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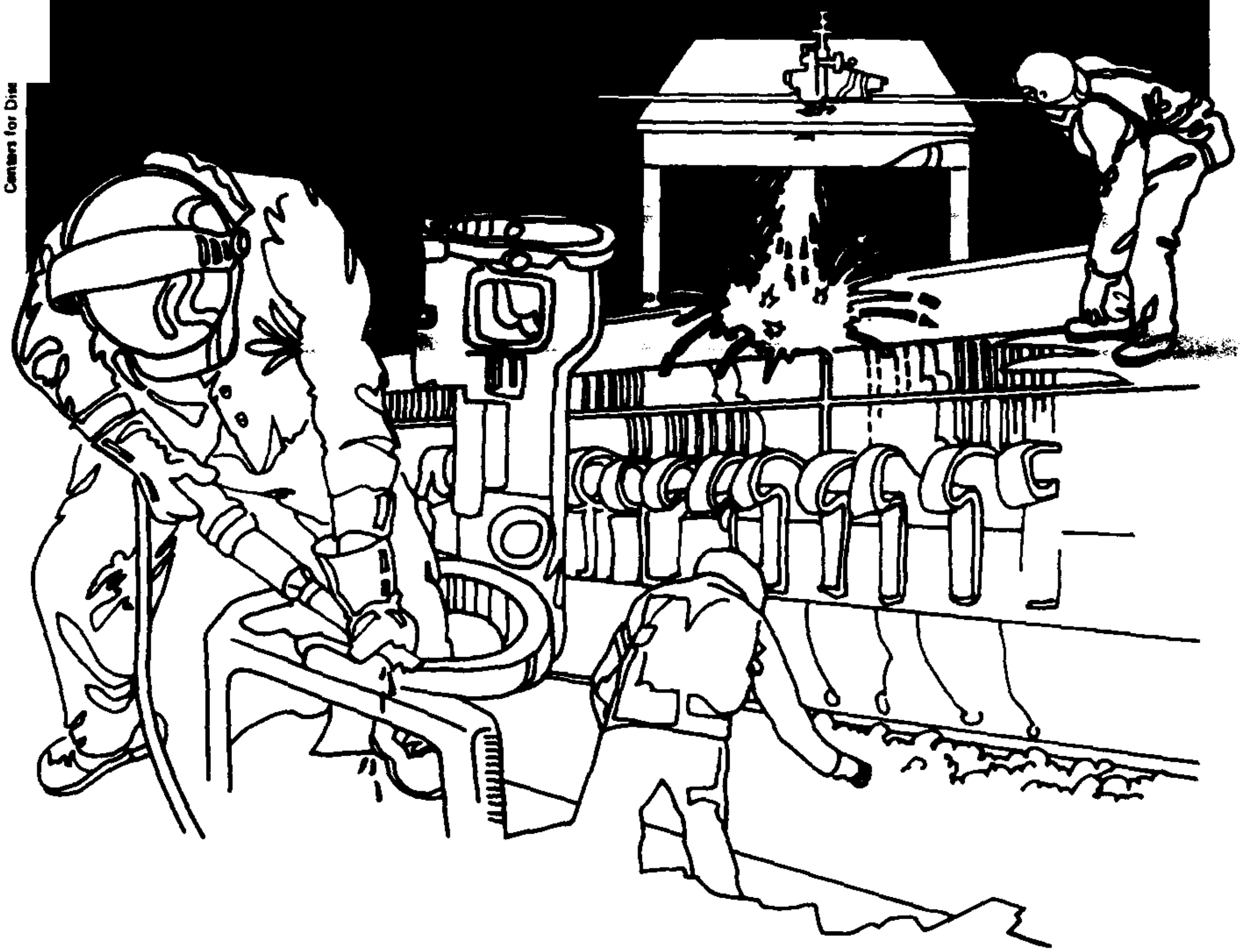

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Health Hazard Evaluation Report

HETA 87-371-1989
TECHNICAL ASSISTANCE TO THE
JAMAICAN MINISTRY OF HEALTH
KINGSTON, JAMAICA

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

HETA 87-371-1989
SEPTEMBER 1989
TECHNICAL ASSISTANCE TO THE
JAMAICAN MINISTRY OF HEALTH
KINGSTON, JAMAICA

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I. SUMMARY

On January 26, 1987, the Principal Medical Officer of the Epidemiology Unit, Jamaican Ministry of Health (MOH), Kingston, requested technical assistance from the National Institute for Occupational Safety and Health (NIOSH) in studying lead poisoning in Jamaica. NIOSH, along with the Center for Environmental Health and Injury Control (CEHIC), assisted the MOH between October 12-16, 1987, by surveying occupational and environmental lead exposure at backyard battery repair shops (BBRS) in Kingston. These small shops, typically located in residential areas, repair and rebuild automotive batteries. This survey was one of three NIOSH studies conducted consecutively with the Jamaican MOH between October 4 and 24, 1987. The two remaining surveys (reported separately) concerned lead exposures at three battery manufacturers in Kingston and in a residential community near Spanishtown, Jamaica.

To assess lead exposure among battery repair shop workers, 10 battery repair shops (involving 23 battery repair workers) were surveyed. Additionally, to investigate the risk of lead poisoning among household members associated with a BBRS, environmental and blood lead (PbB) levels were measured at 24 households (112 individuals). These households either had a BBRS worker living there or were located at a BBRS premises. Measurements were also made at 18 neighborhood control households (74 individuals).

The geometric mean lead concentration of seven work-shift air samples collected at selected repair shops was 21 ug/m^3, time weighted averaged (TWA) over the period sampled. This is well below the U.S. Occupational Safety and Health Administration Permissible Exposure Limit for airborne lead exposure of 50 ug/m^3 for an 8-hour TWA. It should be emphasized that different criteria and exposure limits are applied in various countries regarding exposure to toxic substances in the working environment.

Sixty-five percent of repair shop workers had blood lead (PbB) levels above 60 micrograms per deciliter (ug/dl, geometric mean was 64 ug/dl for all workers tested). The U.S. OSHA standard for lead in blood was selected to evaluate BBRS workers. This regulation requires employees whose PbB level is 40 ug/dl or greater to be retested every two months, and be removed from a lead-exposed job if their average PbB level is 50 ug/dl or more over a 6 month period. A PbB level of 60 ug/dl or greater, confirmed by retesting within two weeks, is an indication for immediate medical removal.

Elevated PbB ($\geq$ 25 ug/dl, non-occupational) was common among subjects of all ages living at BBRS premises, especially among children less than age 12. For screening purposes, the U.S. Centers for Disease Control (CDC) defines an elevated PbB level as $\geq$ 25 ug/dl. Fifteen of 35 children living at BBRS premises (43%) had PbB greater than 70 ug/dl, a level above which acute lead encephalopathy can develop. Potentially hazardous soil and house dust lead levels were also common at BBRS premises, where 84% of yards had soil lead levels above 500 parts per million (ppm) and 73% of households had dust lead levels exceeding 1500 ug of lead per square meter of floor space. Both of these concentrations have been associated with elevated PbB levels in children.

Geometric mean blood and environmental lead levels were significantly lower at control households, where less than 10% of the subjects in all age groups had elevated PbB (maximum 33 ug/dl). Sharing a premises with a BBRS was a stronger determinant of household PbB and environmental contamination than was the presence of a BBRS worker in a household. Blood lead levels were associated with soil and house dust levels in all age groups. Engineering controls and respiratory protection were judged to be inadequate at all the BBRS premises surveyed.

The backyard battery repair shops such as those surveyed in Jamaica create a high lead poisoning risk for workers and nearby residents. It is the opinion of the NIOSH investigators that controlling health hazards created by existing BBRS will be difficult; thus establishment of shops at residential premises should be discouraged. Where shops continue to operate, changes in shop layout, dust suppression measures, and safe work practices by workers (showering and changing work clothing) should reduce ongoing contamination of living areas. Recommendations for reducing lead exposure through work practice changes and limiting access to potentially contaminated areas are included in Section IX.

KEYWORDS: SIC 3691 (Storage Batteries), lead, blood lead, battery manufacturing, occupational diseases, developing countries, adults, children, environmental contamination.

II. INTRODUCTION

The third largest of the Greater Antilles, Jamaica is located 550 miles south of Florida. The island, settled by British farmers in 1655, became independent within the British Commonwealth in 1962 and a prime minister heads the government. Jamaica has approximately 2.3 million English speaking inhabitants and the capital city, Kingston, is its largest metropolitan area (665,000 people). Principal industries include bauxite (aluminum ore) mining, and tourism. Sugar, bananas, and coffee, while fluctuating in prominence, remain the chief export crops.

On January 26, 1987, the Principal Medical Officer of the Epidemiology Unit in the Jamaican Ministry of Health (MOH) requested NIOSH assistance in studying and preventing lead poisoning in Jamaica. Two preliminary visits to Jamaica were made by NIOSH on May 4-8, and August 10-21, 1987. During these planning trips various Jamaican public health officials were contacted and results of blood lead (PbB) testing by the Jamaica Government Chemist were examined.

This NIOSH investigation was planned after a review of Jamaica Government Chemist records revealed that of 22 Kingston children hospitalized for lead poisoning between January 1986 and March 1987, 19 lived at or near a battery repair shop. These companies are commonly referred to as "backyard" battery repair shops (BBRS) because of their location. To better define the risk and mechanisms of lead poisoning associated with BBRS, and to evaluate other possible sources of lead exposure, an epidemiologic and environmental survey was conducted between October 12 and 16, 1987.

The main purpose of this investigation was to gather information needed to develop strategies to control lead exposure among the BBRS workers, their families, and residents of households located at the premises of the BBRS. More specifically, the evaluation had three main objectives:

1. To determine the prevalence of potentially toxic lead levels in workers at BBRS, and what environmental and personal factors influence those levels.

2. To determine the prevalence of toxic lead levels in household members of BBRS employees, and in the members of households located on the premises who may not be related to shop employees, and to determine characteristics of the BBRS that may influence those levels.

3. To determine the degree of lead contamination of soil in yards where BBRS's are located, and in household dust of homes of BBRS

workers and neighbors, so that abatement strategies can be developed to prevent cases of lead poisoning.

III. BACKGROUND

While the risk of occupational lead exposure in the battery industry has been thoroughly studied and regulated in most developed countries, less is known about lead exposure among battery workers in developing countries. Because lead-acid battery manufacture can be carried out in small scale operations, using relatively simple technology, it is an attractive industry for some developing nations.

Small shops involved in the repair or rebuilding of lead-acid automotive batteries are found throughout Jamaica. Officials at the MOH were aware of approximately 50 such shops; more than 30 of which were in Kingston.[1] The actual number is believed to be much larger. These shops generally employ one or two men (including the owner) and are usually located on the same premises with at least one home or apartment where the owner/operator may live. The repair/rebuilding process uses battery plates and other small lead parts salvaged from used batteries or cast in the shop from lead reclaimed by crude smelting processes.

Nearly all aspects of battery rebuilding and repair may be performed, on an intermittent basis, at a BBRS. An average lead-acid battery contains over 20 pounds of lead derived from either primary (separating elemental lead from lead containing ores) or secondary lead smelting (extracting lead from recycled batteries and other salvaged materials containing lead). In Jamaica, secondary smelting is the principal lead source for the larger, more established battery companies. This reclaimed lead, containing trace amounts of antimony, arsenic, and other impurities, is used to cast parts like battery terminals, cell connectors, and battery grids where impurities are not critical to the desired performance. While some of the BBRS premises purchased lead from the largest battery company in Kingston, most shops used crude smelting techniques (ranging from a wood fire and kettle to gas welding torches) to melt and recover lead from used batteries. This smelting was typically performed outdoors on an intermittent basis. Most of the BBRS sites were littered with battery parts and lead-contaminated dross from the smelting process.

During repair or rebuilding the battery grid (a metallic lattice) may be recoated (pasted) with lead oxide PbO (litharge) to make the battery plate. The freshly pasted battery plates are dried, usually by hanging the plates from a line outdoors. Any excess metal and PbO is filed off and the finished battery plates are manually stacked with separators (insulators) and grouped together. Lead connectors are gas-welded onto the terminals of the individual plates to form the battery cell.

The assembled battery cells are placed in plastic battery cases, remaining small lead parts (intercell connectors) are attached, and the battery case cover is installed. The batteries are filled with sulfuric acid and wet-charged by applying an electric current. Throughout the BBRS repair process many parts, such as battery cases, intercell connectors, and acid, may be salvaged from used batteries.

IV. EVALUATION DESIGN

A. Selection of BBRS Premises and Control Households

Since many BBRS operated intermittently and often changed locations, a convenience sample of 11 BBRS located in Kingston, and for which shop owners could be contacted and agreed to participate in the survey, were included. One of the selected shops had closed, but was included in the selection of survey households. The characteristics of these BBRS are summarized in Table 1.

In this evaluation 24 households in Kingston were surveyed with any of three types of "exposure" to the 11 BBRS: (1) all of five worker households at shop premises ("BBRS/worker" households); (2) all of 12 non-worker households at shop premises ("BBRS" households); and (3) seven of 12 worker households located in Kingston, but not at the shop premises. Five worker households in Kingston could not be contacted or refused participation.

For each address where an exposed household (or households) was located, one control household was selected. The control household was selected as the first site identified on the same street (moving in a randomly selected direction from the exposed address) that met the following criteria: (1) it was at least 50 meters from the BBRS site: (2) a responsible adult was at home and agreed to participate; and (3) if the exposed household had a child 6 months to 6 years of age, the control household had a child in this age group. This selection process was intended to choose control households with housing, socioeconomic status, and exposure to automobile lead emissions that were similar to the "exposed" households. Because some exposed households shared the same addresses, only 18 control households were chosen.

B. Medical

At each participating household a responsible adult (usually the female head of household) was interviewed about the household and all members. Depending on the age of household members, information on smoking, pica (the craving for unnatural foods), time spent unattended by an adult, and how often a child played in a BBRS work area was also collected. Venous blood samples were obtained from available household members over the age of 6 months. Household characteristics and participation by household members in PbB testing are summarized in Table 2.

As an additional comparison group for children in the household survey, blood samples were obtained at the principal children's hospital in Kingston from 35 children less than six years of age who presented for minor surgery or acute illness requiring a diagnostic blood-test during four day-shifts in October, 1987. Children with neurologic or gastrointestinal symptoms were excluded.

Lead in blood was analyzed by anodic stripping voltmetry at a NIOSH contract lab which participated in a Centers for Disease Control (CDC) proficiency testing program.[2]

Informed verbal consent was obtained from all participants. Written consent was not used based on advice from the Jamaican MOH that it would be an impractical means of obtaining consent among Jamaicans, many of who have limited literacy and a cultural reluctance to sign any document. This waiver was approved by a NIOSH human subjects review board as not adversely affecting subject rights and welfare. Venipuncture was the only medical procedure performed in this study. Participants with elevated PbB levels (or their guardians) were informed of their results and, if indicated, referred for medical evaluation.

C. Air, Soil and Surface Wipe Sampling for Lead

1. Personal and General Area Air Sampling

Because of the intermittent nature of repair shop operations, air samples (breathing-zone or area) were collected at a shop only if batteries were being repaired on the day the shop was surveyed. Air samples were collected on mixed cellulose-ester filters using a flow rate of 2.5 liters per minute for a period as near as possible to an entire work shift. A total of 3 personal (breathing-zone) air samples and 4 general area air samples were collected from the BBRS surveyed. In the lab, the filters were digested using concentrated nitric and perchloric acids. The residues obtained were then dissolved in a dilute solution of the same acids and the resulting sample solutions analyzed for trace metals by inductively coupled plasma-atomic emission spectrometry. This analytical procedure follows the NIOSH analytical method No. 7300 for elements.[3] The limit of quantitation for the sample set was 1.0 microgram per filter.

2. Soil Sampling

a. Location

An "area" core soil sample from each household was collected in the approximate center of the yard. The lead levels from these soil samples are referred to in this report as "SPb-area". Since it was hypothesized that children with pica might preferentially eat lead-contaminated soil, soil near likely sources of contamination, such as piles of lead scrap, was also sampled. The highest lead levels from these samples are referred to as "SPb-peak". Some yards were shared by several households, therefore each soil lead level was applied to all households in a yard to determine lead exposure for all the household members. Soil samples were inadvertently omitted at two control households and surface dust samples (discussed later) were omitted at two exposed households; all of these households were excluded from analyses involving environmental lead levels.

b. Collection Method and Analysis

Core samples of soil to a depth of eight centimeters (cm) were collected using a Hoeffer® soil sampler and sections between 0 and 1 cm depth and 7 and 8 cm depth were bagged separately (in plastic bags) for analysis. The sections were chosen to represent surface soil conditions (0 to 1 cm) and "deep" soil conditions (7 to 8 cm) at the various BBRS and household locations. In the analysis that follows only the surface (0 to 1 cm) samples were used.

The soil samples were prepared for analysis in the lab by placing 1.000 ± 0.005 gram of dried sample in 100 milliliters (ml) of 4% nitric/1% perchloric acids. This solution was sonicated for 1 hour and allowed to sit overnight before analysis. A sequential scanning inductively coupled plasma emission spectrometer was used for all measurements. The limit of detection (LOD) for this sample set was 5 ug of lead per gram of sample.

3. Surface (Wipe) Sampling

a. Location

Wipe samples for lead in house dust (referred to as DPb) were collected, using a procedure described in the literature (with some modifications), from the floor of the room where children spent the most time.[4] Surface samples were collected at the various indoor locations using an aluminum template with a sampling area of 414 square centimeters. A metal retaining frame from a high volume air sampler was used for the template.

b. Collection Method and Analysis

Surface wipe samples for lead were collected using commercially available pre-moistened towelettes available in a self-dispensing package.[4] While there are a variety of pre-moistened towelettes available, the Wash N' Dri® brand selected for this investigation dissolved readily in the nitric and perchloric acids used in the subsequent lead analysis. Field blank values for lead using this brand were consistently low (less than 1 ug of lead per towelette). Separate towelettes were also used between sampling sites to clean the template. Disposable gloves were worn during sampling to reduce the chance of cross contamination. Following collection, the towelette was placed in a glass scintillation vial for transportation to the lab.

In the lab, the wipe samples were removed from the vials and placed in covered 125 ml Phillips beakers with 20 ml of concentrated nitric acid and 4 ml of 70% perchloric acid. The samples were refluxed overnight at 150°C. The covers were removed and the samples taken to dryness at the same temperature. The residues were dissolved in a 10 ml mixture of 4% nitric--1% perchloric acids. The sample solutions were analyzed for lead content by inductively coupled argon plasma--atomic emission spectroscopy (ICP-AES) according to NIOSH Method 7300 for elements, with modifications.[3] The limit of quantitation (LOQ) for this sample set was 1.0 ug of lead per sample.

4. Paint Chip Sampling

Paint samples were collected if peeling or chipping paint was observed at the study household. The samples were scraped off the surface with a pen knife into a plastic bag for transportation to the lab. In the lab, a representative aliquot of each sample was weighed and then digested with nitric and perchloric acids. The residues were dissolved in a dilute solution of the same acids, and the resulting sample solutions were analyzed for lead by ICP-AES. The LOQ for this sample set was 0.01% lead.

5. Drinking Water Sampling

Although lead contamination was considered unlikely, drinking water samples (20 ml) were collected from a convenience sample of households into plastic vials. The samples were immediately acidified to a pH of approximately 1 to 2 by adding 5 drops of concentrated hydrochloric acid (6N, Supplier: Baker Ultrex, Inc.) to keep any lead that might be present in solution.

The acidified samples were shipped in their plastic containers to the lab where they were analyzed using Method No. 200.7 developed by the U.S. Environmental Protection Agency. A sequential scanning ICP-AES was used for all measurements. The LOD for this sample set was 100 ug/liter. No lead was detected in any of the drinking water samples collected in this evaluation.

6. Other

Vehicle traffic density at each address was recorded using a subjective four-level scale, ranging from "light" (only an occasional vehicle seen) to "heavy" (continuous stop and go traffic).

V. EVALUATION CRITERIA

A. Environmental Lead Determinations

The U.S. OSHA Permissible Exposure Limit (PEL) for lead in air, 50 ug/m^3 calculated as an 8-hour time-weighted average (TWA) for daily exposure, was selected to evaluate BBRS workers. This regulation also requires semi-annual blood lead monitoring of employees exposed to 30 ug/m^3 or greater of lead. Employees whose blood lead level is 40 ug/dl or greater must be retested every two months, and be removed from a lead-exposed job if their average blood lead level is 50 ug/dl or more over a 6 month period. A blood lead level of 60 ug/dl or greater, confirmed by retesting within two weeks, is an indication for immediate medical removal.

It should be emphasized that different criteria and exposure limits are applied in various countries regarding exposure to toxic substances in the working environment. For example, in 1980 a comprehensive Approved Code of Practice was issued in the United Kingdom (U.K.) regarding the control of lead at work. The U.K. occupational exposure limit for lead in air is 150 ug/m^3, 8-hour TWA (compared to the U.S. limit of 50 ug/m^3). In the U.K. workers with a confirmed PbB level in excess of 80 ug/dl are certified as unfit for work which exposes them to lead. For women of reproductive capacity the U.K. PbB level drops to 40 ug/dl.

Soil lead contamination was considered excessive if the concentration exceeded 500 parts per million (ppm), a level associated with increased lead absorption in previous studies.[5] Dust lead levels were considered excessive if they exceeded 1500 ug/m^2, a level associated with increased PbB levels in urban U.S. children.[6] Paint samples were considered "lead free" if they contained less than 0.06% lead by weight.[5]

B. Medical

Inhalation (breathing) of lead dust and fume is the major route of lead exposure in industry. A secondary source of exposure may be from ingestion (swallowing) of lead dust deposited on food, cigarettes, or other objects and is predominant in non-industrial situations. Once absorbed, lead is excreted from the body very slowly. Absorbed lead can damage the kidneys, peripheral and central nervous systems, and the blood forming organs (bone marrow). These effects may be felt as weakness, tiredness, irritability, digestive disturbances, high blood pressure, kidney damage, mental deficiency, or slowed reaction times. Chronic lead exposure is associated with infertility and with fetal damage in pregnant women.[7,8]

Overt symptoms of lead poisoning in adults generally begin at PbB levels between 60 and 120 ug/dl.[7] Neurologic, hematologic, and reproductive effects, however, may be detectable at much lower levels, and the World Health Organization has recommended an upper limit of 40 ug/dl for adult males.[9] For screening purposes, CDC defines an elevated blood lead level as $\geq$ 25 ug/dl.[5] Recent studies suggest that exposure of the developing fetus to blood lead levels far below these levels is associated with subtle neurologic impairment in early life and that there may not be a safe threshold for this effect.[10,11]

D. Statistical Methods

Values for blood and environmental lead levels were log-transformed to correct for skewness in distributions. Differences in group geometric means for environmental lead levels were assessed using t-tests or analysis of variance. Household blood lead data were analyzed using a statistical program that accounted for households (rather than individuals) as sampling units to compute statistical significance of regression coefficients.[12] Analysis was carried out for three age groups: (1) ages 6 months through 5 years (pre-school children); (2) ages 6 through 11 years (school-aged children); and (3) 12 years and older ("adult", beyond the age of compulsory schooling).

Because control households were neighborhood-matched to exposed household addresses, comparisons between exposed and control households were done twice: once using all control households (unmatched) and again by using only the subset of control households associated with a given sub-group of exposed households. Because mean differences were not appreciably affected by either approach, results from the unmatched approach are shown. Instances where comparisons were statistically significant for only one type of analysis have been noted.

VI. RESULTS

A. Blood Lead Levels

The geometric mean PbB among all repair shop workers was 64 ug/dl. All but one of these workers had PbB levels of 40 ug/dl and above, and 13 (57%) had PbB above 60 ug/dl.

Among household members in all age groups, geometric mean PbB **levels were significantly higher among subjects who lived in households at BBRS premises than among subjects living in control households (Figure 1). Blood lead levels were higher in children less than 12 years of age than in subjects 12 and older. Thirty-four of 35 children living at BBRS premises had elevated PbB (≥ 25 ug/dl) with a range of 31 to 170 ug/dl. Fifteen of these children had PbB of 70 ug/dl or greater, a level above which acute lead encephalopathy can develop.**[14]

Living at a BBRS premises was a more important risk factor for elevated PbB than living in a household with a BBRS worker. However, PbB levels were significantly higher among subjects aged six and older from worker households (not at BBRS premises) than among control subjects in the same age groups. For subjects 12 years and older, this difference was not statistically significant (p=0.31) when only neighborhood-matched controls were used.

Hospital control subjects less than 6 years of age had a geometric mean PbB level of 11 ug/dl (range 3-32 ug/dl, 9% ≥ 25 ug/dl). This was somewhat lower than neighborhood controls of the same age, in whom the geometric mean level was 14 ug/dl ($p > 0.20$, t-test); however, this difference was not statistically significant.

B. Environmental Measurements

1. Air Samples in Backyard Battery Shops

The geometric mean of the air lead concentrations in the BBRSs sampled during this evaluation was 21 ug/m^3. The highest "workplace" concentration obtained was 66 ug/m^3, the only air sample which exceeded the U.S. OSHA PEL for lead of 50 ug/m^3.

2. Soil Samples

As shown in Figure 2, soil lead levels were significantly higher at households located at BBRS premises, compared with control households. Peak soil lead levels (SPb-peak) at BBRS premises were very high (geometric mean at BBRS/worker households was 58,884 ppm, range 16,000 to 400,000 ppm). This was not unexpected, as these samples were taken near gross lead contamination. However, SPb-area levels at BBRS premises showed that whole yards were contaminated as well (geometric mean at BBRS/worker households was 3388 ppm, range 51 to 33,000 ppm). Eighty-four percent of SPb-area lead levels exceeded 500 ppm, a concentration above which PbB levels in children are said to increase.[5] This contrasts to only 13% of the SPb-area samples at control households which exceeded 500 ppm (range 3 to 10,500 ppm). The difference in geometric mean SPb-area between BBRS/worker households and control households was still large, but not significant, when only neighborhood-matched controls were compared (3388 ppm vs. 117 ppm, p=0.10). Location at a BBRS premises was a stronger determinant of soil lead than having a BBRS worker in the household.

3. Surface Dust Samples

Dust lead levels were higher at exposed households than at control households. Of those samples taken at BBRS premises, 73% exceeded 1500 ug of Pb per square meter of floor (ug/m^2, range 190 to 53,140 ug/m^2), a level associated with elevated PbB levels in urban children.[6] This threshold was exceeded at 17% of control households (range 120 to 4810 ug/m^2).

Among those households located at BBRS premises, DPb (but not SPb) was associated with the number of batteries repaired per week at the shop (r=0.72, p=0.01). However, there was no association between SPb or DPb levels and the length of time a BBRS had been in operation, or the distance from the house to the shop. Three BBRS had an enclosure for storing lead scrap, but SPb or DPb levels were not significantly different at households located at these BBRS premises compared to those located at premises of shops with no enclosure. Although none of the BBRS surveyed had adequate shower or changing facilities, workers from four of 12 households (BBRS/worker or worker) reported always changing their clothes before going home. Geometric mean house DPb levels at these households were actually higher than at other worker households.

4. Paint Chip Samples

Six of 10 paint chip samples collected exceeded 0.06% lead by weight; however, only 1 of these 10 samples exceeded 1.0% lead by weight. This sample had a 12% lead content and was taken at the control household with the highest house dust lead level.

5. Water Samples

Lead was not detected in any of the drinking water samples collected in this evaluation.

6. Vehicular Traffic

Vehicle traffic density was judged to be "light" at 59% of BBRS premises compared to 71% of control household addresses. However, using analysis of variance to adjust for the type of household, traffic density did not have a significant effect on SPb or DPb levels ($p > 0.40$).

C. Relationship of Environmental to Blood Lead Levels

Blood lead levels were strongly associated with SPb or DPb levels in all age groups, as shown in Table 3. The percent of variance in PbB levels explained by environmental lead (r^2) and the estimated regression slopes (ß's) were higher for children less than 12 years of age than for older subjects. Multivariate models of PbB were derived using a backwards elimination procedure to select a minimal subset of study variables that best explained PbB among study subjects in each age group. These are shown in Figure 3. The final models for all age groups included either SPb-area or SPb-peak as an independent variable. The model for children less than 6 included SPb-peak, while SPb-area was included in the final model for children aged 6 to 11 years. Lead in dust was included in the final models for subjects 6 years of age and older. Playing at least weekly in a BBRS area was an independent predictor of higher PbB in children, and male sex was independently associated with higher PbB levels in subjects age 12 and older.

In order to better understand the routes of lead exposure at households on the premises of BBRS, results for four households located at three "atypical" BBRS were examined in more detail. Two of these atypical BBRS were not currently repairing batteries (one had closed in 1984 and the other was presently limited to charging batteries). Dust lead levels at the three households at these two premises were relatively low (range 193 to 869 ug/m^2), but soil lead levels in the yards ranged from 800 to 6800 ppm. The four children less than 6 years living at these households had PbB levels of 48, 55, 57, and 65 ug/dl.

The third atypical BBRS was completely separated from the exposed household on the premises by a chain link fence, and the shop yard and household yard had separate street entrances. Dust lead levels at the exposed household were high (4600 ug/m^2), but SPb levels in the household yard (280 ppm) and the PbB level in the child living there (31 ug/dl) were moderate.

VII. DISCUSSION

This survey found elevated blood lead levels to be nearly universal among BBRS workers. Air lead levels at BBRS were low compared to those measured at Jamaican battery manufacturers (Ref. draft HHE report 87-371). It is possible that levels are at times quite high, such as during smelting operations. Given the intermittent nature of the processes at these shops, however, we believe the small number of samples collected during actual battery repair may over-estimate the time-weighted average air lead levels.

Despite comparatively low air lead exposure, this survey found elevated blood lead levels to be essentially universal among repair shop workers. These findings may have several explanations, including: (1) nearly all repair shop workers perform gas welding, which generates highly respirable lead fume; (2) repair shop worker households were found to be highly contaminated; and (3) repair shop workers appeared to have poor hygienic practices.

This evaluation found a high risk of elevated PbB levels among subjects living at BBRS, and this risk is not attributable to general environmental contamination in the urban Kingston environment. Children at these premises are at especially high risk of PbB levels that have been associated with acute lead encephalopathy. Blood lead levels in members of households at BBRS premises were higher than those reported in conjuction with home pottery making, cutlery tempering, and printing, but similar to those associated with home battery recycling.[14-16]

Although battery repair was generally limited to one part of a yard, soil contamination appeared to be distributed throughout yards shared by BBRS and households. Soil contamination may result from lead fume generated during the battery repair process or smelting of scrap lead, from lead dust being blown from scrap piles, from lead scrap being dragged or carted through yards, or from lead dust being tracked on the shoes and clothing of workers. The latter two mechanisms are suggested by data from BBRS with a separate street entrance and a fence preventing workers from passing through the residential portion of the yard.

Although based on small numbers of households, the data are also consistent with reports of house dust contamination by lead brought home on work clothes.[17,18] Changing work clothes was not associated with lower DPb levels, possibly because adequate changing and shower facilities were not provided at any of the shops surveyed.

Ingestion of soil lead and, to a lesser extent, dust lead appear to be important routes of lead exposure at BBRS households. This is supported by much higher PbB levels and stronger relationships between environmental and PbB in children (who tend to ingest more soil and absorb more lead) than in adults.[19] Although it was not possible to directly assess the role of inhaled airborne lead (due to the intermittent work at the BBRS during this survey), the presence of high SPb exposures and PbB levels in children living near the two shops where batteries were not being rebuilt (and, correspondingly, where airborne lead fume was not currently being generated), suggest that inhalation is not a major route of lead exposure in the children.

Because of the small sample size, correlations between exposure variables, and the limitations of the backwards elimination procedure for model selection, variables may have been excluded from the final multivariate models which were, in fact, important sources of lead exposure in the study population. Furthermore, it should be noted that households were not sampled to be representative of all Kingston households, so the strongest predictors of PbB levels in the study subjects should not be generalized to the Kingston population as a whole.

Although control children in this evaluation were not a random sample of children living in Kingston, their PbB levels suggest that potentially symptomatic PbB levels ($\geq$ 50 ug/dl) are unusual in Kingston children not exposed to BBRS, while elevated blood lead levels ($\geq$ 25 ug/dl) may not be uncommon in children living in the urban Kingston area. It is interesting to note that neighborhood and hospital control children in Kingston had PbB levels lower than those found among black children surveyed in U.S. cities between 1976 and 1980 (arithmetic mean = 23 ug/dl, 19% above 30 ug/dl).[20] This is despite the fact that

Jamaica, unlike the U.S., still uses leaded gasoline almost exclusively. Most households studied, however, were not on major thoroughfares, and deteriorating, heavily-leaded paint was not common. Among adults, higher PbB levels in males than females is consistent with U.S. data.[20] Some of the sex differences in this evaluation may result from some males participating in battery work, even though they were not formally employed at a BBRS.

In interpreting the results, the limitations of methods used to sample BBRS, households, and individuals should be considered. First, although the shops in this evaluation were typical of BBRS operations, it is a convenience sample. It is possible that more transient shops (which would have been excluded from this survey) relocate before soil lead contamination reaches the levels measured in this survey. Conversely, such transient shops could moderately contaminate multiple yards and expose more residents over time. Second, it is conceivable that lead contamination from a BBRS is not limited to the premises, but this survey did not assess lead contamination at households that were closer than 50 meters to a BBRS but not on the premises. Third, most household members who did not provide blood samples were at school or work when the home was visited by the investigators. These non-participants likely spend less time, on average, at home than participants, and their PbB levels may, therefore, be lower than those of participants in highly contaminated households.

VIII. CONCLUSIONS

Reasons for the proliferation of BBRS in Jamaica are numerous. Probably most important is a market demand for relatively inexpensive repaired or remanufactured car batteries. Small scale battery remanufacturing and/or repair operations have been reported in the Republic of Trinidad and Tobago and in Nigeria, and are likely to be found in other countries with similar economic and social conditions.[21,22] High unemployment, and a lack of awareness of chronic, subclinical lead toxicity, may also contribute to the popularity of BBRS.

The data from this survey suggest several important points, including: (1) BBRS create a high risk of lead toxicity for workers and nearby residents; (2) residential exposure occurs mainly by contamination of soil and house dust; and (3) lead contamination and elevated PbB levels appear to persist even after a BBRS closes. With this in mind, public health officials and clinicians in Jamaica should be alert to the high risk of lead poisoning among both BBRS workers and those individuals living at the premises of these cottage industries.

IX. RECOMMENDATIONS

Controlling health hazards created by existing BBRS will be difficult. The following recommendations are influenced by the myriad of the problems faced by the operators of BBRS, including limited financial resources, intermittent work, and the affordability and availability of materials necessary to make substantive improvements.

1. Establishment of BBRS at residential premises should be discouraged.

2. The layout of BBRS currently in operation should be changed to restrict public access to potentially contaminated areas. This could be achieved by the appropriate use of fencing and provisions for separate entrances for the repair shop and household(s) on the premises.

3. Implementation of dust suppression measures at the repair shops, including the elimination of dry sweeping. Regular wet sweeping and cleaning should be performed to minimize dust generation.

4. Compressed air, if available, should not be used to blow dust from machinery, parts, or worker's clothing.

5. Signs should be posted at all entrances to the BBRS area warning employees and the general public of the hazards associated with lead dust and fume.

6. Repair shop employees should not be permitted to eat, drink, or smoke in the work area since ingestion of lead can be a significant route of exposure.

7. Work clothing and laundering facilities should be provided for the BBRS workers. The changing of work clothing and showering by BBRS employees should <u>not</u> be done in the residential buildings located on the work premises.

8. Chemical splash goggles should be provided and worn whenever acid is handled.

9. In the event that a BBRS closes or relocates, existing contamination of nearby soil will remain a hazard to children unless it is removed or covered.

10. Children and workers exposed to BBRS should be regularly screened for elevated PbB to evaluate the effectiveness of any interventions.

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Acknowledgements:

NIOSH would like to thank the battery shop owners and Kingston residents whose cooperation made the survey possible; many individuals from the Ministry of Health, the Kingston/Saint Andrew health department, and the Environmental Control Division in Jamaica for their work as interviewers, phlebotomists, and drivers during the investigation; Patience Dennis, Sonja Roche and others at the Jamaica Government Chemist and Fred Phipps and Wayne Smallwood of NIOSH for assistance with specimen processing; Dr. Peter Eller of NIOSH for assistance in planning and processing environmental sampling; and Elaine Gunter of the Center for Environmental Health and Injury Control, CDC for assistance with blood lead quality control.

XII. DISTRIBUTION AND AVAILABILITY OF REPORT

Copies of this report are temporarily available upon request from NIOSH, Hazard Evaluations and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226. After 90 days, the report will be available through the National Technical Information Service (NTIS), 5285 Port Royal, Springfield, Virginia 22161. Information regarding its availability through NTIS can be obtained from NIOSH Publications Office at the Cincinnati address. Copies of this report have been sent to:

1. Dr. Peter Figuoroa, Epidemiology Unit, Jamaican Ministry of Health, 10 Caledonia Avenue, Kingston, Jamaica
2. U.S. Department of Labor, OSHA - Region III
3. Dr. Norma Andrews, Pan American Health Organization/World Health Organization Representative, 60 Knutsford Boulevard, Kingston 5, Jamaica.
4. Caribbean Epidemiology Centre, 16-18 Jamaica Boulevard, Federation Park, Port of Spain, Trinidad.
5. Dr. Homero Silva, Environmental Control Division, Life of Jamaica Building, 61 Halfway Tree Road, Kingston, Jamaica.

Definition of Terms Used in Figures 1, 2, and 3

BBRS/Worker:	Worker households at the premises of a backyard battery repair shop (BBRS).
BBRS:	Non-worker households at the premises of a backyard battery repair shop (BBRS).
Worker:	BBRS worker households in Kingston, Jamaica and not located at the premises of a backyard battery repair shop (BBRS).
Control:	A control household was the first site identified on the same street (moving in a randomly selected direction from the exposed premises) that met the following criteria: (1) it was at least 50 meters from the exposed address: (2) a responsible adult was at home and agreed to participate; and (3) if the exposed household had a child 6 months to 6 years of age, the control household had a child in this age group. This selection process was intended to choose control households with housing, socioeconomic status, and exposure to automobile lead emissions that were similar to the "exposed" households.
PbB:	Blood lead level, expressed in micrograms of lead per deciliter of blood.
SPb:	Lead concentration in soil samples collected from both exposed and control premises. SPb-Area refers to an "area" soil sample collected from the approximate center of the yard at each household. SPb-Peak refers to soil samples collected near visually obvious sources of lead contamination, such as piles of lead scrap. All soil lead concentrations are expressed in parts per million (ppm).
DPb:	Lead concentration in house dust. The samples were collected at exposed and control households from the floor of the room where children spent the most time. All dust samples are expressed in micrograms of lead per square meter of surface area (ug/m^2).

TABLE I - Characteristics of Backyard Battery Repair Shops (BBRS) Surveyed*

	Median	Range
Number of employees	2	1-9
Duration of operation (months)	44	12-240
Batteries repaired/rebuilt per week	5	2-12

*N=10, Excludes one shop no longer in operation.

TABLE II - HOUSEHOLD AND SUBJECT SELECTION

		Type of Household			
		BBRS/worker	BBRS	Worker	Control
Households surveyed		5	12	7	18
Mean income ($ US per week)		114	60	76	61
Mean no. persons per household		10.8	6.1	6.4	5.8
Mean months at current address		149	75	104	54
Subjects tested for PbB by Age					
0-5	N (% of those eligible)	7 (58%)	10 (100%)	4 (80%)	20 (87%)
6-11	N (% of those eligible)	5 (83%)	13 (87%)	4 (100%)	21 (88%)
≥ 12	N (% of those eligible)	21 (66%)	30 (67%)	18 (62%)	33 (58%)

BBRS = household located at backyard battery repair shop premises.
Worker = BBRS worker lives in household.

TABLE III - Univariate relationships between environmental and blood lead by age

		Dependent variable - $\log_{10}$(PbB) by age (years)		
		0-5	6-11	$\geq$ 12
Number of Subjects		38	34	95
Independent Variables				
Log_{10}(PbS-area)	r^2	0.53	0.64	0.38
	ß (se)	0.23 (0.04)	0.22 (0.03)	0.17 (0.03)
Log_{10}(PbS-peak)	r^2	0.57	0.57	0.43
	ß (se)	0.21 (0.03)	0.18 (0.03)	0.16 (0.03)
Log_{10}(PbD)	r^2	0.30	0.47	0.30
	ß (se)	0.35 (0.08)	0.31 (0.06)	0.25 (0.06)

Excludes subjects from households with missing PbS or PbD.

PbB - blood lead (μg/dl)

PbS - lead in soil (ppm)

PbD - lead in Housedust ($\mu g/m^2$)

r^2 - proportion of variance in PbB explained

ß - regression coefficient

se - Standard error

All regression coefficients significantly different from 0 at $p < 0.0005$.

FIGURE 1
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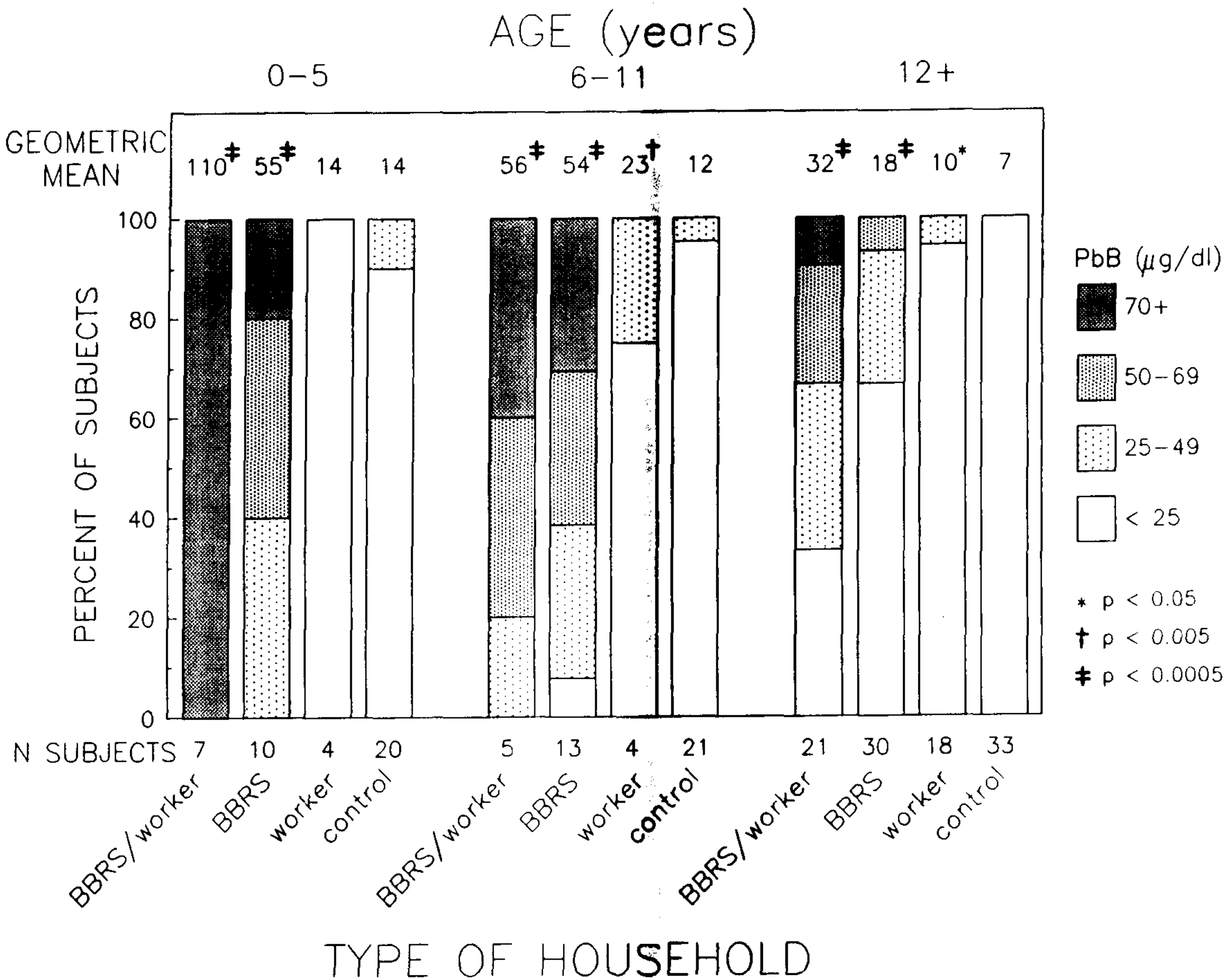

FIGURE 2
TECHNICAL ASSISTANCE TO THE JAMAICAN MINISTRY OF HEALTH
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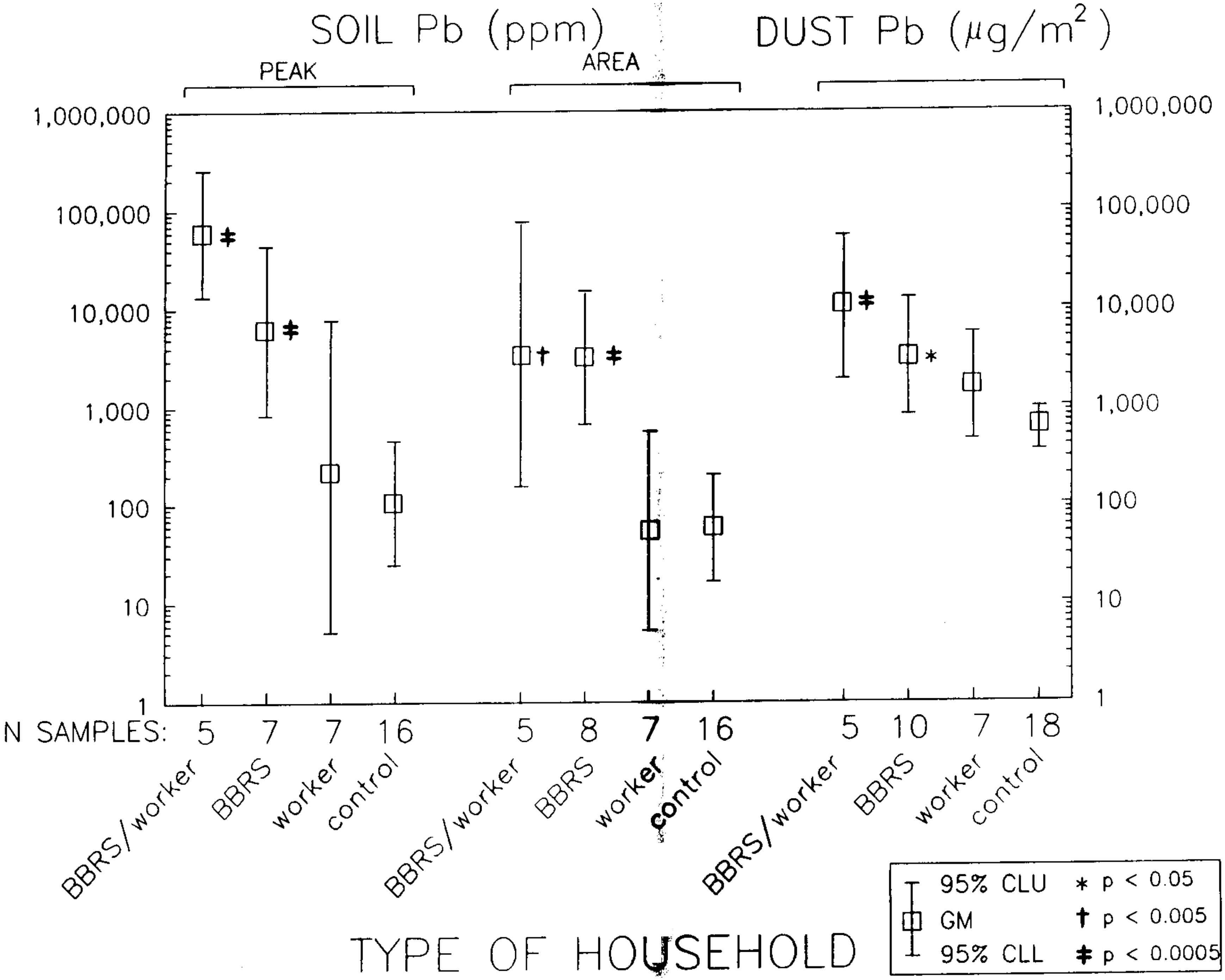

FIGURE 3
TECHNICAL ASSISTANCE TO THE JAMAICAN MINISTRY OF HEALTH
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