Original Research Article

Toxicity Impact on Bioaccumulation of Potentially Toxic Elements in African Giant Land Snail (*Archachatina margenata*) treated with different soils and Its Ecological Risk Assessment

ABSTRACT

The use of dump site and mining site soils for rearing of African giant land snail (AGLS) may lead to the bioaccumulation of metals in AGLS, which is a major food chain route for the human body. This study investigated the concentrations of heavy metals (As, Cd, Cr, Cu, Hg and Pb) in AGLS treated with different soil samples dumpsite, mining site and control soil (reserve area where no activities) use in farming AGLS and also to ascertain if they are within permissible limits and its ecological risk assessment on the consumption. Soil samples; dump site (A), mining site (B) and a control site (C) (where no activities) was collected at 0-30 cm depth with the aid of soil auger and were used for AGLS farming, to ascertain whether the PTEs concentration were within the permissible limits and their ecological risk assessment on AGLS consumption. A total of 54 juvenile snails of similar weights was used for the study. The experiment lasted for six month (182 days), during which the snails were subjected to similar dietary reign and equal quantity of feed. Snail's morphological characteristics such as Weight, length and diameter of its shell were measured after farming. The soil samples were analysed for potentially toxic elements PTEs before and after farming, and snail were also analyzed for PTEs after farming for six month using atomic absorptions spectrophotometer (AAS). The ecological health risk from the consumption of these snails was assessed using standard methods and formulas. The result of different soil before and after farming shows a significant different ($P<0.05$) between the activities sites (dump and mining) and the control site. The concentration of PTEs (As, Cd, Cr, Cu, Hg, and Pb) in snails treated with dump site soil were 3.05, 3.89, 3.60, 2.89, 3.98, and 2.55 mg/kg, and snails treated with mining site soil recorded 2.73, 2.74, 3.91, 4.96, 2.88 and 4.82 mg/kg. The values were greater than the maximum permissible limit of 0.5, 2.0, 0.3, 0.04, 0.1 and 0.1 mg/kg respectively recommended by FAO/WHO compared to the control. The study concludes that snail bioaccumulate toxic elements from the soil used in rearing them which is deleterious to humans when consumed. Also the DIM, HQ, HI on the consumption of snail reared with dumpsite, mining site soilis are nearly free of risks, but continuous consumption can lead to bioaccumulation in the food chain.

Keywords: Archachatina margenata, Dump, Mining, Soil, Toxic elements, Risk assessment.

Abbreviations: STWD: Snail treated with dumpsite soil; STWM: Snail treated with mining site soil; STWC: Snail treated with control soil; AGLS: African Giant Land Snail; AM: *Archachatina margenata*; DIM: Daily Intake of Metal; ADDM: Average daily dose of metal; FAO: Food and Agricultural Organisation; HI: Hazard Index; HQ: Hazard Quotient; MPL: Maximum Permissible Level; PTEs: Potentially Toxic Element; RFD: Reference Oral Dose; BAF: Bioaccumulation factor; WHO: World Health Organization.

1. INTRODUCTION

Heavy metals contamination in soil has become a widespread problem all over the world due to development coupled with population explosion, has led to the increase in the volume of wastes generated and disposal and management remain a growing burden especially in developing countries. Apart from littering and offensive odour, wastes have the potential of polluting the soil and underground water, especially when they produce toxins. Toxins from wastes, mainly heavy metals are potentially harmful when they exceed permissible limits. Heavy metals gradually accumulate in the soil, and the stability of heavy metals in the environment will cause accumulation and pollution since they could not be decomposed or are not biodegradable, like other organic pollutants through biological or chemical processes (1). Municipal solid waste in Nigeria are composed mainly of paper, leather, food scraps, vegetable matter, animals, plastics, metals scraps, ceramics, textiles, rubber, iron, ashes and glass. The big challenge with solid waste management is not only the volume of the wastes, but also the composition of the wastes. All categories of wastes including toxic or non-toxic, biodegradable or non-biodegradable, recyclable or non-recyclable are dumped together making them very difficult to manage. The concentrations of heavy metals in soil around waste dumps are influenced by types of wastes, topography, run-off and level of scavenging.

Mining activity is an abundant source of metal contamination of ecosystems. This activity affects relatively small areas, but could have a significant impact on the environment. Mining causes the destruction of natural ecosystems by altering soil, vegetative covers and covering of organisms beneath excavation sites. Therefore, mining sites portend great toxicological challenges for the surrounding ecosystems and on human health (2). During gold mining, large quantities of waste are produced. Over 99 % of extracted ore in gold mining are released into the surrounding environment as waste (3). One of the wastes that have been implicated around mining sites is heavy metals. However the pollution statues of soil would not stay static, as the mining activity continues, more pollution would emerge. Researchers such as (4) have shown that soil around minning site and dump site are bioaccumulated with toxic elements due to the changes in the physiochemical properties of the soil.

Soil is the main reservoir of toxic elements and is the main source of pollution to the ecosystem at large. There are several pathways by which humans could be exposed to heavy metals contaminations. These could be through direct ingestion of the AGLS (food chain), direct ingestion of soil particles, dermal contact with soil particles, inhalation of soil dust and other particles from the air, oral and or dermal intake from groundwater (5). In human, exposure to high levels of heavy metals is known to pose severe health risk such as damage to the organs (such as liver, kidney), cancer and may result in death, and also pause risk for, animals, plant and whole environmental of our modern society (6). Heavy metals can accumulate in organisms as they are hard to metabolize (process and eliminate) (7). Risk assessment is an effective scientific tool which enables decision makers to manage and control sites so contaminated in a cost-effective manner while preserving public and ecosystem health (8). Ecological risk is the likelihood that a given activity or series of activity may have damaged or will damage the habitat, ecosystem or environment immediately or over a given period of time. Metal pollution index is a value that shows the level of contamination and pollution on a given substance under scientific investigation. On the other hand, human health risk assessment are usually done through a series of calculation to estimating the nature and probability of adverse health effects in humans who may be exposed to chemicals in contaminated environmental media (9).

Heavy metals are described as those metals with specific gravity higher or more than 5 g/cm. Heavy metals tend to accumulate along the food chain, with possible uptake in livestock. Many people could be at a risk of adverse health effect from consuming AGLS farm with dump site and mining soil that is highly contaminated with toxic elements. It is therefore important to monitor the heavy metals levels in AGLS and soil use in farming snails. The use of dump soil and mining soil for farming snails by small scale farmers may result to accumulation of toxic elements into the snail via absorbed. Soils are able to biodegrade organic compounds found in waste, converting them into harmless substances. Since inorganic products such as heavy metals are non-biodegradable, thus they persist and accumulate in the soil. Heavy metals can accumulate and persist in soils at environmental hazardous levels to crops and animals. Exposure to heavy metals may cause several issues such as blood and bone disorders, kidney damage, decreased mental capacity and neurological damage. Heavy metal toxicity can result in damaged or reduced mental and central nervous function, lower energy levels, and damage to blood composition, lungs, kidneys, liver, and other vital organs. One specific threat resulting from inadequate wastes disposal is the contamination by heavy metals that have significant toxic potential for the environment (soil, water and air), human's beings, animals and the exposed biodiversity (10).

Archachatina marginata (AM) belongs to the Phylum *Mollusca* and Family *Achatinidae* (10). Except for insects, mollusca are the largest invertebrate group in the animal kingdom (12). *Archachatina marginata* are bilaterally symmetrical invertebrates with soft segmented exoskeleton, inhabiting mostly marine environments, tolerating varied environmental conditions and thrive best in temperate and tropical areas, where soil pH ranges from 4.5-8.0 (13). Various agricultural/ agronomic inputs such as organic manure, and mining soil are used with the ultimate aim of maximizing productivity and economic returns (14, 13), but the side effects on snails are often neglected. *Archachatina magenata* also known as Dodon kodi in Hausa, Igbin in Yoruba and Ejule in Igbo. Nutritionally, snails are of paramount important as source of balanced and high profile protein, low in fat and rich in iron food ideal for human nutrition especially for diabetic patients (15, 16). They serve as valuable sources of nutrition to human and animals with high levels of protein, iron, lysine, leucine, arginine, calcium and phosphorus, relatively low amount of sodium, fat and cholesterol compared to poultry and other livestock (17). (18) reported that snail meat compares favourably with whole egg in all essential amino acids especially with regard to lysine, leucine, isoleucine and phenylalanine.

Snails are found in many locations and have a very diverse type of habitat where they can be found. They are not able to hear at all. So they rely on their sense of touch to interact with each other. They use their sense of smell to help them find food. You will find that snails are the most active at night and may come out during the early morning hours as well (11). Land snails are particularly well adapted to changes in moisture and some desert species are able to remain sealed within their thick shells for two or more years. Most snails have thousands of microscopic tooth-like structures located on a ribbon-like tongue called a radula used to cut food into small pieces. Many snails are Herbivorous, eating plants or rasping algae from surfaces with their radula. Snail farming is a lucrative business in most part of the world. However while some farmers in Asia and Europe have developed a technology for soilless snail farming, in Nigeria and most part of Africa snails are raised mainly in soil medium. Many snails ingest small amount of soil particles and rasp larger rocks or snail shells in order to obtain the Ca essential to reproduction, shell development (snail shells are composed mostly of calcium carbonate $CaCO_3$), and other physiological needs. In times of Ca demand, such as egg laying, snails mobilize Ca from their own internal organs and shells (19).

Farmers generally, use garden soil for snail rearing without any consideration on the effect of different soil treatments on the PTEs, growth and performance of their snails. (15) reported that soil texture and chemical composition of the soil affect the growth and shell development of snails. According to him, snails thrive better in soils that are rich in organic matter. However, the use of dump and mining soil may result in heavy metals accumulation in the soil. As a result, snails may absorb heavy metals from the soil above the permitted levels and enter the food chain affecting human health (20). Hence, this study was designed with the aim of determining the impact of different soil (dumpsite and mining soil) on the bioaccumulation of potentially toxic elements in african giant land snail (*Archachatina magenata*) and its ecological risk assessment.

2. MATERIALS AND METHODS

2.1 Experimental Site

The study was carried out in Makolo farm, Chanchaga Minna Niger State, Nigeria. Chanchaga is situated at $9^{\circ}34^{'}$North latitude, $6^{\circ}33^{'}$East longitude, with an area of $72km^2$ (Image. 1) and a population of 201,429 at the 2006 census. It has a moderate climate with a very high temperature during the dry season and average rainfall during the rainy season.

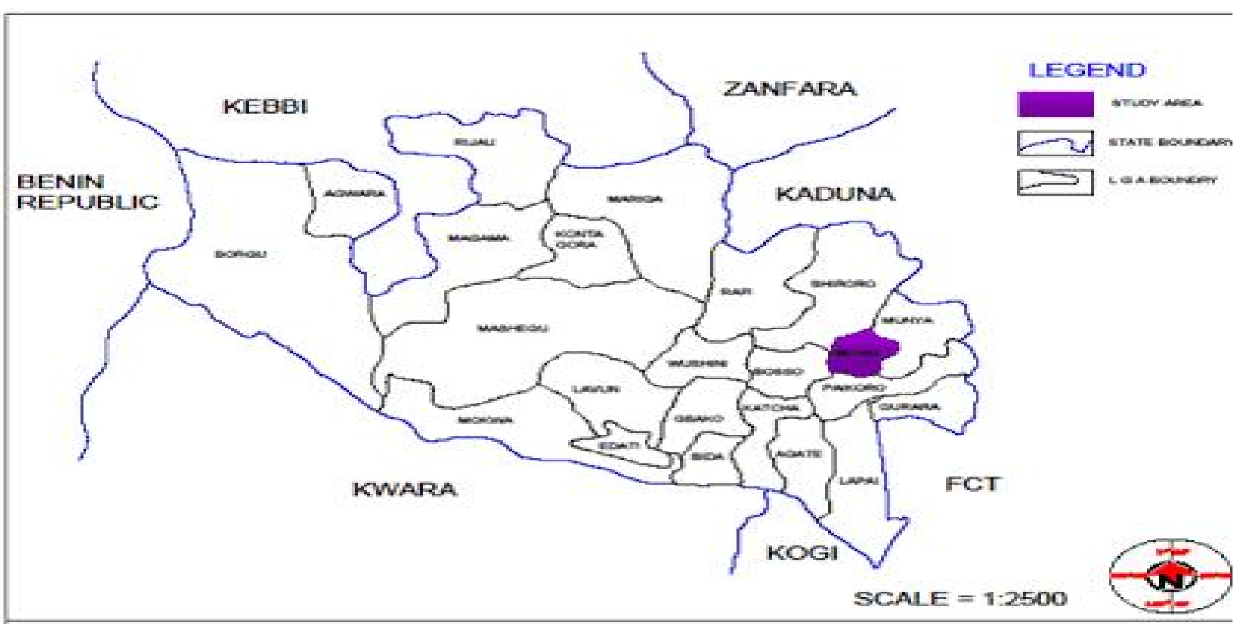


Image 1: Map of Niger State showing study area in purple

2.2 Collection of Samples

Soil samples from dump site, mining site and a control site (where no activities) was collected at 0-30 cm depth with the aid of soil auger and were use in snail farming. The total of 54 juvenile snails of similar weights was collected from Makolo farm Niger state Nigeria were used for the study. The snails were allowed to acclimatize with the environment for seven days before the onset of the experiment.

Plate 1: AGLS after treatment

Plate 2: AGLS before treatment

2.3 Housing of Experimental Animals

Three containers (housing pens for the snails) was labelled A, B and C. treatment A consists of dump soil; treatment B consists mining soil while treatment C contain soil sample with no activities (control) and was filled with 10 kg of soil samples of A, B and C. All the 54 juvenile snails of similar weights were randomly assigned to the 9 plastic containers at the rate of 6 per container. The container measures 22.80 cm in diameter and 12.7 cm in height as recommended by (21). The containers were covered on top with wire netting to allow ventilation and prevent flies while the bottom of each container was drilled in a number of places to allow water drainage and was kept in a cool environment.The experiment lasted for six month (182 days), during which the snails were subjected to similar dietary reign and equal quantity of feed (Paw-paw leaves, pumpkin leaves, potatoes leaves, and water leaves) and water. Leftover feeds were removed to avoid buildup of microorganisms and the pens cleaned out every morning. The soil was changed on monthly basis with similarly treated soil to avoid build up micro-organisms. The environment in each container was humidified by sprinkling water 3 times weekly into the container for easy mobility and to prevent the snails from injury. While water logging was avoided in all cases.

2.4 Experimental Design

The experiment was carried out under a Completely Randomized Design (CRD) with three treatments and three replicate groups for each. The concentrations of the PTEs both in soils and snail sample, were done in three groups, from group 1 to 3, which are samples from dump site, mining site and a control site (where no activities). Both soil and snail sample were randomly collected and analyzed for PTEs As, Cd, Cr, Cu, Hg and Pb.

2.5 Preparation of Snail Sample

The snail samples were sacrificed by striking with a wooden material on the shell carefully. The flesh/foot of the snail was carefully removed from the shell and washed with distilled de-ionized water, dried in an oven at the temperature of 105^{o}C to constant weight in three days. After drying, samples were crushed to fine powder using porcelain mortar and pestle, then sieved using a 0.4 mm mesh. The powdered samples were stored in 100 mL air tight bottles prior to digestion/analysis.

2.6 Determination of Toxic Elements

The soil samples (mining, dump and control site) were spread on glass plates and then dried in an oven at 105^{o}C for six hours. The dried soil was ground and sieved through 0 – 5 cm mesh sieve. The pH values of the soils were determined with a digital pH meter. Exactly 1.0 g of the dried powders sample (soil and snail) was weighed accurately into a 50ml beakers separately, to which 15ml of tri-acid mixture (70% high purity

HNO_3, 65%, $HClO_4$ and 70% H_2S0_4 in 5:1:1 ratio) were added. The mixture was digested at 80^0C till the solution became transparent. The resulting solution were filtered and diluted to 50ml using deionized water and analyzed for As, Cd, Cr, Cu, Hg and Pb, by atomic absorption spectrophotometry.

2.7 Ecological Risk Assessment

2.7.1 Estimation of Bioaccumulation Factor (BAF)

The transfer coefficient was calculated by dividing the concentration of toxic metals in snail by the total toxic metals concentration in the soil. This index of soil – snail transfer or intake of toxic elements from soil through snail was calculated using: BAF = C_{snail}/C_{soil}

Where; BAF represent the transfer factor of snail
C_{snail} = Toxic elements concentration in snail tissue, mg/kg fresh weight
C_{soil} = Toxic elements concentration in soil, mg/kg dry weight.

BAF > 1 indicates that the snail are en-riched in elements from the soil (Bio-accumulation)
BAF < 1 means that the snail excluded the toxic elements from soil (excluder)

2.7.2 Estimation of the Daily Intake of Metal (DIM)

The Daily intake of toxic elements was calculated using the following formula describe by USEPA (22).

$$ADDM = DI \times M_{snail}/WB$$

Where; ADDM = represents the average daily dose (mg,kg/d) of the metal
DI = represent the daily intake of snail for adult is 0.10274 kg/person/day
M_{snail} = is the trace toxic elements (metals) concentration in the snail tissues (mg/kg)
WB = represent the body weight of investigated in adult (60kg for adults).

2.7.3 Estimation of the Potential Hazard of Metal to Human (Hazard Quotient HQ)

The Hazard Quotient (HQ) was used to calculate the possible human health risks associated with the consumption of snail harvested from the contaminated soils from dump, and mining areas. The following equation is used to calculate the Hazard Quotient of snail USEPA (23).
HQ is the ratio between exposure and the reference oral dose (RFD)
If the ratio is lower than one (1), there will be no obvious risk.

$$HQ = ADDM/ RFDM$$

Where; ADDM = represents the average daily dose (mg,kg/d) of the metal
RFDM = is the reference dose of the metal (mg,kg/d)
RFDM = is define as the maximum tolerable daily intake of metal with no adverse effect

2.7.4 Estimation of Hazard Index (HI)

The hazard index (HI) was calculated to determine the overall risk of exposure to all the heavy metals via the ingestion of a particular snail USEPA (22). The hazard index (HI) was calculated as the summation of the hazard quotient (HQ) arising from all the metals examined. The value of the hazard index is proportional to the magnitude of the toxicity of the snail consumed. HI > 1 indicates that the predicted exposure is likely to pose potential health risks. However, a hazard index >1 does not necessarily indicate that a potential adverse health effects will result, but only indicates a high probability of posing health risks.

$$HI = \sum HQ_{As} + HQ_{Cd} + HQ_{Cr} + HQ_{Cu} + HQ_{Hg} + HQ_{Pb}$$

Statistical Analysis

The data obtained were analysed using IBM Statistical Product and Service Solution (SPSS) version 20 and Microsoft excel 2013. The results were expressed as mean ± standard deviation (SD). One way analysis of variance (ANOVA) was carried out as $P<0.05$ considered statistically significant.

3. RESULTS

3.1 Morphological Characteristics of Snails

Measurements on the snails were taken after treatment, in order to know the physical characteristics of the snails collected from different site area. The averages of the measurement taken are presented in table 1. Results analysis shown that the measurements of snails collected varied from different sites. Average lengths of snails in dump site (A), mining site (B) and control site (C) were 9.03, 8.68 and 6.62 cm respectively. The average diameters recorded in site A, B and C were 4.95, 4.40 and 3.89 cm and average weight were 71.58, 60.42 and 38.32 g respectively for site A, B and C. Dump sites soil treatment recorded maximum yield in length, diameter and weight of snails (Table 1).

Table 1: Morphological Characteristics of Different Treatment of Snails

	Morphological characteristics of AGLS		
Soil treatment types	Average length (cm)	Average diameter (cm)	Average weight (g)
Dump site soil (A)	9.03 ± 1.01^{a}	4.95 ± 0.61^{a}	71.58 ± 8.66^{a}
Mining site soil (B)	8.68 ± 0.62^{b}	4.40 ± 0.54^{b}	60.42 ± 7.56^{b}
Control site soil (C)	6.62 ± 0.43^{c}	3.89 ± 0.53^{c}	38.32 ± 6.51^{c}

Results expressed as Mean ± SD. Mean values with different superscript letters on the column are considered significant (*P*<0.05).

3.2 Potentially Toxic Elements Concentration of Soil before Farming

The levels of potentially toxic elements concentration (As, Cd, Cr, Cu, Hg and Pb) in different soil samples (Dump, Mining and a Control site) before farming snails are presented in Table 2. The concentration of As, Cd, Cr, Cu, Hg and Pb in the dumpsite soil were 3.28, 4.01, 3.88, 2.77, 3.11, 2.01 mg/kg, Mining sites soil (2.89, 3.37, 4.75, 4.63, 2.80, 4.92 mg/kg) and control site soil (1.54, 1.82, 0.87, 0.58, 0.20, 0.79 mg/kg) respectively. This study indicates that dump soil and mining soil were highly contaminated with PTEs than the control soil. The study also indicates that Cd in the dump site soil among the metals had the highest concentration, while Pb was the lowest. And in the mining site soil Pb had the highest contamination, while Hg was the lowest. The result of different soil before farming shows a significant different (*P*<0.05) between the activities sites (dump and mining) and the control site. There were significant increase of metals on the activities site than that of the control site. The concentration of Cd and Hg in the activities were above the WHO/FAO (24) permissible limits of 3.0 mg/kg Cd and 2.0 mg/kg Hg for soil except for control soil which recorded a mean value that was below the permissible limit in all the metal analyse. The pH values of dump, mining and control soil were 5.01, 5.92 and 7.08 respectively. The pH of the activities sites were slightly acidic compared to control which is neural (Table 2).

Table 2: Concentration of Potentially Toxic Elements in Soil before Farming

Elements (mg/kg)	**Soil samples before farming**			
	Dump site soil	Mining site soil	Control site soil	PL(mg/kg) in soil by FAO/WHO (24)
As	3.28 ± 0.04^{a}	2.89 ± 0.10^{b}	1.54 ± 0.12^{c}	20
Cd	4.01 ± 0.05^{a}	3.37 ± 0.08^{b}	1.82 ± 0.03^{c}	3.0
Cr	3.88 ± 0.03^{b}	4.75 ± 0.01^{a}	0.87 ± 0.04^{c}	100
Cu	2.77 ± 0.11^{b}	4.63 ± 0.01^{a}	0.58 ± 0.06^{c}	100
Hg	3.11 ± 0.03^{a}	2.80 ± 0.05^{b}	0.20 ± 0.02^{c}	2.0
Pb	2.01 ± 0.08^{b}	4.92 ± 0.05^{a}	0.79 ± 0.07^{c}	50
Soil pH	5.01	5.92	7.08	

Results expressed as Mean ± SD. Mean values with different superscript letters on the rows are considered significant (*P*<0.05). PL=Permissible limit. n=3

3.3 Potentially Toxic Elements Concentration of Soil after Farming

The means concentration (mg/kg) of PTEs Arsenic (As), Cadmium (Cd) Cromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb) analysed on soil after treatment were recorded on table 3. The result indicated that heavy metals were drastically reduce after treatment compared to the soil before treatment. The PTEs concentrations (As, Cd, Cr, Cu, Hg, and Pb) in Dump site soil were 1.80, 1.88, 1.54, 0.87, 1.78 and 0.10 mg/kg, mining site soil were 0.77, 1.08, 2.04, 1.96, 2.03, and 1.83 mg/kg, and control site were 0.97, 0.93, 0.06, 0.10, 0.08 and 0.04 mg/kg respectively .The two activity sites recorded high concentration of PTEs, which is as a result of the high concentration of PTEs present in the soil before treatment. This result indicates that some amount of element were transferred to the snails (Table 3).

Table 3: Concentration of Potentially Toxic Elements in Soil after Farming			
Elements	Soil samples after farming		
(mg/kg)	Dump site soil	Mining site soil	Control site soil
As	1.80 ± 0.04^{a}	0.77 ± 0.02^{c}	0.97 ± 0.01^{c}
Cd	1.88 ± 0.06^{a}	1.08 ± 0.01^{b}	0.93 ± 0.02^{c}
Cr	1.54 ± 0.08^{b}	2.04 ± 0.04^{a}	0.06 ± 0.02^{c}
Cu	0.87 ± 0.05^{b}	1.96 ± 0.02^{a}	0.10 ± 0.02^{c}
Hg	1.78 ± 0.02^{b}	2.03 ± 0.03^{a}	0.08 ± 0.02^{c}
Pb	0.10 ± 0.02^{b}	1.83 ± 0.03^{a}	0.04 ± 0.02^{c}

Results expressed as Mean ± SD. Mean values with different superscript letters on the rows are considered significant (*P*<0.05).

3.4 Potentially Toxic Elements Concentration in Snail

Table 4 presents the summary of the mean concentrations (mg/kg) of PTEs Arsenic (As), Cadmium (Cd) Cromium (Cr), Copper (Cu), Mercury (Hg) and Lead (Pb) analysed in the snail samples treated with dump site soil, mining site soil and a control soil where no activities. The mean concentration of PTEs in the snail indicate bioaccumulation from the soil use in treatment. The concentration of PTEs (As, Cd, Cr, Cu, Hg, and Pb) in snails treated with dump site soil were 3.05, 3.89, 3.60, 2.89, 3.98, and 2.55 mg/kg, snails treated with mining site soil recorded 2.73, 2.74, 3.91, 4.96, 2.88 and 4.82 mg/kg and the snail treated with control soil were 0.28, 1.17, 0.63, 0.33, 0.04 and 0.27 mg/kg respectively. The result shows that snails treated with dump and mining soil were more contaminated with PTEs compared to the control. The concentration of PTEs on the snail treated with dump soil and mining soil were all greater than the maximum permissible limit recommended by FAO/WHO (25, 26), of metals in snail while the snail treated with the control soil were below the maximum permissible limit except Cr and Pb which were slightly higher than the FAO/WHO (26) recommended values of 0.3 and 0.1 mg/kg respectively (Table 4).

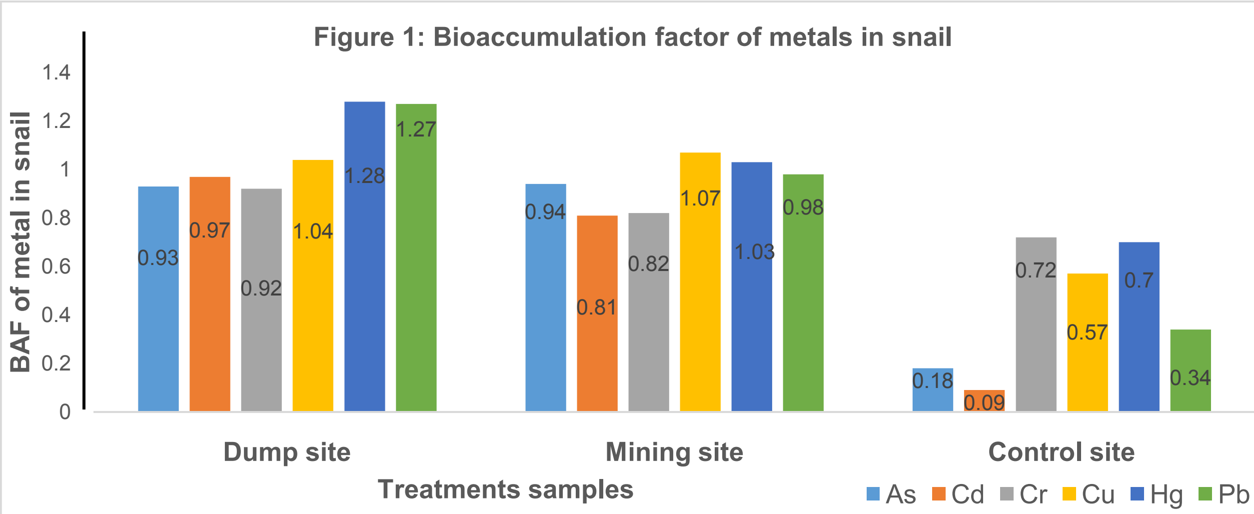
Table 4: Concentration of Potentially Toxic Elements in Snail				
Elements	Snail samples			
(mg/kg)	Dump site snail	Mining site snail	Control site snail	PL(mg/kg) snail FAO/ WHO, (25**, 26*)
As	3.05 ± 0.03^{a}	2.73 ± 0.12^{b}	0.28 ± 0.01^{c}	0.5*
Cd	3.89 ± 0.08^{a}	2.74 ± 0.14^{b}	0.17 ± 0.01^{c}	2.0*
Cr	3.60 ± 0.06^{b}	3.91 ± 0.01^{a}	0.63 ± 0.01^{c}	0.3*
Cu	2.89 ± 0.15^{b}	4.96 ± 0.02^{a}	0.33 ± 0.02^{c}	0.04**
Hg	3.98 ± 0.02^{a}	2.88 ± 0.03^{b}	0.14 ± 0.01^{c}	0.1*
Pb	2.55 ± 0.21^{b}	4.82 ± 0.08^{a}	0.27 ± 0.01^{c}	0.1*

Results expressed as Mean ± SD. Mean values with different superscript letters on the rows are considered significant (*P*<0.05). PL=Permissible limit. n=3

3.5 ECOLOGICAL RISK ASSESSMENT

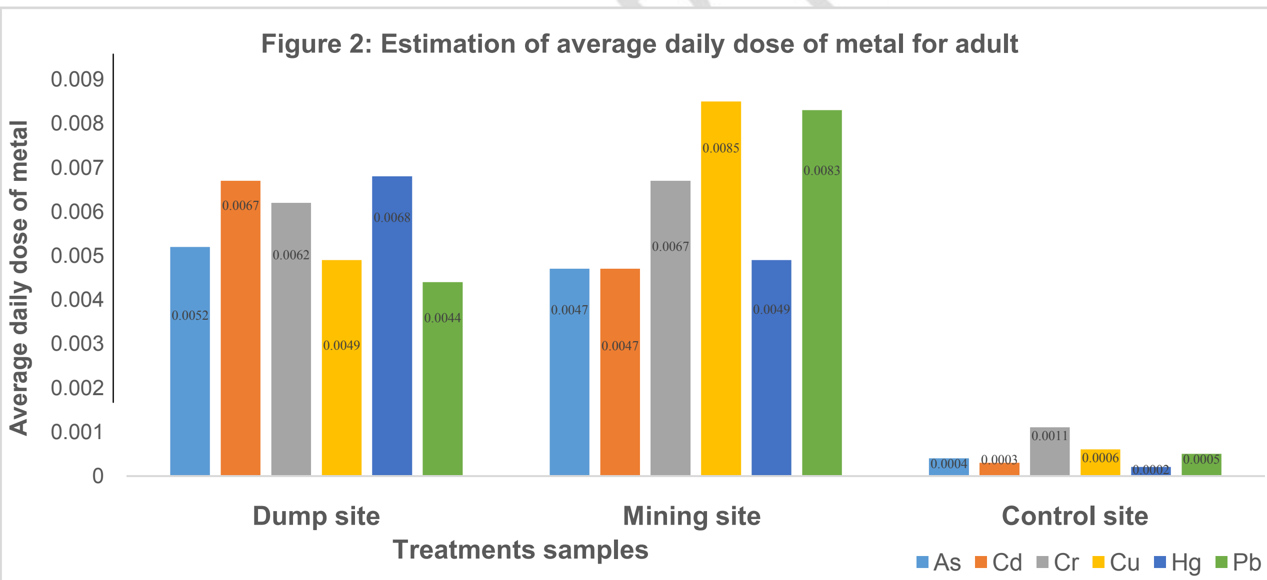
3.5.1 Estimation of Bioaccumulation Factor (BAF) of Toxic Element to Snail

The values of bioaccumulation factor (BAF) of PTEs from the test soil to snail, which gives the ratio of the concentration of PTEs in snail to the total concentration in the soil. The BAF also shows the amount of elements that is transferred from soil to snail. The BAF of metals As, Cd, Cr, Cu, Hg, and Pb obtained in snail treated with dump site soil (STWD) were 0.93, 0.97, 0.92, 1.04, 1.28 and 1.27, snail treated with mining site soil (STWM) were 0.94, 0.81, 0.82, 1.07, 1.03 and 0.98, snail treated with control (no activity) (STWC) were 0.18, 0.09, 0.72, 0.57, 0.70 and 0.34 respectively. Where the BAF is greater than one (>1) indicates that the snails are enriched with the elements from the soil (Bioaccumulators). Also where BAF is less than one (<1) means that the snails exclude the elements from the soil (excluders) (Figure 1).



3.5.2 Estimation of Average Daily Dose of Metal (ADDM) for Adult

The average daily dose of trace metal for adult in snail was estimated according to the average snail consumption through the food chain. The ADDM values for PTEs (As, Cd, Cr, Cu, Hg, and Pb) in STWD (0.0052, 0.0067, 0.0062, 0.0049, 0.0068 and 0.0044), STWM (0.0047, 0.0047, 0.0067, 0.0085, 0.0049 and 0.0083), STWC (0.0004, 0.0003, 0.0011, 0.0006, 0.0002, and 0.0005) respectively for PTEs. The result shows that STWD, STWM has higher values of ADDM in snail (Figure 2).

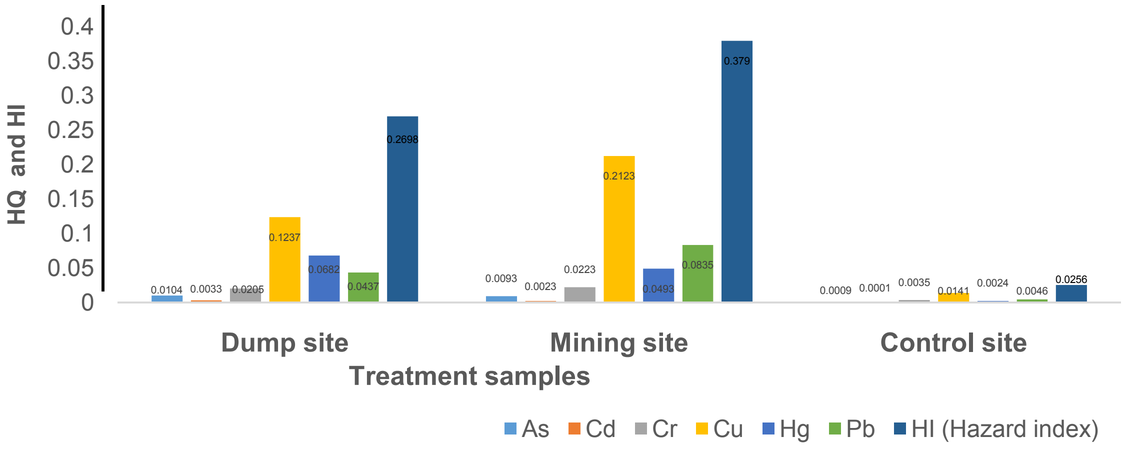


3.5.3 Estimation of Hazard quotient (HQ) and Hazard index (HI)

The HQ and HI of metals through consumption of snails treated with different soil were given in figure 3. The HQ of PTEs As, Cd, Cr, Cu, Hg, and Pb in STWD were 0.0104, 0.0033, 0.0205, 0.1237, 0.0682, and 0.0437, STWM (0.0093, 0.0023, 0.0223, 0.2123, 0.0493, and 0.0835), and STWC (0.0009, 0.0001, 0.0035, 0.0141, 0.0024 and 0.0046) respectively. The HQ for STWD, and STWM recorded high HQ than that Of STWC (Figure 3).

The calculated HI in STWD, STWM, and STWC were represented in figure 3. The HI shows the overall hazard risk of snail. The total concentration of PTEs in STWD, STWM, and STWC were 0.2698, 0.3790, and 0.0256 respectively.

Figure 3: Estimation of hazard quotient and hazard index



4. DISCUSSION

The physical characteristics of the snails treated with different soil samples (dumpsite, mining site and control site) were measured. The length, diameter and weight comparison of each snail species between the different soil treatments studied revealed that the development of each varied very significantly between the different soils treatments studied. The morphological characteristics of snails treated with dumpsite and mining soils were higher than that of the control soil, this is because the soil in this areas are rich in organic matter from dead decay materials and snails ingest small soil particles in other to obtain the Calcium (Ca) essential for reproduction, shall development (snail shells are composed mostly of calcium carbonate, $CaCO_3$), and other physiological needs. Dump site soil has the highest morphological characteristic compare to mining and control as shown on Table 1. This is because nutrient concentration in the upper soil has been long presumed to indicate nutrient availability for snails because these horizons contain snail food and are derived from potential snail food. Soil that will support good performance of snail must be loose, rich in calcium and organic material. This result was also in accordance of (27) who reported an average lengths ranged from 6.79 to 12.07 cm, the average diameters recorded varied between 3.82 and 6.52 cm and the average weights recorded, they varied between 35.69 and 192.68 g for *Archachatina marginata* collected from different locations. This result is similar to the findings of (28) who reported that snails raised on soil treated with poultry droppings performed better in weight gain, shell length, and shell aperture.

As a consequence of growing human activities, heavy metals in soils have become an alarming threat to both the ecosystem and human health. The results of the soils showed that the concentration of heavy metals in the soil before treatment increased at the dumpsites and mining site than the control sites for all the metals (As, Cd, Cr, Cu, Hg, and Pb). The mean concentration of Cd and Hg in snail treated with dumpsite soil (4.01, and 3.11 mg/kg) and snail treated with mining site soil with sludge (3.37 and 2.80 mg/kg) respectively were above the WHO/FAO (24) permissible limits of 3.0 mg/kg Cd and 2.0 mg/kg Hg for soil except for control soil which recorded a mean value that was below the permissible limit. These variations increase could be attributed to the nature, composition and amount of Cd and Hg containing wastes disposed of in these dumpsites and mining site which may not be the same. The concentrations of As, Cr, Cu and Pb recorded were below the WHO/FAO (24) permissible limit of 20, 100, 100, and 50 mg/kg respectively for soil. This result conforms to the findings of (2) who also reported that copper, chromium and arsenic concentrations were, however, lower than the values reported for typical uncontaminated soil. The study revealed that the concentrations of all elements analysed were significantly (P < 0.05) higher at the snail treated with dump and mining site compared to the control soil samples (Table 2). This was in agreement with the findings of Tanee and (29) results which showed that the concentration of heavy metals in the soil increased at the dumpsites than the control sites for all the metals (Fe, Pb, Cd and Zn). The apparent increase of heavy metals concentration in dump and mine site compared to the control site almost certainly confirms the dump waste and mining waste as the potential source of soil contamination and their accumulation in snail.

The pH values recorded for dumpsite soil (5.01), mining site soil (5.92) indicate that PTEs are generally more mobile at pH<7 than at pH>7. The value recorded for the control 7.08 which is little above neutral, which indicate that the soil is not contaminated. The low pH of the soils at dumpsite and mining site might probably be due to the dumping of acid-containing waste materials like batteries on the site as the site was once a dumping site.

Results of the soils PTEs after treatment decreased at the dumpsites, mining site and control sites for all the metals (As, Cd, Cr, Cu, Hg, and Pb) when compared to the initial record before treatment or rearing of snails. The concentrations of all PTEs recorded were below the WHO/FAO (24) permissible limit. This decease indicate that snail's bioaccumulate some amount of trace metals from the test and control soil. The level of PTEs can be attributed to the environment and kind of waste deposited in the area.

Heavy metals are considered the most important constituents of pollution from the terrestrial environment due to toxicity and accumulation by land organisms, such as snails. The entire snail samples reared with dumpsite soil, mining site soil and a control soil contained detectable levels of the elements studied. The accumulation of these heavy metals in snails may represent a health risk, especially for populations with high consumption rates of snail (30). One-way Analysis of variance (ANOVA) revealed a significant ($P<0.05$) variation in the concentrations of PTEs in the STWD, STWM and that of the controls, which is an indication of the extent of metal pollution from the soils. Generally STWD, and STWM had higher heavy metals concentrations (As, Cd, Cr, Cu, Hg, and Pb) than the controls, which were all above the FAO/WHO (25, 26) permissible limit of 0.5, 2.0, 0.3, 0.04, 0.1 and 0.1 mg/kg respectively (Table 4). The mean values recorded at all control sites were below the FAO/WHO acceptable value except Cr and Pb which was above the WHO/FAO (26) permissible limit of 0.3 and 0.1 mg/kg respectively for snails. Heavy metals and nutrients absorbed by snails are usually translocated to different parts of the snail which could limit the concentrations in the soil. However, availability of metals in the soil and continuous absorption by the snail could lead to higher concentration in the snail.

The high concentration of As and Cd at dumpsiteand mining site may be due atmospheric deposition of the metal from non – ferrous metal activities, combustion, etc. which can be absorbed into foliage and translocated through the snail. The levels of As recorded in this study was however much higher than the values of 0.21 to 0.81 mg/kg reported for snail by (31). The result of this study were higher than that of (27) who reecorded the average cadmium concentrations ranged from 0 to 0.032 mg/kg while those from lead ranged from 0.047 to 0.342 mg/kg in ALGS. (32) recorded a concentration of 0.01 mg/kg Cd in snail from Alaro River within Oluyole industrial area in Ibadan Nigeria. Arsenic affects almost all organs during its acute or chronic exposure. Liver has been reported as target organ of arsenic toxicity. Toxicity is due to arsenic's effect on many cell enzymes, which affect metabolism, DNA repair and brain problem. The most prominent chronic manifestations of As involve the skin, lungs, liver and blood systems. Cadmium is a dangerous element because it can be absorbed via the alimentary track; penetrate through placenta during pregnancy and damage membrane and DNA. Significant concentration of Cd may have gastrointestinal effect and reproductive effect on livestock (33). (34) reported that cadmium causes both acute and chronic poisoning, adverse effect on kidney, liver, vascular and the immune system.

The concentration of Cr in this study was lower than (31) who recorded level of Cr in all the sampling areas ranged from 40.8 to 857 mg/kg in snail. High dose of chromium is observed to cause Bronchopneumonia, chronic bronchitis, diarrhea, emphysema, headache, irritation of the skin, itching of respiratory tract, liver diseases, lung cancer, nausea, renal failure, reproductive toxicity, and vomiting. Copper is indeed essential, but in high doses it can cause anaemia, diarrhea, headache, metabolic disorders, nausea, vomiting, liver and kidney damage, stomach and intestinal irritation on human health. According to (33) high levels of copper can cause metal fumes fever with flu-like symptoms, hair and skin decolouration, dermatitis, irritation of the upper respiratory tract, metallic taste in the mouth and nose. Mercury poisoning symptoms include blindness, deafness, brain damage, digestive problems, kidney damage, lack of coordination and mental retardation. The ability of snails to accumulate essential metals equally enables them to acquire other nonessential metals from the soil. Lead has no beneficial biological function and is known to accumulate in the body. (35) reported that lead causes both acute and chronic poisoning and thus, poses adverse effects on kidney, liver, vascular and immune system. Lead can cause serious injury to the brain, nervous system, red blood cells, low IQ, impaired development, shortened attention span, hyperactivity, mental deterioration, decreased reaction time, loss of memory, reduced fertility, renal system damage, nausea, insomnia, anorexia, and weakness of the joints when exposed to high lead.

The sequence of occurrence mean concentrations of the heavy metals in STWD and STWM increased in the order Pb < Cu < As < Cr < Cd < Hg and As < Cd < Hg < Cr < Pb < Cu respectively in table 4. The bio-accumulated PTEs on the snail may interact directly with biomolecules such as nucleic acid, protein, carbohydrate, 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 (36).

The soil-snail BAF is one of the key component of human exposure to toxic elements through the food chain. The BAF values decreased with the increasing respective total metal concentrations in the soils, indicating an inverse relationship between BAF and total metal concentration. The BAF in STWD and STWM were significantly different from the STWC. This indicate the high presence of metals in the dump and mining site. The more the presence of metal in the soil the more the bioaccumulation on the snail. The soil-snail BAF in STWD for As, Cd and Cr were closely below one (<1) except Cu, Hg, and Pb which were greater than one (>1). The soil-snail BAF in STWM for As, Cd, Cr, and Pb were below one (<1), except Cu and Hg which were greater than one (>1). The control samples were all below one (<1) which indicate that the snail do not take up toxic element from the soil shown in figure 1. The soil-snail BAF of different heavy metals in STWD and STWM showed the following increase order –$BAF_{Cr}<BAF_{As}<BAF_{Cd}<BAF_{Cu}<BAF_{Hg}<BAF_{Pb}$ and $BAF_{Cd}<BAF_{Cr}<BAF_{As}<BAF_{Pb}<BAF_{Hg}<BAF_{Cu}$ respectively. Where BAF > 1 indicates the vegetable are enriched in elements from the soil (Bio-accumulation). BAF < 1 means that the vegetables exclude the element from soil (Excluder).

The hazard quotient (HQ) values were significantly <1; indicating that consumers of snails from these sites are not exposed health risk of As, Cd, Cr, Cu, Hg, and Pb. The Hazard index (HI) shows the overall risk of exposure to all the metal in STWD, and SDWM were below <1; the control had the lowest HI, HQ and ADDM (figure 3).it indicate that the consumption of all the snail cannot pose health risk to consumer through the intake of metal. This finding shows that DIM, HQ, HI on the consumption of snail reared with dumpsite, mining site soil is nearly free of risks, but continuous consumption can lead to bioaccumulation in the food chain.

5. CONCLUSION

Farmers generally, use contaminated soil for snail rearing to increase the yield and development of snail without any consideration on the toxic effect associated with it. The present study revealed that African giant land snail samples treated with dumpsite soil, and mining site soil bioaccumulate significantly high levels of trace metals that exceed the maximum prescribed limits for elements in snails, which toxicity disrupts natural ecosystems and affects the food chain, leading to deleterious health problems in humans and animals.

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