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Research Article
Sources and Prevalence of Lead Poisoning Among School Children in Owerri Metropolis, South-East Nigeria

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Abstract

Background and Objective: A few years back, Zamfara State, Nigeria experienced death from lead poisoning in children. Despite this sad occurrence, there appears to be a paucity of literature on the prevalence of lead poisoning in other regions as children continue to be exposed. This study investigated the prevalence of childhood lead toxicity among school children in the Owerri Metropolis. **Materials and Methods:** This cross-sectional study examined 72 school children from 32 primary schools within Owerri Metropolis. Their samples were analyzed for blood lead level using atomic absorption spectrophotometry (AAS). Additionally, 32 pooled soil samples collected from the play-ground of their various schools were analyzed using a flame atomic absorption spectrophotometer (FAAS). **Results:** The results revealed that out of the 72 blood samples analyzed, nine (12.5%) that exceeded the Center for Disease Control and Prevention guideline level at ($\geq$5 µg dL^{-1})are at a toxic level. The findings also revealed that toxic blood lead level was found more in those of age 6-8, those in nursery 1-3 and a higher prevalence in females than male. Additionally, all the pooled soil samples collected from major schools have an average lead level of 0.041$\pm$0.08 ppm (mg kg^{-1}) which is a safe level. **Conclusion:** Prevalence of childhood lead toxicity in Owerri is low compared to some other cities in Nigeria, however, the mere fact that some children had greater than the acceptable levels in their body, shows that there is a level of environmental exposure, especially among females and children less than nine years, hence we recommend that government and related stakeholders should ensure that policies are made and implemented to safeguard children from lead poisoning. Awareness of sources and prevention of lead poisoning should be encouraged.

Key words: Lead, Nigeria, poisoning, school children, prevention, stakeholders

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Lead is an ever-present and multipurpose element that has been of use for centuries by humans[1]. It has become one of the greatest grave toxic substances in our environment. Lead has become a very perceptible substance because of the multiplicity of its use. Lead is a heavy metal and is found in the body as a trace element[1]. Naturally occurring lead makes up about 0.002% (15 g t^{-1}) of the earth crust. They occur as lead ores and in various forms such as galena (lead sulfide), anglesite (lead sulfate), carrusite (lead carbonate), mimetite (lead chloroarsenate) and pyromorphite (lead chlorophosphate)[1].

The poisoning by lead can be organic poisoning or inorganic poisoning depending on whether the source is an organic compound of lead (that contains carbon) or an inorganic compound (without carbon). Organic lead poisons as seen in gasoline additives is more dangerous because it crosses the skin and the respiratory tract easily and affects the central nervous system predominantly. Leaded paint and leaded gasoline which was commercially used in automobile fuel and is still used in aviation have not been completely phased out in Nigeria. It can also be found in pottery, herbal concussions and remedies, used in construction and present in some food like imported candies and spices, contaminated drinking water[2]. A recent study on heavy metals in food crops gotten from Ohaji, South-Eastern Nigeria, reveals that food crops sourced from those areas are not completely safe from lead[3]. The minerals located in various locations in Zamfara, Nigeria is worryingly adulterated with lead[4]. Additionally, during the procession of crude oil, the lead elements could be removed unknowingly. This often results in air, communal water and soil contaminations[4].

Plumbism could also be described as lead poisoning. It could be described as a harmful consequence of the slow and steady buildup of lead in the body tissues. Of course, this could result in repeated contact with lead-containing substances[5]. Elevated blood lead levels (BLL) can trigger serious health conditions. There are no signs and symptoms pathognomonic of lead poisoning, making identification based solely on patient history and physical examination difficult.

The clinical features that can be seen include: muscle weakness, kidney inflammation, anaemia, brain damage (e.g., behavioural changes, mental impairment, seizures, coma) and gastrointestinal symptoms (e.g., abdominal pain, constipation, nausea, vomiting decreased growth in height, delayed sexual maturation, increased dental caries[4,6]. It is a known neurotoxin that has been associated with a reduction in intellectual abilities, learning deficits and irreversible neurobehavioral disorders in children. Studies done in children indicate that the dose-response relationship between blood lead concentrations and intelligent quotient (IQ) is non-linear, with greater loss of IQ as the concentration increases[7,8].

Poisoning is a pattern of symptoms that occur with toxic effects from mild to high levels of exposure, toxicity on the other hand is a spectrum of effects including subclinical ones (those that do not cause symptoms). However, because professionals often use "lead poisoning" and "lead toxicity" interchangeably and official sources do not always restrict the use of "Lead poisoning" to refer only to symptomatic effects of lead[6]. "lead toxicity" is in this work used interchangeably with "lead poisoning" although with greater emphasis on toxicity. Lead poisoning occurs when a child swallows, absorbs or inhales the heavy metal lead in any form[9]. According to the U.S. Centers for Disease Control and Prevention (CDC), the recommended blood lead poison level[10] is from 5-10 µg dL^{-1}. The current reference range for acceptable blood lead concentrations in healthy persons without excessive exposure to environmental sources of lead is less than 5 µg dL^{-1} for children and less than 25 µg dL^{-1} for adults[10]. Recent and emerging research has shown that lead levels less than 5 µg dL^{-1} are linked with a series of adverse health effects such as diminished intellect and educational attainment. It is also associated with social and behavioural issues[11].

Since 2010, about 200 children have died in Zamfara, Nigeria due to lead intemperance[6]. Also, up to 18,000 children and adults have been influenced negatively by lead contamination[12]. The report of the World Health Organization (WHO) revealed that more than 400 children died as a result of the lead poisoning outbreak, 2000 are currently on treatment and 4000 remain at risk of poisoning[13].

There is the paucity of information especially published work on lead poisoning amongst school children in the South-Eastern part of Nigeria, thus the need for this study. The aim was to incite and create awareness in this area of lead toxicity with the view to take necessary preventive measures against disease and death, discuss methods to eliminate sources of exposure to lead and elaborate on the effectiveness of the current preventive actions in place.

MATERIALS AND METHODS

Study design and setting: A descriptive cross-sectional study of school children between ages 3-11 years was conducted in Owerri, Imo State, Nigeria. Owerri is the capital of Imo State in Southeast Nigeria with a population of 908,000 in 2021 according to Macrotrends and United Nations (UN) population projections.

Study population and sample: The population comprised all school children from 32 schools in Owerri between the ages of 3-11 years. The sample size was calculated using:

$$N = \frac{z^2\,Pq}{d^2}$$

Where,
N = Minimum sample size
Z = Confidence level at 95%
P = Prevalence of lead poisoning (25%)
Q = 1-p
d = Precision (0.05)

A total sample size of 317 was obtained, however, the study examined 72 school children selected through a simple random sampling technique. The researchers could not get the initial sample size of 317 because some of the selected children were ill, some had parental consent declined and those with the abject phobia for syringes were all excluded from the study.

Ethical approval and informed consent: Ethical approval to undertake the study was obtained from the headmasters/headmistresses of 32 schools surveyed. Informed consent was sought from parents and guardians for a blood sample collection from their children. The pupils were addressed on appointed days and samples were collected.

Data collection and analysis: The blood samples were analyzed for lead level only, EDTA vacutainer tubes were used to store 2 mL of fresh whole blood samples and analyzed using atomic absorption spectrophotometry (AAS). The blood was measured into a beaker and 6 mL of nitric acid (HNO_3) as the oxidizing agent was added to the beaker to break the sample matrix. Then 2 mL of perchloric acid was added as a reagent with a small amount of anti-bumping. Furthermore, the solution was heated on a mantle to fasten the reaction with little H_2O added to it and heated until the volume reduced and its colour turned yellowish. The solution while still on the hot plate was stirred and distilled water was used to make up its final volume to 25 mL. The solution was aspirated with AAS and analyzed.

The soil samples were collected from the 32 schools playgrounds, the sample was air-dried at room temperature, then pulverized and the total concentration was determined by flame atomic absorption spectrophotometer (FAAS).

Statistical analysis: The data obtained was transferred into statistical analysis software (SPSS Version 25 for windows) and Microsoft excel to generate tables, charts and proportions. The statistical significance was set at p<0.05 and the result were expressed as Mean±SD.

RESULTS

Baseline socio-demographic data: Among the 72 school-children 33 (45.8%) were males and 39 (54.2%) females. The mean age of the children is 6 years. Children between the ages of 6-8 participated more in this study than other age groups, they made up 44.4% of the study population in Fig. 1.

Prevalence of lead poisoning: Out of the 72 blood samples analyzed, 9 (12.5%) are at toxic level ($\geq$5 µg dL^{-1}) and the mean blood lead level of all the samples is 2.38±3.6 µg dL^{-1}. Figure 1 shows the prevalence of lead toxicity concerning gender. Toxic blood lead level is found only in 6.06% of the male students and 17.95% of the female students. There was no significant difference in the prevalence of lead poisoning across gender (p-value 0.177615) and the chi-square value stood at 1.8175.

Figure 2 shows the prevalence of lead toxicity concerning age. Thus, toxic blood lead level was prevalent in pupils 6-8 years old, followed by those 3-5 years and lastly,

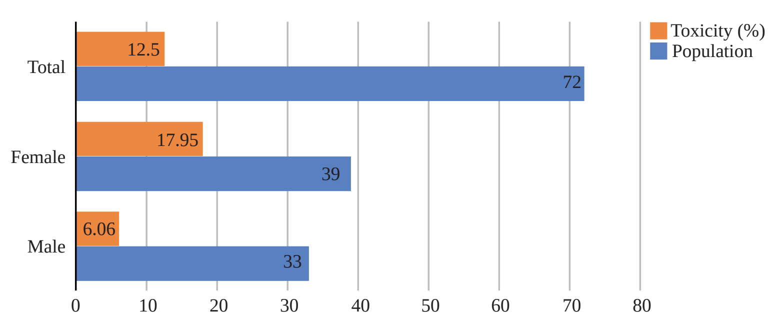

Fig. 1: Prevalence of lead toxicity in relation to gender

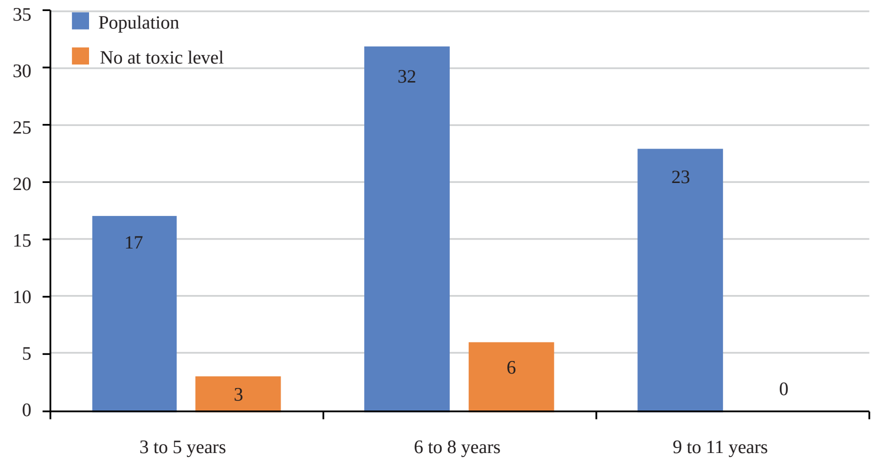

Fig. 2: Prevalence of lead toxicity about age

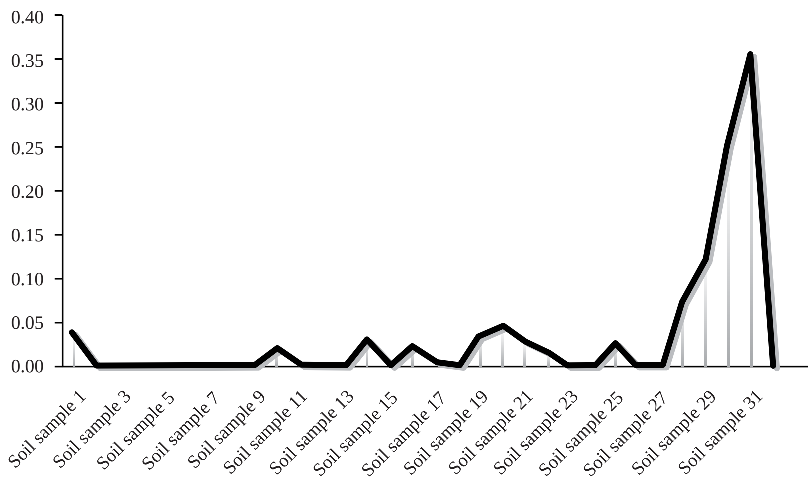

Fig. 3: Concentration of lead according to soil samples

Table 1: Prevalence of juvenile lead toxicity with academic class

		Prevalence of juvenile lead toxicity with academic class		
Class		Population	No of toxicity	Frequency (%)
Nursery	1 to 3	12	3	25
Primary	1	15	3	20
Primary	2	10	2	20
Primary	3	16	1	6.25
Primary	4	10	0	0
Primary	5	9	0	0
Primary	6	0	0	0

3 pupils 9-11 years old had no toxic blood lead level. There was a significant difference ($p = 0.04476$) between those 6-8 years and children 9-11 years, the chi-square value is 4.02775.

Table 1 shows the prevalence of juvenile lead toxicity concerning the academic class. The frequency of childhood lead toxicity with the class was found to be more in younger classes such as nursery 1 to 3, primary 1 and 2 than the older classes.

Table 2 shows the soil concentration of lead among the study population, while Fig. 3 shows the concentration of lead according to soil samples. In Fig. 3, soil samples of 27, 29 and 31 had the highest concentrations of lead ranging from 0.1, 0.25 and 0.4 µg dL^{-1}, respectively. The result of pooled soil samples collected from the 32 primary schools involved in the study has an average lead level expressed in Table 2.

Table 2: Soil concentration of lead among the study population

Sample identity	Concentration of lead (Pb) within the primary school vicinity in Owerri Metropolis
Soil sample 1	0.037
Soil sample 2	0.0011
Soil sample 3	0.001
Soil sample 4	0.00134
Soil sample 5	0.001
Soil sample 6	0.0022
Soil sample 7	0.00116
Soil sample 8	0.001
Soil sample 9	0.0039
Soil sample 10	0.0214
Soil sample 11	0.0047
Soil sample 12	0.001
Soil sample 13	0.001
Soil sample 14	0.0316
Soil sample 15	0.0041
Soil sample 16	0.0234
Soil sample 17	0.0072
Soil sample 18	0.0011
Soil sample 19	0.0363
Soil sample 20	0.0476
Soil sample 21	0.0296
Soil sample 22	0.0172
Soil sample 23	0.001
Soil sample 24	0.001
Soil sample 25	0.0281
Soil sample 26	0.001
Soil sample 27	0.001
Soil sample 28	0.0784
Soil sample 29	0.1247
Soil sample 30	0.2678
Soil sample 31	0.3645
Soil sample 32	0.001

DISCUSSION

This study provides much-needed information on the sources and prevalence of lead toxicity among school children between ages 3-11 years residing in Owerri Metropolis, Nigeria. Childhood lead toxicity remains a complex, intricate complaint that disturbs the health and well-being of the child, but also the security of the family, lodging security, financial standing, work security and anxiety level. Lead plays no biological function in the human body, so any measurable lead level is uncharacteristic and abnormal[14-19].

We can deduct from the result of this work that prevalence of 12.5% among children with lead toxicity (exceeding $\geq$5.0 μg dL^{-1}) as well as the mean blood lead level of 2.38$\pm$3.6 μg dL^{-1} in childhood in Owerri metropolis, Nigeria is not immensely alarming. In a previous Nigerian study by Ugwuja *et al.*[15] the mean blood lead level was 8·7 $\pm$5·4 μg dL^{-1} (range 0·3-17·7), which was higher than what we presently reported. Additionally, in another study, 33% of the children had blood lead levels[15] >10 μg dL^{-1}. In Cameroon, a higher mean lead level of 8.7 μg dL^{-1} was also reported by Monebenimp *et al.*[16] with 88% of the children tested had lead levels larger than 5 μg dL^{-1}. These findings is lower than the findings in Peru where lead was detected in 100% of the infants' blood samples but with a lower median (interquartile range) lead concentration[17] of 1.60 (IQR = 1.72) μg dL^{-1}. Conversely, in 2018, of the 16,539 Hawaii's children under 6 years of age tested for lead, only 1.0% had a blood levels[18] of $\geq$5 μg dL^{-1}.

Another study among preschool children in Uruguay also revealed lower median lead levels of 13.69 μg g^{-1} using hair samples[19]. Additionally, lower hair lead levels have also been reported in children living in urban centres of Sardinia (11.8$\pm$11.7 μg g^{-1})[20], Czech Republic (2.05$\pm$2.02 μg g^{-1})[21] and Poland (2.01$\pm$2.10 mg kg^{-1})[22].

The sample size may not be adequate to draw a full conclusion on this as most parents were not willing to allow their children to participate in the study and a lot of children did not want the invasive procedure of needles on them. However, a similar study done with an even fewer sample size of 20 children in Vietnam showed that all of the 20 children had detectable blood lead levels and every child had levels that exceeded the Centers for Disease Control and Prevention guideline level[23] of 5 μg dL^{-1}.

The 12.5% of pupils in our study who have their blood lead level above 5 μg dL^{-1}, (the reference range for children's blood lead level toxicity) may not have been exposed from their school environment because of the value of the result of the lead analysis of soil samples from their schools is so infinitesimally small: 0.041$\pm$0.08 ppm (mg kg^{-1}) except replete amount of these soil is gulped regularly by these children. The U.S. Centers for Disease Control and Prevention (CDC) has announced that a lead concentration of >5 μg dL^{-1} could be useful to show potential adverse neurodevelopment outcomes in children greater than one year[10]. Comparing this to the reference range for lead content of most soil which is <50 μg kg^{-1} for the soil to be considered responsible. All the soil samples analyzed are considered safe for humans, the children most especially but only at the time of this study since lead can clear or accumulate in the soil over time. Comparatively, the prevalence of childhood lead poisoning in the village of Kawaya Zamfara, Nigeria was as high as 92.5%, with a male preponderance[4]. But why were more females than males found to be lead intoxicated in this research work? For a certainty, there is no outstanding reason but a possible indiscriminate chance occurrence, in addition to the fact that there was no significant difference found (p = 0.177615) of lead toxicity concerning gender from our results. But we can make some logical suggestions that female children in this locality may be more exposed to some lead sources from which they can be acutely infected than their male counterparts. Some of these sources include cosmetics like kohl eyeliner, jewellery and many other leaded consumer products used in adorning these girls. Also, other sources of lead like paint, toys, lead-acid batteries, whole metallic lead and dirt which are ostensibly alleged to be poisoning male than female children or at an equal rate, could be considered.

Lead poisoning was seen to be more common among children 6-8 years in our study, perhaps because they were the largest participants (44.4%) and also due to the following reasons, children 2 years and below whose hand-to-mouth activity are inevitably high were not involved in this research, during childhood competitions children of about 6-8 years of age are adventurous and feel invincible, they could ingest dangerous non-edible materials like chalk and other possible leaded products. Lastly, children at this age tend to explore their environment more with intrinsic ambition for innovations. For example, they can blatantly use their teeth to open an improperly disposed lead-acid battery to repair them to work again.

On the other hand, a similar study conducted in Otukpo, Nigeria among children aged 1-6 years showed blood lead levels to be evenly distributed across age groups and had a male preponderance[24] and also some other published work showed that the prevalence of childhood lead toxicity was highest among school children aged 1-3 years[5,15] and this is not linear with our study for reasons already stated above.

It is reasonable to infer that these children with blood lead level greater than 5 $\mu g \ dL^{-1}$ and/or up-to 10 $\mu g \ dL^{-1}$ may have eccentrically experienced pica or by hand-to-mouth activity, eating with hands contaminated with lead, unintentional consumption of leaded consumer products, deliberate consumption of lead-contaminated junk medicines, or through inhalation if they had frequently been visiting workshops used for processing leaded materials or live in old houses with leaded paint, because childhood lead toxicity although an environmental disease, is also a disease of lifestyle[13,25]. The prevalence of childhood lead toxicity concerning school class was found to be highest among those in lower classes such as nursery and early primary compared to the older classes, it was statistically insignificant. School classes have no definite age distributions, exceptions to this are kindergarten students which usually comprise preschoolers of almost the same age.

The fact that the majority of pupils have at least a detectable level of lead in their blood suggested that the environment around Owerri metropolis is not completely safe from lead metal. This harmonized with a published work in Hawaii that revealed that most children with elevated blood lead levels are asymptomatic, with neuropsychiatric deficits appearing as children age[18]. Symptoms do not classically appear in most cases until toxicity occurs and complications show up. Reduced sample size from the initial calculation due to non-participation of children who were ill, children without parental consent and those with the abject phobia for syringes were all limitations of the study.

CONCLUSION

The prevalence of childhood lead toxicity in Owerri, Nigeria is low compared to some other cities in Nigeria. However, the mere fact that some children had greater than the acceptable levels in their body, shows that there is a level of environmental exposure, especially among females and children less than nine years, hence recommend that government and related stakeholders should ensure that policies are made and implemented to safeguard children from lead poisoning. Awareness of sources and prevention of lead poisoning should be encouraged.

SIGNIFICANCE STATEMENT

This study discovered the prevalence of childhood lead toxicity in Owerri, Nigeria is low compared to some other cities in Nigeria and this information can be beneficial for authorities in environmental health. This study will help the researchers to uncover the critical areas of lead toxicity in childhood that many researchers were not able to explore. Thus we recommend that government and related stakeholders should ensure that policies are made and implemented to safeguard children from lead toxicity.

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