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Lead Levels in Breast Milk and Associated Infant Health Outcomes in Oil-Host Communities of Emuoha and Eleme, Nigeria

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Abstract: Lead exposure is an environmental health concern for lactating mothers and infants. Despite growing body of research, the impact of lead exposure on infant health outcomes remains underexplored in the oil-host communities of Rivers State, Nigeria. This study examined the Lead levels in breast milk of lactating mothers and the associated infant health outcomes in the oil-host communities of Emuoha and Eleme in Rivers State, Nigeria. The examined primary outcomes were lead levels in breast milk of lactating mothers at 6 weeks postpartum (baseline), infant weight, head circumference, morbidity (symptoms and rate of hospitatlisation), and mortality between 6 weeks baseline and 6 months end-line. A prospective cohort design was adopted to follow a random sample of 232 mother-infant dyads recruited from the communities. At baseline, breast milk samples were collected and analyzed for Lead using Atomic Absorption Spectrophotometry. The infants were followed for 6 months to track health outcomes. A structured data extraction form was used to collect data. Data were analyzed using t-test and Chi-square test at $p < 0.05$ significance level. About 17.7% of the lactating mothers had Lead in breast milk above the World Health Organization safety limit. Infants born to mothers with elevated lead levels in breast milk exhibited significantly lower weight, smaller head circumferences, and higher rate of symptoms compared to those whose mothers had lower lead levels ($p < 0.020$). Lead exposure through breast milk negatively impacted infant health. Remediation efforts to reduce lead exposures are recommended to safeguard infant health.

Key words: Environmental health, Infant health, Lactation, Lead, Milk

Introduction

Lead is a toxic heavy metal commonly found in rocks and leaded gasoline, with no known nutritional value in contaminated food and water (Meena et al., 2020). When consumed, lead binds persistently to albumin in the bloodstream for up to 30 days (Kumar et al., 2020) and chemically attaches to the bone matrix, where it can remain for up to 20 years (Charkiewicz & Backstrand, 2020). In lactating mothers, lead stored in the bones can be released into breast milk when calcium levels are low (Philip-Slaboh et al., 2023). Consequently, a breastfeeding mother may continue excreting lead for months after exposure, thereby posing a risk of lead ingestion to the infant (Samiee et al., 2019).

Lactating mothers are frequently exposed to environmental pollution, a global health concern responsible for approximately nine million deaths annually (Fuller et al., 2022). Activities such as mining and fossil fuel exploration contribute significantly to lead contamination in air, soil, and water (Ukaogo et al., 2020). Lead exposure primarily occurs through ingestion and inhalation (Charkiewicz & Backstrand, 2020), leading to lead accumulation in maternal tissues (Philip-Slaboh et al., 2023). The concentration of lead in breast milk depends on the extent and duration of maternal exposure, with some cases exceeding the World Health Organization's recommended safety limits.

Breast milk is an essential source of nutrition for newborns, containing vital nutrients necessary for their growth and development (Koletzko et al., 2020; Christian et al., 2021). Although normal breast milk does not naturally contain Lead, maternal exposure to lead-contaminated environments can result in its accumulation, posing toxicological risks to infants (Lin et al., 2023). Infants are particularly vulnerable to lead exposure, as their developing immune systems and cytokine production may be adversely affected (Pajewska-Szmyt et al., 2019). The World Health Organization has established a safety threshold of 5 µg/L for lead in breast milk (Vahidinia et al., 2019), and exceeding this limit increases the risk of lead poisoning, which may result in severe health consequences (Lin et al., 2023).

Lead contamination in infants may affect multiple physiological systems. Lead inactivates crucial enzymes, weakens antioxidant defenses, and heightens oxidative stress, leading to cellular damage and inflammation (Fu & Xi, 2020). It also disrupts red blood cell parameters, causing anaemia, which manifests as fatigue, weakness, and developmental delays (Debnath et al., 2019). The destruction of immune-mediated cells compromises the infant's ability to fight infections (Lin et al., 2023). Furthermore, Lead disrupts bone marrow precursors, impairing red blood cell production and contributing to lead-induced anaemia (Debnath et al., 2019). Long-term exposure to Lead during early development is particularly detrimental, as it may cause irreversible cognitive impairments and hinder intellectual abilities. The persistent effects of lead exposure highlight the urgent need for intervention to protect infants from contamination.

Crude oil exploration is another major contributor to environmental contamination (Morgunova & Shaton, 2022). The extraction and refining processes release toxicants into the environment, further exacerbating pollution (Selva-Filho et al., 2023). Drilling rigs, transportation vehicles, and other equipment used in these activities disperse lead-containing substances into the air, soil, and water, increasing human exposure risks (Yang et al., 2022).

Nurse-midwives play a crucial role in promoting maternal and child health by educating lactating mothers about healthy habits, breastfeeding techniques, and postpartum care (Turner et al., 2022; Pramono et al., 2022). In cases where breastfeeding is not feasible, they provide guidance on alternative safe infant feeding practices. Their responsibilities also extend to child development education, addressing potential health concerns, and collaborating with other healthcare providers to ensure comprehensive care for mothers and infants (Wang et al., 2023). Given the complexities associated with lead exposure and breastfeeding safety, nurse-midwives are key advocates for infant health and well-being.

Preventing the exposure of lactating mothers to lead is essential for safeguarding infant health. Identifying and mitigating lead exposure sources, ensuring access to clean drinking water, and strict environmental regulations are vital steps to achieving this (Philip-Slaboh et al., 2023). Regular screening and monitoring of lead levels in breastfeeding mothers allow for early intervention and risk reduction. A proactive approach to prevention and surveillance is necessary to ensure the safety of breast milk and protect neonatal development. Therefore, routine monitoring of lead concentrations in breast milk is imperative, particularly in areas prone to environmental pollution, to minimize potential health risks and promote safe breastfeeding practices (Charkiewicz & Backstrand, 2020).

The United Nations SDG aims to improve health for all, with a key focus on reducing infant deaths (Traverso & Nangah-Mankaa, 2023; Raji & Demehin, 2023). In Rivers State (Nigeria), use of heavy duty machinery and crude oil exploration has worsened lead pollution fears (Chinedu & Chukwuemeka, 2018). Some lactating mothers worry about contaminated breast milk and choose infant formula instead. The relative lack of studies on lead in breast milk and associated infant outcomes in the oil-host communities of Emuoha and Eleme calls for more investigations to guide maternal and infant health preservation. This study examined lead levels in lactating mothers' breast milk and their infant outcomes in oil-host communities of Emuoha and Eleme in Rivers State.

Materials and Methods

This study adhered to the principles of the Declaration of Helsinki (2013) for studies involving humans. The study was approved by the University of Port Harcourt Health Research Ethics Committee (ID: UPH/CEREMAD/REC/MM100/001). Informed written

consent were obtained from the lactating mothers before commencing the baseline data collection. A prospective cohort design was adopted for the study.

Emuoha and Eleme, both in Rivers State, are key oil-host communities with numerous crude oil fields. Emuoha with 169,025 residents has benefited from oil exploration, but environmental degradation threatens agriculture and fishing. Eleme with 190,880 residents is known for its crude oil refineries and petrochemical industry, but despite economic gains, pollution remains a major challenge, impacting residents' health and livelihoods. Both regions, strategically located near oil and gas infrastructure, are crucial to Nigeria's petroleum industry, making them suitable for the study.

Out of a population of 418 postpartum mothers in the two communities (Emuoha = 252 and Eleme 166), a sample size of 232 was determined. The sample size was calculated using the Cochran formula for longitudinal studies (Charan & Biswas, 2013) plus an added 10% to account for attrition/non-response (Bolarinwa, 2020).

A simple random sampling technique using the lottery approach was applied in the selection of study participants. In each of the communities, labelled tallies (Yes, n = 5 and No, n = 5) were placed in a scrabble game bag and presented to the lactating mothers to pick from, with replacement. Those who picked a tally labelled "Yes" were selected for the study, while those who picked a tally labelled "No" were excluded. The criteria for inclusion were: Mothers and infants resident in Emuoha and Eleme during the study period, lactating mothers aged 15-49 years, ensuring a focus on the typical reproductive age group, and breastfed infants aged 6 weeks at the beginning of the study. Mothers who smoke tobacco and infants with serious medical conditions were excluded. The selected participants were approached in designated Women Association Halls in Emuoha and Eleme on days designated by the Women Association Chairperson. Each mother-infant dyad was given a unique code number. A data extraction sheet was used to document data on the demographic data of the mothers and about 5 ml of expressed breast milk samples were collected into sterile plastic specimen bottles which were coded and stored at -2 to -4 ^{o}C for further laboratory analysis. The Atomic Absorption Spectrophotometer (AAS) used for sample analysis for heavy metals using established laboratory protocol. After 17 weeks, when the infants had turn 6 months old, anthropometric measurements (head circumference and weight) were measured by the research team and morbidity (symptoms and hospitalization rates) of the infants were documented as provided by the mothers. Confidentiality and anonymity were maintained throughout the study.

The collected data were organized and summarized with descriptive statistics. Comparison between sub-groups was done with t-test for continuous variables and chi squared for categorical variables at a 0.05 level of significance. All analyses were done with the aid of SPSS 25 software.

Result

No more than 232 mothers entered the study, but 229 mother infant dyads completed the study. Three (3) mother infant dyads fell out of the study for undisclosed reasons.

Table 1: Mother and infant's demographic profile at baseline **(n = 232)**

Category	f	%
Age		
20-24	13	5.6
25-29	75	32.3
30-34	67	28.9
35-39	56	24.1
40-44	21	9.1
Marital status		
Single	3	1.3
Married	229	98.7
Parity status		
Primipara	87	37.5
Multipara	145	62.5
Occupation		
Artisan	34	14.7
Civil servant	28	12.1
Trader	159	68.5
Unemployed	11	4.7
Infant gender		
Female	134	57.8
Male	98	42.2

% = percent, f = frequency, n = sample

Table 1 shows that at baseline, most of the mothers were aged 25–29 (32.3%). Nearly all the mothers were married (98.7%) and multiparous (62.5%). Traders made up the largest occupational group (68.5%), followed by artisans and civil servants. There were slightly more female (57.8%) than male infants.

Table 2: Level of Lead in the breast milk of lactating mothers at baseline (n = 232)

Category	n	%	Mean	SD	Min.	Max.
> 5 µg/L	41	17.7	6.42	0.92	5.11	7.97
< 5 µg/L	191	82.3	3.87	0.50	0.00	3.68
Total	232	100.0	4.32	0.57	0.00	7.97

WHO safe limit 5 ug/L, < 5 ug/L = within limit, > 5 ug/L = above safe limit

Table 2 shows that 17.7% of lactating mothers had breast milk lead levels above the WHO safe limit of 5 µg/L, with a mean of 6.42 µg/L. The majority (82.3%) were within the safe range, averaging 3.87 µg/L.

Table 3: Anthropometric outcomes of the infants at 6 months of age born to mothers with Lead in breast milk below and above WHOs recommended limit (n = 229)

Category	**Lactating mothers with Pb in breast milk**		**df**	**χ^2**	**p value**
	Below WHO reference limit	**Above WHO reference limit**			
Head circumference (cm)			1	4.46	0.034
39.0-40.9	85	26			
41.0-42.9	103	15			
Infant Weight (kg)			3	37.84	<0.001
6.1-6.5	6	12			
6.6-7.0	96	23			
7.1-7.5	81	5			
7.6-8.0	5	1			

n = sample size, kg = kilogram, cm = centimeter, WHO safe limit 5 ug/L, < 5 ug/L = within limit, > 5 ug/L = above safe limit, df = degree of freedom, χ^2 = chi square, p < 0.05 = significant

Table 3 shows that infant anthropometric outcomes at six months significantly differed based on maternal breast milk lead levels. Infants of mothers with lead levels above the WHO limit had smaller head circumferences (χ^2 = 4.46, p = 0.034) and lower weights (χ^2 = 37.84, p < 0.001) compared to those within the safe limit.

Table 4: Morbidity outcomes of the infants between 6 weeks and 6 months of age (n = 229)

Category	**Lactating mothers with Pb in breast milk**		**df**	**χ^2**	P value
	below WHO reference limit	**above WHO reference limit**			
Infant hospitalization rate			3	16.86	<0.001
None	182	34			

1-2	4	2			
3-4	2	3			
5-6	0	2			
Symptoms at 6 months old					
Constipation (n = 229)	86	2	1	8.41	0.003
Cough (n = 229)	62	14	1	0.02	0.886
Fever (n = 229)	160	25	1	12.63	<0.001
Diarrhoea (n = 229)	157	34	1	0.01	0.927
Vomiting (n = 229)	181	21	1	65.70	<0.001
Body Rashes (n = 229)	96	16	1	1.95	0.162

n = sample size, WHO safe limit 5 ug/L, < 5 ug/L = within limit, > 5 ug/L = above safe limit, df = degree of freedom, χ^2 = chi square, $p < 0.05$ = significant

Table 4 shows that infants of mothers with breast milk lead levels above the WHO safe limit experienced significantly higher hospitalization rates between baseline and 6 months ($\chi^2 = 16.86$, $p < 0.001$). Significant differences were also observed in rates of constipation ($p = 0.003$), fever ($p < 0.001$), and vomiting ($p < 0.001$).

Discussion

This study found that approximately 2 in 10 lactating mothers had lead in breast milk above the WHO safe limit. This finding suggests that a minority of the mothers face elevated Lead exposure. This result indicates the presence of localized contamination sources. There are several potential reasons for this finding. First, proximity of residence to contamination source can account for the variation For instance, participants who live closer to industrial and crude exploration sites may have higher exposure to Lead (Atoufi & Lampert, 2020). Lead pollution from such sources can leach into soil, water, or air and can easily enter the food chain and accumulate in maternal body over time. Secondly, poor waste management in certain areas could also be responsible for higher localized contamination levels (Collin et al., 2022). When compared to previous studies, this finding aligns with reports from regions with high industrial activities. For instance, studies in heavily polluted regions of Nigeria (Philip-Slaboh et al., 2023) and Ghana (Bansa et al., 2017) have shown that lead concentrations in breast milk often exceed the WHO safe limit, similar to what is observed in this study.

This study shows that by 6 months of infant's age, a significant difference emerged, with infants of mothers having Lead levels above the WHO limit having smaller head circumference and weighing less than their counterparts whose mothers had Lead levels

below the safe threshold. This indicates that prolonged exposure to lead can adversely affect infant growth trajectories. Lead is known to interfere with nutrient absorption and metabolism, which are critical for healthy weight gain and overall development. Infants born to mothers with elevated lead levels may experience deficiencies in essential nutrients like calcium and iron due to lead's competitive binding in the body. Over time, these deficiencies can manifest as slower growth and lower weight gain. Furthermore, lead exposure can impair the endocrine system and disrupt appetite regulation, compounding its adverse effects on infant growth. This finding align with previous studies in similar contexts such as Kim et al. (2020) and Olujimi et al. (2023) that demonstrated that chronic exposure to Lead correlates with growth delays and weight deficiencies in infants.

This study found that at 6 months, infants born to mothers with lead levels in breast milk above the WHO safe limit experienced higher rates of hospitalization than those whose mothers had lead levels below the limit. The infants experienced more constipation, fever, and vomiting. This observation suggests that maternal Lead exposure can have a cascading impact on infant health, contributing to increased morbidity that necessitates hospital care. Lead is a known toxicant that disrupts multiple physiological systems, including the immune system (Raimi et al., 2022). Infants exposed to lead through breast milk may have weakened immune responses, making them more susceptible to infections and illnesses. Lead interferes with the normal functioning of white blood cells and impairs the production of antibodies, both of which are critical for fighting infections (Wei et al., 2024). This immunosuppressive effect explains the higher frequency of hospitalizations among infants with greater lead exposure. This finding aligns with prior research linking elevated lead exposure in early life to increased health complications. For instance, studies by Kim et al. (2020) and Olujimi et al. (2023) observed that infants exposed to lead exhibited higher rates of gastrointestinal health complications.

Limitations

This study has some limitations. The study followed mother-infant pairs for the first six months postpartum. Although this timeframe captures critical early developmental stages, it does not account for potential long-term effects of lead exposure on growth, cognitive development, and health outcomes beyond infancy. Extending the study duration could provide a more comprehensive understanding of the cumulative impact of lead exposure on children. Additionally, the study may not have adequately controlled other confounding factors that could influence infant health outcomes, such as maternal nutritional status and other environmental pollutants, and access to healthcare. These confounding variables might have interacted with lead exposure to exacerbate or mitigate health outcomes, potentially leading to biased or incomplete conclusions about the

observed associations. Addressing these limitations in future research could enhance the reliability and applicability of the findings, offering deeper insights into the relationship between lead exposure and maternal and child health.

Conclusion

Prolonged exposure to lead in breast milk above 5µg/L had significant adverse effects on growth and morbidity. This finding highlights the importance of addressing maternal Lead exposure to safeguard infant health and development, particularly in environmentally at-risk communities.

Author Contributions

Conceptualization: CO, AM, CI, and CE. Data collection: CO and CE. Analysis: CO and CE.Writing and Revison: All authors.

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Conflicts of Interest (or Competing Interests) : Authors declare no conflicts of interest.

Ethical Approval

The study was approved by the University of Port Harcourt Health Research Ethics Committee (ID: UPH/CEREMAD/REC/MM100/001).

Informed Consent

Written informed consent was obtained from participants before data collection.

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Data Availability Statement

The authors will make data supporting the findings available upon request.

Supplementary Materials

Additional materials are available in University of Port Harcourt online repository.

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