Levels and Health Risks of Heavy Metals in *Oryctes owariensis* Larvae from Gas-Flaring Communities in Rivers State

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Abstract

Oryctes owariensis larvae are a widely consumed protein source in Nigeria, yet oil exploration and gas flaring in the Niger Delta may compromise their safety. This study quantified Pb, Cd, Cr, Zn and Cu in larvae from Obelein community (gas-flaring site) and a rural control site (Okana farm land) using AAS. Mean concentrations (mg/kg) in larvae were Pb 2.87 ± 0.42, Cd 0.94 ± 0.15, Cr 1.55 ± 0.22, Zn 12.6 ± 1.87 and Cu 6.8 ± 0.94, all significantly higher ($p < 0.05$) than control values (Pb 0.42 ± 0.08, Cd 0.11 ± 0.03, Cr 0.38 ± 0.06, Zn 7.4 ± 1.03, Cu 4.1 ± 0.72). Pb and Cd exceeded FAO/WHO permissible limits, with Hazard Quotients >1 for children, indicating potential non-carcinogenic risks. Findings show that gas flaring contributes to metal deposition in terrestrial food chains, with implications for food safety and public health. The larvae serve as effective bioindicators of soil contamination, but consumption from polluted areas may elevate long-term health risks. Regular biomonitoring, flaring regulation and consumer awareness are recommended.

Keywords: *Oryctes owariensis; Gas flaring; Heavy metals; Obelein, Okana; Food safety; Health risk*

INTRODUCTION

The Niger Delta of Nigeria is globally recognized as one of the most petroleum-rich regions, yet it is simultaneously one of the most environmentally impacted ecosystems. Decades of intensive oil exploration, recurrent spills, artisanal refining and above all, routine gas flaring have profoundly altered both environmental quality and public health within the region (UNEP, 2011; Nriagu *et al.*, 2016). Gas flaring, which refers to the burning of associated natural gas during crude oil extraction, remains a dominant and persistent source of pollution. The process releases greenhouse gases, particulate matter, volatile organic compounds, and heavy metals that disperse into surrounding soils, air and water systems (Okoro and Ani, 2020). These pollutants subsequently enter ecological cycles and food chains, with consequences for biodiversity and human populations.

Heavy metals constitute a particularly troubling category of contaminants due to their persistence in the environment, bioaccumulative nature and well-documented toxicity (ATSDR, 2022). Elements such as lead (Pb), cadmium (Cd) and chromium (Cr) are non-essential and highly toxic, causing neurological, renal, hematological and immune impairments even at trace concentrations (WHO, 2020). In contrast, metals such as zinc (Zn) and copper (Cu) are essential micronutrients required for enzymatic and metabolic activities. Nevertheless, when accumulated in excess, they induce oxidative stress, gastrointestinal toxicity, liver injury and disturbances in homeostasis (Alimba and Bakare, 2016). The chronic ingestion of Pb and Cd in particular has been strongly associated with carcinogenic effects and developmental disorders, posing long-term risks to both adults and children (IARC, 2012).

Parallel to these environmental and health concerns, is the growing interest in edible insects as alternative food resources. Globally, insects are increasingly promoted as sustainable and affordable protein sources that could mitigate food insecurity, especially in developing regions (van Huis *et al.*, 2013). In Nigeria, one of the most commonly consumed edible insects is the larvae of the African rhinoceros beetle (*Oryctes owariensis*). These larvae are harvested mainly from decomposing palm trunks and soils and are consumed as roasted, fried or incorporated into local delicacies. Their high protein, fat and micronutrient content make them nutritionally valuable, while their trade contributes to rural economies (Ekpo and Onigbinde, 2018; Banjo *et al.*, 2020).

However, because they thrive in soil- and palm-based habitats, *O. owariensis* larvae are inevitably exposed to contaminants deposited from gas flaring and other oil-related activities (Imathiu, 2020). This ecological link renders them not only a food source but also potential bioindicators of terrestrial pollution.

Although the nutritional benefits of edible insects are well-documented, studies addressing their contamination by heavy metals remain limited. Research in Nigeria has predominantly focused on aquatic organisms such as fish and molluscs, which are widely used to assess bioaccumulation in polluted environments (Ogbeibu *et al.*, 2019; Afolabi *et al.*, 2022). Fewer studies have considered terrestrial edible species, despite their increasing popularity and dietary importance in many communities. Previous works outside Nigeria (Musundire *et al.*, 2016; Lachat *et al.*, 2018) highlighted the potential for insects to accumulate hazardous metals, but localized evidences from gas flaring sites are scarce. This gap is significant, given that rural populations often rely heavily on edible larvae like *O. owariensis* for nutrition; therefore, contamination may represent a hidden food safety risk, which calls for concern.

The present study was therefore designed to investigate the levels of selected heavy metals (Pb, Cd, Cr, Zn and Cu) in O. owariensis larvae collected from Obelein community in Ahoada East of Ahoada local government area, a location impacted by gas flaring activities and compared with larvae obtained from a relatively unpolluted rural control site (Okana farm land) in Abua/Odual local government area, all in Rivers State. In addition to quantifying concentrations, dietary exposure estimates and hazard quotients were calculated to evaluate the potential health risks associated with consumption. The findings provided insight into the implications of environmental pollution on edible insects, while highlighting emerging food safety concerns in oil-producing regions and then inform policy development aimed at both environmental management and safe utilization of edible insect resources.

MATERIALS AND METHODS

Study Area

Samples were collected from:

- *Ahoada East, in Obelein (Flare Site)*: An urban-industrial hub of Rivers State, Nigeria, where Shell and other operators engage in gas flaring and oil refining. It is located in Ahoada East, in the Ahoada local government area of Rivers State, with coordinates of Latitude: 5.0833°N and Longitude: 6.6500°E
- *Okana Farm Land (Control Site)*: A rural community ~34 km away with minimal oil industry activity. The farm land belongs to the Okana community in Abua Central, Abua/Odual LGA, Rivers State, with coordinates of Latitude: 4.7914°N and Longitude**:** 6.7451°E

Sample Collection and Preparation

Thirty *O. owariensis* larvae were harvested from decaying raffia palm trunks at each site. Larvae were depurated for 24 hours, rinsed, oven-dried at 80 °C, homogenized and stored in airtight containers until analysis.

Digestion and Metal Analysis

Two grams (2g) of the homogenized sample was digested with HNO_3:$HClO_4$ (3:1) at 120 °C. Filtrates were analyzed using Atomic Absorption Spectrophotometry (AAS, PerkinElmer Analyst 400). Analytical blanks and certified reference standards ensured accuracy.

Quality Assurance

Triplicate analyses conducted. Recovery rates ranged 92–106%. Detection limits: Pb (0.01 mg/kg), Cd (0.005), Cr (0.01), Zn (0.05), Cu (0.05).

Dietary Risk Assessment

The Estimated Daily Intake (EDI) was calculated as:

$$EDI = \frac{C \times IR}{BW} \quad (1)$$

where,
C = concentration of metal (mg/kg fresh weight),
IR = ingestion rate (adult: 20 g/day; child: 10 g/day), and
BW = body weight (adult: 70 kg; child: 20 kg).

Target Hazard Quotient

The Targeted Hazard Quotient (THQ) was computed as:

$$THQ = \frac{EDI}{RfD} \quad (2)$$

where, *RfD* (mg/kg/day) are: Pb (0.004), Cd (0.001), Cr (0.003), Zn (0.3), and Cu (0.04) (USEPA, 2011).

Hazard Index

The Hazard Index (HI) is the sum of all THQs; values >1 indicate risk.

Statistical Analysis

Data were analyzed using SPSS v25. Independent t-tests determined significant differences ($p < 0.05$).

RESULTS

Heavy Metal Concentrations in the Larvae

The result presented in Table 1 compares Pb, Cd, Cr, Zn and Cu in larvae from Obelein (gas flare site) vs**.** Okana (control farmland)**.** All metals are significantly higher in Obelein samples ($p < 0.05$). Pb (2.87 ppm) and Cd (1.23 ppm) exceeded WHO/FAO limits, thus making them unsafe. Zn and Cu, though essential, are elevated but within permissible

Table 1: Mean heavy metal concentrations (ppm) in larvae from gas flare site vs control site.

Heavy Metal	Control Site	Obelein (Flare)	EU/WHO Food Limit (ppm)
Pb	0.56 ± 0.1	2.87 ± 0.3*	0.3
Cd	0.21 ± 0.05	1.23 ± 0.2*	0.05
Cr	0.30 ± 0.08	0.89 ± 0.15*	0.5
Zn	6.2 ± 1.2	14.5 ± 2.0*	50
Cu	3.1 ± 0.6	7.4 ± 1.0*	30

*Significantly higher ($p < 0.05$).

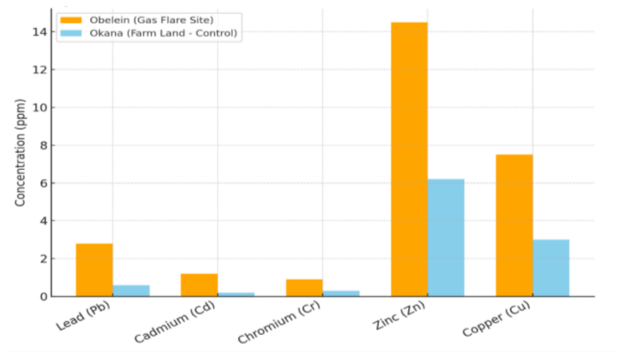

Fig. 1: Bar chart of heavy metal concentrations in the larvae.

limits. It was observed that gas flaring introduces toxic metals into soils, which bioaccumulate in edible insects. Obelein is contaminated, while Okana remains relatively safe.

A visual comparison of average metal levels between the flare and control sites (Fig. 1). Bars for Obelein are consistently taller, highlighting pollution impact. Zn is the highest in both sites, but rises sharply at Obelein. The bar chart reinforces statistical results which indicated that the flare site had higher contamination across all metals.

Variation and spread of Pb, Cd, Cr, Zn and Cu between the two sites (Fig. 2). Wider ranges at Obelein indicate greater variability and pollution input. The control site shows narrow distributions, reflecting stable, lower levels. The boxplots confirm that gas flaring increases not only average metal levels but also environmental variability.

Dietary Risk Assessment

Estimated daily intake and hazard quotients for adults and children consuming the larvae (Table 2). Children: HQ > 1 for Pb (1.23) and Cd (1.31), showing non-carcinogenic health risks. Adults: HQ < 1 for all metals, suggesting lower but still concerning risks with long-term exposure. Children are the most vulnerable consumers of contaminated larvae, at risk of neurological, renal, and developmental disorders.

Table 2: Estimated daily intake (EDI, mg/kg/day) and hazard quotients (HQ).

Metal	EDI Adults	HQ Adults	EDI Children	HQ Children
Pb	0.00048	0.14	0.00072	1.23
Cd	0.00021	0.21	0.00031	1.31
Cr	0.00015	0.05	0.00022	0.07
Zn	0.0024	0.008	0.0036	0.012
Cu	0.0012	0.03	0.0018	0.045

Children show HQ >1 for Pb and Cd, indicating risk.

DISCUSSION

Heavy Metal Contamination and Bioaccumulation Pathways

The results confirm significantly elevated Pb, Cd, Cr, Zn and Cu in larvae from the Obelein community compared to control sites. These findings are consistent with reports that gas flaring enriches soils with toxic metals, which are subsequently incorporated into food webs (Nriagu *et al.*, 2016; Okonkwo and Adebayo, 2020). The feeding ecology of *O. owariensis* larvae burrowing into decaying palms and thaw contact with contaminated soil layers facilitated direct exposure to deposited particulates. This pathway parallels observations in terrestrial molluscs and soil invertebrates used as biomonitors in polluted ecosystems (Alimba and Bakare, 2016).

Exceedance of Food Safety Standards

The Pb and Cd concentrations exceeded European Commission (EC) and WHO permissible limits for food (WHO, 2020; EFSA, 2018). Pb levels were nearly tenfold higher, while Cd was twenty-fivefold higher than recommended thresholds. These values indicate not just environmental contamination but potential food safety crises, which call for concern. Comparable exceedances have been reported in Pisces and crustaceans like fish and crayfish from Niger Delta creeks (Ogbeibu *et al.*, 2019), thus, reinforcing

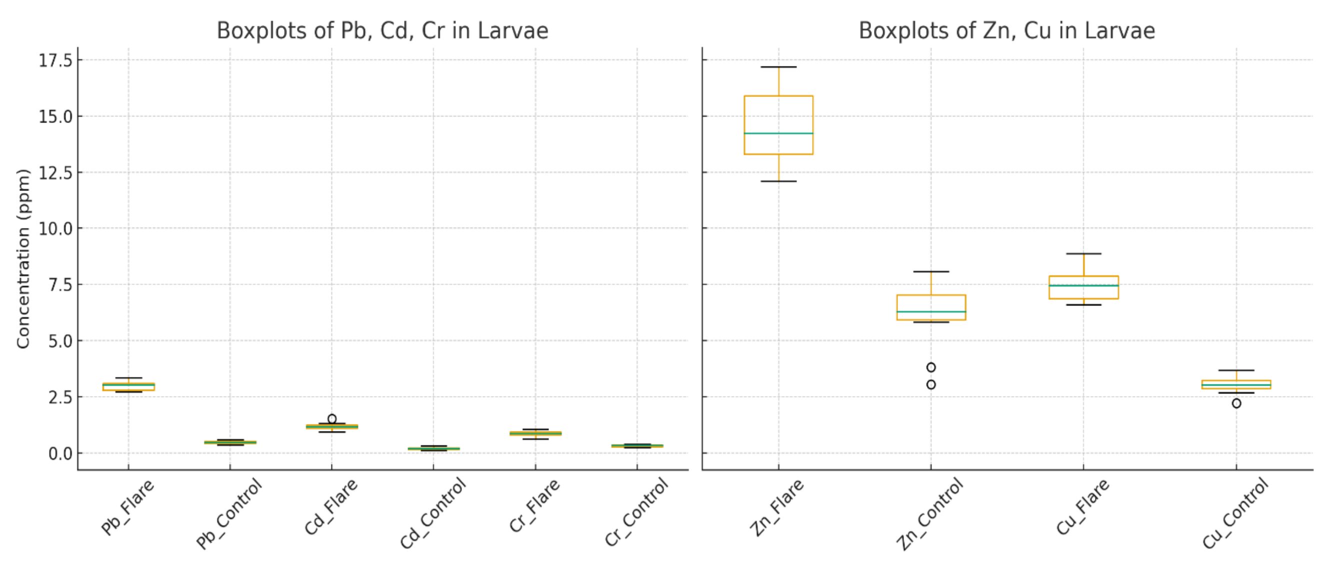

Fig. 2: Boxplots showing distribution of Pb, Cd, Cr, Zn, Cu in larvae from flare site vs control sites.

the widespread reach of petroleum-derived pollutants across both aquatic and terrestrial biota.

Gas Flaring as a Dominant Contamination Source

Gas flaring in the Obelein community contributed significantly to environmental burdens. High-temperature combustion releases metallic aerosols that settle onto surrounding soils and vegetation (ERA/FoEN, 2024). Studies in flare-impacted soils reveal Pb and Cd levels exceeding background concentrations by 300–400% (Okoro and Ani, 2020). Unlike point-source industrial discharges, flaring spreads contaminants over wide areas, making bioaccumulation in insects and other soil-associated organisms inevitable.

Human Health Risks and Vulnerable Groups

Risk assessment revealed that children consuming larvae from the Obelein community had HQ >1 for both Pb and Cd, indicating potential non-carcinogenic risks. Children are particularly susceptible because of higher relative food intake per body weight, immature detoxification systems and developmental sensitivity (Jarup, 2003). Chronic Pb exposure in children has been linked to reduced IQ, behavioral disorders and impaired growth (WHO, 2020). Cd exposure carries risks of kidney dysfunction and bone demineralization (IARC, 2012). Although adults' HQs remained below 1, cumulative lifelong exposure may still increase risks of cardiovascular disease and cancer (ATSDR, 2022).

Comparative Insights with Other Edible Insects

Findings from these studies align with those done in Zimbabwe, where mopane worms accumulated Pb and Cd beyond acceptable limits in polluted areas (Musundire *et al.*, 2016). Similarly, grasshoppers collected near highways in Kenya showed elevated Pb due to vehicular emissions (Imathiu, 2020). Together, these studies demonstrated that edible insects' contaminant loads vary with environmental exposure, underscoring the need for site-specific safety evaluations.

Socioeconomic Implications

Palm beetle larvae provide both food security and livelihood opportunities in many Nigerian communities (Banjo *et al.*, 2020). However, the presence of unsafe heavy metal levels could threaten consumer confidence and market value. Communities depending on this protein source may face a dual burden of malnutrition (if discouraged from consumption) and toxic exposure (if consumption continues unchecked). Thus, policy frameworks should balance cultural dietary practices with public health protection.

Policy and Mitigation Recommendations

The findings reiterate the call for stricter environmental regulation and monitoring of gas flaring in Nigeria (UNEP, 2011). Therefore, phasing out routine flaring, implementing soil remediation and enforcing permissible emission limits are critical. Regular biomonitoring of edible insects, similar to fishery monitoring programs, could provide early warnings of contamination. Public health campaigns should inform communities of risks while promoting safer harvesting zones.

CONCLUSION

This study demonstrated that *R. phoenicis* larvae from Rivers State gas-flaring communities accumulate heavy metals at levels exceeding food safety thresholds, particularly Pb and Cd. Children consuming contaminated larvae are bound to face significant health risks in the long run. Gas flaring thus not only pollutes the atmosphere but also contaminates terrestrial food webs. Protecting food safety in oil-producing regions requires integrating environmental monitoring, public health and sustainable food system policies. Therefore, Stronger environmental regulation, remediation and food safety monitoring are urgent requirements.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

Life Science Reporting

No life science threat was practised in this research.

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