (N04^{o}34.513` and E007^{o}30.630) as a Control station. Three species of shellfish namely land crab (*Cardisomaarmatum)*,purple mangrove crab (*Goniopsispelii*) and blue swimming crab *(Callinectesamnicola*) were collected from the creekfor the study. All samplings were carried out for 6 months, July 2018-June 2019.

Sample Preparation/analysis

Samples of each shellfish species (land crab, mangrove purple crab, and the blue swimming crab) were accurately dried in an oven at a temperature less than 60°C. These were crushed and ground into three composites respectively to reduce subsample variability. Digestion of samples was carried out in accordance with ASTM D 1971B AND EPA METHOD 3050B. 10g of each composite sample were accurately weighed using a high precision analytical weighing balance in a 125ml capacity beaker and 100ml of distilled water and 0.5ml of HNO_3 was added. This was followed by the addition of 5ml HCl to the beaker. The resultant sample mixtures were heated on a stream bath in a well-ventilated hood until the volume has been reduced to 15 to 20ml while ensuring that the sample does not boil. The samples were brought down from the bath and allowed to cool. The digested sample was filtered using a filter paper - Whatman No. 41. The filtrate was diluted with distilled water to 100ml mark. The digested sample was assayed using Atomic Absorption Spectrophotometer (AAS; SensAA GBC Scientific) atomized by using an air–acetylene flame and external standards in accordance with ASTM/USEPA analytical methods.

$$\text{Metal concentration (mg/kg)} = \frac{\text{Metal concentration (mg/l) x volume of sample (L)}}{\text{Weight of sample (kg)}}$$

Non-Carcinogenic Risk Assessment

The potency of heavy metals to impact human health via consumption of shellfish from K-Dere and Kono was evaluated using USEPA (2000) standard indices: Estimated daily intake (EDI), the Hazard quotient (HQ) and the Hazard index (HI)[40] .

Estimated Daily Intake (EDI)

This is an estimate of the amount of potentially hazard substance (contaminant) taken in via consumption of food (Shellfish, etc). This is also referred to as Dietary Intake (DI) or simply Dietary Exposure [40], [32] .

$$EDI = \frac{C_{HM} \text{ x } IR}{B_w}$$

Where EDI = Dietary exposure in $mgkg^{-1}day^{-1}$, IR is the ingestion rate = 0.036kg $person^{-1}day^{-1}$ converted from per capita fish consumption in Nigeria (US FAO, 2013) and B_w is the standard body weight of an adult which is given as 60kg (WHO, 2000) C_{HM} is the average concentration of individual heavy metals in the studied shellfish species[40].

Hazard quotient (HQ)

The hazard quotient designed by the US EPA (2000) is the ratio of the dietary exposure (amount of potential hazardous substance consumed) to a substance and the standard reference doze which represents the dosage of consumption over time without any appreciable health risk[40].

$$\text{Hazard quotient (HQ)} = \frac{EDI}{RfD_o}$$

Where HQ is the Hazard quotient, Estimated daily intake (EDI) and RfD_o is the oral reference doze. A hazard quotient less than or equal to ($HQ < 1$) of a potentially hazardous substance to cause non-cancer effect in human consumer while HQ greater than one ($HQ > 1$) implies the likeliness of a toxic substance to impact non-cancer adverse effect.

Hazard Index (HI)

Hazard index (HI) represents the sum of the hazard quotients (∑HQ*)* of individual chemical substance consumed via the same route and which may produce similar or the same physiological effect in man (EPA, 2002).

$$HI = HQ_1 + HQ_2 + HQ_3 + \text{-------} n$$

$$HI = \frac{EDI_1}{RfD_{o1}} + \frac{EDI_2}{RfD_{o2}} + \frac{EDI_3}{RfD_{o3}} + \text{-------} n$$

Where, 1, 2, 3, ---- n represent the individual heavy metals present in the studied shellfish species. HI value is an estimate of the combined effect of more than one heavy metal[40]. HI less than or equal to one (HI < I) is assumed to produce no adverse non-cancer health impact while HI greater than one (HI > 1) is likely to produce non-cancer health impact.

Cancer Risk Assessment (CRA)

The probability that cancer may arise in humans via consumption of shellfish sampled from K-Dere artisanal refining site was studied using state-of-the-art risk characterization indices developed by US EPA (1986). The indices allows for quantitation of the level of intake of individual potentially carcinogenic substances. The obtained values are then compared to standard Health-Based Guidance Values (HBGV).

Chronic Daily Intake (CDI)

This is a measure of the average consumption of a contaminant via consumption of food (shellfish) over a long period of time. It related the EDI of a target contaminant to the population age. It is expressed as $mgkg^{-1}day^{-1}$.

$$CDI = \frac{EDI \times EF_r \times ED_r}{AT_r} = \frac{EDI \times EF_r \times ED_{tot}}{EF_r \times ED_{tot}} = mgkg^{-1}day^{-1}$$

Where:

EDI= Estimated daily intake of individual carcinogenic substance ($mgkg^{-1}day^{-1}$)

EF_r = Exposure frequency for target population residents = 350days per year[31].

ED_r = Exposure duration for target population residents = 26years[31]

AT_r= Averaging time; the period over which the exposure is averaged = [EF_r x ED_{tot}] = [365years x 70years].

ED_{tot} = Standard lifetime for carcinogenic effect: updated standard defaults exposure factors (EPA, 2014).

Individual Lifetime Cancer Risk (ILCR)

The likeliness of a substance to cause cancer in human is measured by multiplying the chronic daily intake of the substance by a slope factor of the target toxicant [20].

$$\mathbf{ILCR = CDI \times CSF}$$

Where:

ILCR = Individual Lifetime Cancer Risk

CDI = Chronic daily intake

CSF = Cancer slope factor

The cancer slope factor (CSF) is a toxicity value developed by the US EPA (1989). It is an estimate of the probability that an individual may develop cancer due to exposure or consumption of a toxicant over a lifetime of pre-determined 70 years period[29].

An ILCR of 1.0×10^{-6} is considered the safe limit for cancer and represents the probability that one individual may develop cancer in every one million people (1:1,000,000), ILCR of 1.0×10^{-4} is the threshold risk limit and represents the probability of one individual developing cancer in every ten thousand people (1:10,000) and ILCR of 1.0×10^{-3} is the moderate risk level with a chance of one individual developing cancer in every one thousand people (1:1000) [6].

Cumulative Individual Cancer Risk (∑ILCR)

The cumulative individual cancer risk (∑ILCR) like the hazard index in non-cancer risk assessment is a measure of cancer risk due to exposure of more than carcinogenic heavy metal as a result of consuming a particular specie of shellfish [6].

$\sum ILCR = ILCR_1 + ILCR_2 + LCR_3$ ----- + ILCRn

Where n = 1, 2, ----, n is the individual carcinogenic heavy meals in a particular shellfish species.

III. Results

Table 1 shows result obtained from the analysis of heavy metals (Fe, Pb, Cr, Cd, Zn, Ni, As and V) in three shell fish species; *C. armatum, G. pelii* and *C. amnicola* sampled from the intertidal zones and creeks of hydrocarbon polluted environment were activities of artisanal (illegal) refining is on-going and a control site with no evidence of illegal refining activities. Results are presented as mean concentration ($mgkg^{-1}$ wet weight).

Table 2 shows the estimated daily intake (EDI) of all the studied heavy metals, and oral reference doses (RfD_o) obtain via consumption of the three species of shellfish studied

Table 1: Concentration of heavy metals (range, mean ± SEM, mgkg^{-1}) in the tissues of shellfish from two study areas in Ogoni, Rivers State (July 2018 – June 2019)

Heavy metal	Shellfish						Standard
	Cardisomaarmatum		*Goniopsispelii*		*Callinectesamnicola*		
	K-Dere	**Kono**	**K-Dere**	**Kono**	**K-Dere**	**Kono**	
Fe	34.78-98.46 63.46±10.18	16.45-56.32 33.04± 5.93	71.14-90.24 80.43 ± 3.46	16.45-52.12 31.94 ± 5.86	35.62-98.45 73.08± 11.59	10.88-44.21 31.12± 4.89	
Pb	0.11-0.33 0.24± 0.03	0.00-0.10 0.04± 0.01	0.15-2.00 0.60 ± 0.28	0.11-0.68 0.49 ± 0.10	0.30-1.68 0.61 ± 0.22	0.11-0.32 0.21 ± 0.03	0.5 (EC)
Cr	18.21-26.62 22.12 ± 1.42	2.21-4.31 3.14± 0.38	17.23-25.28 19.69± 1.19	2.10-3.33 2.67 ± 0.18	11.66-57.63 34.35 ± 6.39	1.71-5.66 3.45± 0.65	1.0 (WHO)
Zn	2.42-6.89 4.11± 0.61	1.79-6.89 4.29±0.76	2.78-4.32 3.56± 0.24	2.53-3.23 3.10± 0.11	4.22-9.08 6.51 ± 0.87	2.22-5.56 3.4 ± 0.47	
Cd	2.77-4.02 3.47± 0.18	1.29-2.14 1.92± 0.04	1.38-5.06 3.40± 0.61	0.63-0.89 0.81± 0.04	2.25-3.48 3.00 ± 0.24	0.11-2.14 0.73±0.32	0.1 (FAO, 2003)
Ni	10.92-20.52 15.50± 1.35	2.95-4.59 3.89± 0.25	12.43-35.02 19.08± 3.28	2.12-5.16 3.05± 0.43	11.11-448.60 26.07± 6.87	2.25-4.66 3.43 ± 0.35	0.2 WHO (2005)
As	*BDL	*BDL	*BDL	*BDL	*BDL	*BDL	1.4 (EC)
V	*BDL	*BDL	*BDL	*BDL	*BDL	*BDL	

*BDL = Below Detectable Limit

Table 2: Estimated daily intake (EDI) and Oral reference dose (RfD$_o$) of heavy metals via shellfish consumption (mgkg^{-1}day^{-1}) from K-Dere and Kono, Ogoni Nigeria

Shellfish	***Cardisomaarmatum***		***Goniopsispelii***		***Callinectesamnicola***		**RfD$_o$**
Heavy metals	K-Dere	Kono	K-Dere	Kono	K-Dere	Kono	USEPA(2002,2005 ,1986)
Fe	0.038	0.020044	0.04879	0.01938	0.04434	0.01888	0.8
Pb	0.000146	0.0000243	0.000364	0.000297	0.00037	0.000127	0.004
Cd	0.002105	0.001165	0.002063	0.000491	0.00182	0.000443	0.001
Cr	0.0134	0.001905	0.011945	0.00162	0.02084	0.002093	1.5
Ni	0.009403	0.00236	0.011 575	0.00185	0.015816	0.002081	0.02
Zn	0.00249	0.002603	0.00216	0.001881	0.003949	0.002111	0.3
As	*BDL	*BDL	*BDL	*BDL	*BDL	*BDL	0.0003
V	*BDL	*BDL	*BDL	*BDL	*BDL	*BDL	

*BDL=Below Detectable Limit

Table 3 present results obtained from the evaluation of Hazard quotient of heavy metals.The analysis showed HQ>1 for Cd in all studied shellfish at K-Dere whereas only *Cardisomaarmatum* showed HQ>1 at the control site (Kono). Non-cancer risk may arise due to ingestion of Cd from shellfish in Ogoniland.

Results from evaluation of the carcinogenic potency due to consumption of shellfish are presented in Tables 4 and 5. Table 4 shows results for Chronic Daily Intake (CDI) of Heavy metals that have been identified as carcinogenic while Table 5 shows the actual cancer risk that may result if an individual consumes shellfish (C. *amnicola, G.pelii*and *C.armatum)* over a period of 70yrs in Ogoni. The cancer risk is expressed as individual lifetime cancer risk (ILCR) and the cumulative individual lifetime cancer risk (ΣILCR).

Table 3: Hazard quotients (HQ) of heavy metals due to consumption of shellfish from K-Dere and Kono, Ogoni Nigeria

Location	**Shellfish**	**Heavy metals**							
		Fe	Pd	Cd	Cr	Ni	Zn	As	V
K-Dere	*C. armatum*	0.05	0.04	2.10	0.01	0.47	0.01	*BDL	*BDL
	G. Pelii	0.06	0.091	2.06	0.0079	0.58	0.0071	*BDL	*BDL
	C. amnicola	0.05	0.09	1.82	0.01	0.80	0.01	*BDL	*BDL
Kono	*C. armatum*	0.03	0.006	1.16	0.001	0.12	0.008	*BDL	*BDL

G. Pelii	0.024	0.074	0.49	0.001	0.09	0.006	*BDL	*BDL
C. amnicola	0.02	0.03	0.44	0.00	0.10	0.01	*BDL	*BDL

*BDL=Below Detectable Limit

Table 4: Average chronic daily intake (mgkg^{-1}day^{-1}) of carcinogenic heavy metals in shellfish from K-Dere and Kono in Ogoniland Rivers State, Nigeria.

Shellfish	*C. armatum*		*G. Pelii*		*C. amnicola*		Cancer slope factors (CSF)
	K-Dere	**Kono**	**K-Dere**	**Kono**	**K-Dere**	**Kono**	
Pb	$5.2x10^{-5}$	$8.6x10^{-6}$	$0.3x10^{-4}$	$1.4x10^{-4}$	$1.3x10^{-4}$	$4.5x10^{-5}$	0.0085
Cd	$7.5x10^{-4}$	$4.1x10^{-4}$	$7.4x10^{-4}$	$1.8x10^{-4}$	$6.5x10^{-4}$	$1.6x10^{-4}$	0.38
Cr	$4.8x10^{-3}$	$6.9x10^{-4}$	$4.3x10^{-3}$	$5.8x10^{-4}$	$7.4x10^{-3}$	$7.5x10^{-4}$	0.5
Ni	$3.3x10^{-3}$	$8.4x10^{-4}$	$4.1x10^{-3}$	$6.6x10^{-4}$	$5.6x10^{-3}$	$7.4x10^{-4}$	0.91

*CSF = Cancer slope factor is expressed in mgkg^{-1}day^{-1} (US EPA)

Table 5: Individual lifetime cancer risks (ILCR) and cumulative cancer risks (∑ILCR) for consumption of shellfish from K-Dere and Kono, Nigeria.

Study Area	Shellfish	Carcinogenic Heavy metals				∑ILCR
		Pb	**Cd**	**Cr**	**Ni**	
K-Dere	*C.armatum*	$4.0x10^{-7}$	$3.0x10^{-4}$	$2.0x10^{-3}$	$3.0x10^{-3}$	$6.0x10^{-3}$
	G.pelii	$1.0x10^{-6}$	$3.0x10^{-4}$	$2.0x10^{-3}$	$4.0x10^{-3}$	$6.0x10^{-3}$
	C.amnicola	$1.0x10^{-6}$	$2.0x10^{-4}$	$4.0x10^{-3}$	$5.0x10^{-3}$	$9.0x10^{-3}$
Kono	*C.armatum*	$7.0x10^{-8}$	$2.0x10^{-4}$	$3.0x10^{-4}$	$8.0x10^{-4}$	$1.0x10^{-3}$
	G.peili	$1.0x10^{-6}$	$7.0x10^{-5}$	$3.0x10^{-4}$	$6.0x10^{-4}$	$9.0x10^{-3}$
	C.amnicola	$4.0x10^{-7}$	$6.0x10^{-5}$	$4.0x10^{-4}$	$7.0x10^{-4}$	$1.0x10^{-3}$

IV. Discussion

Non-cancer Risk

Results from the evaluation of estimated daily intake (EDI) of Iron (Fe) in the three shellfish species was found in the order of *Goniopsispelii* (0.04879mgkg^{-1}day^{-1})>*Callinectesamnicola* (0.04434mgkg^{-1}day^{-1}) >*Cardisomaarmatum* (0.038 mgkg^{-1}day^{-1}) at K-Dere. This order corresponds with the observed abundance of the studied shellfish species. The normal shellfish population has been decreasing due to high levels of exposure to hydrocarbon as well as an increase in demand for shellfish cum over-fishing at K-Dere community.

The observed order of EDI of Fe at Kono is in contrast to that at K-Dere. The EDI values of Fe from the consumption of all studied shellfish when compared to Health Based Guidance Values (HBGV) showed that the target population (both K-Dere and Kono) were not at risk due to Fe intake. EDI for Fe are all below 0.8mgkg-1day-1 (RfDo) and are all less than a Hazard Quotient (HQ) of 1 (Table 2 and 3).The EDI for Pb at K-Dere ranged from 0.000146 for *Cardisomaarmatum* to 0.00037 in *Callinectesamnicola* while at Kono, the lowest EDI of 0.0000243 for *Cardisomaarmatum* and peaked at 0.000297 for *Goniopsispelii* (Table 2). The consumption of Pb via shellfish is considered not to pose any considerable health risk as all HBGV are well within limit (Table 2).

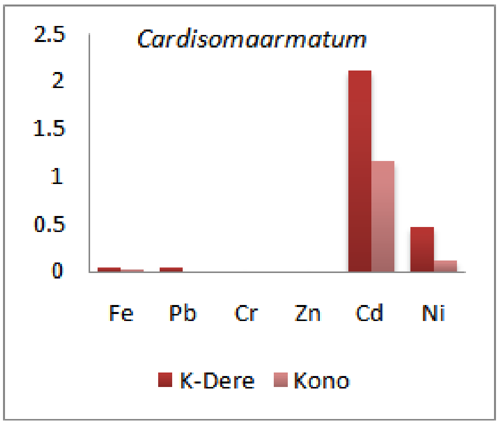
Results show that amount of Cd consumed by the population of K-Dere via all studied shellfish may pose non-cancer risk in humans. Results presented in Table 2 and 3 show that EDI of Cd is greater than oral reference. Dose (RfDo) of 0.001mgkg-1day-1. The Hazard Quotient for Cd at K-Dere, is in the order of *Cardisomaarma*tum (2.105)>*Goniopsispelii*(2.063)>*Callinectesamnicola* (1.82). At the control site (Kono), only *Cardisomaarmatum* shows HQ>1. Non-cancer risk may arise due to ingestion of Cd from shellfish in Ogoniland.

In a recent study conducted around the borders of K-Dere by Npkaa*et al.*, (2017), the calculated EDI of Cd was found to exceed the benchmark intake. The values in the range of 0.34 – 1.35gperson^{-1}day^{-1} obtained in the study were above the RfD$_o$ for Cd as well as the THQ of unity. Outside Nigeria, levels of Cd in shellfish have also been reported. Sharif *et al.*, (2016) have reported EDI for Cd in the range of 0.02 – 1.58µgkg^{-1}day^{-1} with a HQ greater than 1, in scallop [26]. Cd biological half-life has been determined and reported as 30yrs. Therefore, Cd is slowly excreted and can accumulate in the body over a lifetime [14].

Exposure to Zn via intake of shellfish within both K-Dere and Kono creeks is observed to pose no health effect in human consumers. All EDI calculated were within the benchmark intake and agreed with all human health based guidance values. Zinc is an essential human nutrient and required by the body in moderate amount for proper physiological functionally.

Exposure to Cr via shellfish intake at K-Dere peaked at 0.002084mgkg^{-1}day^{-1} in *Callinectesamnicola* and 0.002093 at Kono, while the lowest values were recorded for *Goniopsispelii* (0.011945 and 0.0020162mgkg^{-1}day^{-1}) at K-Dere and Kono respectively. However, all calculated EDI fall below both RfDo and THQ (Table 2 and 3). Therefore, adverse health impact arising from exposure to Cr via ingestion of all studies shellfish is very unlikely to occur.Table2 shows that the highest exposure to Ni due to consumption of shellfish is from ingestion *Callinectesamnicola* (0.0158mgkg^{-1}day^{-1} and the population of K-Dere is less exposed to Ni via intake of *Cardisomaarmatum* (0.000403mgkg^{-1}day^{-1}). The highest intake of Ni at Kono is due to consumption of *Cardisomaarmatum* (EDI = 0.00236mgkg-1day-1). The EDI of Ni in all sampled shellfish species are well below the oral reference dose (0.02mgkg-1day-1) and the HQ for Ni are all below (HQ <1). This implies that the target population is very unlikely to suffer any adverse health effect due to Ni ingestion from shellfish. This result corresponds to other related findings within Ogoniland and Niger Delta at large. For instance, Nkpaa*et al*.,(2017) reportedHQ for Ni less than 1 in shellfish (including *U.tangeri*) from Bodo city and B-Dere.

As and V analyzed in shellfish tissues where found below detectable limit (BDL). Hence, their intake could not be quantified[12].



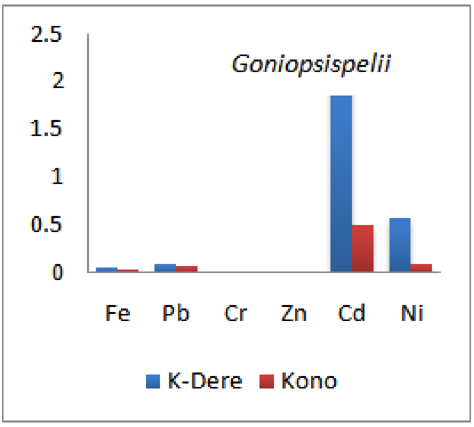


Figure 2Figure 3

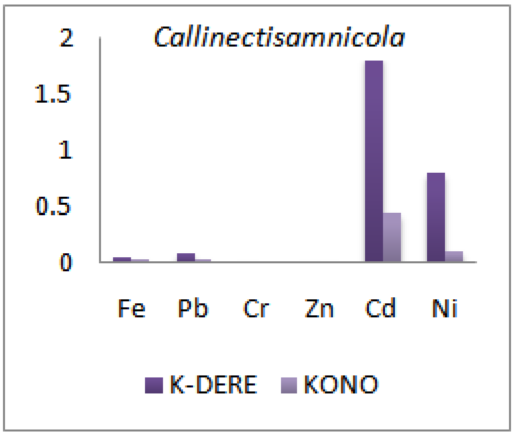


Figure 4

Figure 2-4: Hazard quotient (HQ) due to consumption of heavy metals in shellfish from K-Dere and Kono in Ogoni Nigeria

The Hazard Index (HI) due to consumption of shellfish in K-Dere is in the order of *Goniopsispelii* (2.81)>*Cardisomaarmatum* (2.78) and *Callinectesamnicola* (2.68). These values were due to high level of Cd with a HQ>1 in all shellfish from the artisanal refining site. *Cardisomaarmatum*was the only shellfish with a hazard index above 1 (HI >1) as both *Goniopsispelii* (HI = 0.69) and *Callinectesamnicola* (HI = 0.61) were below the benchmark intake value of I at the control site (Kono). Cumulative intake of heavy metals via shellfish in Ogoniland may pose health effects especially due to Cd toxicity.

Individual Lifetime Cancer risk (ILCR)

Results from ILCR show that the population of Ogoniand is very unlikely to contract cancer due to Pb intake from all three species of shellfish studied as cancer risk values were all below and within the safe limit ($1.0x10^{-6}$) (Table 5). However, ILCR for Cd violates the threshold risk limit and both Cr and Ni violate the moderate risk level of $1x10^{-4}$ and $1.0x10^{-3}$ respectively at K-Dere while ILCR for both Cr and Ni violates the threshold limit risk levels at Kono.

These results indicate that there is probability of one individual developing cancer due to Cd in every 10,000 and one individual in every 1000 people due to Cr and Ni in all shellfish studied within K-Dere. In addition, the cumulative individual cancer risk of all studied shellfish exceeded and violates the standard threshold level ($>1.0x10^{-4}$) in both areas of study. Based on the cumulative individual cancer risk value, the order of the probability of an individual to develop cancer due to consumption of shellfish in K-Dere is in the order of *C. amnicola*>*G.pelii*and *C.armatum* and *G.pelii*>*C.armatum* and *C. amnicola* in Kono respectively (Table 5). Therefore, the population of Ogoniland that are exposed to shellfish over a 70 years period are at high risk of developing cancer due to combined effects of carcinogenic heavy metals intake.

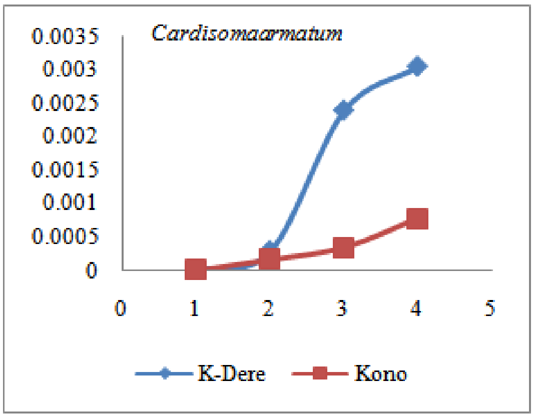


Figure 5

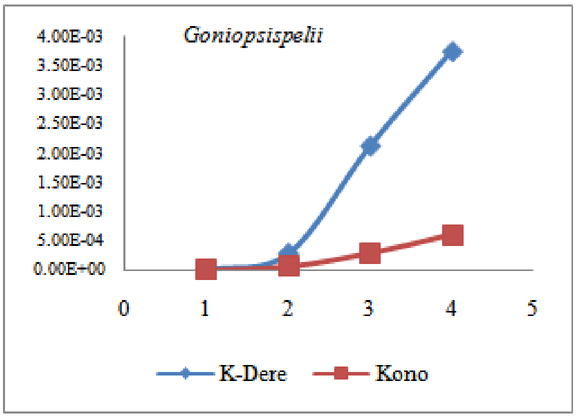


Figure 6

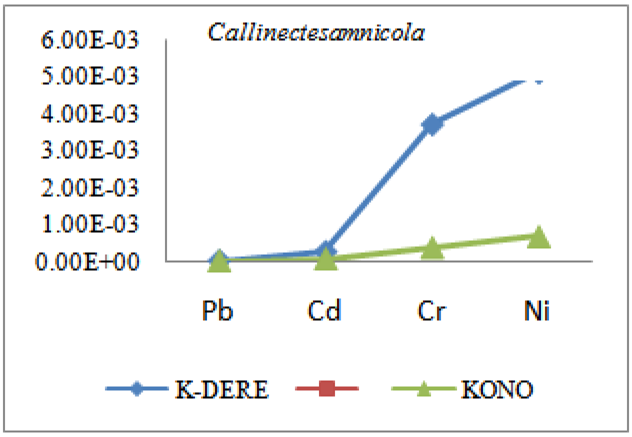


Figure 7

Figure 5-7.Showing Individual Lifetime Cancer Risk due to Consumption of Heavy Metals in shellfishfrom K-Dere and Kono in Ogoni Nigeria

V. Conclusion

This study investigated the Bioaccumulation Heavy metals in the tissues of *Cardisomaarmatum*, *Goniopsispelii* and *Callinectesamnicola* and the possible risk to human health via ingestion. The study found elevated levels of heavy metals such as Cd, Cr, Ni and Fe. Human health risk analysis for non-carcinogenic effect and carcinogenic effect showed that the populations of Ogoni that are exposed to shellfish are risk of developing ailments such as anaemia, edema, amnesia and reproductive defects upon chronic consumption of the studied shellfish while cancer risk assessment indicated high probability of an individual to develop cancer. The ILCR exceeded the US EPA threshold limit of 1.0×10^{-4} for Cd, Cr, and Ni while ILCR for Pb was within the safe limit (1.0×10^{-6}). Furthermore, the cumulative lifetime cancer risk (∑ILCR) due to consumption of the shellfish indicates the probability of one individual in every one thousand (1:1000) people of Ogoni to develop cancer. Therefore, there is high probability of human consumers of shellfish to develop cancer due to combined effects of carcinogenic heavy metals intake.

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