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HEAVY METAL CONTENT IN THE AFRICAN GIANT SNAIL *ARCHACHATINA MARGINATA* (SWAINSON, 1821) (GASTROPODA: PULMONATA: ACHATINIDAE) IN SOUTHERN NIGERIA

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ABSTRACT: Heavy metal concentrations in the African giant snail *Archachatina marginata* (Swainson) from nine localities in southern Nigeria ranged from 0.77 to 7.51 mg kg^{-1} Pb; 3.06–46.9 mg kg^{-1} Fe; 0.03–0.40 mg kg^{-1} Ni; 0.04–0.12 mg kg^{-1} Cu; 0.71–4.51 mg kg^{-1} Co; 0.67–1.27 mg kg^{-1} Mn; 0.99–3.28 mg kg^{-1} Cd; 0.08–0.22 mg kg^{-1} Zn; Cr was below the limit of detection. Concentrations of Pb, Fe, Ni, Cu, Co, Cd and Zn in the snail tissue varied significantly (95% confidence limit) between the localities. No significant variation was observed in the concentrations of Cr and Mn. Pb and Cd concentration exceeded the statutory safety limits for these elements in meat. The results indicate a heavy metal pollution of the habitats.

KEY WORDS: heavy metal pollution, African giant snail, *Archachatina marginata*, Nigeria

INTRODUCTION

In recent years, much research has focused on metal concentration in protein sources: beef, goat meat, mutton, poultry products, as well as fish and other sea foods. In Nigeria, the African giant snail *Archachatina marginata* (Swainson, 1821) is widely consumed by various ethnic groups. Since snail farming is not popular in Nigeria, the snails are usually collected in forests and transported to nearby urban markets. On the other hand, the rapid industrialisation of the Niger Delta region in Nigeria within the last two decades has resulted in a heavy pollution.

Heavy metals contained in the soil find their way into organisms of various trophic levels via detritivores or plants. Though their accumulation in predatory vertebrates has been confirmed (PURCHART & KULA 2007), the levels of accumulation for invertebrates do not depend directly on the trophic level or the body size (LINDQUIST & BLOCK 1997, PURCHART & KULA 2007). The metal load is probably associated with the physiological properties of the species rather than with the trophic level (SPURGEON & HOPKIN 1999).

Metal concentration in invertebrate tissues varies considerably not only among taxa, but also among conspecifics (TYLER et al. 1989). The metal content in the invertebrate body depends on the type of food and on the form in which the metal is bound (LINDQUIST & BLOCK 1997), on the conditions during intake (e.g. concentration in the soil, pH, availability of metals) and – most of all – on the physiological characteristics of the species, such as assimilation and excretion capacity (LINDQUIST et al. 1995, KRAMARZ 1997, PURCHART & KULA 2007). The African giant snail feeds on the debris from the soil surface which may be contaminated with heavy metals and organic pollutants; it may thus accumulate the pollutants to harmful levels. Very little is known of metal levels in the African giant snail consumed in southern Nigeria. This study was aimed at determining the levels of Cd, Pb, Ni, Cr, Fe, Mn, Cu, Co and Zn in the African giant snail, with special reference to hygienic and toxicological aspects.

MATERIALS AND METHODS

A total of 400 snail specimens were collected from nine widely spread locations in southern Nigeria from January to May 2007. The age of the snails was not considered; only fully grown specimens were collected since this is the product consumed by the local population.

In the laboratory the snails were washed thoroughly with distilled water. The shell was cracked with a wooden hammer; the body was again washed with distilled water and stored at –18°C prior to analysis. Samples (5.00 g muscle) were pre-digested in 10 ml concentrated HNO_3 at 135°C until the liquid was clear. Then 10 ml HNO_3 and 2 ml $HClO_4$ were added till the liquid became colourless. The digest was slowly evaporated till near dryness, coded, dissolved in 1 M HNO_3, filtered through Whatman No 1 filter paper and diluted to 25 ml with 1 M HNO_3. The resulting solution was analysed for Cd, Pb, Zn, Mn, Fe, Cu, Cr and Co with graphite furnace atomic absorption spectrophotometry (GBC Scientific equipment Sens AA).

Control procedure was carried out to ensure the reliability of the results. In all the metal determinations, analytical blanks were prepared in a similar manner. All glassware was soaked in 10% nitric acid solution for 48 h, followed by rinsing with deionized water. In order to check the reliability of the instrument a blank and known standards were run after every six samples. In addition, a recovery study of the total analytical procedure was carried out for metals in selected samples by spiking analysed samples with aliquots of metal standards and then reanalysing the samples. An acceptable recovery of more than 92% was obtained for the metals.

RESULTS AND DISCUSSION

Table 1 shows the mean values, standard deviation and ranges of concentration of the studied metals in the African giant snail. The highest mean Pb concentration was observed in Port Harcourt (7.51 mg kg^{-1}), the lowest – in Yenegoa. Samples from Warri and Port Harcourt – the two industrial areas – showed significantly higher Pb concentrations ($p>0.05$), compared to the samples from the other locations. The lead concentrations in these samples were alarming and indicated high levels of pollution. The main sources of lead pollution are automobile exhaust gases (anti-knocking agents added to gasoline), and untreated industrial waste which finds its way to irrigation channels, thus polluting fodder through soil

Table 1. Concentration of heavy metals (mg kg^{-1} weight) in the giant African snail from southern Nigeria

Location	Pb	Fe	Ni	Cu	Co	Mn	Cd	Zn	Cr
Warri	6.53±1.03	7.86±0.36	0.18±0.16*	0.08±0.03	1.42±0.47	0.86±0.06	1.47±0.55	0.13±0.05	<0.001
	5.16–7.87	7.51–8.41	0.07–0.46	0.06–0.13	0.63–1.89	0.77–0.91	0.53–1.95	0.10–0.21	
Agbor	2.46±1.27	3.06±1.24*	0.16±0.04*	0.06±0.04	1.44±0.17	0.85±0.08	2.33±0.22	0.11±0.04	<0.001
	1.15–3.90	1.30–4.15	0.11–0.22	0.02–0.11	1.15–1.58	0.73–0.93	2.01–2.53	0.07–0.17	
Port Harcout	7.51±0.93	46.90±15.49*	0.17±0.05*	0.04±0.02	1.54±0.22	0.98±0.10	0.99±0.18	0.10±0.04	<0.001
	5.92–8.12	35.48–65.08	0.11–0.21	0.02–0.06	1.15–1.67	0.87–1.11	2.72–1.19	0.05–0.15	
Asaba	2.31±0.83*	7.59±1.26	0.03±0.02*	0.09±0.06	1.39±0.75	0.94±0.11	3.28±0.38	0.22±0.06	<0.001
	1.05–3.05	6.34–9.64	0.01–0.06	0.03–0.17	0.72–2.39	0.82–1.08	2.81–3.59	0.16–0.31	
Benin	1.56±0.05	7.11±0.19	0.04±0.02*	0.07±0.02	1.08±0.12	1.06±0.06	1.94±0.09	0.12±0.03	<0.001
	1.51–1.64	6.82–7.34	0.01–0.06	0.03–0.90	0.95–1.24	1.00–1.12	1.82–2.05	0.08–0.15	
Ughelli	2.44±0.61	11.49±1.04	0.11±0.04*	0.12±0.03	0.71±0.19	1.27±0.12	1.64±0.62	0.22±0.05	<0.001
	1.38–2.82	10.10–12.41	0.06–0.15	0.08–0.16	0.49–0.93	1.07–1.39	1.16–2.64	0.17–0.30	
Yenegoa	0.77±0.13	11.18±1.31	0.40±0.07	0.13±0.05	4.56±0.21	1.19±0.22	1.15±0.20	0.11±0.03	<0.001
	0.56–0.92	10.01–12.64	0.33–0.49	0.07–0.19	4.43–4.93	0.91–1.43	0.93–1.47	0.09–0.15	
Onitsha	0.90±0.18	7.23±0.44	0.14±0.03*	0.06±0.02	1.99±0.34	1.01±0.07	1.79±0.05	0.09±0.03	<0.001
	0.67–1.16	6.55–7.65	0.10–0.18	0.03–0.08	1.64–2.54	0.93–1.09	1.71–1.86	0.05–0.13	
Sapele	4.02±0.10	19.39±4.80*	0.03±0.01*	0.07±0.02	1.74±0.04	0.69±0.08	2.07±0.07	0.08±0.02	<0.001
	3.88–4.15	15.86–27.63	0.01–0.04	0.05–0.09	1.68–1.77	0.61–0.81	2.01–2.19	0.06–0.11	

*Significant at $p>0.05$, concentration range of particular metals is given below mean value ± S.D.

(MARIAM et al. 2004). The mean Pb concentrations in the snails from different locations exceeded the ANZA permissible limit of 1.0 mg kg^{-1} Pb for meat, except for samples from Onitsha and Yenegoa. However, Pb concentration in all the samples was higher than 0.4 mg kg^{-1} (EC 2001) and 0.5 mg kg^{-1} (FAO 1983). Lead causes damage to human kidneys and liver (SAVIPERUNAL et al. 2007). MARIAM et al. (2004) reported 2.19 ppm, 4.25 ppm and 3.1 ppm for lean beef, mutton and poultry, respectively. There was no significant variation among samples within the locations, except for those from Agbor, Asaba and Ughelli. The levels of Pb found in the present study were comparable to 0.80–6.00 mg kg^{-1} Pb reported by WEGWU & WIGWE (2006). VIARD et al (2004) reported 21.3 mg Pb kg^{-1} in a land snail collected near a highway in France.

The mean iron concentration in the snail tissues ranged from 3.06 to 48.90 mg kg^{-1}; it varied significantly between the locations (p>0.05). Samples collected within the same location showed no significant variation, except for those from Agbor, Port Harcourt and Sapele. The highest mean Fe concentration was found in snails from the industrial Port Harcourt (46.90 mg kg^{-1}) while the lowest mean level was observed in samples from Agbor. Samples from Warri, Asaba, Benin and Onitsha had similar mean Fe concentrations. The observed iron concentrations were similar to those reported by WEGWU & WIGWE (2006).

The mean concentration of nickel was the highest in the samples from Yenegoa (0.40 mg kg^{-1}). The industrial regions (Warri and Port Harcourt) showed high Ni levels, compared to other locations. There was a significant variation among samples within the locations (variability coefficient 21% to 88.8%), except for those from Yenegoa. Nickel can cause respiratory problems and is carcinogenic (ATSDR 2004). The upper tolerable intake levels of nickel for children (1–3 years old) and adults (19–70 years old) are 7 and 4 mg d^{-1}, respectively. The mean concentrations of nickel found in the snail tissue were lower than the concentration ranges (3.20–10.4 mg kg^{-1}) reported by WEGWU & WIGWE (2006).

Copper concentrations in the snail tissue ranged from 0.04 to 0.13 mg kg^{-1}. There was a slight variation between the locations. In all samples the concentrations of copper were less than 0.2 mg kg^{-1}. The highest mean Cu levels were found in samples from Yenegoa. The observed levels of copper were low compared to the permissible limit of 20 ppm. Copper is an essential component of various enzymes and plays a key role in bone formation, skeletal mineralization and in maintaining the integrity of connective tissues. Its low concentration in the snails is not surprising in view of high requirements for and rapid turnover of the element in the organism.

Cobalt was detected in all the samples; its mean concentrations ranged from 0.71 to 4.4.56 mg kg^{-1} and were the highest in samples from Yenegoa (4.56 mg kg^{-1}), while the lowest mean Co concentration was found in samples from Ughelli. Mostly, there was no significant variation among samples within the locations. However, a significant variation (p>0.05) was observed among the samples from Warri and Onitsha. Cobalt is an essential nutrient for humans and an integral part of vitamin B12. The average intake of cobalt in all forms ranges from 0.30 to 1.77 mg/day (UNDERWOOD 1977). Cobalt is involved in blood pressure regulation and is necessary for the proper thyroid functioning (SIVAPERUMAL et al. 2007). Excessive ingestion of cobalt causes congestive heart failure and polycythemia and anaemia (SIVAPERUMAL et al. 2007). The levels of cobalt reported in this study were higher than the concentration ranges of 0.02–0.85 mg kg^{-1} reported for mollusc tissues by SIVAPERUMAL et al. (2007).

The mean levels of manganese in the Africa giant snail ranged from 0.61 to 1.27 mg kg^{-1}. The highest mean concentration was found in samples from Ughelli. No significant variation was observed between samples within or between the locations (95% confidence limit). Manganese is essential for both plants and animals and its deficiency results in severe skeletal and reproductive anomalies in mammals. It is widely distributed throughout the body with little variation and does not accumulate with age. The daily intake varies from 2.5 to 7 mg (SIVAPERUMAL et al. 2007). The levels of manganese reported in this study are comparable to concentration ranges of 0.08–3.7 mg kg^{-1} reported for some mollusc species in India (SIVAPERUMAL et al. 2007).

Cadmium concentrations in the snail tissue were generally high and alarming; the mean levels ranged from 0.99 to 3.28 mg kg^{-1}. There were no significant differences among samples within the locations, but the mean values varied between the zones. The highest mean Cd level (3.28 mg kg^{-1}) was found in samples from Asaba. Surprisingly, samples from a more industrialized zone (Port Harcourt) showed the lowest levels of cadmium. The results revealed high levels of cadmium pollution. The major source of cadmium contamination of the soil in these zones are oil and gas exploitation, and untreated industrial waste. The concentrations recorded in this study are above the legal limit of 0.1 mg kg^{-1} (EC 2001). MARIAM et al. (2004) reported mean levels of 0.33 ppm, 0.37 ppm and 0.31 ppm of Cd in lean beef, mutton and poultry, respectively. SAVIPERUMAL et al. (2007) found concentrations ranging from undetectable to 0.98 mg kg^{-1} Cd in some mollusc species in India. WEGWU & WIGWE (2006) observed a cadmium concentration range of 0.60–0.84 mg kg^{-1}. The levels of cadmium found in this study were higher than the range reported by these investigators, but lower than the 5.7 mg Cd kg^{-1} reported by VIARD et al. (2004) for land snails collected near a highway in France. Humans are exposed to cadmium through food and the average daily intake for adults is approximately 50 mg (CALABRESE et al. 1985). The threshold for acute cadmium toxicity is the total ingestion of 3–15 mg. Severe toxic symptoms are reported to occur with ingestion of 326 mg. Fatal ingestion of cadmium, producing shock and acute renal failure, occurs from the threshold of 350 mg (NAS-NRC 1982).

Zinc concentrations in the African giant snail ranged from 0.08 to 0.22 mg kg^{-1}. A significant variation ($p>0.05$) existed among the locations, and only slight differencs were observed within the zones. The highest Zn concentrations were observed in samples from Ughelli and Asaba (0.22 mg kg^{-1}). All the values recorded were below the permissible limit (150 ppm) set by ANZFA. SAVIPERUMAL et al. (2007) reported mean concentrations of 3.8–165 mg kg^{-1} Zn in some mollusc species; WEGWU & WIGWE (2006) reported 10.3–20.5 mg kg^{-1} for the African giant snail. The concentrations of zinc found in this study were relatively low compared to values given by VIARD et al. (2004), WEGWU & WIGWE (2006) and SAVIPERUMAL et al. (2007). The low concentration of zinc may be attributed to zinc-deficient soils, consequently the debris available to the snails is zinc-poor; combined with the fact that zinc is an essential metal of a high turnover rate it may results in a low tissue content of the element.

Chromium was not detected in any of the samples examined.

The concentrations of cadmium and lead in the snail tissues collected from different locations exceeded the permissible limits, while the remaining metals (chromium, copper, zinc, manganese, cobalt and iron) were present in levels below the permissible limits. The load these metals in human body is dependent on their concentration in snail tissues, frequency of consumption, amount consumed and the rate of detoxication of contaminants in human body. The choice of snail as a source of protein depends on culture and availability.

REFERENCES

ATSDR (AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY) 2004. Agency for Toxic substances and Disease Registry, Division of Toxicology Clifton Road, NE Atlanta G.A. Available from http://www.atsdr.cdc.gov/toxprofles/

ANZFA (AUSTRALIA NEW ZEALAND FOOD AUTHORITY) http://www. anzfa.gov.au.

CALABERESE E. J., CANADA A. T., SACCO C. 1985. Trace elements and public health. Annual Review of Public Health 6: 131–146.

EC (EUROPEAN COMMISSION) 2001. Commission Regulation No. 466/2001 of 8 March 2001. Official Journal of European Union 1: 426.

FAO (FOOD AND AGRICULTURE ORGANISATION) 1983. Compilation of legal limits for hazardous substance in fish and fishery products. FAO Fishery Circular 466: 5–100.

KRAMARZ P. 1999. Dynamics of accumulation and decontamination of cadmium and zinc in carnivorous invertebrate. The ground beetle *Poecilus cupreus* (L). Bull. Environm. Contamin. Toxicol. 63: 531–537.

LINDQUIST L., BLOCK M., TJALVE H. 1995. Distribution and excretion of Cd, Hg, methyl-Hg and Zn in the predatory beetle *Pterostichus niger* (Coleoptera: Carabidae). Environm. Toxicol. Chem. 124:1195–1201.

LINDQVIST L., BLOCK M. 1997. Influence of life and history of metal accumulation in two beetle species (Insecta: Coleoptera). Bull. Environm. Contamin. Toxicol. 58: 518–522.

MARIAM I., IQBAL S., NAGRA S. A. 2004. Distribution of some trace and macrominerals in beef, mutton and poultry. Int. J. Agricult. Biol. 6: 816–820.

NAS-NRC (NATIONAL ACADEMY OF SCIENCE – NATIONAL RESEARCH COUNCIL) 1982. Drinking water and Health Vol 4. Washington D.C. National Academic Press: p. 299.

PURCHART L., KULA L. 2007. Content of heavy metals in bodies of field ground beetle (Coleoptera: Carabidae) with respect to selected ecological factors. Pol. J. Ecol. 35: 305–314.

SIVAPERUMAL P., SANKAR T. V., VISWANATHAN NAIR P. G. (2007). Heavy metal concentrations in fish, shellfish and fish products from internal markets of India vis-a-vis international standard. Food Chem. 102: 612–630.

SPURGEON S. J., HOPKIN S. P. 1999. Comparison of metal accumulation and excretion kinetic in earthworms (*Eisenia fietida*) exposed to contaminated field and laboratory soils. Appl. Soil Ecol. 11: 227–243.

TYLER G., BALSBERG–PAHISSON A. M., BENGISSON G., BOATH E., TRANVIK L. 1989. Heavy metal ecology of terrestrial plants, micro-organisms and invertebrates. Water Air Soil Poll. 47: 189–215.

UNDERWOOD E. J. 1977. Trace elements in human and animal nutrition, 4th Edition. Academic Press, New York.

VIARD B., PIHAN F. PROMEYRAT S., PIHAN J. C. 2004. Integrated assessment of heavy metals (Pb, Zn, Cu) highway pollution; bioaccumulation in soil, Graminaceae and land snails. Chemosphere 55: 1349–1359.

WEGWU M. D., WIGWE I. A. 2006. Trace metal contamination of African giant snail (*Archachatina marginata*) from southern Nigeria. Chem. Biodivers. 3: 88–93.

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