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Effects of Lead Pollution from Vehicular Exhaust Fumes Against Sentinel Juvenile *Achatina achatina*

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Abstract We investigated lead metal pollution induced by traffic fumes along roads with differing traffic intensity near abandoned battery factory (Niger Delta, Nigeria). Juvenile *Achatina achatina* were positioned as sentinels in plastic snaileries 2 m on road sides. Lead contamination in snail tissue by atomic absorption spectrophotometer increased with increasing vehicular traffic intensity. Snails showed low positive ($r^2 = 0.40$) relationship and significant ($p < 0.05$) accumulation of atmospheric lead pollution. Edible snails sold along road sides are prone to lead contamination.

Keywords Edible snail · Lead accumulation · Vehicular fumes

Atmospheric metal inputs from anthropogenic activities dates back to early mining efforts and can predominate in many locations (Simonetti et al. 2000). Increased vehicular traffic and emissions are major contributors to air pollution and a matter of growing importance in many city centers (WHO 2000). In rural and urban areas, and near mining centers, average atmospheric Pb concentration reach 0.5–3.0 μg/m^3, above US standard of 0.1–0.2 μg/m^3 (USEPA 1986). Petrol sold in most African countries contain 0.5–0.8 g/L Pb, far exceeding the WHO's guideline of 0.15 g/L Pb, with vehicular exhaust fumes at 11 μg/vehicle/km and 30 tonnes/year. Lead profiles are strongly related to use of leaded gasoline (Shotyk et al. 1997). The dispersion of contaminants is influenced by traffic intensity (Garcia and Millan 1998). The study of bioindicator organisms (Ebenso and Ologhobo 2008a) can reveal the biologic impact of pollution over a geographical and temporal scale. Among terrestrial invertebrates, the gastropods *Helix* have the capability to accumulate different classes of chemicals and serve a pertinent species for monitoring trace metals for monitoring air and urban pollution (Regoli et al. 2006; Berger and Dallinger 1993).

Snails in Nigeria are hawked and sold along road sides (Ebenso 2002). The use of sentinel species is of particular interest to assess biologic reactivity of such complex mixtures including Pb related chemicals from vehicular exhaust and those associated with tyre manufacturing (Regoli et al. 2006). The particulate matter (PM) from vehicular engine emissions is often very small, less than $PM_{1.0}$ (1.0 μm in aerodynamic diameter) in size, making them readily respirable by animals and humans (CAI 2007); many settle on surfaces, or undetected by atmospheric Pb analyzers. In this study, the aim was to validate a sentinel approach to evaluate both bioaccumulation and toxicological effects caused by Pb pollution from vehicular fumes.

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Materials and Methods

The design of the experiment was completely randomized. The experimental area had an annual precipitation 1,300 mm, temperature 26 ± 2°C, relative humidity 80–90% and photoperiod 12 h light:12 h darkness. The experimental area was near the abandoned Sunshine Batteries Limited (SBL), Ukana, within latitude 5°80′N and longitude 7°41′E, Essien Udim Local Government Area, Akwa Ibom State, Niger Delta, Nigeria. Sample sites were selected at a 4.00 km radius from of the SBL.

A total of 120 juvenile *Achatina achatina* with mean fresh weight 32.00 ± 0.50 g, from unpolluted laboratory reared species. The snails were randomly assigned to 4 treatment sites of 10 snails replicated three times. The microcosms were plastic snaileries 0.24 × 0.24 × 0.12 m^3, with mosquito netting on the lid to allow for light, air and protect snails against predators. Floor of snailery had uncontaminated soil (dried at 80°C for 4 days) up to 3 cm, from previous study (Ebenso and Ologhobo 2008b). The snails, as sentinels to detect atmospheric Pb pollution were transferred to microcosms placed on plastic tables away from sunshine and rain, positioned 2 m from the road margin at each site.

Four sampling sites were selected at 700 m from each other, with different vehicular intensities, viz: residential (<5 cars/h) as control, untarred road (5 > 30 cars/h), motor park (30 > 50 cars/h) and tarred road (>50 cars/h) respectively. Tarred road (highway) was the farthest site from SBL. No other source of pollutants was noted during study. During the experimental period of 12 weeks (April–June, rainy season), fresh *Raphanus sativus* harvested from unpolluted site of previous study (Ebenso and Ologhobo 2008b), were fed ad libitum to snails. Weekly feed intake was estimated according to Coeurdassier et al. (2003). Weekly shell thickness was measured according to previous study (Ebenso and Ologhobo 2008b).

A 1 g tissue sample of snail oven-dried at 60°C for 2 days was digested in 2 ml 4:1 HNO_3 (65%) and HCl (37%) at 140°C for 7 h. The sample volume was made up to 10 mL with distilled water. All digestion procedures included 3–5 control blanks. Atomic Absorption Spectrophotometer (AAS) was used to analyze for Pb using Perkin Elmer Graphite Furnace AAS 2100. AAS was calibrated using standard reference materials, as described by Hopkin (1990).

All data collected from each site for all parameters considered were subjected to ANOVA using SAS (1999). The means were separated using Duncan Multiple Range Test.

Results and Discussion

The growth performances of sentinel juvenile *A. achatina* at vehicular fume sites are shown in Table 1. All the parameters measured differed significantly ($p < 0.05$) among the sites. Feed intake of snails at the control site was 30.03 g. However, at the polluted sites, feed intake decreased with increasing vehicular intensity. Snails at the control site were heavier than snails placed at polluted sites.

Snails recorded the best feed conversion to meat value of 1.30 at highway with the highest traffic intensity. Snail shells at polluted sites were thinner than the control snails. The Pb accumulation in *A. achatina* at vehicular fume sites are shown in Table 1. The Pb concentration differed significantly ($p < 0.05$) among the sites. Lead accumulation in this study ranged from 0.14 to 8.42 μg/g.

The results of this study compare with reports of Regoli et al. (2006). These authors suggested that growth performance of snails demonstrated the possibility of an approach for assessing the biologic impact from atmospheric and vehicular pollutant. The trend of weight gain of the present study (Table 1) compares with findings of Gomot-de Vaufleury and Pihan (2000) that snails placed as sentinels at unpolluted sites become heavier than those at polluted road sides. From the present study, *A. achatina* may be termed an efficient bioindicator for monitoring air quality, as it compares with report of study with *H. aspersa* by Regoli et al. (2006). Further, these authors concluded that it is unknown whether the response of sentinel snails to pollutants can be influenced by natural fluctuations in biologic features like metallic status, reproductive cycle or raining regime.

Snail Pb accumulation was low (Table 1). However, transfer of atmospheric Pb to snail had a significant ($p < 0.05$) positive log-log relationship $Y = 1.52x + 1.07$, with $r^2 = 0.40$. These results suggested a low transfer of atmospheric Pb pollution to snail in the food chain.

Superior value of Pb accumulation at highway could have been caused by diesel truck passage along site.

Table 1 *Achatina achatina* at fume sites

Parameter	Control	Untarred road	Motor park	Highway	SEM
Growth performance					
Feed intake (g)	30.03 c	30.14 a	30.10 b	29.31 d	0.01
Weight gain (g)	22.88 a	22.80 b	22.64 c	22.57 d	0.01
Feed conversion ratio	1.31 b	1.32 b	1.33 a	1.30 c	0.001
Shell thickness (mm)	0.19 a	0.18 b	0.18 b	0.17 c	0.01
Lead accumulation					
Pb (μg/g)	0.14 d	1.00 c	2.68 b	8.42 a	0.01

Means followed by different letters are significantly different by Duncan Multiple Range Test $\alpha = 0.05$

According to Van Gestel and Van Straalen (1994), snails may have absorbed atmospheric Pb deposits on leaves fed to them in the microcosm. However, pollution through dietary route was not considered in the present study.

Deleterious health effects caused by airborne chemicals have been widely documented (Maynard 2004), although only a few evidence have been related to epidemiological evidence and deleterious health effects caused by vehicular traffic (Sioutas et al. 2005). It therefore can be suggested from the results of this study that, edible snails could accumulate atmospheric Pb pollutants with far reaching human health implications when hawked and sold along road sides with high vehicular intensity.

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