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Full Length Research Paper

Social and ecological mediators of environmental Lead exposure in Nigeria

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This study aimed to identify socio-ecologic variables contributing to lead poisoning among children in suburban regions of Nigeria. We surveyed 306 children and their families to determine the statistical association between specific social ecological factors and measured blood lead levels (BLL). The BLL among children ($\leq$ 6 years old) ranged from 2.1 to 31.8 µg/dl (mean = 9.4 µg/dL; SD = 4.2), with 35% of the children exhibiting a BLL > 10 µg/dL. Mean BLL was significantly associated with household size, maternal literacy, parental occupation, home floor type, time spent outside the home, residential proximity to a ceramics shop, and by parental employment in a print shop ($p < 0.05$), but not with age, years of parental education, housing situation, drinking water, and frequency of hand-to-mouth behavior. Although gasoline remains the main source of environmental lead, occupational circumstances also contribute to the predisposition of children to high exposures.

Key words: Lead (Pb) poisoning, cottage industry, exposure assessment, maternal literacy, ceramics manufacturing, printing shop, leaded gasoline, children, Africa, Nigeria.

INTRODUCTION

Lead (Pb) is a ubiquitous pollutant, and its adverse health effect is well documented (Pruss-Ustun et al., 2004; Needleman 1999). Changes in regional planning and health educational programs can mediate exposures to reduce health impacts in situations the recalcitrance of Pb ensures long-term risk. Therefore, it is important to understand the parameters of exposures, and to use the information to implement preventive strategies that protect the most vulnerable individuals from lead poisoning (WHO, 2000). Although much can be inferred from studies in industrialized countries regarding predisposition of children to Pb exposure, there are peculiar socio-ecological factors that are relevant to the understanding of Pb exposure among African children in less urbanized regions (OECD, 1999; Nriagu et al., 1996 and 1997). These factors relate to land use patterns, drinking water sources, crowding, and literacy (Omokhodion, 1994). For example, estimates of nationwide lead emissions in Nigeria are approximately 2.5 g per year, but about 20% of this amount is accounted for in the largest urban center (Ogunsola et al., 1994; Kapu et al., 1989).

The goal of this research is to identify the linkages between socio-ecologic factors that predispose children to lead exposure in domestic settings. The specific objectives were (a) to determine the blood-lead content of Nigerian children (ages 1 - 6 years) residing in a suburban region; (b) to identify the common parameters of family and community variables that predispose children to Pb exposure.

METHODS

Assessment of Lead exposure

Children (ages 1 – 6 years; N = 306) were recruited for this study through the scheduled immunization clinic in Otukpo, Nigeria (population = 136,800; 45% < 14 years) (Population Reference Bureau, 2002). Blood lead concentrations were determined by means of an automatic blood lead analyzer with a sensitivity range of 1.4 - 65 µg dL^{-1} based on blood sample volume of 50 µl (Lead care, ESA Inc., Chelmsford, MA and Care Inc., Durham, NC.; provided by the U.S. Centers for Disease Control and Prevention, Atlanta, Georgia). A minimum sample size of 300 subjects was estimated within the desired margin of error for predicting the population mean, based on estimated standard deviation of (3.8 µg dL^{-1})

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and desired margin of error of 0.65 µg dL^{-1} (Nriagu et al., 1996; Moore and McCabe, 2005). Both healthy and ill, but not severely ill or disabled, children were tested to avoid either a "fitness" or an "illness" bias. The immunization programs were funded by the government, and the hospital accepted people of all socio-economic classes. Informed consent was obtained for all human subjects according to standard research ethics, and as approved by the Institutional Review Board. Exclusion criteria included those previously treated for Pb poisoning, those who had not been living in the same residence for at least the past 6 months, and those not accompanied by a legal guardian.

Questionnaire survey

A questionnaire was administered for each child, completed by the legal guardians to record demographic and socioeconomic variables. The survey was based on the standard lead exposure surveys developed by cooperative agreement between the U.S. Centers for Disease Control and Prevention, and the U.S. Environmental Protection Agency. With written consent, the nurse/phlebotomist administered the survey and offered the subject a fact sheet containing health information on Pb exposure. Participating parents were asked to respond to questions designed to reveal risk of lead exposure relating to domestic activities.

RESULTS AND DISCUSSION

Blood Lead levels

The mean BLL measured in children of Otukpo was 9.4 µg/dL (SD = 4.2, n = 306). The mean value for males was not significantly higher than for females. The highest BLL measured was 31.8 µg/dL, which is below the U.S. threshold of 45 µg/dL for lead poisoning treatment with chelation therapy. However, more than a third of the children have BLL above the USEPA action level of 10 µg/dL.

Demographic characteristics

The population sample was approximately 55% male, and the subjects were nearly evenly distributed across the age groups from 1 – 6 years (Table 1). Almost 90% of the children, but < 50% of parents were born in Otukpo. The average household size was approximately 7 individuals and most lived in attached compound houses constructed of cement bricks with groundwater wells being the main source of drinking water. About half of all mothers and a third of all fathers were self employed. A large majority (84.3%) of the children spends most of their time at home because the age group is primarily pre-school; hence there is reasonable assurance that the measured BLL represents exposures at or around the home.

Socioeconomic and cultural factors and Lead exposure

The data do not support the conjecture that exposure to environmental sources of Pb depends on the specific age of children. No significant association was found between MCBLL and the age of the child, although the distribution appears very similar to what is expected. The trend of the curve is higher for ages 1 - 2 and 5 - 6 years.

Because houses constructed with mud bricks are common, and may represent a constant source of exposure to Pb entrapped in the soil, we asked respondents about the quality of their domicile. Housing type (that is, detached, attached, apartment and others) and construction material (that is, brick/block, wood, others and unknown) did not show significant correlation with MCBLL. However, as shown in Figure 1, there was an association between the type of floor (that is, bare earth, concrete cement, panted cement, or vinyl carpet) within the child's domicile and the MCBLL. In particular, children living with painted cement floors showed a MCBLL of 11.4 µg/dL (±2.6 µg/dL), which was higher than the other floor types, Earth, carpet, and unpainted cement ($p < 0.05$). There is no current information on the status of the use of lead-containing paint in Nigeria, and it is likely that the paint used in concrete cement floors contain measurable amounts of Pb.

There has been no systematic survey of the Pb content of potable water in Nigeria, but the results of this study showed no significant association between MCBLL and the source of drinking water for participating families (piped water in homes, public faucet, groundwater well, rain water barrels, or bottled water). In addition, no significant association was found between MCBLL and the frequentcy of five different hand-to-mouth behaviors involving objects potentially containing lead (fingers, paint chips, color pencils, painted surfaces, and printed materials).

Crowding is an indicator of predisposition to hazardous indoor environmental exposures. However, crowded households may also encourage children to spend more time outdoors, especially in hot weather conditions.

Spending more time outdoors may predispose children to increased Pb exposure from industrial and transportation sources. Figure 2 shows the results of the correlation between household size and MCBLL. Household size was disaggregated into three groups: children, 0 - 6, children, 7 - 18, and adults older than 18. Overall household size was almost significantly associated with $MCBLL_{HS}$ ($p = 0.06$), and the number of children, ages 7 - 18 years was positively associated with MCBLL ($MCBLL_{7-18}$ = 11.1 ± 5.5 µg/dL, $p < 0.05$). There also appears to be a general trend of increase in MCBLL as the household size increases.

To understand the role of parental education and occupation on the exposure of children to environmental Pb, we included several questions to solicit information that is relevant to suburban social infrastructures in Nigeria. There was no significant association between MCBLL and the number of years of parental education. However, a significant relationship existed between maternal literacy and MCBLL ($MCBLL_{Illit}$=10.1 ± 2.4 µg/dL, $p < 0.05$). Literate mothers had children with an average BLL that

Table 1. Summary of demographic characteristics in children, ages 1 - 6, Otukpo.

Characteristics	Percentage	
Female	**45.1**	
Age distribution		
1 year	19.9	
2 years	18.3	
3 years	15.0	
4 years	13.7	
5 years	15.4	
6 years	17.6	
Born in Otukpo		
Child	87.9	
Mother	42.8	
Father	34.6	
Average household size	6.8	
Maternal literacy	64.7	
Education level	**Mother**	**Father**
0 - 4 years	61.5	55.6
5 - 8 years	17.9	21.6
9 - 12 years	18.2	15.0
> 12 years	2.3	7.8
Occupation	**Mother**	**Father**
Self-employed	54.6	30.9
Professional	10.1	15.4
Factory worker	1.0	4.9
Homemaker	14.1	0.0
Farmer	13.4	27.8
Other	13.1	18.6
Years child has lived in current residence		
1 year	28.1	
2 years	20.9	
3 years	15.0	
4 years	12.4	
5 years	10.1	
6 years	12.1	
Type of housing		
Detached	21.2	
Attached	62.4	
Apartment	15.4	
Other	1.0	
Housing construction material		
Brick/block	98.0	
Wood	0.7	
Other	0.7	
Unknown	0.7	
Source of drinking water		
Pipes	29.7	
Public faucet	1.6	
Well	61.8	

Table 1. contd.

Barrels	2.3
Bottled	1.6
Combination	3.0
Time spent away from home by child	
0 hours	84.3
1 hour	0.3
2 hours	0.7
3 hours	2.9
4 hours	2.6
> 4 hours	9.4
Children that wash hands	40.8
Mothers that cook or store food/water in clay pots	36.0

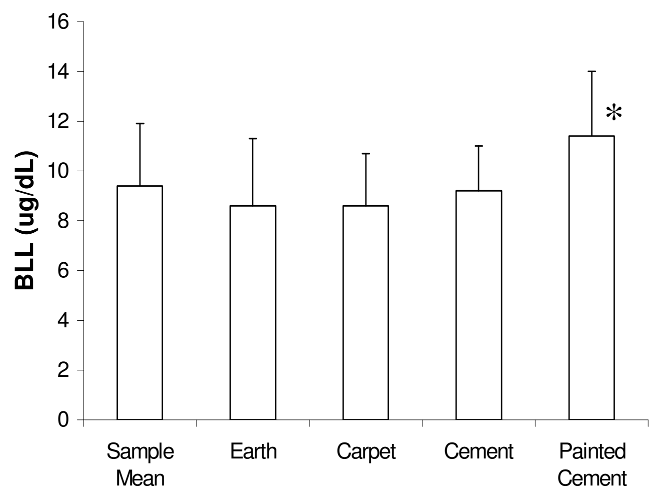

Figure 1. Mean childhood blood Lead level distributed by domicile floor type. *$MCBLL_{pc}$ = 11.4 ± 2.6 µg/dL, $p < 0.05$.

was approximately 1.1 µg/dL lower than illiterate mothers. Furthermore, a significant association was found with self-employed mothers and MCBLL ($MCBLL_{s-e}$ = 10.0 ± 2.5 µg/dL, $p < 0.05$). Self-employed mothers had children with BLL significantly higher than children whose mothers were professionals, farmers, or homemakers. Paternal occupation showed no significant association with MCBLL. To further explore potential opportunities for exposure in children whose parents association with MCBLL. To further explore potential opportunities for exposure in children whose parents work outside the home, we asked questions relating to alternative child care arrangements. Figure 3 shows the association between MCBLL and time spent outside the home in some form of provided care, either relatives, day care, or pre-school. Children in custody of relatives for >4 h daily showed higher BLL (MC-

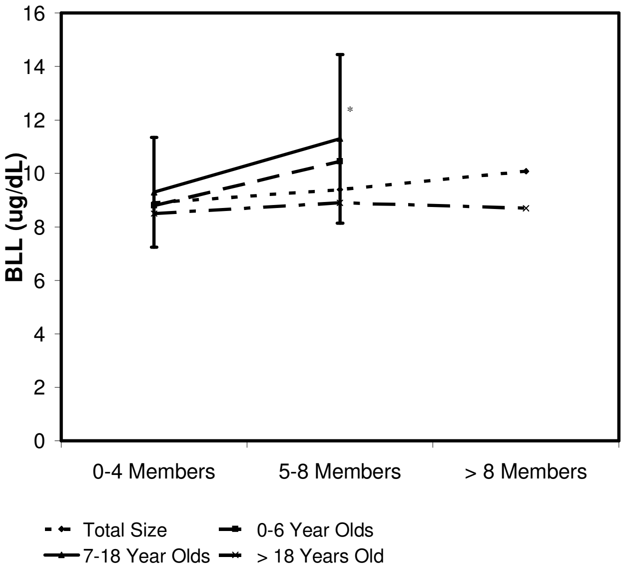

Figure 2. Mean childhood blood Lead level distributed by household size.* $MCBLL_{7\text{-}18} = 11.1 \pm 5.5$ µg/dL, $p < 0.05$.

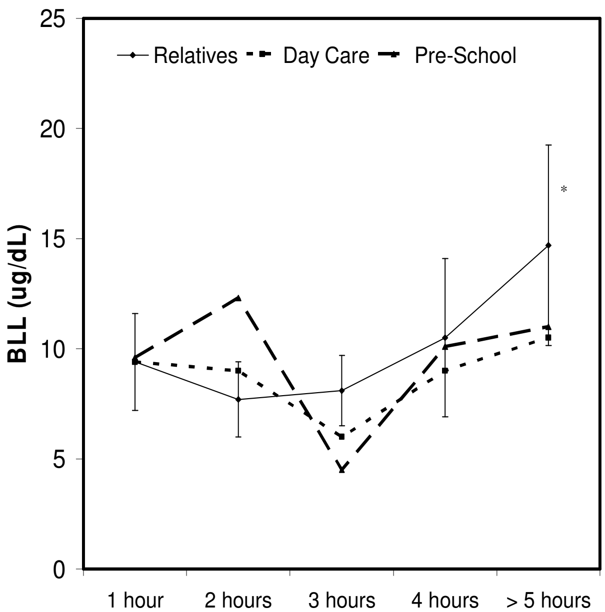

Figure 3. Mean Childhood Blood Lead Level Distributed by Time Spent Outside the Home with Caretakers. *$MCBLL_{rel>5} = 14.7 \pm 4.55$µg/dL, $p < 0.05$.

$BLL_{rel>5} = 14.7 \pm 4.55$ µg/dL, $p < 0.05$). Although there was a slight but insignificant trend of increasing BLL as time spent outside the house with care takers increases. Cottage industries are not well regulated in terms of land use planning to prevent environmental pollution. We explored the association between two such industries and BLL in

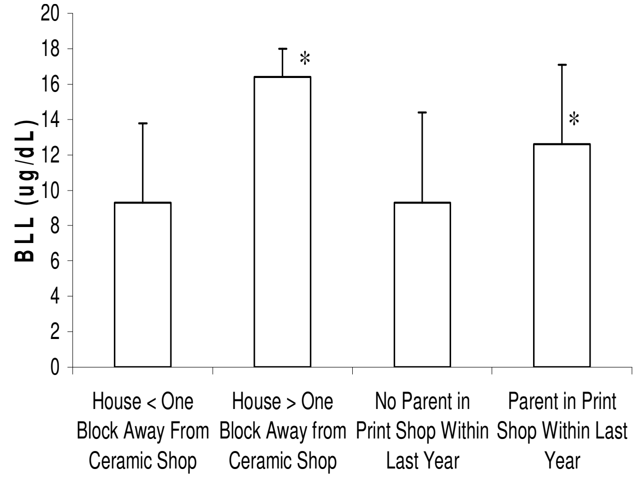

Figure 4. Comparison of mean childhood blood lead level in relation to cottage industry *$p < 0.05$.

children. A positive correlation existed between distance of homes from a ceramics shop and MCBLL. Children living in houses within a block from the ceramics shop had significantly higher BLL than those who lived more than a block away ($MCBLL_{<b\ l} = 16.4 \pm 0.8$ µg/dL, $p < 0.05$). BLL also showed an association with parental occupational exposure from a print shop. Children with a parent working at a print shop had BLLs 3.3 µg/dL higher than children who did not ($MCBLL_{ps} = 12.0 \pm 2.25$ µg/dL, $p < 0.05$) (Figure 4).

Conclusions

Lead poisoning continues to exact a major toll on the health of children world-wide (Kristensen et al., 1993; Landrigan et al., 2002; Adeniyi and Anetor, 1999). Several factors associated with poverty level contribute to the Mean childhood blood lead level (MCBLL). For examples, MCBLL was significantly higher in children who lived in larger households, and for children whose mothers were illiterate. Maternal occupation also showed a significant correlation with MCBLL. Mothers who were self-employed had children that had higher BLL than the children who had mothers who were farmers, professional or service worker, factory workers or homemakers. In Otukpo, self-employed women typically sell agricultural or textile goods at the market. Marketplaces are crowded and dusty with numerous automobiles powered by leaded gasoline and poor exhaust systems. Women working in these areas are likely to suffer lead exposure with the potential of risking transmission to children beginning with pregnancy. Very young children in households that cannot afford childcare typically accompany their mothers to the marketplace, also predisposing them to Pb exposures.

Women who were homemakers and farmers had children who tested the lowest for blood lead. It is interesting that paternal occupation showed no significant association with MCBLL. This is not too surprising because children under 6 years of age in semi-rural Nigerian culture have most parental contact with their mothers, especially in polygamous families, where fathers tend to have sepa-rate rooms from the rest of the household.

An interesting interaction between indicators of socioeconomic status and physical environment was observed in the relationship between floor type in the home and MCBLL. Children who lived in houses with earthen floors had some of the lowest BLL when compared to children living on other floor types. A possible explanation is that the predominant soil type in this region of Nigeria is red clay which contains considerable amounts of iron and manganese. Manganese and other soil minerals have high affinity for Pb, potentially reducing its bioavailability. However, relatively wealthy families that could afford painted cement floors may inadvertently increase the risk of lead exposure in children. This may be because floor paint contains lead, but also contaminated dust may accumulate more freely on painted surfaces than barren ones. Children who spent more than 5 h per day outside the home with a relative had BLL that were significantly higher than children who did not. Outside the home was defined as being with a non-parent caretaker, such as a relative, a pre-school, or daycare. Orphaned children living in extended family situations tend to be less well supervised than children living with their birth parents and therefore more likely to have pica and other exposing behaviors go unnoticed.

Proximity to cottage industries was also observed to influence MCBLL. Children who lived less than one block (~ 100 m) from a ceramics shop, most likely a cottage industry, had significantly higher BLL higher than those who did not. Also, children with parents working in a print shop had higher BLL than children with parents who did not. These results are consistent with lead exposure in these types of industries that use lead glaze for ceramic pots, and lead-containing ink for printing. As Pb is phased out of these older technologies, new threats continue to emerge from contemporary cottage industries such as the local recycling and refurbishing of electronic products such as cellular phones (Lincoln et al., 2007).

Figure 4 shows a comparison of cottage industries and MCBLL. Children living less than one block from a ceramics shop had the highest BLL. A child with a self-employed mother, in a large household, in a house with a painted cement floor located less than one block from a ceramics shop, and with a father working in a print shop would be at the highest risk for having high blood lead in this region of Nigeria. These results should be used to identify which children in the community are in the high-risk category. A screening program could be set up to query the parents for these variables without having to assess individual blood lead content. Children with a combination of high-risk factors could be selectively screened for blood lead analysis and chelation therapy if necessary. This could be a non-invasive approach for decreasing the cost of blood lead screening in developing countries. The goal of eliminating Pb from all consumer products such as gasoline (Thomas and Kwong, 2000), and industrial processes such as printing presses should be accompanied by targeted socio-ecologic interventions designed to protect the most vulnerable individuals.

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