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Human Health probabilistic Risk Assessment of *Achatina achatina* (African Giant Snail) consumption as models of mining Activities

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Abstract— Most anomalies and health challenges faced by individuals can be related to repeated exposures of copious amounts of heavy metals found in snails and consumed by humans. This research study was conducted to investigate the levels of heavy metals (As, Cr, Ni, Pb, Zn, Cu) in *Achatina achatina* (snails as burrowing organism in mining sites) and also to ascertain through probabilistic models and USEPA standards the extent of health risk and carcinogenicity to the inhabitants of the limestone mining area. In this study, 27 snail samples from three major sites were collected and analysed. Multivariate analysis indicates that the concentration of heavy metals in the order (Pb> As> Cr> Ni> Cu> Zn) of snails from mining sites increased significantly (P< 0.05) as compared to those from snails farms. Measured concentrations were then used to calculate the health risk for adults and children. Probabilistic Human Health risk assessment Model for Estimated Daily Intake (EDI) showed a major deviation from the Tolerable Daily Intake, likewise Toxic Hazard Quotient (THQ) were above the USEPA standard condition (0<THQ<1) showing Hazard quotient as high as 58 (>>1) for children. Carcinogenic risk models showed predictions above the USEPA acceptable limits (ILCR<10^3) having a likelihood of over 87 cancer cases per 1000 persons as highest risk, indicating that 1 person out of 12 persons may be affected.

Index Terms—*Bioaccumulation, carcinogenic risk, Mining, probabilistic model, risk assessment, probabilistic model, pollution, Snails, Toxicity*

1 INTRODUCTION

In a world where mining activities are almost indispensible and there is increased drive for use and exploration of natural mineral resources, the ecosystem and all biospheres is left to the direct and mostly indirect effect of human anthropogenic activities [11]. While many heavy metals are naturally present in the Earth's crust and atmosphere, humans may promote heavy metal pollution through activities such as mining, smelting, transportation, military operations, and industrial manufacturing, as well as applying metal-containing pesticides and fertilizers in commercial agriculture. These activities release metals into the environment through waste disposal, runoff, and application of heavy metal-laden chemical products, which then may enter terrestrial systems via aerial deposition, surface waters, or soil [18] [2]. Unlike organic pollutants, heavy metals cannot be degraded. As a result, heavy metals persist in the environment for years, well after point sources of pollution have been removed [16]. These metals are able to bio-accumulate in the systems of most organisms (like snails) and in time increase to levels that are deleterious to the organism, a process called bio-magnification [18]. These may interact directly with biomolecules, disrupting critical biological processes, resulting in toxicity and the concomitant transfer of these metals through the food chain could ultimately pose risk to human life.

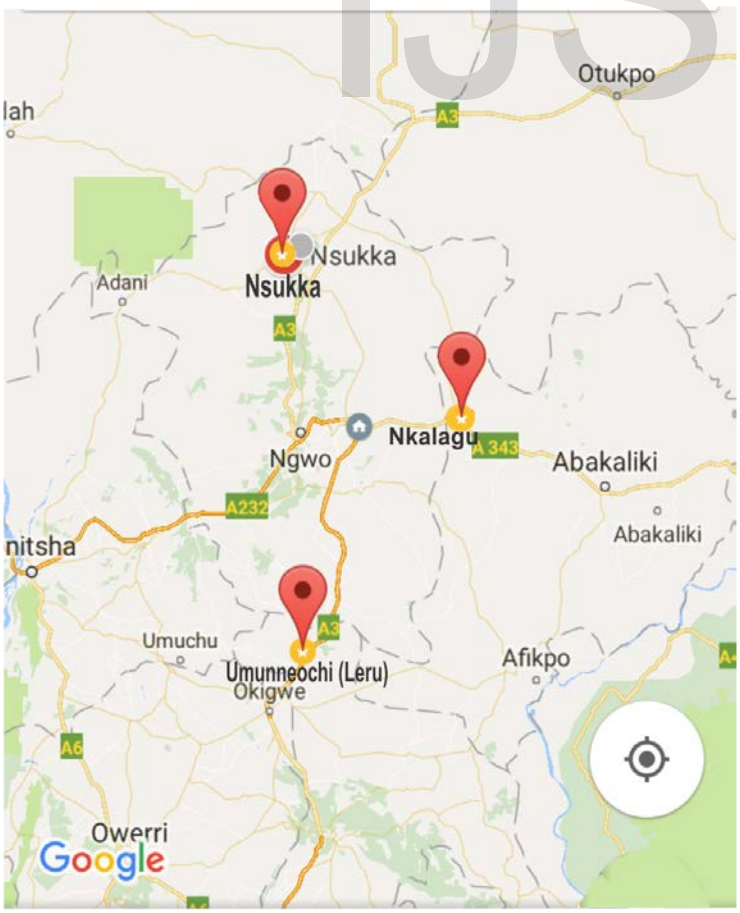
Fig 1: A typical African Giant Snail (*Achatina achatina*) [8]

Consumptions of snails picked up from these mining-polluted regions elicit reasons for public health concern. Snails as burrowing organisms are capable of taking in these heavy metals, adapting to the harsh conditions of the mining environment and even reproducing [4][2]. While the human body may have evolved to combat these heavy metals, frequent exposure may hamper the human system either by stimulating a disease condition or exacerbating some salient health risk condition[5] [15]. With the crusade for environmental sustainability, mining emerges as an opposition to the tenets of salvaging the ecosystem, thus, there is an estimable ecological risk that such activities could portend [25]. Snails are 'large sinks' or reservoir of heavy metals accumulated over time. According to [13] these accumulations may alternate its antioxidant enzyme properties impairing its ability to function maximally.

Estimated Daily Intake is the presumed daily exposure or consumption of a nutrient or chemical residue. It is an assumption of the level of a particular toxic substance (in this case, heavy metal) that an individual is likely to take when he consumes a specified amount of the particular food under investigation [19]. An EDI below or above standards set by the USEPA would possibly denote toxicity or unhealthy mode of nutrition [21][26]. The Esti-

mated Daily intake (EDI) varies for both adults and children, as an assumed average body weight is taken to across both children and adults respectively. Toxic Hazard Quotient is the ratio of the potential exposure to a substance and the level at which no adverse effects are expected, It is the ratio between exposure and reference oral dose (RfDing), used to express the risk of non-carcinogenic effects [3][21]. If the Hazard Quotient is calculated to be less than 1 (THQ<1), then no adverse health effects are expected as a result of exposure. If the Hazard Quotient is greater than 1(THQ >1), then adverse health effects are possible [21]. Carcinogenic risk is the probability of an individual to develop cancer over a lifetime while consuming a particular food under investigation. In general, USEPA considers excess cancer risks that are below about 1 chance in 1,000,000 (1×10^{-6} or 1E-06) to be so small as to be negligible, and risks above 1 in 10,000 (1×10^{-4}) to be sufficiently large that some sort of remediation is desirable. An ILCR greater than one in ten thousand (ILCR > 10^{-4}) is benchmark for gathering additional information whereas 1/1000 or greater (ILCR > 10^{-3}) is moderate increased risk and should be given high priority as a public health concern [3].
The aim of the study is to access quantitatively and qualitatively the levels of heavy metals in land snails. More importantly it is to conduct a human health risk assessment using probabilistic risk assessment models, as to determine the extent of risk in which the inhabitants of this region may be exposed to.

2.0 Materials and methods
2.1 Materials



All chemicals used were of analytical grade.

2.2 Studied area
Two major mining sites in the South-East were chosen: Leru mining site of Ummuneochi LGA of Abia State with coordinates (6° 01'46.7N, 7° 23'11.1E) and Nkalagu mining site of Ishelu LGA of Ebonyi state with coordinates (6° 28' 45.1N, 7° 46'32.4E). Etana Snail farms, Nsukka Enugu state (A non-mining site was also taken into considerations) with cordiantes (6° 52' 25.1N, 7° 22' 10.0E)

2.3 Sample collection
Snail samples were collected at mining regions of Nkalagu, Ebonyi state and Leru, Abia State. Snail samples were also collected from Etana snail farms at Nsukka, Enugu state. Snails collected were divided into three groups: Group A: snails from snail farms, Group B: Snails from mining site at Nkalagu, Group C: Snails from mining site at Leru.

2.4 Digestion of Snail samples
3g of each of the Snails samples were weighed into the digestion flask and $30cm^3$ of aqua regia was added and digested in the fume cupboard, for the evaporation of HCl until a clear solution was obtained, it was cooled, filtered and then made up to 100ml mark in a standard volumetric flask with de-ionised water. The digested samples were analysed for Arsenic (As), chromium (Cr), Nickel (Ni), copper, Lead (Pb), Zinc (Zn) and Mercury (Hg) using atomic absorption spectrophotometer (AAS) at respective wavelengths [12].

2.5 AAS configuration
A four lamp turret Varian 200 flame AA spectrometer was optimized for the determination of arsenic (As), Chromium (Cr), Nickel (Ni), Copper (Cu), Lead (Pb), Zinc (Zn). The concentrations were measured in parts per million (ppm). The instrument mode was absorbance. The sampling mode of the instrument was manual, set at the prompt measurement mode. The photomultiplier voltage was set at 330 V. Precision of the standard, sample and expansion factor was 1%. A background correction factor was not used in the determination of any of the metals. The reslope was carried out after every 12 samples and the reslope standard was 2.0. The reslope lower limit was 75% and upper limit 125%. The lamp current for all the metals were set between 5-8 mA [12].
Statistical Analysis: Data obtained were expressed as mean ± SD and test of statistical significance were carried out using one-way analysis of variance (ANOVA). Mean with p values < 0.05 were considered as significant.

All values for different model parameters estimated were compared to the standards and permissible limits of the updated versions of the United States Environmental Protection Agency [26]

2.6 Probabilistic Risk Assessment Model
Human Health Risk Assessment
2.6.1 Estimated Daily Intake (EDI
Estimated Daily Intake of metals for adults and children was determined by the equation

$$EDI = \frac{\text{Concentration of Metals x Daily Snail Intake}}{\text{Average Body Weight}}$$

Where body weight Average for Adult was considered to be 60kg

Heavy Metals [25][26]	Ingestion Reference Dose RfDing	Carcinogenic Slope Factor CSFing $(MgKg^{-1} day^{-1})^{-1}$
Arsenic (As)	0.0050	1.5000
Chromium (Cr)	1.5000	0.5000
Nickel (Ni)	0.0200	1.7000
Copper (Cu)	0.0400	0.0020
Lead (Pb)	0.0035	0.0085
Zinc (Zn)	0.3000	0.0000

Table 1: ingestion Reference Dose/ Carcinogenic Slope Factor of Specific Heavy metals
Source: [3] [21] **[25][26]**

and Daily snail intake (Ingestion rate) for Adult is considered to be 0.10274 Kg/person/day [3] [19][21].

2.6.2 Toxic Hazard Quotient (THQ)
Toxic Hazard Quotient was calculated using the equation below

$$THQ = \frac{\text{Concentration of Metals x Daily Snail Intake}}{\text{RfD x Average Body Weight}}$$

Where RfD is the Oral / Ingestion Reference Dose [3] [21].

2.6.3 Incremental Lifetime Carcinogenic Risk (ILCR)
The life-time probability of cancer or carcinogenic risk was estimated according to [26] by

CR = Estimated Daily Intake x Ingestion Carcinogenic Slope Factor(mg/kg/day) (mg/kg/day)-1.

A slope factor and the accompanying weight-of evidence determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks. The slope factor is a plausible upper-bound estimate of the probability of a response per unit of a chemical over a lifetime. The slope factor is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen. Cancer slope factors are estimates of carcinogenic potency and are used to relate estimate daily dose of a substance over a lifetime exposure to the lifetime probability of developing tumours. The Ingestion cancer slope factors are expressed in units of (mg/kg/day)-1 (Onuoha *et al.*, 2016). The USEPA approved ingestion reference dose and carcinogenic slope factors for heavy metals are shown in Table 1.

All values for different model parameters estimated were compared to the standards and permissible limits of the updated versions of the United States Environmental Protection Agency [26].

3.0 RESULTS
Table 2 shows the results of heavy metals in snails from both snail farm and mining sites. Snails harvested from mining sites showed a significant increase ($P < 0.05$) in the levels of heavy metals as compared to the snails from the snail farms. Meanwhile levels of heavy metals (specifically Arsenic) in Snails from Leru were significantly higher ($P < 0.05$) than those from Nkalagu, the reverse is the case for chromium which showed a significantly higher proportions for snails from Nkalagu as compared to those from Leru. However, other heavy metals (Ni, Cu, Pb and Zn) showed no significant difference ($P> 0.05$) comparing snails from Leru and Nkalagu Mining site. It is noteworthy that Lead and Arsenic, two very important deleterious metals were found in highest concentrations in the mining sites.
where
A2: Snails from snail farm, Enugu
B2: Snails from Leru
C2: Snails from Nkalagu
MPL : Maximum Permissible Limit [28]

3.1 Probabilistic Human Health Risk Assessment
3.2 Estimated Daily Intake (EDI)
Estimated Daily Intake of Snails from the Snail Farm and mining site
Table 3 shows the Estimated Daily intake of snails. Results from Probabilistic Human Health risk assessment Model for Estimated Daily Intake showed a major increase above the Tolerable Daily Intake for heavy metals such as As, Ni and Pb and falls below the Tolerable Daily Intake for heavy metals such as Cr, Cu, and Zn. Generally, estimated daily intake for heavy metals from snails farm were significantly low ($P < 0.05$) as compared to those from the mining regions for both adults and children.
A3: Estimated Daily Intake of heavy metals through consumption of snails from snail farm
B3: Estimated Daily Intake of heavy metals through consumption of snails from Leru Mining Site
C3: Estimated Daily Intake of heavy metals through consumption of snails from Nkalagu Mining Site
TDI: Tolerable Daily Intake

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TABLE 2: Heavy metal content of snail samples from mining sites and snail farm (Mean + SD)

	As (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
A2	5.594+ 1.18^{a}	< 0.0001^{a}	8.98+ 0.75^{a}	7.879+ 0.36^{a}	61.914+ 2.66^{a}	5.521+ 0.44^{a}
B2	43.02+ 1.53^{b}	21.92+ 0.23^{b}	11.89+ 0.865^{b}	9.848+ 0.85^{a}	114.559+ 3.47^{b}	7.395+ 0.394^{a}
C2	33.05+ 2.92^{c}	37.90+ 1.52^{c}	12.821 + 1.42^{b}	12.817+ 0.42^{b}	111.066+ 1.94^{b}	6.265+ 0.275^{a}
MPL	< 2.00	10.00	11.00	40.00	5.00	60.00

TABLE 3: Estimated daily intake (EDI) of heavy metals for the Leru and Nkalagu population through consumption of snails as compared to Snails from snail farms and the tolerable daily intake (TDI)

Groups	Arsenic(As)(Mg/Kg/day)		Chromium(Cr)(Mg/Kg/day)		Nickel(Ni)(Mg/Kg/day)		Copper(Cu)(Mg/Kg/day)		Lead(Pb)(Mg/Kg/day)		Zinc (Zn)(Mg/Kg/day)	
	Children	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**	**Children**	**Adult**
A3	**0.0159**	**0.0096**	**< 0.0001**	**< 0.001**	**0.0255**	**0.0154**	**0.0223**	**0.0135**	**0.1925**	**0.1060**	**0.01565**	**0.0095**
B3	**0.1220**	**0.0737**	**0.0604**	**0.0365**	**0.0337**	**0.0204**	**0.0279**	**0.0169**	**0.3248**	**0.1961**	**0.021**	**0.0127**
C3	**0.0937**	**0.0566**	**0.1074**	**0.0649**	**0.0368**	**0.0220**	**0.0363**	**0.0220**	**0.3149**	**0.1902**	**0.017**	**0.0107**
TDI	**0.0021**		**0.1500**		**0.004**		**0.500**		**0.00357**		**1.000**	

3.3 Toxic Hazard Quotient

3.3.1 Toxic Hazard Quotient (THQ) of Snail consumption of the snail from the Snail Farm and mining site

Figure 2 and Figure 3 represent the toxic hazard quotient of mining snail consumption. Toxic hazard quotient Results from Probabilistic Human Health risk assessment Model for Toxic Hazard Quotient showed increased values above the standard THQ (0<x<1) for an acceptable human population for As, Ni and Pb, whereas values for Cr, Zn and Cu were below (<1) the standard THQ, thus within acceptable range. Results again reiterated the fact that children were more at risk than adults, and that Snails from snail farms possessed the lowest THQ values for all Heavy metals. These results are shown in graphs for both children and adult to elicit greater extent of variations, as shown below in

(Mg/Kg/day)

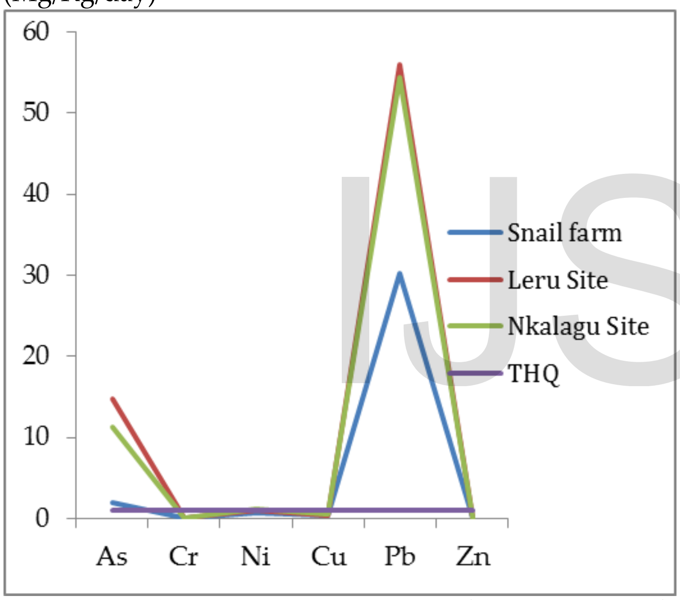

Fig 2: Toxic hazard quotient (THQ) of heavy metals for the Leru and Nkalagu population through consumption of snails from as compared to snails from snail farms (Children)

3.2.2 Incremental Lifetime Carcinogenic Risk (ILCR) of Snail consumption from the Snail Farm and mining site

Table 4 shows the incremental lifetime carcinogenic risk of snail consumption over 70 years. Carcinogenic Risk (CR) values from the probabilistic Human Health Risk Assessment model showed that all values estimated (As, Cr, Ni and Pb)for both Leru and Nkalagu mining site exceeds the value of the USEPA Incremental Lifetime Carcinogenic Risk (ILCR>10^{-3}) having more than 1cancer cases per 10,000 persons. However, CR values for the snail farms fell with an acceptable range (10^{-3}< ILCR <10^{-6}) for heavy metals (Cr and Pb) while As and Ni were otherwise, a reason for concern.

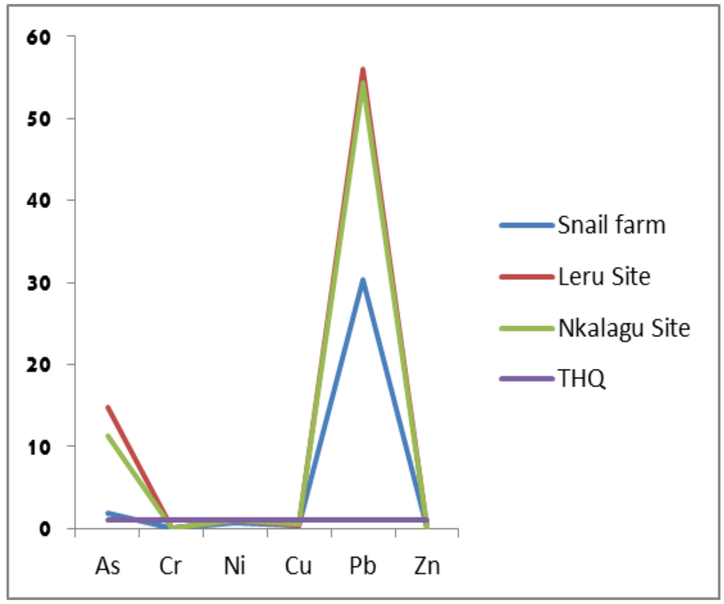

Fig 3: Toxic hazard quotient (THQ) of heavy metals for the Leru and Nkalagu population through consumption of snails from as compared to snails from snail farms (Adults)

Table 4: Carcinogenic Risk of heavy metals for the Leru and Nkalagu population through Consumption of Snails as compared to snails from snail farm

Groups	As	Cr	Ni	Pb
A5	1.4E-2	5.0E-7	2.6E-2	9.0E-4
B5	1.1E-1	1.8E-2	3.5E-2	1.7E-3
C5	8.5E-2	3.3E-2	3.7E-2	1.6E-3

A5: Carcinogenic Risk of Heavy metals through consumption of snails from snail farms.

B5: Carcinogenic Risk of Heavy metals through consumption of snails Leru mining site

C5: Carcinogenic Risk of Heavy metals through consumption of snails from Nkalagu mining site

DISCUSSIONS

This study is primarily an investigation into mining sites, how it affects the environment and how *Achatina achatina* consumed from such sites could affect human health. Moreover it is majorly the cause-and-effect of human anthropological activities that pose danger to both human and environmental sustainability [11].

Results from snails harvested from mining sites showed a significant increase ($P < 0.05$) in the levels of heavy metals (As, Cr, Ni, Pb, Zn and Cu) as compared to the snails from the snail farms. The challenge with this result is not that it followed the trend of the heavy metal analysis of the soil, but that it exceeds by far the maximum permissible level of heavy metalsn food materials (FAO/WHO (2011), USEPA, 2017). For snails from Leru mining site (As: 43.02, Cr: 21.92, Ni: 11.89, Pb: 114.559) (Mg/Kg) and Nkalagu mining site (As: 33.05, Cr: 37.90, Ni: 12.821, Pb: 111.066) (Mg/Kg) as compared to the maximum permissible limits (As: 2, Cr: 10, Ni: 17, Pb: 5) (Mg/Kg), the levels of heavy metals that have been deposited over time in these snails from the mining site are terribly high and portends a potential level of deep concern. It is notable that the levels of heavy metals in the soil directly affects the concomitant levels of heavy metals in the burrowing snail in that environment, this is because snails take in food substances together with soil particles and become large sinks for heavy metals, the snail's morphology does not readily metabolize this heavy metals (Basapor and Ngabaza, 2015), as such it continues to build-up with time, such that its level of heavy metals could surpass the levels of heavy metals in their respective soil, as seen in the result, where the Arsenic and Lead levels of snails in Leru mining site (As: 43.02, Pb: 114.559) (Mg/Kg) and Nkalagu Mining site (As: 33.05, Pb: 111.066) (Mg/Kg) exceeds the level of heavy metals in their respective soil for both Leru (As: 31.068, Pb: 83.045) (Mg/Kg) and Nkalagu(As: 28.225, Pb: 111.065) (Mg/Kg) mining sites. Heavy metal levels of the snails (As: 5.594, Cr: < 0.001, Ni: 8.98, Cu: 7.879, Pb: 61.914, Zn: 5.521) (Mg/Kg) and soils (As: 9.409, Cr: 128.434, Ni: 12.821, Cu: 6.95, Pb: 70.124, Zn: 16.982) (Mg/Kg) from the snail farms were significantly low ($P < 0.05$) when compared to those of the mining site; this confirms that most snails become close "representatives" of the soil they inhabit, with the increased consumption of snail meat, and its "perceived qualities", the risk may as well offset the merits and even cause more debilitating problems, especially in consumption of snails from mining sites.

The accumulation of heavy metals may pose considerable level of health risk to the consuming population especially those with high consumption rates. Hence, the Estimated Daily Intake (EDI) which describes the tolerable level of heavy metal ingestion: From the results, the EDI values of Arsenic (As) for both children and adults for Leru and Nkalagu mining site snails (0.1220, 0.0737; 0.0937, 0.0566) (Mg/Kg/day) exceeds the EDI standard (0.0021) (Mg/Kg/day) for tolerable levels of Arsenic [26], these suggests that people who consume snails from Leru and Nkalagu over a long period of time, would stand a severe risk of Arsenic intoxication which have been proven to be lethal even in small quantities, arsenic is capable of disrupting the antioxidants systems, inducing spontaneous abortion in pregnant women and have been indicated as an exacerbating agent peripheral neuropathy, gastrointestinal symptoms, cardiovascular diseases, destruction of erythrocytes and possibly death [17] [20].

EDI values of Nickel for both children and adults for the Leru and Nkalagu mining site Snails (0.0337, 0.0204; 0.0368, 0.0220) (Mg/Kg/day) still exceeds the EDI standard (0.004) (Mg/Kg/day) for tolerable levels of Nickel [26], as such the Leru and Nkalagu Populace who consume these snails on a frequent basis could also be at risk of Nickel poisoning, which could cause mild symptoms like vomiting, nausea, insomnia, vertigo or pulmonary symptoms such as oedema, cell derangement or even chronic effects, such as rhinitis, sinusitis, nasal septal perforations, and asthma, as have been reported in nickel refinery [7] [27].

EDI values of Lead for both children and adults for the Leru and Nkalagu mining site Snails (0.3248, 0.1961; 0.3149, 0.1902) (Mg/Kg/day) far exceeds the EDI standard (0.00357) (Mg/Kg/day) for tolerable levels of Lead [26], in retrospect, Lead intoxication is likely imminent for the people who with high snail consumption rate from both Leru and Nkalagu. Increased lead presence in the body is capable awakening salient molecular carcinogenicity [1]. One of the major mechanisms by which lead exerts its toxic effect is through biochemical processes that include lead's ability to inhibit or mimic the actions of calcium and to interact with proteins [1] [9] [10]. Within the skeleton, lead is incorporated into the mineral in place of calcium. Lead is capable of binding to biological molecules and thereby interfering with their function by a number of mechanisms. Lead binds to sulfhydryl and amide groups of enzymes, altering their configuration and diminishing their activities. Lead may also compete with essential metallic cations for binding sites, inhibiting enzyme activity, or altering the transport of essential cations such as calcium [10] [1].

The EDI values of both children and adult in Leru and Nkalagu for Chromium (0.0604, 0.0365; 0.1074, 0.0649) (Mg/Kg/day), Copper (0.0279, 0.0169; 0.0363, 0.0220) (Mg/Kg/day) and Zinc (0.021, 0.0127; 0.017, 0.0107)

(Mg/Kg/day) falls below the TDI limits of Cr (0.1500) (Mg/Kg/day), Cu (0.500) (Mg/Kg/day) and Zn (1.000) (Mg/Kg/day) respectively [26]. This would suggest that Zn, Cr and Cu may not pose any health risk to the Snail consumers in Leru and Nkalagu. Zinc is considered to be relatively non-toxic as compared to other heavy metals; it is a component of several enzymes and as such indispensible in human biochemical metabolism [24][6]. Copper toxicity may lead to loss of cognitive ability as it has been indicated in Alzheimer's diseases (Brewer, 2014); Chromium could also cause high level mutations from DNA fragmentation [23]. All these symptoms/diseases are most likely not to occur since the EDI values of these three heavy metals falls considerably below their respective TDI as meted out by the USEPA.

From the EDI values of all heavy metals, it is obvious that children have higher EDI values, this would mean that children exposed to these snails take in higher quantities of heavy metals and given their rate of metabolism as much less than adults, stand a much higher risk of being affected by the plethora of adverse effect capable of being caused by heavy metals, as such children should be as much as possible prevented from frequent snail consumption from sites like Leru and Nkalagu. Another observation is the fact that the snail from snail farm possesses the lowest risk of heavy metal contamination, there EDI values fall much more below, as such they are safer for consumption.

Toxic Hazard Quotient (THQ) through snail consumption is a measure of chemical contaminants. It is not a measure of risk but indicates a level of concern. The interpretation of THQ values is binary which can either be THQ >1 or THQ <1, where THQ >1 indicates reason for public Health concern. The observed THQ of children and Adult for Cr (0.0403, 0.0243; 0.0716, 0.0433) (Mg/Kg/day), Zn (0.07, 0.042; 0.0593, 0.036) (Mg/Kg/day) and Cu (0.7541, 0.4225; 0.9811, 0.55) (Mg/Kg/day) were less than 1 indicating that consumers of snails from these sites may not be exposed to the health risk of Chromium, Zinc and Copper suggestive that consumers of snails from these sites may not experience significant health risk from levels of Cr, Zn and Cu.

However, the observed THQ values for children and Adults for As (24.40, 14.74; 18.74, 11.32) (Mg/Kg/day), Ni (1.685, 1.02; 1.84, 1.10) (Mg/Kg/day) and Pb (92.80, 56.029; 89.97, 54.343) (Mg/Kg/day) are greater than 1, suggesting that there may be an increased concern for consumers from the Leru and Nkalagu mining sites. From the THQ values lead and Arsenic possess incredible high values; this is a call for serious public health concern as it infers that the hazard potential that could be caused by this high toxicity may be deleterious. As reported by Onuoha *et al.* 2016 highest THQ value poses relatively higher potential health risk to human beings particularly for the people residing in the area with serious metal pollution.

Carcinogenic Risk (CR) as estimated is expressed as the probability of contracting cancer over a lifetime of 70 years as a result of continuous consumption of snail from the study sites over one's entire lifetime (Onuoha *et al.* 2016). In general, USEPA considers excess cancer risks that are below about 1 chance in 1,000,000 (1×10^{-6} or 1E-06) to be so small as to be negligible, and risks above 1 in 10,000 (1×10^{-4} or 1E-04) to be sufficiently large that some sort of remediation is desirable. An ILCR greater than one in ten thousand (ILCR > 10^{-4}) is benchmark for gathering additional information whereas 1/1000 or greater (ILCR > 10^{-3}) is moderate increased risk and should be given high priority as a public health concern [3].

From the results, carcinogenic risk values for Arsenic in snail consumption from the snail farm, Leru and Nkalagu site are 1.4E-2, 1.1E-1, and 8.5E-2 respectively. These risk values indicate that consumption of snail meat from Leru mining site and Nkalagu sites would likely result into an excess of 11 cancer cases per 100 people, and 85 cancer cases per 1000 people as opposed to 14 cases per 1000 people of snail farms, since these carcinogenic risk value for Leru and Nkalagu sites specific for Arsenic exceeds USEPA standards (ILCR>10^{-3}), It is indicative of a highly increased chance of contracting cancer over one life's time and should be given high priority as a public health concern.

Carcinogenic risk values for Chromuim in snail consumption from snail farm, Leru and Nkalagu sites are 5E-7, 1.8E-2, and 3.3E-2 respectively. These risk values indicate that the consumption of snail meat from Leru and Nkalagu mining site would likely result into an excess of 18 cancer cases per 1000 people and 33 cancer cases per 1000 people as opposed to 5 cancer cases per 10,000,000 people of snail farm consumers. This implies that the value of the snail farm probable cases is below the USEPA standard (ILCR < 1E-6) and as such is as small as to somewhat negligible; In Contrast, carcinogenic risk values of Cr for snail from Leru and Nkalagu sites exceeds USEPA standards (ILCR>10^{-3}), It is indicative of an increased chance of contracting cancer over one life's time and should by implication be regarded as a public health concern.

Carcinogenic risk values for Nickel in snail consumption from Snail farm, Leru and Nkalagu sites are 2.6E-2, 3.5E-2 and 3.7E-2 respectively. These risk values indicate that the consumption of snail meat from Leru and Nkalagu mining site would likely result into an excess of 35 cancer cases per 1000 people and 37 cancer cases per 1000 people as opposed to 26 cancer cases per 1000 people of snail farm consumers. Carcinogenic risk values of Ni for snail from Leru and Nkalagu sites exceeds USEPA standards (ILCR>10^{-3}), It is indicative of an increased chance of contracting cancer over one life's time and should by implication be regarded as a public health concern.

Results for carcinogenic risk values for Lead in snails includes: 9E-4, 1.7E-3, 1.6E-3 for snail farm, Leru and Nkalagu mining site respectively, showing excess of probable cancer cases for 9 in 10,000 persons, 17 in 10,000 people and 16 in 10,000 people respectively. Carcinogenic risk values of Ni for snail from Leru and Nkalagu sites exceeds USEPA standards (ILCR>10^{-3}), It is indicative of an increased chance of contracting cancer over one life's time and should by implication be regarded as a public health concern. Notably Zinc haS no values for Carcinogenic slope factor as they did not belong to class A or B group of potential carcinogen [14][26].

Conclusion

Generally, it would not be illogical to assert that snail meat (escargot) consumption needs to be checkmated, and if snails must be consumed, snails must be raised in areas whose soil are not exposed to heavy metal, or any other form of toxicity because there would probably be a greater harm in consumption of snails from mining sites. While it may be impossible to stop mining, it is also expedient to restrict access to people who pick snails from mining sites for sale.

Recommendation

Different methods of cooking should be applied to snails to see which method would most significantly reduce its heavy metal load. Research should be carried out on Miners, because they are constantly exposed first-hand to all fumes, dust and machineries that come with mining, there is likelihood that their body metabolism may have changed or be at risk, as such their health and safety may need to be reassured. Positions ticked for mining activities should be taken far from agricultural farmlands and livestock and also away from flowing water sources which may be the source of water for some villages.

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