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Janvier Gasana
Florida International University, Janvier.Gasana@fiu.edu

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Blood Lead Levels in Children and Environmental Lead Contamination in Miami Inner City, Florida

Janvier Gasana[1*], WayWay M. Hlaing[1], Kristy A. Siegel[1], Armando Chamorro[2], Theophile Niyonsenga[1]

[1]Stempel School of Public Health, College of Health & Urban Affairs, Florida International University, 11200 SW 8th St. (HLS 595), Miami, Florida, USA.
[2]Ambient Environmental INC, 425 SW 17th Street, Miami, Florida, USA.
* Correspondence to Dr. Janvier Gasana. E-mail: gasanaj@fiu.edu

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Abstract: Studies have shown that the environmental conditions of the home are important predictors of health, especially in low-income communities. Understanding the relationship between the environment and health is crucial in the management of certain diseases. One health outcome related to the home environment among urban, minority, and low-income children is childhood lead poisoning. The most common sources of lead exposure for children are lead paint in older, dilapidated housing and contaminated dust and soil produced by accumulated residue of leaded gasoline. Blood lead levels (BLL) as low as 10 μg/dL in children are associated with impaired cognitive function, behavior difficulties, and reduced intelligence. Recently, it is suggested that the standard for intervention be lowered to BLL of 5 μg /dl. The objectives of our report were to assess the prevalence of lead poisoning among children under six years of age and to quantify and test the correlations between BLL in children and lead exposure levels in their environment. This cross-sectional analysis was restricted to 75 children under six years of age who lived in 6 zip code areas of inner city Miami. These locations exhibited unacceptably high levels of lead dust and soil in areas where children live and play. Using the 5 μg/dL as the cutoff point, the prevalence of lead poisoning among the study sample was 13.33%. The study revealed that lead levels in floor dust and window sill samples were positively and significantly correlated with BLL among children ($p < 0.05$). However, the correlations between BLL and the soil, air, and water samples were not significant. Based on this pilot study, a more comprehensive environmental study in surrounding inner city areas is warranted. Parental education on proper housecleaning techniques may also benefit those living in the high lead-exposed communities of inner city Miami.

Keywords: Childhood lead poisoning, environmental exposure, child under six years of age, pre-1950 housing, minority

Introduction

For many Americans living in substandard housing, home is where the harm is [1]. Because Americans spend as much as 90% of their time indoors [2], home environment is also where indoor contaminants have the potential for greatest influence on health [3]. Housing is a multi-dimensional construct embodying the house, the home, and the neighborhood [4]. Literature suggests that residents of poor neighborhoods suffer a diverse set of inferior health outcomes than those in richer neighborhoods. Location of a neighborhood, as a result of urban sprawl, also has a negative impact on health. Vicinity to traffic and its related air pollution, and lack of quality housing have been shown to impact children's health [5-7]. Lack of quality housing is common in inner cities of the United States (U.S.). In spite of the economic prosperity, over 2.5 million and 770,000 households with children live in substandard and severely substandard housing, respectively in the U.S. [8-10]. Such severe housing problems can result in a variety of health conditions in children including lead poisoning especially among minority population [9]. For example, children with elevated blood lead levels (BLL) are more likely to be African American, live in metropolitan cities, be poor, and be exposed to lead due to peeling/flaking paint of homes and highly contaminated soil that contributes to household dusts [11].

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Lead exposure may come from the home (paint, dust, and soil), work, other environments (parents' occupation and hobbies), and folk remedies [11]. Lead exposure may occur through ingestion of flaking paint and inhalation of dust and soil contaminated with paint [12]. Children are more prone to lead poisoning and toxicity compared to the adult counterparts because of their hand-to-mouth behavior. Furthermore, the children's digestive system absorbs lead more readily than an adult's system, and their premature and still developing central nervous system (CNS) is more vulnerable to lead toxicity than a mature CNS [13, 14]. Lead is a pervasive environmental toxin that affects virtually every system in the body. Evidence of harmful effects in various organs has been found in children whose BLLs exceed 10 μg /dL [15, 16].

However, it has been debated that there is no "safe" level of lead in children's blood. According to the National Research Council (NRC) [14], even very small exposure to lead could produce subtle effects in human health. The NRC offered evidence that lead at 5 μg /dL (half the official "safe" level) could cause attention deficit disorders, and hearing loss in children. In the same report, summary of recent studies indicated that there was no effective threshold for some of the adverse effects of lead [14]. At the Joint Meeting of the Pediatric Academic Societies and American Academy of Pediatrics, Lanphear et al. reported that the current limit of 10 μg /dL of BLL was "inadequate to protect the children". Impaired cognitive functioning and academic achievement were reported among children with BLL below 5.0 μg /dL [17].

Although lead-based paint and lead in gasoline had been banned in the U.S. in 1978 and 1986, respectively, the use of it since 1920 left harmful residue in the environment [18, 19]. Lead residues are disproportionately concentrated along roadways with high traffic flows especially in urban, inner cities [18, 20]. National data confirmed that regardless of age, race, and socio-economic class, people living in urban areas with a population of over one million had higher blood lead concentrations than urban areas of less than one million, which in turn had higher blood lead concentrations than rural areas [21].

Several inner city areas in Miami-Dade County (Liberty City, North Miami, Little Havana, Little Haiti, Overtown, and Downtown Miami) represent a disproportionate percentage of lead poisoned children less than 72 months of age when compared to the distribution of the children of the same age in the population. Liberty City, for example, accounted for approximately 23% of all childhood lead poisoning cases. However, it only represented 8% of children less than 72 months of age in the county. Over 60% of all childhood lead poisoning cases reported were residents of the Liberty City, North Miami, Hialeah/Miami Lakes, Little Havana, and Little Haiti areas. The areas contain 20% of their housing stock built before 1950 [22]. Additionally, these areas are closest to converging traffic flow into the downtown epicenter, as well as populated by families with urgent social and economic needs. Furthermore, these areas have high proportions of children at risk for exposure to other environmental health hazards.

Inner city Miami's housing stock is in deteriorating and dilapidated condition and is composed mainly of one-story wood-framed houses in poor repair. In the South Florida climate, windows and often doors of these homes are kept open most of the year. Many homes lack air conditioning, increasing the need to keep the house well-ventilated and open. The combination of small, open homes surrounded by uncovered dirt yards in areas known to contain lead-contaminated soil contributes to lead-contaminated house dust problems. The Florida Childhood Lead Poisoning Prevention Program has identified lead-contaminated soil and dust as major sources of childhood lead poisoning in the county and in the state of Florida [23, 24].

Nationally, the Center for Disease Prevention and Control (CDC) has identified poverty as a risk factor for childhood lead poisoning. In Miami-Dade County, one-fourth of two million residents are children and one-fourth of them live in poverty. Of children less than five years of age, over 50,000 are estimated to be uninsured. There are approximately 200,000 children under the age of six residing in Miami-Dade County [25, 26]. Miami-Dade County is unique in that it serves as a major port of entry to many immigrants and refugees. Approximately 22% of all cases of childhood lead poisoning in the county were reported from the Refugee Health Assessment Center (RHAC) [22]. Therefore, health officials are concerned about imported cases of childhood lead poisoning in the county. Due to imported lead poisoning cases among immigrant children, and other socio-economically disadvantaged children who live in lead-exposed environment, Miami-Dade County presents a unique setting to study childhood lead poisoning.

Our pilot study was conducted in inner city Miami (Liberty City and Little Haiti) where predominantly African Americans as well as Hispanic and Haitian immigrants reside. The objective was to quantify blood lead levels (BLL) in children and correlate BLL and lead exposure levels in their environment. This pilot study was the first study that assessed the correlations between blood lead levels (BLLs) with environmental lead level among children under 6 years of age in inner city Miami, Florida.

Material and Methods

Design

The study was a cross-sectional study centered on biological and environmental assessment of lead exposure among children less than six years of age in inner city communities of Miami. This community-based childhood lead poisoning pilot study was designed as an interdisciplinary research activity for expanding research training, and mentoring graduate students in environmental health and behavioral sciences through the concept of community health workers (CHW).

Using the Bresser's Criss-Cross directory CD-ROM, the project personnel drew a random sample of 137 children under six years of age in the six zip code areas of two communities (Liberty City and Little Haiti) heavily

affected by lead poisoning from the total number of 24,682 children. The Bresser's directory contained updated listings of residents and businesses in over 678 communities, arranged in sequence by address for every street and telephone exchange. It combined the name, the street address, and the phone number information with the point-and-click ease of windows to give the user a simple-to-use look-up and marketing tool. It has numerous ways to search for information, including entering complete or partial names, streets, phone numbers and zip codes. Information about the directory can be found elsewhere [27].

Flyers explaining the goals and objectives of the project in English, Spanish, and Creole language were distributed in churches, community health fairs, and clinics in target areas of Miami-Dade County. Some project personnel attended church services in the areas in order to talk to the congregations about childhood lead poisoning and the study. Eligibility requirements included households and parents willing to take the child for a blood test and submit their house to a lead inspection. The child had to be less than 6 years of age. The survey consisted of limited lead inspections performed at homes (sites) in the six zip code areas (33127, 33142, 33147 and 33150 in Liberty City and 33137, and 33138 in Little Haiti). These zip code areas were selected because they are located in inner city Miami where 50% of the childhood lead poisoning cases of the county were found [22]. The environmental inspections involved the collection of representative samples from the floors, window sills, window wells, tap water, soil and air. In addition to these environmental samples, the presence of lead containing paint was investigated *in situ* via X-ray fluorescence (XRF) XRF analysis. The inspections of specific areas in the homes were tailored to the subject of the investigation, i.e. the child under 6 years of age. Areas indicated as most utilized, or occupied by the subject child were targeted during the onsite investigations.

Subject Recruitment

Through Miami-Dade Resident College, Inc., the project was able to apply the concept of the primary health care worker or community health worker (CHW). This concept, originated with the World Health Organization (WHO), has been widely used by many countries to provide increased access to health services at costs affordable by the community [28]. The CHWs were trained in interview and safety techniques. They went from door to door to enlist participation. A family was contacted and asked if they had a child less than 6 years of age and if the parents were willing to participate in the study. A child (and family) was eligible if one of the parents/guardians provided the consent to 1) answer questions relating to the child's risk for lead poisoning; 2) have blood drawn from the child for blood lead level; and 3) inspect the home environment for evaluation of lead exposure in paint, dust, soil, air, and drinking water.

Only one child was eligible in any one household. Children were recruited through direct contact with the caretaker of the child (mother, father, grandmother, or a guardian) who participated in the survey. As incentives, T-shirts with messages that promote lead poisoning study and educational brochures on lead exposure were provided to the participants.

Study Sample

Of the 137 eligible participants, only 121 children were willing to participate in the study. Of the 121 subjects that participated, 75 children submitted to blood lead tests (62% response rate).

Sample size of 75 would provide an 85% study power to detect the medium effect size of 0.30 (rho=0.30) when the null hypothesis of zero or no correlation between blood lead and environmental lead levels was tested using 5% one-sided Fisher's Z-test. Number of children participated (n = 75) in the zip code areas 33127, 33142, 33147, 33150, 33137, and 33138 were 6, 22, 20, 9, 8, and 10 respectively. Barriers to participation included absence of the consenting parents, refusal by parents on the day of the survey, and access restrictions to certain residences.

Measurements and Analysis

Blood samples were collected in 75 children. Venous blood samples were sent to the State Laboratory in Jacksonville, FL for analysis. Home inspections involved the collection of representative samples from the floors, windowsills, window wells, tap water, soil, and air. In addition to samples collected for analysis, the presence of lead-containing paint was investigated *in situ* via analysis. Detailed description of sampling methods and techniques utilized are given ~~in~~ elsewhere [29]. Briefly, a composite air sample was collected from three indoor locations within each housing unit included in the project, namely in the bedroom, the living room, and the dining room. For each housing unit, two representative water samples were collected from the faucet used to supply the child with potable water: one "plug" (first draw) followed by a "flow" sample (after 30 seconds). Surface dust testing for lead was executed using the wipe sampling technique. A five-part composite sample was collected from bare, unvegetated areas located near the dwelling in the child's play areas, or near the dripline. Samples were collected by coring, or scooping the top half-inch of soil from five independent areas and combining them into a composite sample.

Data Analysis

Analysis of this report was restricted to the 75 children who provided blood samples. Among 75 households, environmental samples were obtained from most of the homes. Data were managed and analyzed using the SAS software. Descriptive statistics were computed for all categorical variables and distributions of continuous variables were evaluated. Correlations between blood lead levels and environmental and biological variables were assessed using the nonparametric method due to small

ultimate sample size and skewed distributions of some outcome variables. Spearman correlation coefficients (rho), its corresponding confidence interval, and p-values were reported.

Ethical Aspects of the Research

All research procedures were reviewed and approved by the Florida International University (FIU) Institutional Review Board (IRB). This pilot study's participants were not at risk from invasive procedures with the exception of blood drawing. Informed consent was obtained from the primary caretaker (parent or guardian) of the participants. A unique identifier was assigned to each participant and only the unique identifiers were accessed to assure confidentiality. Database was stored on a password protected computer at FIU. All data collection instruments with identifications were kept in locked cabinets and only the principal investigator of the study has access to the key.

Results

Table 1: Comparison of Selected Demographic Characteristics between Study Participants (n=75) and Appropriate Segments of US Population
* Data from 1999 US Census.

	Study Participants (%)	US Population* (%)
Race/Ethnicity		
Black	52.00	13.00
Hispanic	38.67	12.50
White	1.33	64.40
Other	8.00	10.10
Annual Household Income		
Under $2,500	49.33	1.60
$ 2,500 to $ 4,999	8.00	1.23
$ 5,000 to $ 7,499	10.67	3.11
> $ 7,500	32.00	62.86
Marital Status		
Single/Never Married	42.67	26.44
Married	45.33	53.52
Separated	4.00	2.27
Divorced	2.67	8.32
Widowed	5.33	7.39

More than half (52%) of the participants were African Americans and 39% were Hispanics. This was expected because the target areas were heavily populated by these minority residents who were also the most at-risk for childhood lead poisoning. The mean age of participants was 4.05 (± 1.79) years. More than half of the participants lived in single-parent households with annual income of less than $7,500 in 68% of these families. Less than $8,000 per year income is equivalent to an economic indicator of 100% below poverty level. Study participants had far worse annual household income compared to the general US population (Table 1). For example, 49.3% of participants had an annual income under $ 2,500, while only 1.6% of the US population had the same level of income. Most of the participants in the study did not have prior knowledge of childhood lead poisoning. Majority of the caretakers were mothers (57 mothers or 76.0%). The preferred language of interview by the caretakers was English (75%), Spanish (21 %), and Creole (3%). About 15% of the participants lived in homes built before 1950; 27% lived in homes built between 1950 and 1978 but 56% of them did not know the year that their home was built (data not shown).

Among 75 participants who provided the blood samples for lead screening, environmental assessment of lead exposure in and around 69 homes were available. Although most of the environmental lead levels were below the Housing and Urban Development/ Environmental Protection Agency (HUD/EPA) standards in our sample, average lead level in window well was above the HUD/EPA standard (Table 2). The minimum to maximum values were as follows: air (0.00 to 1.66 ug/m^3); water plug (1.00 to 150.00 parts per billion or ppb); water flow (1.00 to 20.00 ppb); floor dust (0.80 to 88.0 ug/ft^2); window sill (0.69 to 2,300.00 ug/ft^2); window well (4.00 to 78,000.00 ug/ft^2); and soil (0.00 to 0.16 parts per million or ppm).

Table 2: Measures of Environmental Outcomes
* Source: Reference # [10]

Medium	*n*	*HUD/EPA Standard**	*Mean*	*SD*	*Median*
Air (ug/m^3)	69	15	0.15	0.22	0.08
Water Plug (ppb)	68	15	4.53	18.09	1.00
Water Flow (ppb)	68	15	1.46	2.33	1.00
Floor Dust (ug/ft^2)	69	40	12.66	16.92	8.30
Window Sill (ug/ft^2)	69	250	65.22	278.58	11.00
Window Well (ug/ft^2)	68	400	1472.18	9427.00	215.00
Soil (ppm)	69	400	0.03	0.03	0.02

Average BLL among our sample was below the standard [14, 17] of 5 μg/dL (Table 3). However, the prevalence of lead poisoning using the 5 μg/dL as the cut-off level was 13.33% (10 out of 75 subjects) in this study. Only one child had the BLL of 9 μg/dL. Hence, the prevalence using the 10 μg/dL as the cut-off level was zero.

Interestingly, blood hemoglobin level among the participants was below the standard for children aged 2-6 years.

Table 3: Measures of Biological Outcomes

Parameters	*n*	*Standard*	*Mean*	*SD*	*Median*
Blood Lead Level (ug/dl)	75	5*	3.41	1.85	3.00
Blood Hemoglobin (g/dl)	71	12.5**	11.96	0.93	11.90
Blood Hematocrit (%)	71	0.37**	1.44	6.35	0.37

* Source: Reference # [14, 17]
** Source: Reference # [40]: Age-specific for children 2 -6 years

Correlation of Environmental Lead Levels with Blood Lead Levels

Health risk of exposure to lead at present is assessed by measure of BLL, where a level of 10 µg/dL and higher [15] or 5 µg/dL and higher [14, 17] is considered an elevated blood lead level in a child. Spearman correlation coefficients (rho) revealed that blood lead level (BLL) is positively correlated with all seven environmental lead outcomes (Table 4). The correlations were neither strong nor statistically significant between BLL and air, water plug, water flow, window well and soil. However, BLL and floor dust (*rho = 0.27*) and window sill (*rho = 0.28*) were statistically significant ($p < 0.05$).

Table 4: Correlations between Blood Lead Levels and Environmental Outcomes

Variable	*n*	*Rho^*	*Confidence Interval*		*p-value*
			Lower Limit	*Upper Limit*	
Air (ug/m^3)	69	0.044	-0.1947	0.2778	0.72
Water Plug (ppb)	68	0.005	-0.2337	0.2431	0.97
Water Flow (ppb)	68	0.03	-0.2099	0.2665	0.81
Floor Dust (ug/ft^2)	69	0.27	0.0356	0.4763	0.03*
Window Sill (ug/ft^2)	69	0.28	0.0464	0.4846	0.02*
Window Well (ug/ft^2)	68	0.11	-0.1319	0.3395	0.38
Soil (ppm)	69	0.11	-0.1301	0.3379	0.36

^ Spearman Correlation Coefficient
* p-value < 0.05

Discussion

This report is a sub-group analysis on a relatively small number of participants in high-risk areas of inner city Miami. The participants consisted predominantly of minority, low-income population who lived in dilapidated homes of poor neighbourhoods in Miami. Findings with a larger sample size in the same areas of Miami was reported elsewhere [29], and it revealed that more than half of the houses in the areas had unacceptably high levels of lead dust and soil where children lived and played. In this report, floor dust and soil levels were found to be below the HUD/EPA standards which may likely be due to small sample size. Small sample size also contributed to the variability of many of the blood and environmental measures.

Our findings were supported by another study [30] which also examined multi-source lead exposure in house paint and soil or dust as part of the evaluation. While no significant relationship between BLL and lead paint was found, a positive relationship between blood lead concentrations and either soil or dust lead was found [30]. In another study, Sayre and Katzel [31] found that in lead dust contaminated housing, window sills and the floor nearby had consistently higher dust lead levels than other interior surfaces. Although we also found the correlation between BLL and soil to be positive, it was not significant. The correlation between blood lead concentration and floor dust was significant and consistent with that of Charney et al.'s study [30]. A previous study reported that dust lead loading on all three surfaces (floors, windowsills, and window wells) correlated with BLLs in children [32]. However, our study did not find a correlation between the window wells and the BLLs, which is an unusual finding that is not supported by other studies including HUD's. This may be due to the sampling bias and small sample size in our study. Although, correlations between BLL and other blood parameters were not our primary objective, we found the hemoglobin levels of the participants to be lower than the standard, as indicated in Table 3. This finding was not unexpected as children living in substandard housings of poor neighbourhood may likely suffer from conditions other than lead poisoning (example: malnutrition).

Strength of our pilot study was that it was the first study that measured and documented the lead exposure among low-income ethnic-minority populations of inner city Miami. One of the limitations of our study was due to non-participation: 38% of the subjects refused to provide blood lead samples. Due to the small sample size, the correlation between environmental lead and blood lead levels may not have achieved statistical significance level. Post-hoc power analysis revealed that a sample size of n=68 would get 80.9% power to detect an effect size of rho=0.295 (close to medium effect size or 0.30) for one-sided test at 5% level of significance. However, observed significant correlation coefficients (rho=0.27 and rho=0.28) were below the medium effect size but have associated study power of 75% and 77% respectively. The difference between those that agreed to participate and those that did not may have introduced bias in our results. Hence,

we caution the generalizability of our results to all inner city Miami residents. It is noted that the selection of samples representative of larger populations in the statistical sense will not generally enhance the ability to extrapolate universal statements from observations, but selection of study groups for characteristics that enable the study to distinguish effectively between competing scientific hypotheses will do so [33].

Despite small number of participants, our study should serve as a foundation for future studies to address this environmental hazard – lead – that disproportionately affects minority populations. Studies that assess the correlation or relationship of blood and environmental lead levels among these hard-to-reach sceptical minority populations are much needed to reduce health disparities. Hence, we recommend future studies to utilize a better sampling strategy and recruitment method, a more accurate measure of lead in environment, and culturally appropriate instruments. Although our study used trained CHWs and allowed participants to select the preferred language to be interviewed, these strategies alone did not reduce the refusal rate in the study.

A few of the study participants were Haitians, and because of prior victimization and stigmatization, they have a high level of distrust of strangers, particularly of health and medical professionals. This also contributed to high refusal rate for blood lead screenings. Hence, future studies should over sample Haitians and other minority populations to increase participation in these groups.

Shifting the lead paint paradigm to the lead soil/dust contamination paradigm will allow more effective and efficient methods of prevention and case management. Lead paint removal is costly and produces additional hazards-mainly the accumulation of lead dusts [34], whereas repainting and thorough dust cleanup is relatively inexpensive [35]. Dust cleanup, though not permanent, has been shown to result in the reduction of children's blood lead levels with regular vacuuming and washing of homes without resorting to stripping of paint [36, 37]. Moreover, the shift in paradigm also moves the burden from the home owner to the community. Contaminated soil/dust is a community environmental health problem, requiring appropriate remedies to prevent its continuation.

We believe that many of these children may benefit from a cleaning program that physicians can confidently recommend and that families may be willing and able to undertake. For example, in a randomized, controlled trial in Jersey City, NJ, regular home cleaning, accompanied by maternal education, was found to be a safe and partially effective intervention to prevent exposure to lead for children with blood lead levels less than 25 µg/dL [38]. Along with a prescribed cleaning regimen, our evidence lends credence to the utility of lead screening in the many communities where exposure to environmental lead continues to be a problem. Ultimately, prevention is the only plausible strategy of eliminating childhood lead poisoning as a public health problem. "Children should not live in housing that exposes them to hazardous amounts of lead, and children who are already exposed need to be identified and their source of exposure interrupted" [39], irrespective of BLL result of below 10 µg/dL. As a result of our pilot study, we have incorporated lead awareness programs in these areas through "Partnership Against Lead (PAL)" project.

Further studies are required to determine the extent of lead contaminated dust-soil in the surrounding areas and any new approaches to dust control measures. Experiences and the lessons learned from our pilot study should benefit future studies in planning and reaching ethnic minority groups that live in urban settings with multiple sources of lead exposure surrounding their residences.

The disease burden from exposure to lead resulting in adverse physical and mental outcomes among children in different parts of the world has been documented. Thus, our report of lead poisoning problem among children in a localized region would also have significant public health implications globally.

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