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Lead (Pb) Contamination of Dust from Schools in an Urbanized City in the Philippines

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***Abstract*—Exposure to lead-contaminated dust poses a health risk particularly to young children who are highly predisposed to the adverse effects of lead pollution. The study investigated the extent of lead contamination of dust collected from floors of classrooms in selected public and private elementary schools in Tarlac City, Philippines in order to provide policy makers, public health managers, and the community at large the necessary background information to make further efforts to curb lead pollution and develop meaningful actions and responses to address environmental health problems. A total of 108 dust samples were collected from the six sampling sites. Instrumental analysis for lead content of the dust samples through atomic absorption spectrophotometry showed the presence of lead in all the dust samples. The average lead levels in the dust samples ranging from 158.3 ug/ft^2 to 287.8 ug/ft^2 did not vary significantly among the six schools investigated and were all found to exceed the maximum exposure limit (40 ug/ft^2) set by the United States Environmental Protection Agency (EPA). The findings of the study suggest that schoolchildren in Tarlac City, Philippines are at risk of exposure to the hazards of lead dust.**

***Index Terms*—lead (Pb), dust, floor, schools, health hazard**

I. Introduction

Environmental contamination with lead has become widely recognized as a public health concern. Lead affects several organs of the body, including the nervous system, the blood-forming system, the kidneys, and the cardiovascular and reproductive systems. The neurotoxicity of lead, particularly in young children, has been widely documented [1],[2],[3],[4]. Increased blood pressure and hypertension in adults have been shown to be related to elevated blood lead levels [5],[6],[7].

Lead is ubiquitous and can be found in all types of environmental media. As a result of the extensive use of alkyl-lead compounds as fuel additives, vehicular traffic is the largest source of atmospheric lead in many urban areas, accounting for as much as 90% of all lead emissions into the atmosphere [8]. Lead-based paint and dust contaminated by such paint still represent significant sources of human exposure in several countries. Lead-acid batteries contribute to the contamination of all environmental media during their production, disposal, and incineration. Lead compounds may be also used as stabilizers in plastics. Other lead-based products include food-can solder, ceramic glazes, crystal glassware, lead-jacketed cables, ammunition, and cosmetics [9].

Lead pollution remains a problem in both developing and developed countries. The WHO claims lead continues to be a menace- up to 30% of urban children show high blood levels in some places. The findings of a comprehensive study conducted by the WHO and the University of Udine, Italy suggest that lead is the single most important damaging chemical for children. In 2001, the estimated percentage of European children in urban areas with elevated blood levels (above 10 micrograms per deciliter) ranged from 0.1% to 30.2%. Globally, the WHO says, 15 to 18 million children in developing countries suffer permanent brain damage from lead poisoning [10]. In the United States, exposure to flakes or dust from deteriorating lead paint remains the number one cause of childhood lead poisoning. Even though 25 years have passed since lead was banished from paint, and amounts of lead in children's blood are steadily dropping as a result, many buildings built before 1978 contain lead paint. A study by the U.S. Centers for Disease Control and Prevention found that approximately 2.2 percent of U.S. children ages 1 to 5 still have dangerously high lead levels in their blood[11].

After measures to control lead pollution were undertaken in the United States beginning in 1970, blood lead levels in children declined by more than 80 percent [12]. However, in developing countries such as India, control of lead pollution has been much slower and more sporadic. Studies conducted by the Indian National Family Health Survey found that approximately 5o percent of children in Mumbai and 45 percent in Delhi had blood lead levels $\geq$ 10 microgram per deciliter [13].

The continued use of leaded gasoline in the Philippines exposes people to the hazards of lead pollution through atmospheric deposition of lead particles from vehicular exhaust more particularly from motor vehicles that use leaded gasoline.

This study investigated the extent of lead contamination of dust collected from floors of classrooms from selected public and private elementary schools in Tarlac City, Philippines in order to provide policy makers, public health managers, and the community at large the necessary background information to make further efforts to curb lead pollution and develop meaningful actions and responses to address environmental health problems. More specifically, the study aimed to 1) measure the levels of lead in dust collected from floors of classrooms in selected public and private elementary schools in Tarlac City, Philippines; 2) determine if lead dust hazards are present in the study areas by comparing the results to lead dust hazard standards set by the United States Environmental Protection Agency; and 3)

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recommend measures for lead hazard reduction and abatement of adverse health effects.

II. Materials and Methods

A. Study sites

Dust samples for lead content determination were collected from floors of classrooms in the six elementary public and private schools in Tarlac City, Philippines selected as study sites. These schools had the highest number of enrolled schoolchildren among schools within the City Schools Division of Tarlac, Philippines.

Tarlac City is a first class city in the landlocked province of Tarlac located in the island of Luzon, Philippines. It has recently been proclaimed as one of the highly urbanized cities in the Philippines. Tarlac City has a population of 314, 155 people with a land area of 274.66 square kilometers[21].

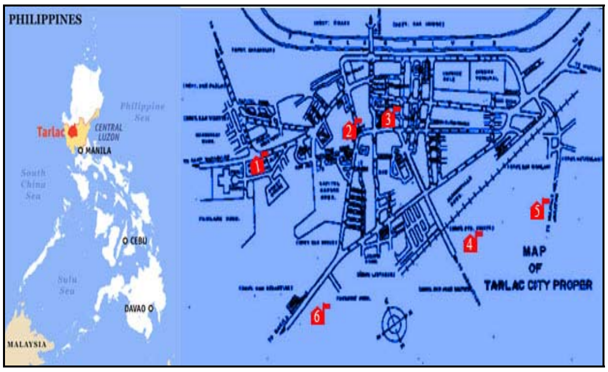

Figure 1. Location of selected public and private elementary schools in Tarlac City, Philippines

Figure 2. The study sites

B. Collection of dust samples

One square foot (12 inches by 12 inches) of sample area was laid out using a disposable cardboard template. All four corners of the template were taped to the floor. With clean disposable gloves worn on each hand, the space inside the template was wiped with a wet wipe. The wet wipe was held between the thumb and the fingers so that the four fingers are holding the wipe against the floor. Starting at the upper left corner of the sample area, an "S" like shape was made wiping from side to side while moving down the area. The wipe was folded in half, dirty side to dirty side and another "S" shape was made in the opposite direction wiping up and down instead of side to side. The folded wipe was placed in an acid-washed Erlenmayer flask which was also used as digestion vessel. The Erlenmayer flask was then placed in an acid-washed zip lock bag . The bag was sealed and labeled. The floor template used for sampling was disposed and a new template was used on the next floor sample. A new pair of gloves was also used for each sampling activity[14].

Dust samples were collected from three classrooms in each school. Sampling was done once a week for six weeks for each sampling site. The dust samples were collected in the months of September and early October coinciding with the rainy season in the Philippines.

C. Sample digestion and analysis

Forty ml of the digesting solution, *aqua regia*, consisting of three parts concentrated hydrochloric acid and one part concentrated nitric acid, both reagents of analytical grade, was poured into the digestion vessel containing the dust sample. The mixture was digested at about 100^{o}C inside the fume hood until the digest was clear. *Aqua regia* was added slowly during the digestion process to keep the mixture from drying. The resulting digest was cooled, filtered into a 250 ml volumetric flask and diluted to 100 ml volume with deionized water. The filtrate was then transferred to an acid-washed polyethylene bottle and stored at room temperature until required for instrumental analysis. Analysis of the dust samples for lead content was conducted using an atomic absorption spectrophotometer.

D. Statistical Analysis

The average levels of lead in dust from each sampling site was computed and recorded in micrograms per square foot (*ug*/ft^2). The results were compared to the lead dust hazard standard set by the United States Environmental protection Agency.

Variations on lead dust levels due to sampling locations were analyzed statistically following the Randomized Complete Block Design (RCBD) procedure. Differences among means were checked for significance using the Duncan's Multiple RangeTest (DMRT) at p=0.05.

III. Results and Discussion

Instrumental analysis for lead content of the 108 dust samples collected from the six public and private elementary schools in Tarlac city showed the presence of lead in all the samples. Lead levels in the dust samples ranged from 40 *ug*/ft2 to 650 *ug*/ft2 with average lead concentrations in sampling sites ranging from 158.3 *ug*/ft2 (Site 3) to 287.8 *ug*/ft2 (Site 4). Table 1 shows the summary statistics for urban Pb dust (*ug*/ft2) in selected public and private elementary schools in Tarlac City, Philippines.

The average levels of Pb in the dust samples did not vary significantly among the six schools investigated and were all found to exceed the maximum value (see Fig. 2) set by the United State Environmental Protection Agency (EPA). Under the EPA standards, lead is considered a hazard if there are greater than 40 micrograms of Pb in dust per square foot on floors (40 ug/ft^2) [15].

Comparing the results of individual samples to the EPA standard revealed that of the 108 dust samples collected and analyzed for lead, only one was within the clearance level of 40 ug/ft^2. The rest of the 107 dust samples showed lead levels exceeding the EPA clearance standard by as high as 16 times. The average level of lead in dust in Site 3 where dust was found to be least contaminated was about four times greater than the clearance standard while in Site 4 where dust was found to be most highly contaminated was about seven times greater than the clearance standard.

TABLE I. SUMMARY STATISTICS FOR LEAD DUST IN SCHOOLROOMS

Site	No. of Samples (n)	Mean (ug/ft^2)	Std Dev	Min Value (ug/ft^2)	Max Value (ug/ft^2)	Coeff Var (%)
Site 1	18	200	87.6	50	370	29.3
Site 2	18	222.8	106.5	50	410	47.8
Site 3	18	158.3	108.6	60	480	68.6
Site 4	18	287.8	173.4	40	650	60.2
Site 5	18	243.9	90.3	80	400	37.0
Site 6	18	185	104.7	60	390	56.6

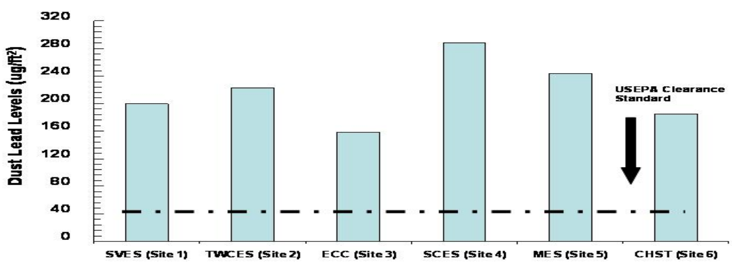

Figure 2. Average lead levels in dust from sampling sites compared with EPA lead hazard standard

The possible sources of lead dust in the schoolrooms include atmospheric deposition of lead particles from vehicular exhaust more particularly from vehicles that use leaded gasoline, deteriorating lead-based paint used in classroom interiors, and lead dust tracked into the classrooms by schoolchildren treading on lead contaminated soil.

Prior to 1993, gasoline in the Philippines was said to have the highest lead content in the world. Recognizing the problem of lead pollution, petroleum companies in the Philippines voluntarily signed a clean air pact with government. Lead content in gasoline was lowered from 0.6 g/l to 0.15 g/l in April 1993, and low-lead gasoline (0.013 g/l lead) was introduced in February 1994. With unleaded gasoline achieving 15.8% of the market share by 1994, ambient lead levels in monitoring stations in Manila recorded a decrease from 1.07 ug/m^3 in 1992 to 0.66 ug/m^3 in 1993 and to 0.30 ug/m^3 by 1994. Monitoring at other stations in 1994 and in 1997 showed that ambient Pb levels have stayed within the WHO Air Quality Guidelines [16].

In an all-out campaign to improve the urban environment, Philippine legislators passed into law Republic Act No. 8749 otherwise known as the "Philippine Clean Air Act of 1999'. Among others, RA 8749 prohibited the manufacture, import, and sale of leaded gasoline and of engines and components requiring leaded gasoline. The same law called for the complete phase out of leaded gasoline by December 2000 [17]. More than a decade has passed since the passage of RA 8749 designed to improve the quality of air in the country. And yet the use of alkyl lead in gasoline has not been totally eliminated in the Philippines.

A survey among gasoline stations in Tarlac City (Table II), conducted in 2004, revealed that unleaded gasoline still gets the least share in the market [18]. The same conditions persist to the present.

Another possible source of lead dust in the classrooms is lead- contaminated soil tracked into the schoolrooms by the schoolchildren . The findings of a study revealed that, on the average, soil lead concentration in Tarlac City measured 16.8 mg kg^{-1} [18].

Although deteriorating lead paint may also be a possible source of lead dust in the schoolrooms, it has not been investigated in this study and thus no empirical data can be presented.

TABLE II. FUEL TYPES RANKED BASED ON FUEL CONSUMPTION IN TARLAC CITY, PHILIPPINES

Fuel Type	Rank
Diesel	1
Premium Gasoline	2
Regular Gasoline	3
Unleaded Gasoline	4

Ranking 1 to 4: 1- highest consumption, 4-lowest consumption

The implications of these preliminary findings may be clinically important. Soil and dust act as pathways to children for lead deposited by primary lead sources such as lead paint, leaded gasoline, and industrial or occupational sources of lead [3]. Because lead does not dissipate, biodegrade, or decay, the lead deposited into dust and soil becomes a long-term source of lead exposure for children. For example, although lead emissions from gasoline have largely been eliminated in the United States, an estimated 4-5 million metric tons of led previously used in gasoline remain in dust and soil, and children continue to be exposed to it. In the 1992 ATSDR document, it was noted that several investigations have shown a highly significant correlation between blood lead levels and lead concentration in dust and soil. Several studies were cited that described the quantitative relationships between blood lead levels and soil or dust lead levels [19]. Repeated exposure to lead-contaminated dust may adversely result to lead poisoning in children without causing obvious symptoms. A child may have lead poisoning and not feel sick. Or the child may have stomach aches, headaches, a poor appetite or trouble sleeping, or may be cranky, tired or restless. Children are susceptible to the adverse health effects from extremely low exposures to environmental lead. A child is considered "poisoned" with greater than 20 ug/dl of lead in the blood and is considered at risk with greater than 10 ug/dl [15].

IV. CONCLUSIONS AND RECOMMENDATIONS

Quantitative analysis showed that the average levels of lead in the dust samples collected from the six schools exceed the maximum exposure limit for lead in dust set by the Environmental Protection Agency. The findings of the study suggest that schoolchildren in Tarlac City, Philippines are at risk of exposure to the hazards of lead-contaminated dust. Government, school authorities, and parents should note the implications of the findings of this study and make more substantial efforts to curb lead pollution. These sectors should work together to reduce children's risk of lead exposure carefully considering a multi-part approach to reduce lead hazards and address lead-related health problems. Such approach should consider environmental, nutritional, educational, and medical issues.

A. Environmental Intervention

Reducing children's risk of lead exposure can be accomplished using a number of interim controls and permanent abatement methods. A feasible interim technique for protecting children from lead exposure includes regular wet-cleaning, dust control, and personal hygiene.

Lead dust is very fine, can be invisible, and is hard to clean up. Regular broom sweeping does not clean up lead-contaminated dust. Hence the Centers for Disease Control and Prevention suggests that floors and hard surfaces should be wet-mopped and wet-wiped regularly [20]. Wet-mopping floors and wet-wiping hard surfaces may keep dust levels low.

Most young children get lead dust on their hands and toys which then gets into their mouths through normal hand-to-mouth behavior thereby increasing the opportunity for ingestion of lead-laced dust. Children and adults alike should thus be made aware of the benefits of frequent hand washing in reducing lead hazards. Further, new technology and engineering controls to reduce airborne lead levels below the permissible exposure limit should be continuously explored to effectively reduce lead dust in the environment.

Aside from atmospheric deposition of lead dust from vehicular exhaust, lead dust may be tracked into homes and classrooms from lead-contaminated soil in the surrounding areas. One promising abatement technique is to cover lead-contaminated soil with grass species that have been shown to act as phytoremediators or have the ability to absorb lead from various environmental media. Planting trees around the school perimeter that may act as biological curtains may also effectively reduce exposure of schoolchildren to lead dust coming from vehicular exhaust.

Although deteriorating lead-based paint as a source of lead dust in the classrooms has not been investigated in this study, appropriate measures should also be undertaken to address this possible source of lead hazard such as regular repainting of classroom interiors to prevent exposure of schoolchildren to lead-laced paint dust and paint flakes.

However, there is little point in carrying out interim controls to reduce lead dust hazards unless steps are also taken to control the source of lead. Permanent abatement methods should be carried out by removing the source of lead contamination within the environment. Crucial to this is the strict implementation of the Philippine Clean Air Act that prohibits the manufacture, import, and sale of leaded gasoline and of engines and components requiring leaded gasoline. Lead-based paints should likewise be eliminated from the market.

B. Nutritional Intervention

Nutrition can have an impact on the amount of lead that is absorbed into the blood. Studies of lead-nutrient interactions have shown that defects in nutrition will enhance lead absorption and retention and thus the toxicity risk. Nutritional guidelines specifically recommended to reduce lead absorption rate in children include eating regular and nutritious meals since more lead is absorbed on an empty stomach. Diets should also be supplemented with plenty of iron and calcium. It has been reported that children with elevated blood lead (PbB) levels had lower dietary intakes of calcium and phosphorus than did a reference population. The similar ionic radii of $Pb2+$ and $Ca2+$ suggest that lead can substitute chemically for calcium and hence that lack of dietary calcium may predispose children to lead toxicity[19]. The results of a study suggest that iron deficiency is strongly associated with some of the observed toxicities of lead [22]. Iron fortification has been found to reduce blood lead levels in children [23]. Thus improving the nutritional status of children at risk of lead exposure greatly increases the effectiveness of environmental lead abatement

C. Educational Intervention

The wealth of evidence suggesting that lead poisoning could do so much harm to the nervous system particularly in children coupled with the fact that lead poisoning has no identifiable symptoms require that people be educated about the potential problems with lead exposure. Public education is crucial to the success of lead hazard reduction programs. Parents and children should be counseled and provided instruction on sound intervention techniques to reduce lead hazards. By understanding lead toxicity, people can gain useful insights on the nature and remedy of environmental lead hazard. If the public knows where lead is, what it does to children, and how to get rid of it, then we would know enough to effectively reduce this type of environmental hazard.

D. Medical Intervention

Respiratory protection and medical surveillance are essential for controlling lead exposure levels and preventing lead-related diseases when engineering controls fail to reduce air-borne lead levels below the permissible exposure limit. Frequent hand washing and wet cleaning of floors and surfaces can diminish the hazard from lead-contaminated dust but more drastic measures are called for when there is significant exposure to lead. Children exposed to dangerous levels of lead should be tested for lead poisoning. The Centers for Disease Control recommends testing every child at 12 months of age and at 24 months if resources allow. Based on what is known today, children should have under 10 micrograms per deciliter of blood lead concentration. Children with 10 to 19 micrograms per deciliter of blood lead have mild lead poisoning [20]. In such cases, there is usually no medical intervention, since the problem can be addressed by the nutritional and environmental treatment components. Children with blood lead levels of 20 micrograms per deciliter and above have severe lead poisoning. The primary intervention in a severely poisoned person is lead removal with medicines. This treatment is known as chelation therapy. The procedure involves administering a drug that binds to lead orally, intramuscularly, or intravenously, depending on the blood lead level. The drug reduces the acute toxicity of lead. The chelating agent picks up the lead and force it out of the body. Until recently, it was a pretty risky procedure and reserved only for cases of severe poisoning. Recent improvements in the treatment has resulted in much more aggressive use early on [24].

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