# Childhood Lead Exposure in a Vietnamese Battery Recycling Village

Ryan Wallace

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Bill Daniell

Catherine Karr

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## Introduction

Lead has been utilized by humans for thousands of years. The earliest evidence of lead use dates to 6400 BCE in what is now Turkey, where lead beads were discovered adorning jewelry.[1] In subsequent millennia, lead has been used in ceramics, plumbing, gasoline, paint, batteries, and cosmetics. While the negative health effects of lead are now widely recognized and risk factors for exposures have been identified, so much lead has been mobilized from natural deposits - and is being broadly circulated - that the risk for exposure persists throughout the world. [2]

In the past decade the demand for lead has risen as much as tenfold, the majority of which can be attributed to the battery industry.[4,17] In 2010, of the nine million tons of lead mined or reprocessed, seven million was utilized in battery manufacturing processes.[3,4] Furthermore, as battery demand is expected to continue to rise throughout the world, most acutely in India and other rapidly developing nations, conservative estimates project battery demand will increase 4.8% annually.[6] An important component of this growing market, responsible for approximately $14 billion each year, is the automotive, or lead-acid battery industry.[4]

The growth of the automotive battery industry is associated with the rapidly increasing sales of automobiles, particularly in Southeast Asia and India.[4] Consequently, countries have been pressed to secure vital lead resources even as lead mining activities have become more challenging and costly due to the depletion of easy-to-reach deposits. It is therefore becoming more common for countries to reprocess used batteries, which can each contain between 20-40 pounds of lead, as a ready and relatively inexpensive source of this valuable commodity. To illustrate, as of October 2011 one pound of lead cost approximately $1.20 to mine, but only around $0.70 if it was reprocessed. [7] Consequently, lead acid battery recycling, and the utilization of salvaged lead, has become common practice.[5,7] Globally, 60-80% of lead used in new batteries originates from recycled sources.[7]

While the recycling industry has flourished in response to an ever increasing demand for lead, controlling for the various health hazards associated with recycling has been problematic. In developed countries, such as the United States and throughout Europe, occupational and environmental regulations have been created and are strictly enforced, thus increasing the costs of reprocessing operations. In contrast, in the developing world where there are lax or nonexistent regulatory policies, financial costs are typically much lower relative to developed countries. Consequently, there has been a shift of recycling activities from developed to developing countries.[8,17] To illustrate, in 2010 the US Environmental Protection Agency (EPA) finalized revisions to its Ambient Air Monitoring Requirements, which, through more stringent regulation, made domestic lead recycling a more expensive undertaking.[17,30] As a result, in 2010, 20% of America's used batteries were sent to Mexico for re-processing, a 112% increase over 2009 levels.[7,17] This phenomenon has also been noted in India, Mexico, and the Philippines, and likely occurs in many other developing countries as well.[4, 5, 8, 17]

While there are certainly some benefits associated with battery reprocessing activities in these areas, there are significant dangers as well. [4] In Vietnam, as in many locations throughout the world, recycling processes often consist of informal secondary smelters run by lower income individuals, unaware of the risks of lead exposure.[5] These informal lead reprocessing facilities take little if any precautionary measures and involve pulverization of whole batteries using an axe or a hammer mill, separation of the metal and plastic battery components, and melting down recovered lead in large vats (sometimes within residences or in backyards) to be cast in easily managed ingots. The ingots are then sold to battery manufacturing companies.[7] These practices, which typically lack the use of safety precautions and can occur in close proximity to living quarters, have contributed to environmental contamination and significant human exposures to lead. [4, 5,8] Particularly concerning is the fact that these practices often disproportionately affect children, who are more susceptible to the health-related risks associated with lead.[10]

## The Effects of Lead on Children

There are three main routes of exposure to lead: inhalation, ingestion, and dermal absorption. Dermal absorption predominately occurs with the organic lead used in aviation fuel and is consequently not a principal concern among children.[11]

Inhalation of lead can be, but is not usually, an important source of exposure in children.[2] While inhaled lead, particularly lead vapors or fumes, can be readily absorbed into the body, it is uncommon for children to be exposed to settings, most frequently occupational settings, where this is a major concern. However, if lead is being melted down close to the child or if leaded gasoline is still in use, inhalation and absorption of lead vapors and fumes can pose a significant exposure risk.[23] In fact, lead vapors or fumes are almost completely absorbed into circulation when inhaled into the lungs.[24] In most communities, however, the particle size of airborne lead dusts is larger than 10 μm, above the size for which inhalational absorption occurs. These particles are frequently swallowed and can enter the system through ingestion and gastrointestinal absorption which typically is the main form of exposure to lead in children.[2,24]

Given their behavioral patterns and innate inquisitiveness, children are likely to engage in behaviors, such as exploring their environments by putting objects into their mouths, that put them at a high risk for ingesting lead.[2] Furthermore, lead consumed by children has a relatively high rate of absorption, typically 35-50%, when compared to adults who absorb approximately

10% of ingested lead. During states of malnourishment, specifically if the child's diet is deficient in iron and/or calcium, intestinal absorption of lead will be further increased to levels as high as 70%.[11] Regardless of the source, once lead is absorbed into the body it has a wide array of adverse consequences in children.

Lead exposure in children and adults is measured through determination of Blood Lead Level, or BLL. The effects of BLLs greater than 10 µg/dL (clinical toxicity) are similar at comparable levels in children and adults, although effects generally occur at lower BLLs in children. Children with clinical toxicity will demonstrate decreased vitamin D metabolism, colic, constipation, fatigue, decreased hemoglobin synthesis leading to anemia, decreased nerve conduction velocities, and potentially abnormal neurological function. At BLLs greater than 50 µg/dL, nephropathy and encephalopathy can manifest and, depending on acuteness and magnitude of BLL elevation, may potentially result in death. Often, children who survive toxicity will demonstrate irreversible neurodevelopmental abnormalities in the future.[2,12]

However, exposure to lead as a child during embryonic, fetal, and early post-natal development, is associated with sequelae not observed in adult populations. This is especially true at subclinical levels which have been associated with intellectual deficits as measured by Intelligence Quotient (IQ), decreased reading comprehension, and decreased math abilities.[2,13] In an important study conducted by Canfield, et al published in 2003, children with BLL concentrations of 10 µg/dL had, on average, 7.4 points lower IQ than children with BLL concentrations of 1 µg/dL. This actually demonstrated a greater decremental impact on IQ than what was observed in the clinical range (> 10 µg/dL). [20] Further studies have demonstrated negative associations between BLL and IQ scores down to BLLs of 1 µg/dL. It is generally agreed cognitive deficits are observed at every level of BLL, even those at the lowest end of the spectrum.[22]

While, on an individual level, decreasing IQ by five points may not seem meaningful, the effect of a five point reduction in IQ, when applied throughout a population, is potentially dramatic. Given that IQ scores of less than 70 define mental retardation, while those above 130 signify intellectual giftedness, a five point shift in IQ can potentially increase the mentally handicapped population and decrease the gifted population, each, by over 50%.[10,24] These changes on a population level can contribute to decreased leadership, increased need for special education and service programs, and widening socioeconomic gaps between communities with and those without lead exposure. [2, 10,24]

In addition to the cognitive effects of lead in children, behavioral effects have also been extensively documented.[22] A landmark study by Needleman et al. in 1979 demonstrated that subclinical levels are associated with behavioral and cognitive problems in children including trouble concentrating, hyperactivity, impulsivity, disorganization, poor overall functioning, and decreased performance on verbal and full scale IQ measures.[14, 15] Follow-up conducted on this same study population demonstrated increased delinquency, increased absenteeism, and decreased chance of graduating high school among those with higher lead exposures.[15]

The average BLL among the United States population of children aged 1-5 years is less than 2 µg/dL.[31] Current Centers for Disease Control and Prevention (CDC) guidelines for childhood BLLs in the United States recommend an upper limit of 5 µg/dL.[22] This was updated in May, 2012 from the previous level of concern of 10 µg/dL based on the current distribution of BLLs among 97.5% of American children aged one to five years, the understanding that there is no safe level of lead in children, and the recognition that the physical and cognitive effects of lead are irreversible.[21] Furthermore, the current guidelines recommend a reevaluation of the reference level in order to assure recommendations stay abreast of changes within the population.[21,22]

## Vietnam and Lead

The battery market in Vietnam generates over $65 million annually and is expected to continue growing in the foreseeable future.[4] An increasingly important component of this market, both financially and in terms of lead acquisition, is the battery recycling industry. It is projected that over 70,000 tons of lead-based batteries will be reprocessed in 2015, a sizeable increase over the 40,000 tons reprocessed in 2010. For a relatively poor country with a finite supply of natural resources, battery recycling has proven to be a valuable activity.[4] This is particularly true in rural settings where poverty has concentrated over the past three decades.[16]

In 1986 Vietnam launched what is termed the “Doi Moi”, or economic renovation, with the intent of transitioning from a struggling planned economy, where all financial decisions were made by the government, to a socialist-oriented market economy, where the free market was seen as a necessary tool to achieve the socialist vision.[26] While the rising economy has brought more money and power into Vietnam, it has also exacerbated inequalities between the rich and the poor. Income disparities are higher than at any other time in recent history.[27] Rural areas have been particularly affected by poverty, experiencing rates as high as 20%.[28] To supplement income and to integrate with rapid economic development, many rural villages, known as handicraft villages, have turned to craftwork, such as basket weaving, wood carving, and battery recycling. There are currently over 1,450 handicraft villages in Vietnam.

While handicraft villages have made remarkable strides in reducing poverty in rural settings, they have also generated substantial hazards for their residents. The rate of craft production has far outpaced the rate of infrastructure development and considerations for environmental and occupational regulations have been broadly overlooked. Consequently, residents in handicraft villages frequently live in polluted environments, work in potentially hazardous conditions, and ultimately experience more disease than their strictly agricultural counterparts.[16] This is especially apparent in Dong Mai, a handicraft village specializing in battery recycling.

Dong Mai village, located in the northern province of Hung Yen, has been involved in battery recycling activities since 1978.[19] Over 500 of Dong Mai's 2300 residents are actively involved, in one capacity or another, with recycling activities.[29] According to an environmental briefing note released by the Korea-Worldbank Environmental Partnership in East Asia regarding environmental management in Handicraft villages in Vietnam, 100% of workers involved with lead recycling activities in Dong Mai suffer from chronic lead toxicity, approximately 71% of residents have mental diseases and 65% have respiratory diseases associated with recycling activities.[16]

A cross-sectional study in 2006 conducted by the National Institute of Occupational and Environmental Health (NIOEH), a Vietnamese government research organization, reportedly found elevated environmental levels of lead in air, surface soil, and wastewater samples.[19] Furthermore, 27.6% of measured urine lead levels among screened school children were $\geq$ 80 μg/dL. Following this investigation, Dong Mai villagers decided to improve the safety of battery recycling processes by outlawing home-based recycling practices and centralizing legal recycling practices at a large warehouse located on the outskirts of the village.[19] Therefore, the purpose of this study is to describe the distribution of BLLs among children aged 1-10 years old in Dong Mai village and to identify risk factors associated with elevated BLL levels.

## Hypotheses

H0: Children living in households with adults employed in the battery recycling industry, with dirt floors, or located close to known battery recycling operations have BLLs that are the same as children in households that do not meet these criteria.

HA: Children living in households with adults employed in the battery recycling industry, with dirt floors, or located close to known battery recycling operation are more likely to have an increased BLL than children in households that do not meet these criteria.

## Methods

This cross-sectional study was conducted with children in Dong Mai village of Hung Yen province, Vietnam, in collaboration with Vietnam's National Institute of Occupational and Environmental Health (NIOEH), as signified by a letter of collaboration between the NIOEH and the University of Washington (UW) (*see Appendix A*). All study procedures were reviewed and approved in advance by the Institutional Review Boards (IRB) at the UW and the NIOEH.

This study screened a sample of children, aged ten years or less, from the village in order to determine their BLLs using a portable screening device, the LeadCare® II . With parental consent and child assent, each child underwent a single BLL measurement using a finger stick blood sample. The study also included a short interview of the parent/guardian and systematic observations of the home setting for each participating child. Blood lead levels were examined for association with various risk factors identified in the home observations and family questionnaire in the interest of identifying the primary sources of exposure and controlling for them. An important aspect of the study was to provide education about lead toxicity effects and management options to the members of the NIOEH, the health commune and provincial staff, and the families of Dong Mai village.

My role (Ryan Wallace) was to assist in the study design process; work with my advisors to obtain human subjects approval; educate members of the NIOEH in regards to lead toxicity, screening procedures and clinical management; and assist in data collection in Dong Mai village. Data analysis was conducted independent of the NIOEH analyses.

Study population: The study findings are potentially applicable to other trade villages in Vietnam where lead recycling is conducted. The specific population for this study is all households in Dong Mai village, particularly those with one or more children 10 years of age or younger.

Sample Selection: Investigators met with the village commune health leaders prior to initiating the study. The commune health leaders provided a list of all children less than 10 years of age in Dong Mai village. Of approximately 300 identified children, a randomly ordered list of 120 children were invited for participation in the study. Of these, data was collected on 109 individuals (a 91% participation rate). The number of participating children in each household was not restricted. The sample included 56 households with 1 participating child, 25 households with 2 children, and 1 household with 3 children.

Recruitment: A recruitment team consisting of representatives from the NIOEH, the Hung Yen Provincial Preventative Medical Center, and the commune health center of Dong Mai village visited family homes on December 17$^{th}$ and 18$^{th}$, 2012 (prior to data collection) to invite participation. During this visit the researchers explained the study, its voluntary nature, and the consent process. Families were told that an incentive of 10 USD would be given at the time of blood sampling for each child who participated in the study. Families were given the opportunity to ask questions and voice concerns and were reassured that if they did not want their children to participate in the study, there would be no adverse consequences.

Family questionnaire/Home observation form: For families that agreed to participate in the study, researchers administered a short structured questionnaire consisting of 21 questions exploring possible risk factors for high lead exposures (*see Appendix B*). Researchers also completed a home observation form examining potential risk factors for lead exposure relating to the home environment (*see Appendix C*). Following completion of the family questionnaire and the home observation form, subjects were scheduled to one of five hour-long blocks at the Dong Mai Clinic during the following weekend for blood sample collection.

Clinical measures/BLL measurement: Families arrived for BLL measurement during hour long blocks on December 24$^{th}$, 2012. Approximately 20 subjects were scheduled to arrive during each hour long block. Health commune workers instructed the families on thorough hand-washing techniques. A wash station was set up consisting of three wash basins- the first for scrubbing, the second for soap application and removal, and the third for final rinsing. Many subjects also ran tap water over their hands prior to the wash station. Subjects then visited a station to obtain height, weight, and age. Lastly, the subjects were then sent to researchers for collection of a blood sample.

The NIOEH researchers were trained in the use of the LeadCare® II Blood-Lead Test System (Bionostics, Inc.) and proper aseptic blood sample collection technique the week prior to BLL measurement. To gather the sample, the subject's fingers were cleaned with an alcohol swab and a new, sterile, lancet was used to penetrate the finger tip. After the first drop of blood was wiped off using a clean and dry swab, a capillary tube was used to collect the desired quantity of blood (50 µL). The collected sample was placed in a reagent tube and then run through the LeadCare® II which was housed inside an examination room at the Dong Mai Clinic. The LeadCare® II is functional between 54˚F and 97˚F and between 12% to 80% relative humidity. As data collection occurred during the dry season in December, temperature and humidity were well within these bounds. The LeadCare® II was calibrated prior to the opening of each new lot of test supplies (every 48 tests), and controls were run to ensure accuracy of the machine. The limits of detection for the LeadCare® II are between 3.5 µg/dL and 65 µg/dL. Values outside this range yield a "low" or "high" reading.

<u>Delivery of Results/observation survey:</u> The Dong Mai clinic was crowded during the sample collection process and the pace of sample collection exceeded the pace of researchers' ability to run samples through the LeadCare® II. Consequently, families were not provided the results of their children's test immediately. Results were recorded in a laboratory notebook by subject number and were later transferred to the health commune which held the master list with subject number matched to identifying information. The head of the Commune Health Center and commune health workers informed subjects of their results on the evening of sample collection (Dec 24$^{th}$), along with an interpretation of the results and education regarding exposure reduction. Interpretation of results and exposure reduction education were provided in oral and written form (*see Appendix D and E, respectively, for written documents*).

Recommendations for treatment were based upon current treatment guidelines. There are no Vietnamese or international guidelines for management of lead poisoning and US CDC guidelines were used.

- For BLLs exceeding 44 µg/dL, the head of the Commune Health Center and a village health worker immediately notified the families and requested that the child have venipuncture sampling and confirmatory laboratory BLL analysis. Of the 32 children who were initially screened to have a BLL >44 µg/dL, all but nine were able to undergo confirmatory venipuncture on the day following initial screening (Dec 25th). These samples were analyzed using Graphite Furnace Atomic Absorption Spectrometry (GFASS) at the NIOEH laboratory. The cost of repeat testing was covered by the study.

  The team emphasized the importance of removing the child from all possible sources of exposure and recommendations were given to do so. If BLL> 44 µg/dL was confirmed, chelation therapy was recommended, but only after reducing or removing child from lead exposures first. Chelation would have limited or no benefit, and depending on the chelating agent could be harmful, if children were unable to minimize exposures during and after treatment. Consequently, it was essential to identify and control the sources of exposure prior to beginning treatment. Clinical evaluation was recommended to identify possible symptoms or signs of lead toxicity that might warrant urgent treatment or hospitalization.

- For BLLs between 10 – 44 µg/dL, the importance of removing the child from the exposure was emphasized with the family. Education was provided to these families regarding how to reduce exposure. Recommendations were made to the NIOEH for follow-up monitoring of these children. Note (see results), 24 confirmatory BLL values were equal to or mostly lower than the LeadCare ® II values, and retesting was not recommended for BLLs 10-44 µg/dL.

- There were no BLL measurements less than or equal to 10 µg/dL.

Education: An important goal in this project was to provide training and education for the researchers at the NIOEH, the provincial and health commune workers, and the families of children involved in the study.

An educational presentation and discussion at the NIOEH highlighted the significance of lead poisoning, current US recommendations for the diagnosis and treatment of lead poisoning, considerations for the use of chelating agents, and case studies throughout the world of communities that have had problems with childhood lead exposure and how these issues have been addressed. The goal of this discussion was to ensure that the NIOEH understood the significance of potential elevated BLLs that might be found in this study, and to make further plans to address lead exposure or intoxication potentially discovered in this study.

Informal education was given to the health commune workers. This again highlighted the significance of potential elevated BLLs and described what could be done by the community to reduce child lead exposure.

Lastly, a picture based educational pamphlet was distributed to families involved in the study describing simple ways of reducing their children's lead exposure (*see appendix E)*.

# Analysis

## *Variable transformations*

For analysis of potential risk factors identified in the questionnaire and observation form, the outcome (BLL) was categorized into three categories, 10-29.9 µg/dL, 30-44.9 µg/dL, and ≥ 45 µg/dL, based upon the distribution of BLLs and the current CDC recommendations for treatment (> 45 µg/dL).

Age was categorized into two broad categories based on age of enrollment in school at six years of age. Children under six years of age were further split into two categories of approximately equal size. There were 31 children between 0-2, 34 children between 3-5, and 44 children 6-10 years old.

Stature was categorized based on percent predicted values when compared with the CDC growth charts.[32] The lowest tertile of percent-predicted statures was compared against the rest of percent-predicted statures.

## *Statistical analysis*

All analyses were done with Stata (version 12.1).

Bivariate analysis was conducted between potential risk factors and the outcome using chi-square or Fisher exact tests. Bivariate analysis was repeated separately within younger (0-5) and older (6-10) age groups, after analysis of all children revealed a strong association between age and BLL. Oneway ANOVA was used for numeric variables.

Variables identified in the bivariate analysis as likely risk factors for very high BLL (≥ 45 µg/dL) were sequentially entered into a multinomial logistic regression of the three-category

BLL variable, controlling for household effects. Variable entry started with characteristics of the child (age), followed by lead recycling activities (home recycling, family involvement in recycling activities), followed by possible environmental contributors to exposure (brick materials used in yard, proximity to recycling facility). Two variables, home recycling and proximity to recycling facility, could not be entered into the model as there were no observations in critical categories (i.e., cells with 0 values).

Possible household effects were addressed through several means. First, the bivariate analysis was repeated using just the youngest and then just the oldest child from each household. Results from these analyses were then examined for substantial differences against the analysis using all children. Second, the multinomial logistic regression controlled for household effects. Lastly, within-household concordance between the BLL of the youngest and oldest child was examined for all households containing more than 1 child (note, 25 households had 2 child subjects, 1 household had 3).

Correspondence between the LeadCare® II measurements and the GFAAS analysis (for the 24 subjects who were able to undergo confirmatory venipuncture), was characterized by a correlation coefficient and measurement of bias (distribution of difference between paired LeadCare® II and GFASS values).

## Results

Of 109 study participants, 51 were male. The mean age of participants was 4.5 years (standard deviation [sd]= 2.62 years). The Youngest child enrolled in the study was 11 months, oldest was 10 years. Mean BMI of study participants was 15 $kg/m^2$ (sd= 1.78). Minimum BMI was 9.8 $kg/m^2$, maximum was 20.7 $kg/m^2$. Mean percent predicted height/stature of participants was 96%. Minimum percent predicted height/stature was 84%, max was 110%.

Home-based recycling activities were still occurring in Dong Mai village despite efforts made to outlaw this practice. Four of 109 children lived in households where recycling activities took place in the home environment (Table 1). Furthermore, 60 subjects had family members involved in legal recycling activities, and 21 of these had more than one family member involved. About half of subjects (n=58) lived within 100m of the centralized recycling facility, and four subjects lived less than 10 m from a legal or illegal recycling facility. About one-quarter (n=27) lived within 100m of areas where recycling waste was burned. There was no substantial difference between age groups in any of the examined variables, except for living "<100m to burning of recycling waste" which occurred most often in the oldest age group.

Old battery casings were used inside or outside the home at about half of the households. Most households had finished yard surfaces but approximately two-thirds had gardens. About half of households had soil floors.

**Table 1: Characteristics of family and home environment, relative to child's age (n=109)**

| | Age (years) | | | | | | Total (n) |
|---|---|---|---|---|---|---|---|
| | 0-2 | | 3-5 | | 6-10 | | |
| | n= 31 | | n= 34 | | n= 44 | | |
| **Household Lead Recycling Activities** | | | | | | | |
| **Lead recycling at home** | | | | | | | |
| Currently | 2 | 6.5% | 1 | 2.9% | 1 | 2.3% | 4 |
| Past (not currently) | 6 | 19.4% | 6 | 17.6% | 8 | 18.2% | 20 |
| Ever | 8 | 25.8% | 7 | 20.6% | 9 | 20.5% | 24 |
| Lead removed from batteries | 4 | 12.9% | 3 | 8.8% | 8 | 18.2% | 15 |
| Lead cooked | 2 | 6.5% | 3 | 8.8% | 5 | 11.4% | 10 |
| Lead casted | 1 | 3.2% | 2 | 5.9% | 1 | 2.3% | 4 |
| Lead cooked or casted | 3 | 9.7% | 5 | 14.7% | 5 | 11.4% | 13 |
| **Family involvement in recycling** | | | | | | | |
| Currently | 15 | 48.4% | 22 | 64.7% | 23 | 52.3% | 60 |
| Currently: >1 family member | 4 | 12.9% | 9 | 26.5% | 8 | 18.2% | 21 |
| Past (not currently) | 5 | 16.1% | 6 | 17.6% | 8 | 18.2% | 19 |
| Ever | 20 | 64.5% | 28 | 82.4% | 31 | 70.5% | 79 |
| Ever: >1 family member | 7 | 22.6% | 11 | 32.4% | 13 | 29.5% | 31 |
| **Home Environment** | | | | | | | |
| **Distance from home to recycling** | | | | | | | |
| <100m to central facility | 16 | 51.6% | 18 | 52.9% | 24 | 54.5% | 58 |
| <100m to burning of recycling waste | 6 | 19.4% | 5 | 14.7% | 16 | 36.4% | 27 |
| <10m to nearest legal or illegal facility | 1 | 3.2% | 2 | 5.9% | 1 | 2.3% | 4 |
| ≤10m to nearest legal or illegal facility | 4 | 12.9% | 3 | 8.8% | 4 | 9.1% | 11 |
| **Battery casings used at house** | | | | | | | |
| Used outside (reported) | 11 | 35.5% | 18 | 52.9% | 23 | 52.3% | 52 |
| Used outside (observed) | 14 | 45.2% | 16 | 47.1% | 19 | 43.2% | 49 |
| Used inside (reported) | 12 | 38.7% | 16 | 47.1% | 19 | 43.2% | 47 |
| Used inside (observed) | 15 | 48.4% | 18 | 52.9% | 15 | 34.1% | 48 |
| **Floor surface** | | | | | | | |
| Soil | 1 | 3.2% | 3 | 8.8% | 0 | 0.0% | 4 |
| Mats over bare soil | 17 | 54.8% | 14 | 41.2% | 19 | 43.2% | 50 |
| Brick | 10 | 32.3% | 9 | 26.5% | 18 | 40.9% | 37 |
| Cement | 0 | 0.0% | 1 | 2.9% | 1 | 2.3% | 2 |
| Tile | 0 | 0.0% | 1 | 2.9% | 1 | 2.3% | 2 |
| Finished materials (brick, cement, tile) | 10 | 32.3% | 11 | 32.4% | 20 | 45.5% | 41 |
| **Yard surface** | | | | | | | |
| Brick | 21 | 67.7% | 17 | 50.0% | 27 | 61.4% | 65 |
| Cement | 7 | 22.6% | 11 | 32.4% | 12 | 27.3% | 30 |
| **Garden** | 11 | 35.5% | 19 | 55.9% | 20 | 45.5% | 50 |

All children in the study had elevated BLLs as can be seen in Figure 1. This figure shows a bimodal distribution of BLLs. The lowest recorded value was 12 µg/dL, the highest was >65 µg/dL (upper limit of detection of the LeadCare® II), and the median was 34.8 µg/dL. As all children in the study had an elevated BLL, we examined the risk factors in terms of *very high* BLL. That is, we examined the trends of various risk factors across the three previously defined BLL categories.

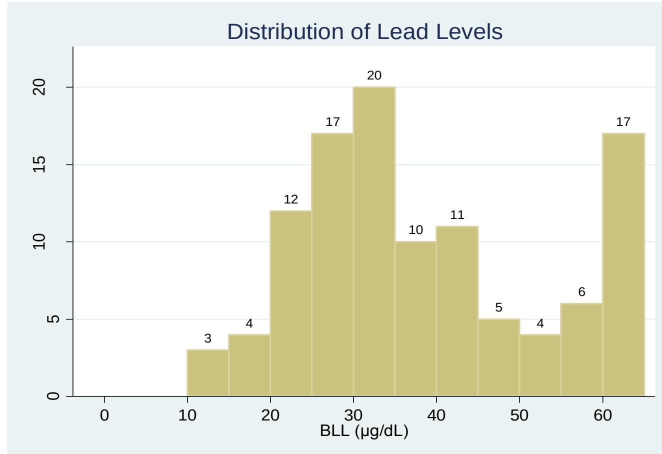


Figure 1: BLL distribution of study participants (n=109).

Children whose screening BLL was ≥ 45 µg/dL underwent confirmatory venipuncture sampling and laboratory-conducted GFAAS analysis. These measurements are compared in Figure 2, Figure 3, and Figure 4.

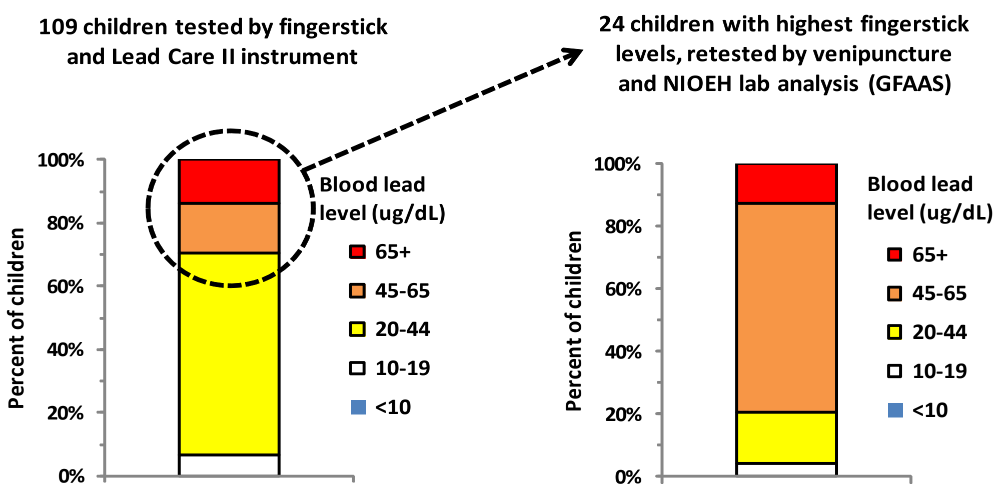


Figure 2: A comparison of the BLL distribution identified using LeadCare II (fingertip) and using GFAAS (venipuncture) analysis

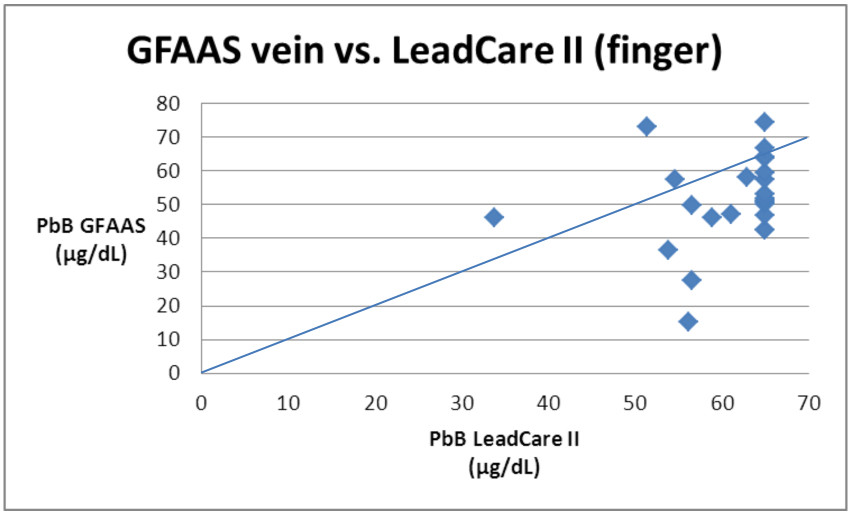


Figure 3: Scatterplot comparing the GFAAS and LeadCare II BLL values. Line of perfect agreement shown.

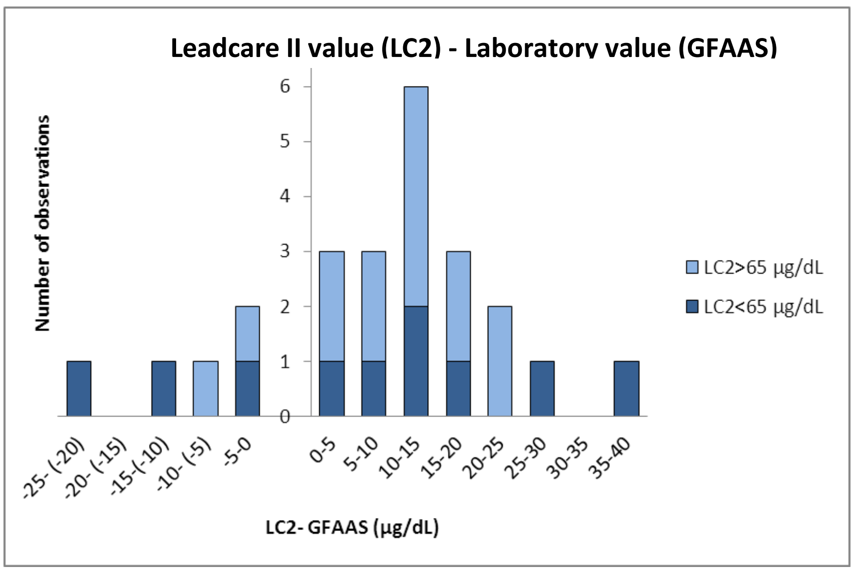


Figure 4: Distribution of the differences between LeadCare II results and GFAAS results (n=24).

**Table 2: Survey and observation results for 109 children in Dong Mai village, relative to their BLL.**

| | Capillary Blood Lead level (µg/dL) * | | | | | | |
|---|---|---|---|---|---|---|---|
| | 10-29.9 n= 36 | | 30-44.9 n= 41 | | >44 n= 32 | | Signif (p)** |
| **Child** | | | | | | | |
| **Age (years)** | | | | | | | 0.008 |
| 0-2 | 10 | 28% | 9 | 22% | 12 | 38% | |
| 3-5 | 6 | 17% | 13 | 32% | 15 | 47% | |
| 6-10 | 20 | 56% | 19 | 46% | 5 | 16% | |
| **Male** | 13 | 36% | 20 | 49% | 18 | 56% | 0.24 |
| **Child attends school** | 30 | 83% | 34 | 83% | 25 | 78% | 0.83 |
| Kindergarten: Dong Mai | 7 | 70% | 12 | 86% | 16 | 80% | |
| Kindergarten: Dinh To | 3 | 30% | 2 | 14% | 4 | 20% | |
| Primary School: Dong Mai | 20 | 100% | 20 | 100% | 4 | 80% | |
| Primary School: Dai Do | 0 | 0% | 0 | 0% | 1 | 20% | |
| **Symptoms** | | | | | | | |
| Abdominal pain | 13 | 36% | 14 | 35% | 6 | 19% | 0.22 |
| Constipation | 19 | 53% | 17 | 43% | 16 | 50% | 0.65 |
| "Other" health problems | 15 | 42% | 25 | 63% | 15 | 47% | 0.17 |
| **Physical size** | | | | | | | |
| BMI (mean and SD) | 15.4 (1.6) | | 15 (1.8) | | 15.5 (1.8) | | 0.99 |
| Age 0-2 years | (10) | | (9) | | (12) | | |
| Stature (Length) <94% predicted | 5 | 50% | 4 | 44% | 3 | 25% | 0.15 |
| Age 3-5 years | (6) | | (13) | | (15) | | |
| Stature (Length) <94% predicted | 0 | 0% | 4 | 31% | 3 | 20% | 0.30 |
| Age 6-10 years | (20) | | (19) | | (5) | | |
| Stature (Length) <94% predicted | 7 | 35% | 9 | 47% | 1 | 20% | 0.48 |
| **Household Lead Recycling Activities** | | | | | | | |
| **Lead recycling at home** | | | | | | | |
| Currently | 0 | 0% | 0 | 0% | 4 | 13% | 0.007 |
| Past (not currently) | 7 | 19% | 10 | 28% | 3 | 8% | 0.25 |
| Ever | 7 | 19% | 10 | 24% | 7 | 22% | 0.87 |
| Lead removed from batteries | 6 | 17% | 7 | 17% | 2 | 6% | 0.34 |
| Lead cooked | 2 | 6% | 5 | 12% | 3 | 9% | 0.60 |
| Lead casted | 1 | 3% | 1 | 2% | 2 | 6% | 0.65 |
| Lead cooked or casted | 3 | 8% | 5 | 12% | 5 | 16% | 0.65 |
| **Family involvement in recycling** | | | | | | | |
| Currently | 11 | 31% | 26 | 63% | 22 | 69% | 0.001 |
| Currently: >1 family member | 3 | 8% | 9 | 22% | 9 | 28% | 0.09 |
| Past (not currently) | 7 | 19% | 10 | 28% | 2 | 6% | 0.10 |
| Ever | 18 | 50% | 36 | 88% | 24 | 75% | 0.001 |
| Ever: >1 family member | 9 | 25% | 13 | 32% | 9 | 28% | 0.80 |
| **Home Environment** | | | | | | | |
| **Distance from home to recycling** | | | | | | | |
| <100m to central facility | 23 | 64% | 19 | 46% | 16 | 50% | 0.28 |
| <100m to burning of recycling waste | 13 | 36% | 10 | 24% | 4 | 13% | 0.08 |
| <10m to nearest legal or illegal facility | 0 | 0% | 1 | 2% | 3 | 9% | 0.10 |
| ≤10m to nearest legal or illegal facility | 3 | 8% | 2 | 5% | 5 | 16% | 0.28 |
| **Battery casings used at house** | | | | | | | |
| Used outside (reported) | 14 | 39% | 23 | 56% | 15 | 47% | 0.32 |
| Used outside (observed) | 14 | 39% | 17 | 41% | 18 | 56% | 0.30 |
| Used inside (reported) | 14 | 39% | 20 | 49% | 13 | 41% | 0.64 |
| Used inside (observed) | 17 | 47% | 17 | 41% | 14 | 44% | 0.88 |
| **Floor surface** | | | | | | | 0.62 |
| Soil | 1 | 3% | 2 | 5% | 1 | 3% | |
| Mats over bare soil | 16 | 44% | 19 | 46% | 15 | 47% | |
| Brick | 14 | 39% | 13 | 32% | 10 | 31% | |
| Cement | 1 | 3% | 1 | 2% | 0 | 0% | |
| Tile | 0 | 0% | 0 | 0% | 2 | 6% | |
| Finished materials (brick, cement, tile) | 15 | 42% | 14 | 34% | 12 | 38% | 0.85 |
| **Yard surface** | | | | | | | 0.07 |
| Brick | 17 | 47% | 26 | 63% | 22 | 69% | |
| Cement | 15 | 42% | 9 | 22% | 6 | 19% | |
| **Garden** | 17 | 47% | 27 | 75% | 20 | 56% | 0.28 |

* Blood lead level (BLL) determined by fingerstick blood sample and Lead Care II ™ test instrument.

** Significance determined by chi-square or Fisher exact test or oneway ANOVA. P-value shown in red if ≤0.10.

Note: There were 26 households with 2 tested children, and 1 household with 3 tested children. The between-group differences and statistical significance shown in this table did not change substantially when analysis was restricted to 1 child/household (ie, youngest or oldest child).

Younger age was significantly associated with very high BLL (p=0.008). Figure 5 demonstrates the trends in BLL over the age range of the children in the study.

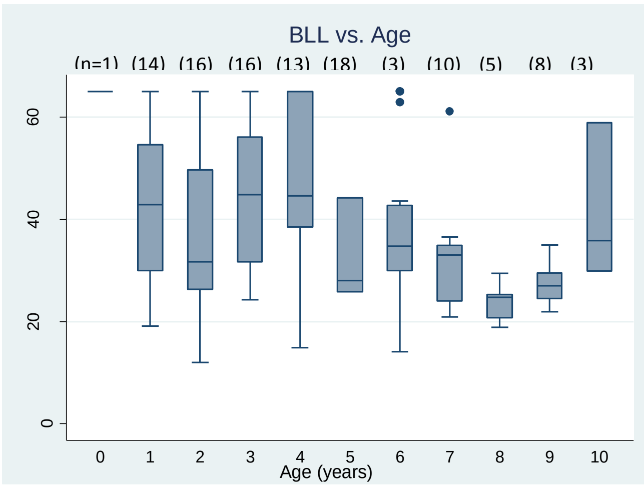


**Figure 5: Distribution of BLL at each year of age**

Current recycling activities in the home were significantly associated with very high BLL (p=0.007). All four children whose families recycled in the home were in the highest outcome category. Past home recycling activities (p=0.25) conferred no risk of *very* high BLL, regardless of the nature of involvement in recycling (although BLLs were high in the entire sample).

Current family involvement in recycling activities at the centralized facility on the outskirts of town conferred a significant risk of very high BLL (p=0.001). Furthermore, more than one family member being involved in recycling activities was suggestive of an association with very high BLL (p=0.09; figure 6). In contrast, past family member involvement did not confer increased risk of further elevated BLL (p=0.14).

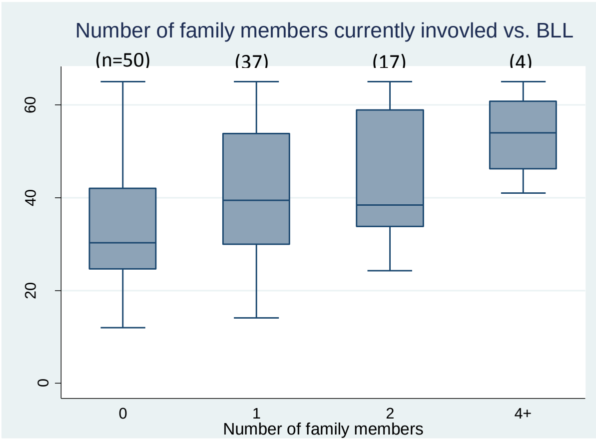


**Figure 6: Distribution of BLL relative to the number of family members involved in legal recycling activities.**

There were two variables relating to the home environment that suggested risk for very high BLL: the use of brick in the yard (p=0.07) and home proximity to a recycling facility. While location within 100m of a central recycling facility was not a risk factor (p=0.28), proximity of less than 10m from an illegal or legal recycling facility was suggestive (p=0.10) of elevated risk. Proximity to the burning of recycling wastes was suggestive of a decreased risk (p=0.08). Battery casing usage inside or outside the house, material used as flooring within the house, and the presence of a garden did not yield any significant associations with very high BLL.

Gender and school attended were not significantly associated with risk of very high BLL. There was no increased incidence of physical symptoms, such as abdominal pain, constipation, or general “other” health problems between the outcome categories. Similarly, there was no significant difference in BMI or stature among the outcome categories.

Results of the multinomial logistic regression are shown in Table 3. When compared to the lowest BLL category (reference) current family involvement was significantly associated with moderately elevated BLL (30-44.9 µg/dL). Relative to reference outcome category all variables included in the model were significantly associated with very high BLL ($\geq$ 45 µg/dL).

Table 3

**Results of multinomial logistic regression controlling for household effects.***

| **BLL (µg/dL )** | | | **RR** | **95% CI** | | **Signif** (p) ** |
|---|---|---|---|---|---|---|
| **10-29.9** | *Reference Lead Level Category* | | | | | |
| **30-44.9** | Age (years) | | | | | |
| | | 6-10 | *Reference age category* | | | |
| | | 3-5 | 1.9 | 0.5 | 7.5 | 0.35 |
| | | 0-2 | 0.7 | 0.2 | 2.6 | 0.60 |
| | Current Family Involvement in recycling | | 5.2 | 1.6 | 16.8 | 0.01 |
| | Brick Yard Surface | | 3.5 | 0.9 | 13.7 | 0.07 |
| **≥45** | Age (years) | | | | | |
| | | 6-10 | *Reference age category* | | | |
| | | 3-5 | 7.8 | 1.6 | 38.0 | 0.01 |
| | | 0-2 | 4.1 | 1.2 | 14.3 | 0.02 |
| | Current Family Involvement in recycling | | 7.6 | 1.9 | 30.0 | 0.00 |
| | Brick Yard Surface | | 4.6 | 1.0 | 20.6 | 0.05 |

* Current home recycling and proximity to recycling centers could not be included in the regression due to 0 values in critical categories.

** P-values shown in red if $\leq$ 0.05.

Note that there were 56 households with one child, 25 households with two children, and one household with three children. When this analysis was replicated using the oldest and then using the youngest child in each household, the results did not appreciably vary. A comparison of the

| | | **Old (µg/dL)** | | | Total |
|---|---|---|---|---|---|
| | | 10-29.9 | 30-44.9 | ≥ 45 | |
| **Young (µg/dL)** | 10-29.9 | 6 | 1 | 0 | 7 |
| | 30-44.9 | 3 | 7 | 1 | 11 |
| | ≥45 | 1 | 3 | 4 | 8 |
| | Total | 10 | 11 | 5 | |

Figure 7: Household concordance table

oldest and youngest children within each household (household concordance) is shown above in Figure 7.

## Discussion-

Even with the centralization of recycling processes at the outskirts of town and a law banning home-based recycling practices in 2006, the BLLs of all children screened in this study were elevated, many substantially. It is therefore likely that there is a high level of generalized environmental contamination throughout the village requiring broad remediation efforts. However, there are clearly additional risk factors such as younger age, home-based recycling, proximity to recycling facilities, family member involvement in recycling, and materials used inside or outside the house that further increase the child's risk for high BLL. The risk factors identified in this study are relevant to the intervention in Dong Mai village and potentially also in other similar battery recycling villages in Vietnam.

### *Home based recycling operations*

While home-based battery recycling was outlawed following a 2006 study demonstrating environmental contamination and elevated urine lead levels among children, it is still a common practice in Dong Mai village. Four children in three of the 82 households involved in this study were exposed to home-based operations. These children had among the highest BLL values recorded. Home recycling was noted by village health workers at three other households in the village. Essentially all aspects of the recycling process, from demolishing the raw batteries to melting and casting the lead, were observed in some or all of the home-based recycling facilities visited. These facilities were located in the front yards of the houses, frequently covered with tin roofing, and had no observable dust or emission control precautions in place.

From conversations with village leaders and families, there appears to be awareness among villagers that lead exposure, resulting from home-based recycling operations, is harmful to children and adults. However, recycling at home allowed individuals to keep their own hours, be closer to their children and family, work in a more comfortable environment relative to the centralized facility, and ultimately make more money. Of the homes I visited, the largest houses belonged to the families that had recycling operations. In a traditionally poor community with few alternatives, it seems likely that home-based battery recycling may be too lucrative and convenient for many to give up.

### *Take-home exposure*

A far more common situation than home-based recycling was for family members to be involved in legal recycling activities located in a large warehouse on the outskirts of the village. Exactly half of the 82 households, or 60 of 109 subjects, had family members who participated in recycling activities. As family involvement was significantly associated with very high BLL and increasing family members (>1) was suggestive of increasing risk, it would appear that take-home exposure is a significant contributor to the children's risk of exposure. I was only briefly permitted to visit the centralized facilities, but noticed no facility for workers to wash or change into or out of work clothes. Furthermore, not all employees wore uniforms and few wore appropriate personal protective equipment (PPE).

### *Proximity to legal or illegal recycling facilities*

One of the risk factors we examined in this study was proximity of the child's home to legal or illegal recycling facilities. As home-based recycling operations were scattered throughout the village one would expect ample opportunities for exposure. Living in homes less than 10 meters from a recycling facility was suggestive of an increased risk of very high BLL. The lack of significance is likely influenced by the relatively small number (n=4) of children living this close to recycling operations. Two other variables looking at proximity to recycling used a 100m cutoff as the distance of risk. In retrospect this number is likely far too high and neither variable proved informative. In fact, living less than 100 m from the burning of recycling waste suggested a reduced risk for very high BLL. This is likely due to the uneven distribution of ages – there were a greater number of older children among those living within 100m of burning processes than those that lived farther away. As older age is inversely associated with risk, a spurious decrease in risk was observed.

### *Younger age and yard materials*

Younger age was significantly associated with increased risk of further elevated BLL. There is a striking drop in BLL value at ages five and older. Of the 44 children in the oldest age category, only five were in the highest BLL category.  This is expected given the behaviors of younger children, such as crawling on the ground and age-appropriate hand-to mouth behaviors, which are known to put them at elevated risk for exposure. Furthermore, we found that the use of certain materials that children are likely to come into contact with in the yard, specifically brick, conferred increased risk of exposure. Again, this makes sense due to the fact that bricks contain a greater surface area in which to hold dusts, including lead dusts.

### *General exposures at the home*

Battery casings were used widely throughout Dong Mai village. They are used for fences, tables, chairs, and as storage containers both inside and outside of homes. It was anticipated that the battery casings likely harbored some residual lead dusts and would be a risk for exposure. While it is possible, or perhaps even likely, that battery casings do in fact harbor some lead dusts, the amount of exposure form these casings was  not a major risk factor for very high BLL in this study. Similarly, the material used for the floor inside the home and the presence of a garden at the home were not associated with higher BLL category (p=0.62 and p=0.28, respectively).

### *Symptoms*

The questionnaire for the family contained several brief questions examining symptoms commonly associated with elevated lead levels. Interestingly, neither the prevalence of GI effects, such as GI discomfort or constipation, nor the prevalence of "other health problems" demonstrated any trends within the outcome categories. Furthermore, there was no sign of stunting, as measured by BMI, or decrease in stature associated with outcome categories.

### *Agreement between the LeadCare® II and the GFAAS analysis*

The GFAAS analysis was conducted at the NIOEH laboratory. UW researchers were not involved in this process and there was no calibration curve or other form of quality control demonstrated by NIOEH researchers. While there are no particular reasons to expect the results of the laboratory analysis to be flawed, it is also difficult to be certain about their accuracy. Regardless, when comparing GFAAS with the LeadCare® II, it would appear that, in general, the LeadCare® II read higher BLL values than did the laboratory analysis. In several instances the discrepancy was particularly large (ranging from -22 to 40 μg/dL). While precautions were taken to minimize contamination of the capillary blood sampling including observed hand washing, residual contamination of the finger with environmental lead is certainly possible.

### *Next Steps*

Further work is required in Dong Mai village to identify individuals in need of immediate attention. Of the approximately 300 children in the village, 109 were screened in this study. All of these children had BLLs sufficiently high to warrant at least monitoring, exposure reduction, and potentially chelation therapy. Thirty-two subjects had screening BLLs above the treatment threshold as defined by the CDC. Upon confirmatory venipuncture analysis, BLLs generally decreased but were still substantial enough to require the urgent attention of the public health and medical authorities. Importantly, over 200 children in Dong Mai village who did not participate in this study may also be in danger and similarly in need of exposure reduction and medical attention. Furthermore, none of the more than 500 lead battery recycling workers have been screened for lead exposure though many of these individuals likely have very high exposures.

While screening is important to identify individuals requiring immediate medical attention, it is clear that all villagers, especially the children, living in Dong Mai are at risk for lead exposure. Based on the results of this study, the first action item should center on enforcing the law banning home-based recycling activities. This is likely a major contributor to the BLLs observed. Subsequently, clean-up efforts along with stricter occupational controls are necessary to reduce the degree of exposures to both children and adults. Community-wide cleanup efforts should focus on past or recent recycling locations, homes located close to current recycling centers, homes with young children living in them, and homes that contain materials, such as brick, that are thought to be harboring residual lead.

Lead battery recycling communities similar to Dong Mai village are located throughout Vietnam and, thus, there are likely many more children and adults suffering from the preventable adverse physical and cognitive effects of lead. The potential significance of the results of this study therefore extends beyond Dong Mai. This study has described *1)* what the possible extent of exposure is in other locations, *2)* what the addressable risk factors are for very high BLL, and *3)* has informed the approach necessary to identify and address problems with lead exposure in these communities.

1. Research in other Battery Recycling villages is needed, but this study's findings suggest that, as compared to children in urban areas, BLLs are much higher and more likely to require clinical attention in children residing in battery recycling villages. Screening should be conducted in similar battery recycling villages throughout Vietnam to determine if the trends observed in Dong Mai hold true.
2. As risk factors for very high BLL among children in other battery recycling villages in Vietnam will likely be quite similar, the interventions and lessons that are being learned in the process of reducing lead exposure in Dong Mai can be applied to these other locations as well. Enforcing a ban on home-based recycling, minimizing take-home exposure from centralized facilities, and generalized clean-up of the home environment is important in other battery recycling villages in Vietnam.
3. A significant challenge is that, even with governmental and community concern regarding lead exposure, there is a lack of administrative capacity and financial resources necessary for prompt wide-scale remediation projects. However, through partnership with the NIOEH it is clearer what the Vietnamese public health and medical communities require for identifying and addressing childhood exposures in Vietnam and how to channel our energies in the most efficient way possible. The use of a portable screening device was useful in the rural village of Dong Mai as was the enlistment and education of local health authorities in screening efforts.

The LeadCare® II, under ideal climatic conditions is potentially very useful in Vietnam. There are several considerations that must be taken into account, however. This study was conducted in Vietnam in December, when the temperature and humidity were well within the operating range of the LeadCare II. During many times of the year the LeadCare® II must be housed in an air-conditioned location. This can potentially pose practical challenges, especially when working in rural locations. Investigators must also be very careful regarding environmental contamination of the fingertips if capillary samples are to be drawn. Of the 24 subjects in this study whose BLLs were evaluated using the LeadCare II and the laboratory analysis, a majority had higher BLLs values using the LeadCare II indicating likely fingertip contamination. Potential solutions to this problem include rigorous hand washing protocol and using pre-packaged wipes, such as LeadTech wipes, to remove environmental lead from the fingertip prior to sampling.

Based on the household analysis in this study, the youngest child in a given household is most likely to have a higher BLL than their older siblings. In 24 out of 26 households with two or more children, the youngest child had an equivalent or elevated BLL relative to the oldest child. Further, the degree to which the youngest child represents the BLLs in the household is more conservative as the younger child's BLL is more likely to be disproportionately elevated relative to their older siblings than vice versa. Therefore, in settings with limited resources for screening programs, such as in Vietnam and other limited resource settings, focusing household screening efforts on the youngest child is likely the most conservative and sensitive approach.

According to our partners at the NIOEH, clinics in Vietnam do not use the oral chelating agent, succimer, in chelation treatment, and they were under the impression that Succimer is not available in Vietnam. However, a separate contact at Can Tho College of

Medicine confirmed that "The Ministry of Health of Vietnam is importing BAL, CANA2-EDTA and Succimer." This suggests a need for better communication within Vietnam for handling intoxication cases.[33] Succimer is ideal for the treatment of most of the children in this study who potentially require chelation therapy. It is recommended by CDC for children with BLLs between 45 and 69 µg/dL, can be used on an outpatient basis, does not appear to increase gastrointestinal absorption of lead in situations of persistent low level exposures, and has a relatively minimal side effect profile. In contrast, the available chelating agent (EDTA) must be administered on an inpatient basis via IV infusion and is associated with greater risk of BLL rebound following treatment, can be associated with increased absorption of lead in persistent exposure settings, and has a greater side effect profile. Clearly, outpatient treatment with succimer is preferable, especially in a resource poor area like Dong Mai. We will continue to work with the NIOEH and other Vietnamese and international health authorities to make this drug more readily available to populations in need.

As we continue to work with Dong Mai village and the NIOEH, we hope to gain knowledge as to the responsiveness of handicraft villages in eradicating illegal home recycling activities in the face of increased education and knowledge of the compromised health of their children.

## Conclusion

This study of Dong Mai village shed light on a much greater systemic problem among battery recycling handicraft villages throughout Vietnam. Fortunately, the Vietnamese government as well as the residents in the handicraft villages are aware of the problem and are engaging in a long though challenging process of reducing childhood lead exposure. In the United States, the average BLL of a child in the 1970s was close to 20 µg/dL, it is now under 2 µg/dL. It took significant time and a concerted effort among the US public health and medical communities to achieve reduced childhood BLLs. Likewise, considerable effort and time is required from the Vietnamese public health authorities, the medical community, as well as outside organizations to reduce the BLLs among susceptible children in Vietnam.

Lead has immense potential to harm children and to stunt communities. Fortunately, with enough commitment and dedication, lead exposure is entirely preventable. The children of Vietnam deserve the full attention of their government and the international community.

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# Appendix A

National Institute of Occupational and Environmental Health LETTERHEAD

Date

Dr. Bill Daniell

Dr. Catherine Karr

University of Washington

Fax: 1-206-744-9935

RE: Lead recycling practice and childhood lead exposure in Dong Mai village [Vietnam]

Dear Drs. Daniell and Karr,

On behalf of the National Institute of Occupational and Environmental Health, we are excited with this opportunity to collaborate with the University of Washington on this important pediatric blood lead testing project. Lead battery recycling is an important industry in Vietnam, and we look forward to working with you to identify children with elevated blood lead levels. This project also will also indirectly help to build pediatric environmental medicine capacity on this topic in Vietnam.

Sincerely,

Nguyen Bich Diep, MSc, PhD.
*Vice Director*
National Institute of Occupational & Environmental Health

WHO Collaborating Center for Occupational Health
57 Le Qui Don Street, Hanoi, Vietnam
Tel: 84.4.39714361

Email: diepyhld@yahoo.com

Cc: Lo Van Tung, MD

National Institute of Occupational & Environmental Health

# Appendix B

**QUESTIONNAIRE FOR RISK OF LEAD EXPOSURE**

1. Full name of child …………………………….. Male ☐ Female ☐

2. Address……………………………………………………………………

3. Date of Birth ………………..

4. Today's date…………………

**Occupational Risks of Lead Exposure**

1. Does the child go to school outside of the home?

   Yes ☐ School Name.................................................

   No ☐

2. Now or at any time in the past, did a member of the household participate in lead recycling activities? If no, skip to question number **6.**

   Yes ☐ No ☐ Don't Know ☐

3. How many household members have been involved in lead recycling?

   Currently ……………….

   In past ……………..

4. Has this child ever participated in lead recycling?

   Yes ☐ No ☐ Don't Know ☐

5. Has lead ever been recycled in this house:

   In the past? Yes ☐ No ☐

   Currently? Yes ☐ No ☐

6. If yes, what activities?

   Lead Removal ☐ Cooking Lead ☐ Others ☐

7. Did your family use casings of old batteries inside the house for:

   Walls ☐ Furniture ☐ Other ☐

8. Did your family use casings of old batteries for making outdoor items:

   Driveway ☐

   Fences ☐

   Other ☐

9. Now or at anytime in the past, was there a household based lead battery recycling operation within 100m of the home where this child lives?

   Yes ☐ No ☐ Don't Know ☐

10. Approximate distance to nearest recycling facility…………m

11. Now or at any time in the past was there a centralized lead battery recycling factory within 100m of the home?

    Yes ☐ No ☐ Don't Know ☐

12. Now or at any time in the past, has waste from lead recycling activities been burned within 100m of the home where this child lives?

Yes ☐ No ☐ Don’t Know ☐

**Household Sources of Lead Exposure**

13. Source of drinking water for the family:

Tap ☐
Bottled water ☐
Rainwater ☐

14. Does this child live in a home where cooking containers or utensils are made from lead?

Yes ☐ No ☐ Don’t Know ☐

**Clinical Symptom**

15. Body height………cm; body weight………...kg
16. Did your child usually have abdominal pain?

Yes ☐ No ☐

17. Did your child usually have constipation?

Yes ☐ No ☐

18. Did your child have any health problems?

Yes ☐ No ☐

19. What are health problems?..........................................................................
.......................................................................................................................
.......................................................................................................................
.......................................................................................................................
.......................................................................................................................

# Appendix C

**Observations of the Investigator**

20. What the floor inside the child's home paved with?

Bare Soil ☐ Brick ☐ Cement ☐ Wood☐ Mats over bare soil ☐ Other ☐

21. What does the yard consist of? (what if there are several that apply?)

Bare Soil ☐ cement ☐ brick☐ grass/weeds/vegetation ☐ Other ☐

22. What is on the garden?

No garden ☐ Uncultivated ☐ Planting grass ☐ Planting trees ☐ Cultivated ☐

23. Do you see any battery casings inside the house?

Walls ☐
Furniture ☐
Other ☐
None observed ☐

24. Do you see any battery casings outside the house?

Driveway ☐
Fences ☐
Other ☐
None Observe ☐

# Appendix D

**National Institute of Occupational and Environmental Health**

**University of Washington (USA)**

Lead recycling practice and childhood lead exposure in Dong Mai village [Vietnam]

**Blood Lead Level Family Reporting Form**

Child's Name ______________________________________________

Investigator's Name ________________________________________

Recently we tested this child's blood for lead. The child's blood lead level was________ ug/dl.

**We recommend the below actions for your child.**

□ <10 ug/dl. This child's blood lead level is normal. This child does not require any additional medical testing or care.

□ 10 – 14 ug/dl. This child's blood lead level is slightly elevated. We recommend you try to reduce this child's exposure to lead by making the changes described in the lead exposure reduction factsheet. We also recommend this child eat a healthy diet.

□ 15 – 19 ug/dl. This child's blood lead level is slightly elevated. We recommend you try to reduce this child's exposure to lead by making the changes described in the lead exposure reduction factsheet. We also recommend this child eat a healthy diet. In 3 months, we recommend this child have a repeat blood lead level test.

□ 20 – 44 ug/dl. This child's blood lead level is elevated. It is important to try to reduce this child's exposure to lead by making the changes described in the lead exposure reduction factsheet. We also recommend this child eat a healthy diet. In addition, we recommend this child have a medical evaluation which may include a medical and exposure history and a physical examination. The medical evaluation may include additional testing. Someone may visit this child's home to recommend ways to reduce this child's exposure to lead.

□ > 44 ug/dl. This child's blood lead level is very high. It is very important to try to reduce this child's exposure to lead. Ways to reduce lead exposure are described in lead exposure reduction factsheet. We also recommend this child eat a healthy diet. In addition, we recommend this child have a medical evaluation which may include a medical and exposure history and a physical examination. The medical evaluation may also include additional testing. This child may be offered special treatment to reduce his or her blood lead level. Someone may visit this child's home to recommend ways to reduce this child's exposure to lead.

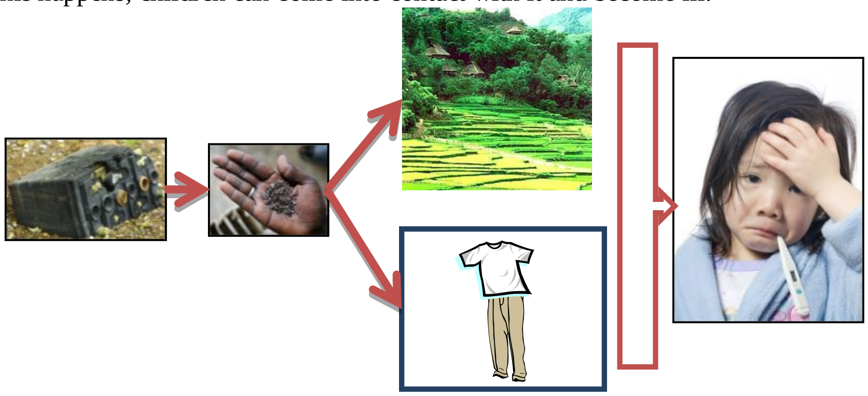
**For more information contact Dr. Tung, MD, Deputy Head, Department of School Health, National Institute of Occupational and Environmental Health, Hanoi. 84.4.39716003**

# Appendix E

## What is Lead and where is it found?

Lead is a metal and can be very useful. It is currently used in batteries, paints and other building materials. While it is useful in many ways, if people, especially children, are exposed to too much lead it can make them sick.

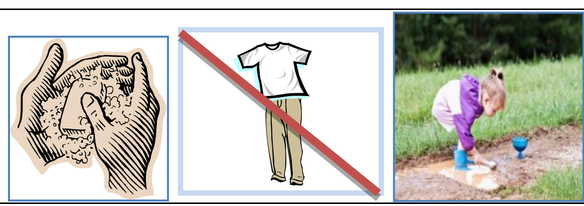
Lead becomes problematic when it gets out of batteries and into the environment. It can pollute the soil, water, air, even clothing. If this happens, children can come into contact with it and become ill.



## Why is it bad for your children?

Even low levels of lead in the environment can have bad effects on children, even if they don't appear sick. At low levels lead can have bad effects on the brain such as decreased intelligence, behavioral problems, and problems concentrating. It can also slow the growth and development of the child. At higher levels, lead can have bad effects on the stomach, the kidneys, and the liver.

## How to Prevent Lead poisoning:

| | |
|---|---|
| **Keeping the Home Clean** | |
|  | • Decrease dust in the home by mopping with water and dusting<br>• Remove shoes before entering the home.<br>• Have a mat at entrance to home to keep dirt outside |
| | |
|  | • Wash children's hands frequently, especially with meals<br>• Remove work cloths and wash hands before entering home<br>• Discourage children from playing in soil. |
| **Encourage a healthy diet** | |
|  | A healthy diet helps protect against lead poisoning:<br>• **Iron-** eggs, beans, and red meat<br>• **Vitamin C-** fruits, citrus<br>• **Calcium-** green beans, yogurt, cheese |