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Evaluation of Heavy Metals Concentrations in the Giant Land Snails (*Archachatina marginata* and *Achatina achatina*) as a Bioindicator of Environmental Pollution

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Abstract

The environmental impact of heavy metal pollution is considerable, largely due to its persistent presence, bioaccumulative properties, and harmful toxicity to both ecosystems and human well-being. Land snails, particularly *Archachatina marginata* and *Achatina achatina*, are increasingly recognized as effective bioindicators of heavy metal contamination due to their limited mobility, feeding behaviours, and ability to bioaccumulate pollutants from their surroundings. This study investigates the presence, concentration, and accumulation of cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) in the soft body parts and shells of snails (*A. marginata* and *A. achatina*) procured from Oje Market, Ibadan, Nigeria, as well as comparing the concentration with established regulatory standards. Using Atomic Absorption Spectrophotometry (AAS), metal concentrations were analyzed and compared across different snail body parts (shell, foot, and digestive gland) to assess their distribution patterns. The results indicate significant variations in metal accumulation, with Zn (0.866 µg/g ± 0.2616, 0.377 µg/g ± 0.0954) predominant in *A. marginata* and *A. achatina*, while Cd has the lowest mean concentration (0.007 µg/g ± 0.0037, 0.005 µg/g ± 0.0070). Notably, Pb concentrations (0.190 µg/g, 0.235 µg/g) in edible snail tissues exceeded FAO/WHO safety limits. These results underscore the need to monitor heavy metal pollution in edible organisms and reinforce the role of land snails as reliable bioindicators for environmental contamination assessment.

Keywords: *Pollution, Heavy Metal, Bioindicator, Archachatina marginata, Achatina achatina.*

I. INTRODUCTION

The introduction of pollutants into an environment leads to pollution, resulting in imbalance, instability, harm, or disruption to the ecosystem, including its physical components and living systems (Asein, 2005). It can take the form of chemical agents or energy types, including noise, heat, or light. Pollutants from different environmental sources contaminate land, water, and soil, posing significant risks to both humans and ecosystems (Wilson, 2024). As the global population grows rapidly and industrial activities expand, the harmful impacts of pollution on ecological balance and human wellbeing, and biodiversity have become increasingly evident (WHO, 2025). These pollutants harm the environment, contribute to climate change, and threaten the long-term goals of sustainable development (UNSDG, 2025). Heavy metals are naturally occurring elements, marked by high densities and atomic weights (Tchounwou *et al*., 2012).

Some heavy metals, such as copper and zinc, are vital for biological functions in small amounts, while others, such as mercury and lead, have no beneficial role and highly toxic (Gonzalo *et al*., 2022, Singh *et al*., 2011, Lane and Morel, 2009, Chronopoulos *et al*., *1997*). Heavy metals are introduced into the environment from multiple sources, such as industrial waste, pesticide application, mining activities, and fossil fuel combustion (Angon *et al*., 2024). Once introduced, these metals persist in soil, water, and air, where they can undergo complex chemical transformations and accumulate in living organisms. Heavy metals have deleterious effects on biotic ecosystems (Azeh *et al*., 2019). They persist in the ecosystem, pollute food chains, and cause a range of health issues because of their toxic nature (Ali and Khan, 2019).

These metals are especially known for interfering with various physiological, biochemical and cellular activities (Prabhu and Gadgil, 2021).

In recent years, the utilisation of bioindicator species, which provide insights into environmental quality, has gained popularity as a cost-effective and dependable method for monitoring pollution. Land snails serve as good bioindicators of heavy metal contamination owing to their sedentary nature, significant bioaccumulation potential, and intimate associations with soil and plant (Ajayi and Oyewole, 2023). Land snails, especially species such as the giant African land snail (*Achatina spp*.), accumulate heavy metals in their tissues, serving as a quantifiable indicator of environmental contamination (Ajayi and Oyewole, 2023). In addition to functioning as bioindicators, land snails significantly contribute to economic and ecological systems. Economically, they provide a livelihood for many communities, especially in areas where they are farmed or harvested for food. Snail farming, or heliculture, has emerged as a prominent sustainable agricultural method, providing nutritional, medical, and economic benefits (Anaekwe 2025, Cobbinah *et al*., 2013, Ngenwi *et al*., 2010, Chinaka and Wilson, 1995). Land snail serve as an essential protein supply for human populations, particularly in regions where alternative protein sources are scarce or expensive. Their meat is abundant in essential amino acids, low in fat, and easily digestible, rendering it an optimal dietary complement (Matsakidou and Paraskevopoulou, 2022, Akinnusi *et al*., 2018). Land snails have an important ecological role in nitrogen cycling and soil fertility. Their feeding habits promote the breakdown of organic debris, and their faeces enrich the soil with necessary nutrients. Snails also serve as prey for a variety of predators, making them an essential component of the food chain. However, environmental pollution, especially heavy metal contamination, threatens these ecological functions by compromising snail health and their role as a food source (Agida *et al*., 2022, Wehner *et al*., 2019). This study investigates the bioaccumulation of heavy metals in snail shells and soft tissues, focussing on their potential as bioindicators of pollution.

II. MATERIALS AND METHODS

➢ *Investigation Area*

Oje Market, situated in Ibadan, Nigeria, is one of the oldest and most notable traditional markets in the region. The market is located in the densely populated Ibadan North-East Local Government Area, at approximately 7.3878° North latitude and 3.9163° East longitude. Its strategic location makes it easily accessible through major routes such as Oje-Iwo Road and Oje-Bere Road, which are essential for connecting traders and customers from surrounding neighborhoods.

➢ *Sample Collection*

Twenty-five (25) Giant African land snails were purchased from traders at Oje market, who sourced them from local farmers. The snails were brought to the University of Ibadan’s Department of Zoology, for identification. Shell shape was used to identify two distinct species. *A. achatina*, characterized by a pointed apex (broadly ovate), and *A. marginata* with a slightly flattened apex (ITP, 2025).

➢ *Snail Sample Dissection*

Forceps were used to crack the snail shells, allowing for the careful removal and collection of the soft tissues in a container. The tissues were rinsed with distilled water, and then the digestive glands and foot tissues were subsequently dissected out. These parts, along with the snail shells, were stored in a freezer for future analysis.

➢ *Drying of Snail Tissues*

The snails' dissected body parts were defrosted for two hours, placed in crucibles, and samples were dried in a hot air oven (Gallenkamp) at 90°C. Samples weights were monitored every two hours until they reached a stable weight. The dried samples were pulverised into a fine powder using clean ceramic mortar and pestle, then sieved to a particle size of 0.02 mm. A 0.5-gram portion of each powdered sample was weighed and stored in plastic containers until digestion.

➢ *Determination Of Heavy Metals*

0.5 g samples were digested in 5 ml of aqua regia, filtered, and made up to 25 ml for atomic absorption analysis.

➢ *Atomic Absorption Spectrophotometer*

Heavy metal analysis of the sample was performed using the Buck Scientific Model 205 Atomic Absorption Spectrometer (AAS). The instrument was initialized by powering it on and electing the appropriate lamp for the element. The wavelength was calibrated to the specific absorption line of the target element, and gas flow rates for air and acetylene were configured. Sample preparation involved diluting the sample in a suitable solvent, such as deionized water, while calibration standards of known concentrations were prepared in the same matrix. Calibration was performed by analyzing a blank and the prepared standards to establish a calibration curve, ensuring accuracy and correlation of results.

For the analysis, the aspirator tube was immersed in the sample solution, enabling the spectrometer to atomize the liquid using a flame and measure its absorbance. Quality control was maintained throughout the procedure by testing blanks and standards to confirm accuracy and precision, while replicate measurements ensured consistency. At the end of the process, the system was flushed with deionized water to remove any sample residues, and the spectrometer was shut down in accordance with the guidelines.

➢ *Data Analysis*

Statistical analysis of data was done using SPSS version 25, involving ANOVA, t-tests, and Tukey’s HSD post-hoc test to compare groups, with $p < 0.05$ considered significant.

III. RESULTS

➢ *Heavy metals in Snail Samples from Oje Market*

Table 1 revealed the presence of heavy metals – cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) in all samples tested. These metals were detected across the sample examined: foot, digestive gland and shell.

Table 1 Heavy Metals in Snail Samples from Oje Market

Snails	Tissue Part	Cd	Cu	Pb	Zn
A. achatina	Foot	+	+	+	+
	Digestive Gland	+	+	+	+
	Shell	+	+	+	+
A. marginata	Foot	+	+	+	+
	Digestive Gland	+	+	+	+
	Shell	+	+	+	+

➢ *Concentration of Heavy Metals in A. marginata*

The results in Table 2 indicate significant variation in heavy metal concentrations across tissues in *A. marginata*. Zinc (Zn) was most concentrated in the digestive gland (0.866 ± 0.2616 µg/g), while the foot has the lowest concentration (0.3091 ± 0.0865 µg/g). Copper (Cu) concentrations was highest in the shell (0.3835 ± 0.0736 µg/g) with the foot having (0.2804 ± 0.0834 µg/g), which is the lowest. Lead (Pb) was predominant in the shell (0.3715 ± 0.0847 µg/g), with the lowest levels quantified in the foot (0.1872 ± 0.0627 µg/g). Cadmium (Cd) exhibited the highest concentration in the digestive gland (0.0350 ± 0.0208 µg/g), with lowest concentration in the shell (0.007 ± 0.0037 µg/g). One-way ANOVA revealed tissue-specific differences in zinc levels ($p < 0.05$), with the digestive gland showing the highest concentrations. Similarly, Cu was significantly lower in the foot compared to the shell and digestive gland, while no significant difference was observed between the shell and digestive gland. Pb concentration was significantly lowest in the foot than in both the shell and digestive gland, though no significant difference was found between the shell and digestive gland. The digestive gland had significantly higher cadmium levels than the shell and foot, which were comparable. These results suggest that different tissues of *A. marginata* exhibit varying capacities for metal concentration, with the digestive gland functioning as the predominant site for Zn and Cd retention, the shell acting as the principal medium for Pb and Cu.

Table 2 Concentration of Heavy Metals in *A. marginata*

Concentration of heavy metals in *A. marginata*			
Heavy metals	**Tissues**		
µg/g	**Shell**	**Foot**	**Digestive gland**
Zn	0.356 ± 0.0600^{b}	0.309 ± 0.0864^{b}	0.866 ± 0.2616^{a}
Cu	0.383 ± 0.0736^{a}	0.280 ± 0.0834^{b}	0.374 ± 0.0828^{a}
Pb	0.371 ± 0.0847^{a}	0.187 ± 0.0627^{b}	0.328 ± 0.0725^{a}
Cd	0.007 ± 0.0037^{b}	0.012 ± 0.0050^{b}	0.035 ± 0.0208^{a}

Mean ± SD followed by the same letter in a row do not differ significantly ($p < 0.05$, Tukey HSD).

➢ *Concentration of Heavy Metals in A. achatina*

The average heavy metals concentrations in *A. achatina* are shown in Table 3, showing variations in metal distribution across tissues. Zinc (Zn) had the highest concentration in digestive gland (0.3775 ± 0.0954 µg/g) compare to the foot with lowest concentration (0.2475 ± 0.0530 µg/g). Copper (Cu) was most concentrated in the shell (0.3775 ± 0.1308 µg/g), whereas Cu concentration was lowest in the digestive gland (0.095 ± 0.0141 µg/g). Pb exhibited the highest concentration in the shell (0.340 ± 0.2969 µg/g), while the digestive gland had the lowest concentration (0.055 ± 0.0353 µg/g). Cadmium (Cd) exhibited a different accumulation pattern, with the lowest concentration in the shell (0.005 ± 0.070 µg/g), and the highest concentration in foot (0.035 ± 0.0000 µg/g). One-way ANOVA showed no significant differences in Zn, Pb, and Cu levels among tissues ($p > 0.05$), but Cd levels differed significantly. Tukey's HSD test revealed higher Cd concentrations in the foot and digestive gland compared to the shell, with no difference between the foot and gland. These results suggest that while Zn, Cu, and Pb are relatively distributed, Cd preferentially concentrate in the foot and digestive gland, with minimal retention in the shell.

Table 3 Concentration of Heavy Metals in *A. achatina*

Concentration of heavy metals in *A. achatina*			
Heavy metals	**Tissues**		
µg/g	**Shell**	**Foot**	**Digestive gland**
Zn	0.362 ± 0.1308^{a}	0.247 ± 0.0530^{a}	0.377 ± 0.0954^{a}
Cu	0.377 ± 0.1308^{a}	0.265 ± 0.0707^{a}	0.095 ± 0.0141^{a}
Pb	0.340 ± 0.2969^{a}	0.235 ± 0.0989^{a}	0.055 ± 0.0353^{a}
Cd	0.005 ± 0.0070^{b}	0.035 ± 0.0000^{a}	0.025 ± 0.0000^{a}

Mean ± SD followed by the same letter in a row do not differ significantly ($p < 0.05$, Tukey HSD).

- *Heavy metal Levels in Tissues of A. marginata and A. achatina*

Figure 1 shows the heavy metal accumulation levels in snail species, highlighting variations in metal uptake patterns. In *A. marginata*, the trend of accumulation follows the order Zn > Cu > Pb > Cd, indicating that zinc is most accumulated heavy metal in the species. Copper follows as the second most accumulated metal, followed by lead while cadmium shows comparatively lower concentrations. However, in *A. achatina* zinc exhibits the highest accumulation, followed by copper, then lead, with cadmium having the lowest concentration (Zn > Cu > Pb > Cd).

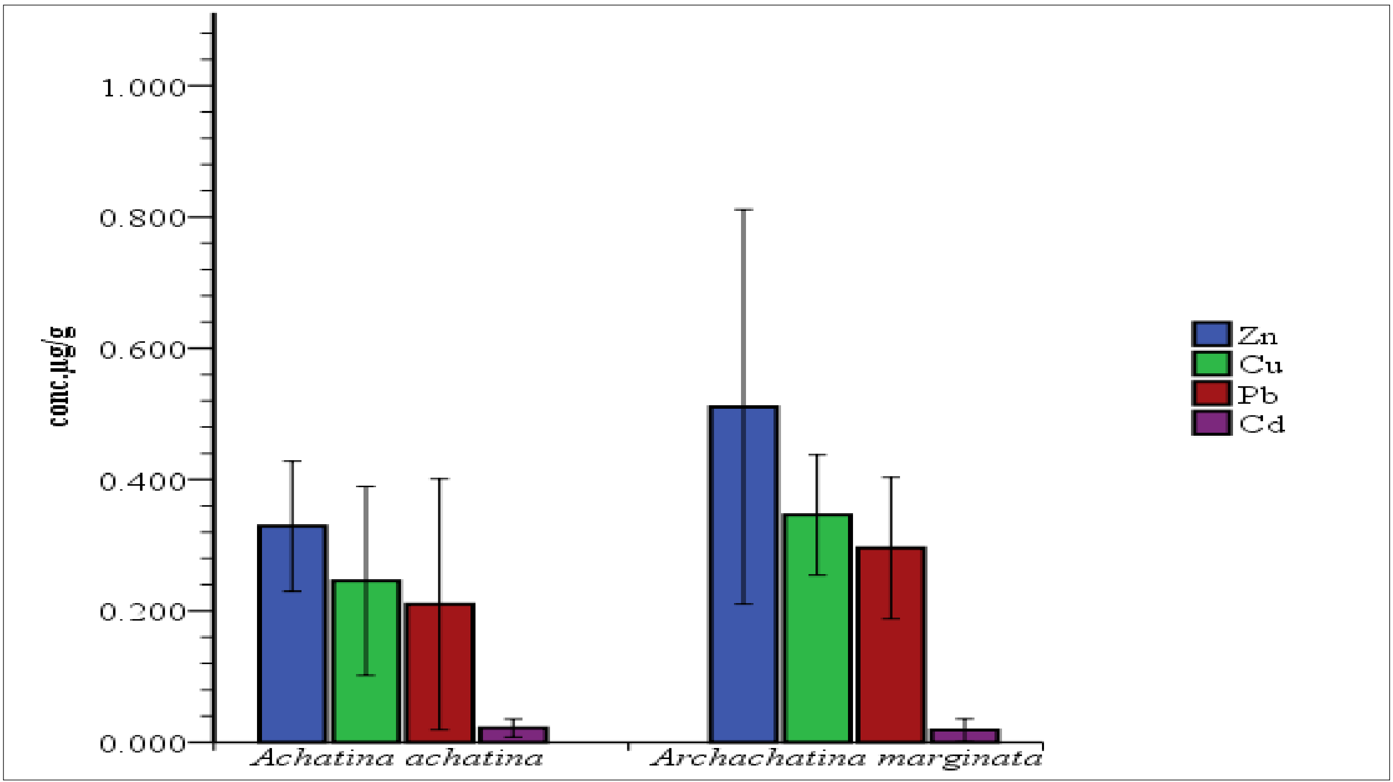

Fig 1 Heavy Metal Levels in Tissues *A. achatina and A. marginata.*

- *Distribution of Heavy Metals Across Snail Body Parts*

Figure 2 shows distinct heavy metal accumulation patterns in *A. marginata* (digestive gland > shell > foot) and *A. achatina* (shell > foot > digestive gland).

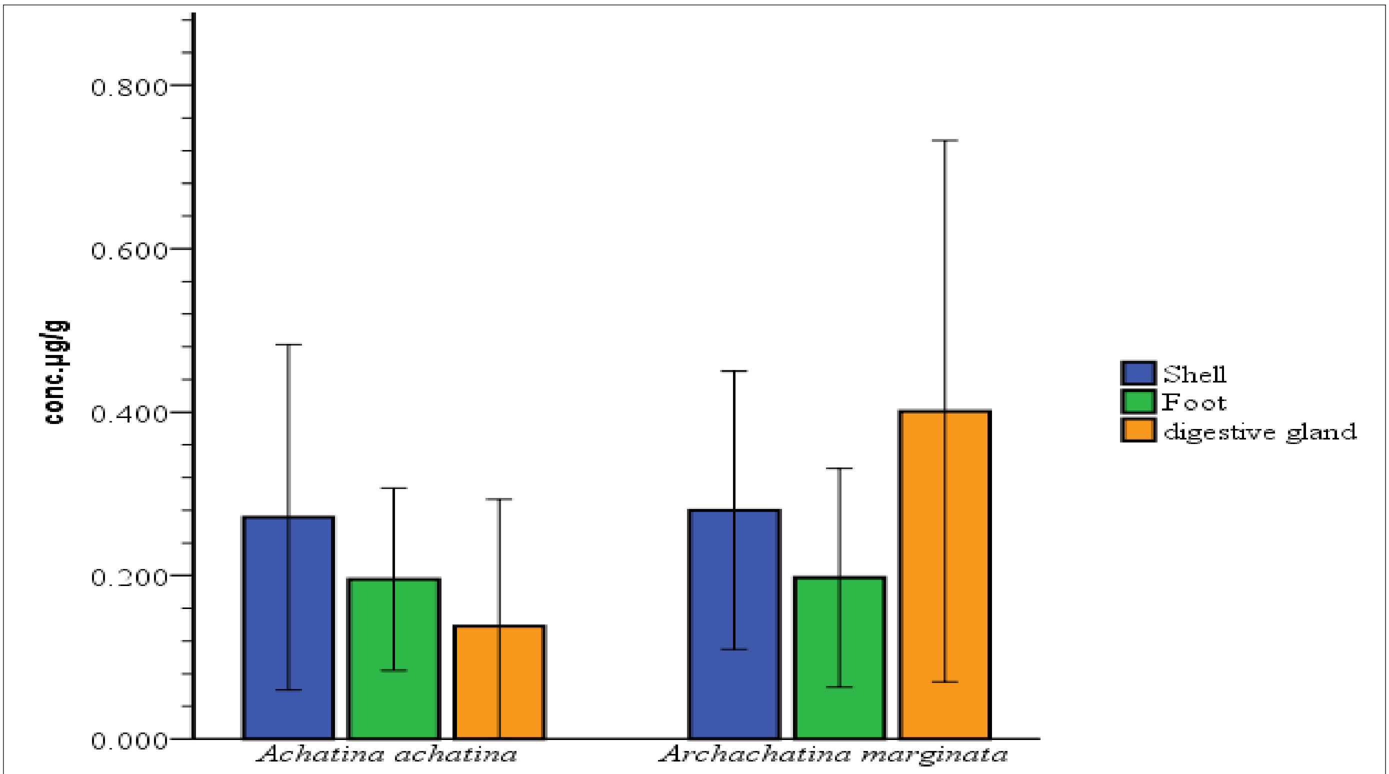

Fig 2 Distribution of Heavy Metals Across Snail Body Parts

➢ *Comparison of Heavy Metals Against Standard Limits.*

The levels of heavy metal in the edible foot tissue of *A. marginata* and *A. achatina* were compared to the FAO/WHO (2023) safe limits for human consumption (Table 4) using a one-sample test. While most metals were within permissible limits, lead (Pb) levels exceeded the threshold in both species, with concentrations of 0.190 µg/g in *A. marginata* and 0.235 µg/g in *A. achatina*. Statistical analysis confirmed that Pb levels were significantly above the safe limits.

Table 4 Comparison of Heavy Metal Levels with Regulatory Limits

Heavy metals µg/g	***Archachatina. Marginata***	***Achatina. achatina***	**Acceptable maximum limits (µg/g) FAO/WHO (2023)**
Zn	0.310	0.248	3.000
Cu	0.280	0.265	NL
Pb	**0.190**	**0.235**	0.100
Cd	0.013	0.035	2.000

NL: No limit. Values in bold denote concentrations above safe limits

IV. DISCUSSION

Gastropods, especially large African land snails, function as significant bioindicators due to their ability to absorb heavy metals from their surroundings (Ajayi and Oyewole, 2023, Salih *et al*., 2021) They are at risk of heavy metal absorption due to their diet and proximity to contaminated soil (Madugu, 2019). The research conducted by Ajayi and Oyewole (2023) revealed that different snail species exhibit varying capacities for heavy metal accumulation, which is largely influenced by differences in their physiology, habitat preferences, and environmental conditions. Dallinger (2024) and Adebisi-Fagbohungbe *et al*. (2021) emphasized that metal concentrations in snails vary with species and environmental contamination, making regular monitoring crucial for pollution assessment.

In *A. marginata*, the digestive gland had highest Zn and Cd levels, while the shell had highest Pb and Cu levels. In *A. achatina*, Cu was highest in the shell, Cd in the foot, and Zn in the digestive gland. Most metal levels were within FAO/WHO limits, except Pb in edible parts. Cadmium levels were low in both species. Earlier research by Adedeji *et al*. (2011) reported low Cd (0.01 mg/kg) levels in snails from Ibadan. Moreover, the high zinc (Zn) levels found in *A. marginata* are within safe consumption limits. This finding aligns with Ajayi and Oyewole (2023) who reported Zn level and found 0.96 ± 0.007 µg/g in *A. marginata* from Ekowe community and noted that this species tends to bioaccumulate more Zn than other metals like Cd and Cu. In contrast, by Iwegbue *et al.* (2009) reported higher Pb levels (6.53 ± 1.03 µg/g) in *A. marginata* tissues from industrial sites in Warri. Zinc was predominant in digestive glands of *A. marginata* (0.866 ± 0.2616 µg/g), lead in the shell (0.371± 0.0847 µg/g). While cadmium level was significantly lower compared to other heavy metals. The study by Ajayi and Babatunde (2022) revealed low Cd detection rates and high Pb levels, particularly in samples from Oyo State. Zn and Cu, are essential for enzymatic functions and protein structures, tend to accumulate in the mantle due to its role in shell formation and mineral ion deposition (Marin *et al*. (2012). In *A. marginata*, heavy metals tend to accumulate more in the shell and digestive gland, while the foot accumulates less. In contrast, *A. achatina* accumulates more heavy metals in its shell and foot compared to *A. marginata*. Studies have reported varying levels of heavy metals in *A. achatina*, such as 2.003 ± 0.0014 µg/g of Zn in the shell (Ajayi and Oyewole, 2023) and 1.80 µg/g of cadmium in foot (Ugbaja *et al*., 2020). Research also suggests that bioaccumulation patterns differ among species and tissues. For instance, Ogidi *et al*. (2020) found high Zn levels in *A. marginata*, while Iwegbue *et al*. (2009) confirmed species-specific variations in bioaccumulation. Notably, Pb levels exceeded FAO/WHO tolerance limits, while other metals remained within safe ranges. The primary source of snail heavy metal pollution is largely driven by emissions from vehicles, agrochemical use, and industrial activities. Ajayi and Babatunde (2023) study on heavy metal levels in snails found significantly elevated lead (Pb) levels in samples from Oyo, an area known for its dense traffic and industrial operations. The presence of Pb in these snails suggests atmospheric deposition as a primary contamination source, further supported by Eltier and Sivacioglu (2021), who found that Pb content in crops and animals tends to increase within a 50-meter radius of highways. Oguh *et al.* (2019) found higher Cr, Pb, and Cd levels in snails from dumpsites and mining areas, underscoring the role of human activities in snail metal accumulation.

Lead and cadmium, being non-essential elements, pose significant health risks. WHO, 2024 reported that lead lacks biological function and builds up in the body, causing neurodevelopmental issues in children, cardiovascular complications, and inhibition of hemoglobin synthesis. Similarly, Maobe *et al*. (2012) found cadmium to be highly toxic, damaging cellular membranes and DNA through alimentary tract absorption. Studies by Ajayi and Oyewole (2023) highlight cadmium's association with zinc, often entering the food chain through phosphate fertilizers and municipal sludge. Furthermore, research by Nkpaa *et al*. (2016) and Bello *et al*. (2015) confirms that excessive Pb intake from contaminated food sources can contribute to cognitive impairment, making the consumption of snails from polluted areas a potential public health concern.

Despite concerns about heavy metal accumulation, the nutritional benefits of snail meat remain significant. According to Omole (2002), snail meat contains high iron levels. However, a study on *A. achatina* and *A. marginata* found Pb levels above safe limits in some samples, emphasizing the need for continuous monitoring to ensure food safety. Adedeji *et al*. (2011) highlighted that snails can bioaccumulate essential and toxic metals, making them valuable indicators of environmental pollution. The study of metal contamination across different locations suggests that Pb and Cd levels in snails reflect broader environmental pollution trends, particularly in urban and industrialized areas. As pollution levels continue to rise, understanding how heavy metals accumulate in snails is vital for assessing ecological risks and protecting public health. To mitigate health risks while preserving the nutritional value of snails, regular monitoring of heavy metal levels in edible snails and effective pollution control measures are necessary.

V. CONCLUSIONS

Consuming *A. achatina* and *A. marginata* as a protein source may pose health risks due to heavy metal contamination, particularly lead, which exceeded safe limits. While zinc, copper, and cadmium levels were within permissible limits, the lead findings raise concerns about potential health impacts on consumers. Stringent measures should be put in place by policymakers to regulate pesticide use and solid waste management to prevent leaching during rainfall, which can lead to increased heavy metal build-up in the environment, further exacerbating the pollution problem.

DECLARATIONS

➢ *Author Contribution Statement*

Wasola Eniola: Developed the research concept, designed the experiment, and prepared the manuscript.

Ayobami Oluwatobi Oni: Conducted the experiments.

➢ *Conflict of Interests*

The authors have not declared any conflict of interests.

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