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EVALUATION OF CARCINOGENIC AND NON-CARCINOGENIC RISK OF CADMIUM AND NICKEL IN LAND SNAILS (*A. ACHATINA* AND *L. FLAMMEA*) AND MARINE SNAILS (*P. AURITA* AND *T. FUSCATUS*) COMMONLY CONSUMED IN NIGERIA

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ABSTRACT

The Carcinogenic and non-carcinogenic health risk of Cd and Ni in Land Snails (*A. achatina* and *L. flammea*) and Marine Snails *P. aurita* and *T. fuscatus*) commonly consumed in Nigeria were investigated. The metal concentrations were determined using atomic absorption spectrometer (GBC Avanta 2.02 model). The results of the mean concentrations (mg kg^{-1} dry wt basis, mean ± SD) of Cd were 17.8 ± 4.37 (*A.achatina*), 6.3 ± 0.47 (*L. flammea*), 2.1 ± 0.26 (*P. aurita*) and 2.8 ± 0.64 (*T. fuscatus*), while Ni values were; 16.7 ± 5.03 (*A. achatina*), 7.3 ± 1.04 (*L. flammea*), 17.7 ± 7.68 (*P. aurita*) and 11.3 ± 1.65 (*T. fuscatus*), respectively. The mean concentrations of Cd and Ni in the Snail samples were higher than the acceptable limits set by WHO, FAO, FEPA and EU. For Cd the mean concentrations are in the decreasing order of *A. achatina* > *L. flammea* > *T. fuscatus* > *P.aurita,* while Ni mean concentrations are in the order of *P. aurita* > *A.achatina* > *T. fuscatus* > *L. flammea.* The provisional tolerable daily and weekly intake (PTDI and PTWI) of Cd estimated in this study were all higher than the limits set by WHO and FAO, while for Ni, *A.achatina* and P.*aurita* were higher than the limits of WHO and FAO, and *L. flammea* and *T. fuscatus* were lower than the limits. For the non-carcinogenic and carcinogenic risk evaluation, the results showed that the hazard index, HI (Sum of THQ) for all the snail samples were higher than the acceptable limits of 1 set by USEPA. The HI values are in the decreasing order of *A. achatina* > *L. flammea* > *T. fuscatus* > *P. aurita* and the risk values were 7.67, 2.74, 1.22 and 1.38 with Cd been the major risk contributor, contributing up to 70-95% of the HI values. This is a source of concern considering the fact that excessive consumption of these snails may lead to severe chronic cadmium poisoning. Also, the target Cancer risk (TR) values for Cd and Ni in all the Snail Samples were higher than the acceptable limits of $10^{-6} – 10^{-4}$ established by USEPA, indicating a potential health risk effects to consumers. Therefore, moderate intake of these snails from Bayelsa State is strongly recommended to consumers.

Key words: Heavy metals, Bioaccumulation, Toxicity, Bio-indicators, Gastropods, Carcinogenic and Non-carcinogenic risks.

INTRODUCTION

Heavy metals according to Lide[1] are subset of chemical elements with a specific gravity that is at least five (5) times the specific gravity of water. These include; arsenic, cadmium, mercury, lead, Nickel, iron, copper, zinc, cobalt, cerium, manganese, etc. These elements have biological accumulation, toxicity and environmental sustainability properties[2]. In recent years, the presence of these metals has become an

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international environmental and health concern[3] due to rapid development of industrialization which has resulted in the alteration of the ecosystem[4]. This has a significant environment hazard for invertebrate, fish, animal and humans, respectively[5]. These metals are released or discharged into the environment through numerous anthropogenic sources such as oil and gas activities (combustion of fossil fuel), transportation process industrial activities (especially metal production), solid waste combustion, agricultural application and domestic application and are collectively received by sediment, soil, water and air[6-8]. Heavy metals are one of the pollutants that can spread in sediment soil and water components and react through ion exchange, absorption andprecipitation[9], which may directly or indirectly be toxic to the aquatic and terrestrial fauna and flora[10].

Heavy metals tend to accumulate in advanced organisms through bio-magnification effects in the food chain. They enter into the human body, and accumulate in the human tissues to pose chronic toxicity. Chronic assimilation of some heavy metals is known to cause cancer[11] and can damage vital organ functions. Accumulation of heavy metals in the food web can occur either by accumulation from the surrounding medium, such as soil, water or sediment, or by bioaccumulation from food source[12]. Reports have shown that, heavy metals may affect organisms directly or indirectly by transferring to the next tropic level of the food chain[13] due to their persistence nature. In the aquatic environment, (water & sediment) heavy metals in dissolved form are easily taken up by aquatic organisms where they are strongly bound with sulfhydryl groups of proteins and accumulate in their tissues[14], while in the terrestrial environment (soil), heavy metals occur in various chemical forms such as carbonates, metal hydroxides organic matter and silica[15] and remobilized in to plants & animal tissues through adsorption and inhalation[16]. The accumulation of heavy metals in the tissues of organisms can result in chronic illness and cause potential damage to the population.

Geochemical factors that influence bioaccumulation of heavy metals in an aquatic environment are; organic carbon, water hardness temperature, pH, Salinity, dissolved oxygen, sediment, grain size and hydro logic features of the system,[17] while the bioavailability of metals in the soil depends on the soil properties such as; pH, organic matter, redox potential, cation exchange capacity, sulphate, carbonate, hydroxide, soil texture and clay content[18,19]. These properties in turn influence the uptakes of these metals by plants and animal in both terrestrial and aquatic environment. For instance, it has been reported that very low transfers of heavy metals to plant tissues occur at high pH[20].

Recent studies[21,22] have shown that heavy metals such as Cd, Ni, AS, Pb pose a number of health hazards to humans, which include damage or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidneys, liver and other vital organs. These metals are also potent carcinogenic and mutagenic[23]. Long–term exposure may result in slowly progressing physical, muscular and Alzheimer's disease, Parkinson' disease, muscular dystrophy and multiple Sclerosis[24]. According to Ferner[25], heavy metal toxicity is a clinically significant condition when it does occur especially, if unrecognized or inappropriately treated, toxicity can result in significant illness and reduced quality of life.

The awareness and concern about the protection of the public from avoidable contamination and exposure to heavy metals (especially Pb, Cd, Ni, Hg and As) and their attendant adverse effects on health have led to increase in strategies and methodologies for detecting their presence in the environment. One of such methods is by using non-vertebrate wildlife species (gastropods) as bio-indicators[26]. These organisms detect both the levels of pollutants in an ecosystem as well as their long-term effects[27,28] because of their ecological role as intermediate consumers in pelagic as well as benthic food chain of aquatic ecosystem[29]. The effectiveness of biomonitors for environmental pollution assessment as revealed by many studies[30,31] is based on the ability of these organism to accumulate contaminants such as heavy metals in their tissues. Examples, uptake and accumulation of these pollutants in deposit feeders would be expected to correlate to metal concentrations in sediments, whereas accumulation in filter feeders would most likely reflect metal concentration in water[32]. Presence of heavy metals in edible tissue of organisms (depending on the type and concentration) could pose series of health hazards to consumers especially in the Niger Delta region of Nigeria, where gastropods and bivalves are abundant and therefore serve as cheap sources of protein for indigenous people who could not afford meat from domestic species and bush meat. It is against this background that Land and Marine Snails (*A. achatina, L. flammea, P. aurita* and *T. fuscatus*) were chosen in order to assess the concentration of Cd and Ni in the tissues of these edible gastropods and relate their effects to the exposed population.

Another important method in evaluating the levels of heavy metals in environmental biota is to assess the human health risk arising from the presence of these pollutants in foods products. This is done by estimating the actual dietary intake of the metal and comparing with corresponding toxicological reference intake[33]. Risk assessment is one of the fastest method, which is needed to evaluate the impact of the hazards on human and also needed to determine the level of treatment which are tend to solve the environmental problem that occur in daily life[34]. The risks may be divided into carcinogenic and non-carcinogenic effects[10]. The carcinogenic risk is based on the Target Cancer Risk (TR_C), while the non-carcinogenic risk is based on the Target Hazard Quotient (THQ)[35].

Therefore, the purpose of this study is to determine the total concentration of Cd and Ni in edible tissue of land and marine snails and evaluate the carcinogenic and non-carcinogenic risk associated with the consumption of these gastropods by human.

EXPERIMENTAL

Materials and methods

Sample collection and preparation

Land and marine snails, *Achatina achatina* (Giant Land Snail), *Limicolaria flammea* (Garden Snail), *Pachymelenia aurita* (Periwinkle with Spiny Shell) and *Tympanotonus fuscatus* (periwinkle Without Spine) were purchased from commercial sellers from Yenagoa main market Bayelsa State. The giant land snail and garden snail (terrestrial mollusks) and the periwinkle (aquatic mollusks) have hard shells, which house and protect the soft tissue (visceral lump). The shells are often greater in quantity than the tissue. Upon collection, the samples were washed with tap water and rinsed thoroughly with distilled water. There after samples were raped in a cellophane bag labeled accordingly and transported to the laboratory. These mollusks were properly identified at the Departments of Animal and Environmental Biology, University of Port Harcourt, Nigeria. The whole soft tissues (edible parts) of these snails were obtained by cracking the shells. Thereafter, the samples were thoroughly washed several times and rinsed with distilled water. Samples were dried in the oven at 105^{o}C to a constant weight. The oven-dried samples were ground and sieved with 0.15 mm mesh size to obtain uniform particles size.

Sample digestion

Heavy metal (Cd and Ni) were determined from 0.5 g of finely ground and sieved tissue samples of the snails and homogenized with 10 mL of 3.1 (v/v) of con.HCl/HNO_3 (aqua regia) then 1 mL of $HClO_4$. The mixture were boiled off to near dryness, cooled and diluted with 25 mL distilled water and filtered[36]. Metal concentrations were analyzed using flame atomic absorption spectrometer (GBC, Avanta Ver 2.02 model). Cd and Ni were determined using acetylene flame. For quality assurance, the samples were digested in triplicate along with blanks to minimize error. The instrument was calibrated with series of standard solution supplied by the manufacturer. All determinations were replicated three times. Thus, the results obtained from this analysis were the average of triplicate determination.

Human health risk evaluation for the snail consumption

The exposure pathway of heavy metals to human through ingestion of contaminated food has been studies by many researchers[33,34,37]. The estimated daily (EDI) and intake (EWI) of each metal in this exposure pathway was determined by the equation[38].

$$\text{EDI/EWI (mg kg-bw/day/week)} = \frac{MI_S \times CM_S}{BW}$$

Where EDI/EWI are the daily/weekly intake of the metals, MIs is the mass of the snail ingested per day; CM_S is the concentration of metal in snail; BW is the body weight (60 kg for adult).

Non-carcinogenic risk evaluation

For the non-carcinogenic risk evaluation, the target hazard quotient (THQ) was calculated as per USEPA Region III Risk Based Concentration Table[35].

The equation used for estimating THQ was as follows.

$$THQ = \frac{EF \times ED \times MI \times CM}{RfD \times BW \times AT} \times 10^3$$

Where; THQ is the target hazard quotient, EF is the exposure frequency (day year^{-1}) or number of exposure events per year exposure, ED is the exposure duration, total for adult (year), MI is the mass of snail ingested (g, day $^{-1}$), CM is the metal concentration in the snail (mg kg^{-1}), RfD is the reference dose (mg kg^{-1} day^{-1}), BW is the body weight, adult (60 kg) and AT is the average time, non-carcinogenic (day year $^{-1}$), 10^{-3} is the unit conversion factor. Also, the hazard index (HI) from THQ_S can be expressed as the sum of the hazard quotient[35]. HI = THQ_{Cd} + THQ_{Ni}. Where HI is the hazard index; THQ_{Cd} is the target hazard quotient for Cd intake and THQ_{Ni} is the target hazard quotient for Ni intake, respectively.

Target cancer risk (TR)

The target cancer risk (TR) was used to indicate carcinogenic risks. The method to estimate TR was also provided in USEPA Region III Risk-Based Concentration Table[35]. The model for estimating TR was shown as follows:

$$TR = \frac{EF \times ED \times MI_S \times CPS_O \times MC_S}{BW \times AT}$$

Where; TR is the target cancer risk, EF is the exposure duration (i.e. incremental probability of an individual developing cancer over a life time of 70 years[35], MIs is the mass of the snail ingested, (mgg^{-1}), CPSo is the Carcinogenic potency slope, oral (mg kg^{-}bw- day^{-1}), MC is the snail mass of the snail ingested g day^{-1}). AT is the averaging time, carcinogens (day year^{-1}). The input parameters used in the health risk estimation for the snail intake from Bayelsa state are represented in Table 1.

Table 1: Summary statistic of input parameters in the health risk estimation

Symbol	Description	Unit	Value
MC	Metal concentration	mg kg^{-1}	Presented in table 2
MI	Mass of the snail ingested	g day^{-1}	24.7

Cont…

Symbol	Description	Unit	Value
EF	Exposure	Days	365
	Frequency	$Year^{-1}$	
ED	Exposure duration	Year	51.86
RfD	Reference dose	$mg\ kg^{-1}day^{-1}$	Cd = 0.001; Ni = 0.002
BW	Body weight (adult)	kg	60
ATn	Averaging time non-carcinogens	Days	365 × 51.86 = 18928.9
ATc	Averaging time carcinogens	Days	365 × 70 = 25550
CPSo	Carcinogenic potency slop, oral	$mg\ g^{-1}\ day^{-1}$	Cd = 0.38: Ni = 1.7

Exposure duration

The exposure duration is defined as the exposure frequency of 365d/yr for 51.86 yr (which corresponded to the average life expectancy of a Nigerian[32]. The averaging time and number of fish consumed are required to provide input for an estimate of human health risk from exposure through snail ingestion. An averaging time of 365 d/yrs for 70 yrs (ie AT_C = 25550 days) was used for to characterize lifetime exposure for cancer risk calculation and averaging time of 365d/yr for 51.86 yr (i.e. ATn = 18928.9 days) was used in charactering non-cancer risk[35].

Snail ingestion

The per capita consumption of fish and shellfish in Nigeria for human food is averaged 9.0 kg[39], which is equivalent to 24.7 g per day was used for the risk estimation.

Body weight

We used body weight of 60 kg for average Nigerian adult.

Toxicity factors

The reference dose (RfD) and carcinogenic potency slop factor (CPS) used for health risks (TR & THQ) evaluation was provided by USEPA[35]. The cancer slop factors for ingestion of cadmium and Nickel (subsulfide) are 0.38 and 1.7, respectively. While the RfD (reference dose) for Cd and Ni are 0.001 and 0.02 (i.e. the dose that is likely to be without appreciable risk of deleterious effects during a life time).

Acceptable risk distribution

The acceptable risk distribution was assigned by constraints on percentiles. The lower end of the range of acceptable risk distribution is define by a single constraint on the 95th percentile of risk distribution that must be equal or lower than 10^{-6} for carcinogens (TR) and may be up to 10^{-4} in some circumstance. While the health protection standard of life risk for THQ is 1.[40]

RESULTS AND DISCUSSION

Concentration of Cd and Ni in the snail sample

Concentration range and mean of cadmium and Nickel in the edible tissue of the snail sample from Bayelsa state were presented in Table 2. The concentration in the snail samples varies considerably among species. This was possibly due to differences in metabolism and feeding patterns of the snails.

Table 2: Cd and Ni levels (mg kg^{-1} dry wt.) in selected land and marine snails from Bayelsa State, Nigeria

Snail samples	Statistics	Cd	Ni
Achatina achatina	Range	14.4-24.0	13.5-20.0
	Mean ± SD	17.8 ± 4.37	16.7 ± 5.03
Limicolaria flammea	Range	6.0-7.0	6.2-9.1
	Mean ± SD	6.3 ± 0.47	7.3 ± 1.04
Pachymelenia aurita	Range	2.0-2.2	11.5-28.5
	Mean ± SD	2.1 ± 0.26	17.7 ± 7.68
Tympanotonus fuscatus	Range	2.0-3.5	9.5-13.5
	Mean ± SD	2.8 ± 0.64	11.3 ± 1.65
Guidelines			
FAO/ WHO (1993)		0.5	-
WHO (1985)		2.00	0.60
FEPA (2003)		2.00	0.50
EU (2006)		0.02	-

The concentration of Cd in *A. achatinar* ranged from 14.4-24.0 mg kg^{-1} with the mean of 17.8 ± 4.37 mg kg^{-1}, *L. flammea* ranged from 6-7.0 mg kg^{-1} with mean of 6.3 ± 0.47 mg kg^{-1}, *P.aurita* ranged from 2.0-2.2 mg kg^{-1} with mean of 2.1 ± 0.26 mg kg^{-1} and *T. fuscatus* value ranged from 2.0-3.5 mg kg^{-1} with mean of 2.8 ± 0.64 mg kg^{-1}, respectively. The highest concentration, 17.8 ± 4.37 mgkg^{-1} was recorded in *A. achatina*, while the lowest mean concentration 2.1 mg kg^{-1} was recorded in *P.aurita*. The amount of Cd found in the snail samples exceeded the limit set by regulatory bodies, FAO, WHO[41], WHO[42], FEPA[43], EU[44]. This call for concern, because report[45] has shown that ingestion of high levels of Cd can lead to acute renal failure in humans. From the results, it can be predicted that consumption of snail species such as *A.achatina, L. flammea, P. aurita and T.fuscatus* from Bayelsa state can lead to severe chronic Cd poisoning, if consumed excessively. While Ni concentration in *A. achatina* ranged from 13.5-20.0 mg kg^{-1} with the mean ± SD of 16.7 ± 5.03 mg kg^{-1}, *L.flammea* value ranged from 6.2-9.1 mg kg^{-1} with the mean ± SD of 7.3 ± 1.04 mg kg^{-1}, *P.aurita* ranged from 11.5-28.5 mg kg^{-1} with the mean of 17.7 ± 7.68 mg kg^{-1} and *T. fuscatus* value ranged from 9.5-13.5 mg kg^{-1} with the mean of 11.3 ± 1.65 mg kg^{-1}, respectively. For Ni, the highest concentration, 17.7 ± 7.68 mg kg^{-1} was recorded in *P. aurita*, while the lowest concentration, 7.3 ± 1.04 mg kg^{-1} was recorded in *L. flammea*. Also, the amount of Ni found in all the snail samples exceeded the limits set by WHO[41] and FEPA[43].

Nickel is essential for growth and reproduction in animal and human beings, but shows carcinogenic effects when consumed in high amount while Cd has no known biological or beneficial role in human body. The concentration Ni & Cd in this study is higher than the values reported by Kumar and Mukherejee[33], Osakwe[39], Ijeoma et al.[26], and Akoto et al.[46]

Generally it was observed that the concentration of Cd and Ni in these snail samples were higher than the limits set by regulatory bodies. This call for concern considering that both Cd and Ni are toxic and their accumulation overtime may lead to serious health issues.

Table 3: Comparison of Cd and Ni levels (mg/kg) in the four snail samples from Bayelsa state with other fish and shell fish species in other states/countries

Samples	Cd	Ni	State/Country	Reference
A. Achatina	17.8	16.7	Bayelsa/Nigeria	This study
L. Flammea	6.3	7.3		This study
P. aurita	2.1	17.7		This study
T. fuscatus	2.8	11.3		This study
Crab	0.023	0.69		[26]
Water snail	0.037	1.007	Delta/Nigeria	
Periwinkle	0.028	0.63		
Oyster	0.029	0.76		
Sarotherodon melanotheron Muscle	0.275	0.36	Cape Coast/Ghana	[45]
African catfish (auriasgariepinus) Edible part	1.125	1.12	Imo/Nigeria	[39]
Catlacatla	-	3.74	Tropic Wet-Land/India	[33]
(*oreochromisnilotica*		1.95		
Labeorohita		3.49		

Human health risk assessment of Cd and Ni inLand and marine snails

Risk assessments are based on assumptions. The USEPA Region III, Risk- Based Concentration Table[35] presents methods for estimating the target cancer risk (TR) and the non-cancer risk (THQ_S). The risk associated with the carcinogenic effects of target metals is expressed as the excess probability of contracting cancer over a lifetime of 70 years. The USEPA established the acceptable guideline values for THQ and TR as 1 and 10^{-6} and 10^{4}, respectively. The theoretical and estimated lifetime target cancer risk (TR) and target hazard quotient (THQ_S) as well as dietary intakes of Cd and Ni in the snail samples were calculated and presented in Table 4. THQ higher than 1, implies that the estimated exposure exceed the USEPA reference dose for the contaminant of interest.

As indicated in Table 4, the estimated daily intake (EDI) and estimated weekly intake for Cd in the snail samples were; 7.33 and 51.31 mg kg^{-1}bw day^{-1} & $week^{-1}$ in *A. achatina*, 2.59 and 18.13 mg kg^{-1}bw day^{-1} & week in *L. flammea*, 0.86 and 6.02 mg kg^{-1}bw day^{-1} & $week^{-1}$ in *P.aurita* and 1.15 and 8.05 mg kg^{-1} bw day^{-1} & $week^{-1}$ in *T. fuscatus*, respectively. The highest daily and weekly intake of Cd is record in *A. achatina*, while the lowest daily and weekly intake is recorded in *P. aurita*. The provisional weekly intake of Cd is set at 2.5 µg kg^{-1} bw, while provisional daily intake Cd is set at 0.36 µg kg^{-1}bw by the European Food Safety Authority (EFSA)[47]. But the results obtained from this study are all higher than the provisional daily and weekly intake of Cd set by EFSA. This implies that the daily and weekly consumption of these snails based on the per capita consumption of 24.7 kg, which is equivalent to 9.0 g may cause health risk effects to consumers in future.

Table 4: Estimated dietary intake, (mg kg^{-1}bw/day/week), Target hazard quotient (THQ), Hazard index (HI) and Target cancer risk (TR) for intake of Cd and Ni in Land and Marine Snails from Bayelsa state

Snail samples	Risk model	Cd	Ni	Hazard index (HI)
A.achatina	EDI	7.33	6.87	
(Giant land snail)	EWI	51.31	48.09	
	THQ	7.33	0.34	7.67
	% HI	95.56	4.43	
	TR	2.9×10^{-3}	1.2×10^{-2}	
L.flammea	EDI	2.59	3.01	
(Garden snail)	EWI	18.13	21.07	
	THQ	2.59	0.15	2.74
	% HI	94.53	5.47	
	TR	9.8×10^{-4}	5.1×10^{-3}	
P.aurita	EDI	0.86	7.29	
(Periwinkle with spine)	EWI	6.02	51.03	
	THQ	0.86	0.36	1.22
	% HI	70.49	29.51	
	TR	3.3×10^{-4}	1.2×10^{-2}	
T. fuscatus	EDI	1.15	4.65	
(Periwinkle without spine)	EWI	8.05	32.55	
	THQ	1.15	0.23	1.38
	% HI	83.33	16.67	
	TR	4.4×10^{-4}	7.9×10^{-3}	

The estimated daily intake (EDI) and estimate weekly intake (EWI) for Ni calculated for snail consumption in this study were; 6.87 mg kg^{-1} bw day^{-1} and 48.09 mg kg^{-1}bw $week^{-1}$ in *A. achatina*, 3.01 mg kg^{-1}bw day^{-1} and 21.09 mg kg^{-1}bw $week^{-1}$ in *L. flammea*, 7.29 mg kg^{-1} bw day^{-1} and 51.03 mg kg^{-1} bw $week^{-1}$ in *P. aurita* and 4.65 mg kg^{-1}bw day^{-1} and 32.55 mg kg^{-1} bw $week^{-1}$ in *T.* fuscatus, respectively. The highest Ni EDI and EWI intake is obtained from the consumption of *P. aurita* while the lowest Ni EDI and EWI are obtained from the consumption *L. flammea*. The Joint FAO/WHO Expert Committee on food Additives has established a PTWI and PTDI for Ni and its compounds, which is 35 µg kg^{-1}bw $week^{-1}$ and 5 µg kg^{-1} bw day^{-1},[33] which is equivalent to 0.035 and 0.005 mg kg^{-1}bw day^{-1} & $week^{-1}$, respectively. Based on the results obtained from this study the EDI and EWI for all the snail sample were higher than the PTDI and PTWI of FAO/WHO for Ni, which indicates an adverse health effects to the consumers.

The THQ_S of Cd and Ni in the four snail samples were *A. achatina* is 7.33 and 0.34 with HI values of 7.67, *L. flammea* is 2.59 and 0.15 with HI value of 2.74, *P. aurita* is 0.86 and 0.36 with HI value of 1.22 and *T. fuscatus* is 1.15 and 0.23 with HI value of 1.38, respectively. The hazard index (HI) of Cd and Ni in *A. achatina* and *L. flammea*is 7.76 and 2.74, which were all higher than the acceptable limits of 1 set by USEPA[35]. This implies that the continuous consumption of these snails over a long period of time will pose a potential health risk to consumers. While for the periwinkles (*p.aurita* and *T.fuscatus*) the hazard Index values (i.e. the sun of THQ) is equal to 1, this indicates no adverse health effects to consumers. However, it is advisable that these periwinkles should be consumed moderately.

The average values of target cancer risk (TR) for Cd and Ni for the consumption of the four snail samples were; *A. achatina* is 2.9×10^{-3} and 1.2×10^{-2}. These values are higher than the USEPA[35] acceptable limits of $10^{-6} – 10^{-4}$, respectively. This implies that out of one thousand and out of one hundred there would be like-hood that up to two (2) and one (1) consumers of this snail will be contracting cancer if exposed continuously over 70 years (the assumed lifetime), rather than the acceptable limit of one in million (10^{-6}) and one in ten thousand (10^{-4}). TR values for Cd and Ni in *L. flammea* were 9.8×10^{-4} and 5.1×10^{-3}, these values are also far greater than the acceptable limits of one in a million (10^{-6}) and one in ten thousand established by USEPA, rather it implies that nine (9) consumers out of ten thousand and five (5) in one thousand would likely contract cancer if exposed continuously to given concentration over 70 years (the assumed lifetime). For *P. aurita*, the TR values for Cd and Ni were 3.3×10^{-4} and 1.2×10^{-2}, these values are also higher than the acceptable limits of 10^{-6} - 10^{4} (i.e one in a million and one in ten thousand). Rather, there will be a likelihood that up to three (3) out of ten thousand and one out of one hundred consumers will be contracting cancer if exposed continuously. While for *T. fuscatus* the TR values were 4.4×10^{-4} and 7.9×10^{-3}. Again, these values are higher than the acceptable limits set by USEPA[40], which is $10^{-6} – 10^{-4}$, rather it implies that out of ten thousand there will be four (4) consumers (for Cd) and out of one thousand there will be seven (7) consumers (for Ni) contracting cancer over 70 years (assumed life time). The TR values of Cd in the snail samples are in the decreasing order of *A. achatina* > *L. flammea* > *T. fuscatus* > *P. aurita* with TR values of 2.9×10^{-3}, 9.8×10^{-4}, 4.4×10^{-4} and 3.3×10^{-4}, while the TR values for Ni are in the decreasing order of *A. achatina* and *P. aurita* > *T. fuscatus* > *L. flammea* with TR values of 1.2×10^{-2}, 1.2×10^{-2}, 7.9×10^{-3} and 1.2×10^{-2}, respectively. These values are comparable to result obtained by Kumar and Mulcherjee[33] in some fish species but lower than the values obtained by Manual et al.[47] in some shellfish from Todos and 0S Santos Bay, Bahia, Brazil. Also the THQ of the individual metals and the combined THQ (i.e. the hazard index, HI) in the presents study is higher than the value obtained by Osakwe et al.[39] in African catfish from Imo river, Nigeria.

CONCLUSION

In this study, concentrations of Cd and Ni in land snail (*A. achatina and L. flammea*) and marine snails (*P.aurita and T .fuscatus*) were investigated. Generally, the results shows that the mean concentrations of Cd and Ni in all the snail samples were higher than the acceptable limits set by regulatory bodies[41-44] and the concentrations varies considerably among species. This is a source of concern because; literature revealed that Cd and Ni are human carcinogens[23]. More so, Cd has no known biological or beneficial role in humans rather, report[24] has shown that Cd is an endocrine disturbing substance and high accumulation may lead to development of prostate cancer and breast cancer in humans. The provisional daily and weekly intake (PDI and PWI) of Cd and Ni in all the snail samples were higher than the limits set by FAO /WHO. For the non-carcinogenic and carcinogenic risk evaluation, the results shows that the hazard index (sum of THQ) for all the snail samples were higher than the acceptable limits of 1 set by USEPA35. The HI values for each snail were mainly contributed by Cd, which ranged between 70-95% respectively. Also, the TR values for all the snail samples were higher than the limits established be USEPA[35], which implies that potential health risk for excessive consumption of snails from Bayelsa State is significant as per Cd and Ni contents. Therefore, moderate amount of intake is advisable to prevent human health risk to consumers in future.

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