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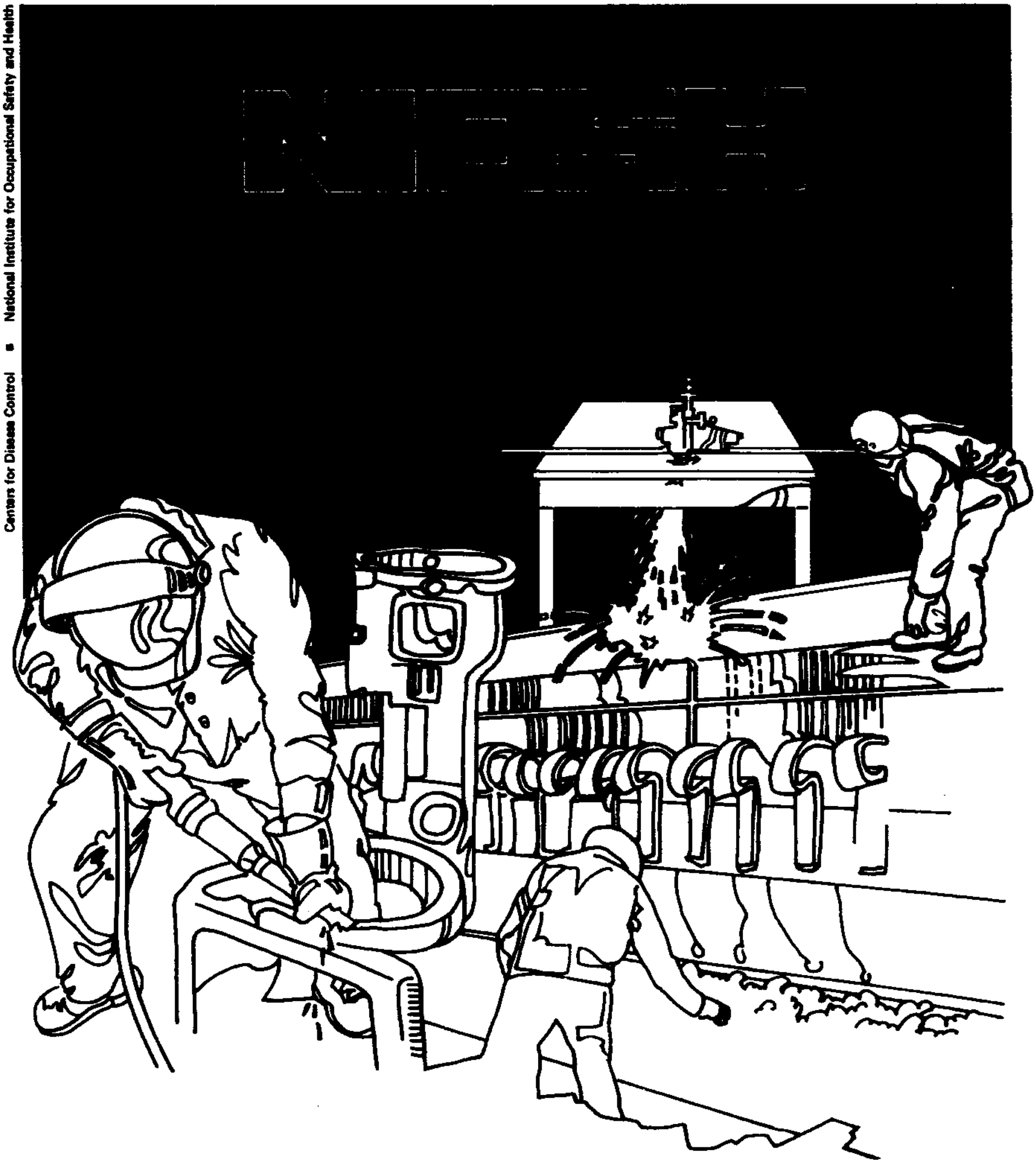

Health Hazard Evaluation Report

HETA 87-371-2000
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.

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TECHNICAL ASSISTANCE TO THE
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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 and preventing lead poisoning in Jamaica. A survey was conducted to assess causes of lead poisoning near a conventional secondary lead smelter ("established smelter") near Spanishtown, Jamaica. Fifty-eight households in the Red Pond Road community, the site of the established smelter and several small "backyard" lead smelters, and 21 households in Ebony Vale, an adjacent middle class community upwind from Red Pond, were investigated using questionnaires, soil and house dust lead measurements, and blood lead (PbB) measurements from 372 residents.

Soil lead levels in Red Pond exceeded 500 parts per million (ppm) at 24% of the households surveyed (maximum soil lead was 18,600 ppm). Soil lead concentrations in excess of 500 ppm have been associated with elevated PbB levels in children. In comparison the maximum soil lead was 150 ppm in Ebony Vale. Concentrations of lead in surface dust collected from Red Pond households ranged from 50 to 294,680 micrograms of lead per square meter (ug/m^2). This compares to the much lower range of 20 to 338 ug/m^2 of lead in dust collected from Ebony Vale residences. 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. Peeling housepaint was observed at one Ebony Vale and 27 Red Pond households. Ten paint samples exceeded 1% lead by weight (maximum 6.0%), all obtained from Red Pond households. Paint samples were considered "lead free" if they contained less than 0.06% lead by weight.

The geometric mean PbB level of those tested in Red Pond was more than twice that of those tested in Ebony Vale in all age groups ($p < 0.0005$). In Red Pond, 44% of children under age six years had PbB levels of 25 micrograms per deciliter (ug/dl) and above (range 5-98 ug/dl), compared to 0% in Ebony Vale. The World Health Organization has recommended an upper PbB level of 40 ug/dl for adult males. For screening purposes, the U.S. Centers for Disease Control (CDC) defines an elevated PbB level as $\geq$ 25 ug/dl.

Within the Red Pond community, proximity to a backyard smelter, proximity and direction to the established smelter, and a history of solid lead waste contamination in a yard were independent predictors of soil lead ($p < 0.05$). Soil lead was the strongest predictor of PbB among Red Pond subjects under 12 years of age, while lead smelter work was an important predictor in older subjects. Elevated PbB levels in children occurred at lower than expected soil lead levels.

NIOSH has concluded that the backyard lead smelting sites surveyed in the Red Pond Road community, in addition to the nearby conventional secondary lead smelter, create a high lead poisoning risk for nearby residents. It is the opinion of NIOSH investigators that controlling health hazards created by existing backyard lead smelting sites will be difficult, thus this activity should be discouraged. Recommendations for reducing lead exposure through hazard abatement (removing lead contaminated soil, dust, and contaminated debris), educational efforts for community residents, establishment of "clean" play areas for young children, and other aspects of a comprehensive intervention program are included in Section VIII.

KEY WORDS: SIC 3341 (Secondary Smelting and Refining of Nonferrous Metals), lead, blood lead, smelting, soil contamination, children, developing countries.

II. INTRODUCTION

Lead poisoning associated with conventional lead smelting in developed countries has been well described among both workers and community residents.[1-4] While airborne lead fume from smelters is the main vehicle of environmental contamination, the most important route of community lead exposure in such settings appears to be ingestion of lead-contaminated soil or house dust, especially by children.[5] Children of smelter workers may be at particularly high risk from exposure to lead dust brought home on work clothes.[6,7] Workers, and their families, may also be at risk of lead poisoning when lead-related work, including lead smelting, is done at home.[8]

Lead-related cottage industries have caused lead poisoning in both developed and in less developed countries.[9-11] These cottage industries appear to be more prevalent, however, in developing countries. This is a survey of residents living near a conventional, secondary lead smelter in Jamaica, where both smelter emissions, and a cottage industry known as "backyard" lead smelting, appear to be causes of environmental contamination and excessive lead absorption. An interim report, containing environmental and medical results and interim recommendations for reducing residential lead exposures, was provided to the Jamaican MOH on May 25, 1988. An earlier interim letter, dated February 11, 1988, was provided which recommended procedures for conducting a community survey to measure air lead levels when the established smelter was in operation.

III. BACKGROUND

A conventional lead smelter ("established smelter") has operated in a rural area of Saint Catherine Parish, Jamaica, since 1963. Operating as a secondary smelter, this facility reclaims lead from scrap, mainly used car batteries. In 1974, the emission controls of the plant were upgraded, including the addition of a bag filtration system to reduce lead particulate in stack emissions. The smelter usually operates for approximately two weeks out of every two month period, with the majority of the refined lead being transported to nearby Kingston.

The established smelter is located at the southeast corner of the Red Pond Road community (estimated population 2500), where earlier inquiries by public health workers identified other potential sources of lead contamination. Several crude "backyard" lead smelters operate in this relatively poor community. Operation of these backyard smelters was clandestine, but it was believed that some of the scrap used by these smelters was obtained from the established smelter, and that some established smelter employees also worked at backyard smelters. Some Red Pond residents reportedly used lead oxide-containing drums and dross (slag) obtained from the established smelter for, respectively, fencing and landfill material. A recently constructed middle-class housing development, Ebony Vale (estimated population 1600), is located east of the established smelter. Prevailing winds in the area, based on information obtained from the Jamaica MOH, are from the northeast. A general map of the Red Pond Road and Ebony Vale communities, and their proximity to the established lead smelter, is shown in Figure 1.

According to Jamaican health officials, lead poisoning cases in Red Pond have occurred for at least 10 years, and a review of records from the Jamaica Government Chemist and local hospital charts indicated that 19 children from Red Pond were hospitalized for lead poisoning between January 1986 and March 1987. No lead poisoning has been observed in Ebony Vale residents. In order to better define the prevalence, distribution, and causes of lead contamination and elevated blood lead (PbB) levels near the smelter, a cross-sectional survey of Red Pond and Ebony Vale was performed by NIOSH investigators during October 1987. It should be noted that the established smelter did not operate for several weeks before or during this survey; thus, no evaluation of the airborne lead emissions from this facility was made by NIOSH investigators.

IV. EVALUATION DESIGN AND METHODS

A. Household and Subject Selection

Potential study households were selected at random within Red Pond and Ebony Vale from maps of dwellings. Households with children less than six years of age were intentionally oversampled in Ebony Vale to increase the precision of the mean blood lead estimate in that age group. Survey procedures were completed at 49 Red Pond households (86% of those sampled) and 21 Ebony Vale households (68% of those sampled). Of the households sampled, but not surveyed, three households refused participation (one in Red Pond, two in Ebony Vale) and no adults were at home at 15 other households. In addition, all nine households in Red Pond that were reported by employees of the established smelter to be at, or adjacent to, backyard smelter sites were also surveyed.

B. Medical

At each participating household a responsible adult was interviewed. Information collected included demographics on household members, household income, whether lead smelting was performed at (or near) the household, and finally whether lead oxide drums or lead dross were present in the yard. Depending on the age of household members, information about occupation, smoking, pica (craving for unnatural foods), and time unattended by an adult was also collected. The results of household demographics and subject selection are summarized in Table 1.

Venous blood samples were obtained from available household members over six months of age. Lead in blood was analyzed by anodic stripping voltometry at a NIOSH contract lab which participated in a Centers for Disease Control (CDC) proficiency testing program.[12] The limit of quantitation (LOQ) was 5 micrograms per deciliter (ug/dl) for the PbB samples.

Informed verbal consent was obtained from all participants. Written consent was not sought 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.

C. Soil and Surface Wipe Sampling

1. 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 "Pb soil-area". Since it was hypothesized that children with pica might preferentially eat lead-contaminated soil, soil near likely sources of contamination, such as oxide drum fencing or lead scrap, was sampled and these peak values were reported as "Pb soil-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. Area soil samples were lost or omitted for five households (four in Red Pond and one in Ebony Vale).

b. Collection Method and Analysis

Two hundred and four 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 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 parts per million (ppm) for soil lead.

3. Surface (Wipe) Sampling

a. Location

One hundred and fifty-one surface 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 floors of rooms where children spent the most time.[13] 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. Dust samples were lost or omitted at four households (three in Red Pond and one in Ebony Vale)

b. Collection Method and Analysis

Surface wipe samples for lead were collected using commercially available pre-moistened towelettes available in a self-dispensing package.[13] 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 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.[14] The limit of quantitation (LOQ) for this sample set was 1 ug of lead per sample, or 24 ug of lead per square meter (ug/m^2). Samples with lead levels below the LOQ were assigned a value midway between zero and the LOQ for data analysis.

4. Paint Chip Sampling

Twenty-eight paint samples were collected where peeling or chipping 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 random 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.

D. Data Analysis

Blood and environmental lead levels were log-transformed to correct for skewness in distributions, and distances to (1) the nearest confirmed backyard smelter; (2) the secondary smelter; and (3) any lead waste contamination in a household yard (ie. dross landfill, lead oxide drum fencing) were square root-transformed to correct apparent non-linear relationships with environmental lead levels. T-tests and ordinary least squares regression were used to analyze environmental lead data. Blood lead data were analyzed using statistical programs that employ a Taylor series approximation to compute standard errors of estimated means and regression coefficients using households (rather than individuals) as sampling units.[15,16] Partial F tests were used to assess the significance of independent variables in multivariate models.

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 from among several guides in evaluating the "occupational" lead exposures in the Red Pond community.[17] Since smelting operations within the Red Pond community were intermittent, generally performed outdoors, and typically involved only one individual, it was difficult for NIOSH investigators to evaluate these "occupational" exposures. As a result, no samples for airborne lead were collected at these backyard smelters.

It should be emphasized that different criteria and exposure limits are enforced by various countries regarding occupational exposure to toxic substances. As an 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).

Soil lead contamination was considered excessive if the lead concentration exceeded 500 parts per million (ppm), a level associated with increased lead absorption in previous studies.[18] 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.[19] Paint samples were considered "lead free" if they contained less than 0.06% lead by weight.[19]

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 deposited on food, cigarettes, or other objects. 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.[20,21]

Overt symptoms of lead poisoning in adults generally begin at PbB levels between 60 and 120 ug/dl.[20] 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.[22] For biological monitoring purposes, the U.S. OSHA regulation requires semi-annual PbB monitoring of workers exposed to airborne lead concentrations of 30 ug/m^3 or greater.[17] A PbB level of 60 ug/dl or greater, confirmed by retesting within two weeks, is an indication for immediate medical removal. 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.

For screening purposes, the U.S. Centers for Disease Control (CDC) defines an elevated PbB level as $\geq$ 25 ug/dl.[18] The U.S. CDC also recommends that the PbB level of children and fetuses (and, therefore, in pregnant women) never exceed this level. This is based on the fact that lead may cause learning and behavioral difficulties in young children and that lead can cross the placenta and affect the developing fetus. Recent studies, in fact, suggest that exposure of the developing fetus to PbB levels far below 25 ug/dl is associated with subtle neurologic impairment in early life and that there may not be a safe threshold for this effect.[23,24]

VI. RESULTS

A. Environmental lead levels

Geometric mean Pb soil-area, Pb soil-peak, and Pb dust were 22, 31 and 7 times, respectively, higher in Red Pond than Ebony Vale ($p < 0.0005$, Table 2). Furthermore, 24% of randomly selected Red Pond households had Pb soil-area samples greater than 500 ppm, a threshold above which elevated PbB levels in children have been described.[18] In contrast, the highest Pb soil-peak in Ebony Vale was 150 ppm, and 14 Ebony Vale households had Pb soil-area below 5 ppm. Geometric mean Pb soil-peak was 30 times higher at possible backyard smelter households than at other Red Pond households ($p < 0.005$), and four possible backyard smelter households had Pb soil-peak levels greater than 50,000 ppm. Peeling housepaint was observed at one Ebony Vale and 27 Red Pond households. Of these 28 paint chip samples, ten exceeded 1% lead by weight (maximum 6.0%), all from Red Pond.

B. Blood Lead Levels

Blood lead levels were analyzed for three age groups: (1) six months through five years (pre-school children); (2) six through 11 years (school-aged children); and (3) 12 years and older ("adult", i.e. beyond the age of compulsory schooling). As shown in Figure 2, among subjects of randomly-selected households, the geometric mean PbB level was significantly higher in Red Pond than Ebony Vale in each age group ($p < 0.0005$), and decreased with age in both communities. Elevated PbB levels ($\geq$ 25 ug/dl) were common in Red Pond (44% of children under six years) but unusual in Ebony Vale. The prevalence of elevated PbB was higher among subjects living at possible backyard smelter households than at randomly-selected Red Pond households, and the geometric mean PbB levels were significantly higher at smelter households among subjects six through 11 years ($p < 0.0005$) and subjects 12 and older ($p < 0.05$).

C. Determinants of Environmental Lead Levels in Red Pond

Because elevated environmental and PbB levels were largely limited to Red Pond, subsequent analyses are reported for only that community. For these analyses, four sites were identified at, or adjacent to, possible backyard smelter households. Three additional sites at, or adjacent to, randomly-selected Red Pond households were identified as "confirmed" backyard smelter sites based on questionnaire responses and/or field observations which confirmed that smelting had occurred at those locations. NIOSH investigators were unable to confirm smelting at or near four other possible backyard smelter households. These sites were identified as "suspect" backyard smelter households. Two additional smelter sites were confirmed just outside of the community; one possible backyard smelter household had been chosen because it was nearest to one of these smelters, located in a wooded area about 50 meters away. This household, and all other randomly-selected households, were classified as non-backyard smelter households.

In assigning "sectors" of direction from the established smelter for subsequent analyses, the northeast and southeast quadrants were combined because of small numbers and similar environmental lead levels. The northwest quadrant was divided into two sectors because most study households were in that quadrant. Definitions, units, and categories for variables used in multivariate models are given in Table 3.

Higher Pb soil-area in Red Pond clustered near both the established smelter and backyard smelter sites (Figure 1).

Despite the prevailing wind direction, higher levels were also found near the road running northwest from the established smelter past four backyard smelter sites. Univariate analysis was consistent with the observed spatial pattern as soil and dust lead levels were strongly and inversely correlated with both distance to the nearest confirmed backyard smelter and distance to the smelter stack (Table 4). The correlations were stronger with backyard smelter distance. The strongest correlate of DPb was Pb soil-peak ($r=0.66$, $p < 0.0005$).

Multivariate models of environmental lead levels were arrived at by backwards selection, eliminating the least statistically significant predictors until only those significant at the $p < 0.05$ level remained. Distance to the nearest backyard smelter, distance and direction from the established smelter stack, and lead waste contamination (backyard smelting, dross landfill, or lead oxide drum fencing in a yard) were significant, independent predictors of soil lead levels. As shown in Table 5 these predictors together explained 82% of the variance in Pb soil-area and 75% of the variance in Pb soil-peak. Multivariate models predicted 14 ($10^{1.15}$) times higher Pb soil-peak levels and 2.7 ($10^{0.43}$) times higher Pb soil-area levêls in yards with a history of lead waste contamination than those in yards without such a history. Direction from the smelter stack and Pb soil-area explained 59% of the variance in DPb levels. Adjusted for other variables, the highest soil lead levels occurred in the southwest quadrant, downwind from the stack, while the highest dust levels occurred in the north-northwest quadrant. Lead level in peeling paint was not an independent predictor of soil or dust lead levels.

D. Determinants of Blood Lead Levels in Red Pond

To assess predictors of PbB levels within Red Pond, the 51 households where Pb soil-peak, Pb soil-area, and DPb were all obtained were included. In each age group, PbB was more strongly correlated with soil than dust lead (Table 4). The relationship with soil lead was strongest among children under 6 years of age ($r=0.75$ for Pb soil-area, $p < 0.0005$). Subjects "directly" exposed to backyard smelters, defined as persons living, working, or playing where lead is smelted, had an especially high risk of PbB levels of 50 ug/dl and above: 5 years, 67% risk; 6-11 years, 55%; 12 years, 22%.

Multivariate models for each age group, as shown in Table 6, were derived by backwards selection. Lead soil-area was a significant ($p < 0.05$) independent predictor of PbB levels among subjects less than six years and 6-11 years of age, but not among older subjects. Lead soil-area was the only significant predictor of PbB levels among children 6-11, explaining 51% of the variance. Among children under six, PbB level varied with direction from the established smelter, and increased with the percent of a household yard that was dirt-covered.

Among subjects 12 and older, distance to a backyard smelter, occupation, and sex were significant, independent predictors of blood lead. Seven community residents included in this survey were employed at the established smelter, but were not working full-time at the time of this study. The multivariate model indicated a geometric mean PbB in these individuals 1.9 ($10^{0.29}$) times that of adults not working in smelters, greater than the relative increase of 1.1 ($10^{0.06}$) for the 9 individuals working exclusively at backyard smelters. Males had a predicted geometric mean PbB level 1.4 ($10^{0.14}$) times that of females.

VII. DISCUSSION AND CONCLUSIONS

This survey documented environmental lead contamination and elevated PbB levels in the Red Pond Road Community. The lead hazard there is related to a well-known source, conventional lead smelting, and to a less familiar cottage industry, "backyard" lead smelting. Use of lead oxide drum fencing or dross landfill in Red Pond yards appears to cause not only the expected focal contamination (high peak soil lead levels) but also contamination of whole yards (high area soil lead levels). Leaded paint did not appear to be an important cause of either dust or soil contamination. The limited impact of lead smelting in middle class Ebony Vale community is probably due partly to wind direction near the established smelter and to dilution of lead contamination by the more recent grading of land during construction of this community. In addition, cottage smelters were found only in the older, poorer Red Pond community.

The spatial distribution of soil lead in Red Pond and the multivariate analysis support the conclusion that the established smelter and backyard smelters in Red Pond have both contributed to existing lead contamination. In addition to emissions of airborne lead fume from smelter operations, lead contamination may be spread by other routes. The relatively high soil lead concentrations along the road running northwest (and largely upwind) from the established smelter and through the Red Pond community may reflect both non-stack lead dust emissions from the grounds of the established smelter being spread by pedestrian and vehicular traffic and the presence of nearby backyard smelters. While the efficiency of the backyard smelting process has not been formally studied, such operations may reclaim as little as 30% of the lead in scrap; thus, much of the remainder is discarded as heavily contaminated dross skimmed from the molten lead.* Contamination may also be spread by lead dust that is blown or tracked from piles of dross or lead scrap at backyard smelter sites. The strong correlation between soil and dust lead levels, and the high dust lead levels along the road running northwest from the established smelter, suggest that tracking of lead-contaminated dust on shoes or feet may also cause house dust contamination.

Lead-contaminated soil appears to be a major route of lead absorbed by children in Red Pond. This is supported by higher PbB levels and stronger correlations between soil and PbB levels in children (who tend to ingest more soil and absorb more lead) than in adults. Pica did not explain higher PbB levels in children in our multivariate analysis. As in other studies near smelters, unintentional soil ingestion from normal hand to mouth behavior is probably a more common source of absorbed lead among Red Pond children than is true pica.

Soil lead of 500 ppm is a level above which PbB levels in children are said to increase, and a model derived from surveys near two smelters in the U.S. predicts a geometric mean PbB level of 11 ug/dl among children less than six years old at a soil lead level of 500 ppm.[18] In contrast, elevated PbB levels in Red Pond children occurred at lower soil lead levels, and the univariate model of blood vs. soil lead predicts a geometric mean PbB level of 32 ug/dl among children under age six at a soil lead level of 500 ppm.[27] This observation may have several explanations, including children playing with battery scrap or being exposed to high "peak" soil lead levels. It is also possible, however, that children in Red Pond ingest and absorb more lead from soil than children in developed countries with temperate climates because of differences in time spent outdoors, hygiene, and nutrition.

Among subjects age 12 and older, occupational exposure to lead smelting was associated with higher PbB levels. It is possible that backyard smelter work was not always reported. It is also probable that male sex and proximity to backyard smelters, which were also predictive of higher blood lead, were associated proxies with unreported smelter work by some individuals.

Certain limitations of this data are evident. First, NIOSH investigators could not measure air lead levels during operation of the estabished smelter or assess the impact of this airborne lead on the PbB levels of the residents in both communities. Second, because of small sample size and collinearity between many study variables,

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*A. Elliot, unpublished report.

some variables may contribute to environmental or PbB levels but not be statistically significant in multivariate models. Third, imprecise measurement of certain study variables may have diluted real associations. Therefore, the analyses indicate the strongest, but not the only, determinants of environmental and PbB levels in the Red Pond Road community.

The "epidemic" of elevated PbB levels in Red Pond is not large compared to those reported near other smelters, but it is a major public health problem for this community.[3,28] As stated earlier, CDC has defined an elevated PbB level as 25 ug/dl or greater because of biochemical changes and neurobehavioral effects observed in children above this level, and recent data suggest adverse effects at even lower levels.[18,23,24] From this evaluation NIOSH investigators estimate that 44% of the approximately 390 children aged six months through five years in the Red Pond Road community have elevated PbB levels. Direct exposure to backyard smelting of lead was associated with a high risk of PbB levels above 50 ug/dl, levels where symptoms can occur and the risk of permanent neurologic damage increases.[29]

The findings of this survey have significance beyond a single community because backyard lead smelters are not limited to the area surveyed. It is estimated about one third of spent lead-acid batteries in Jamaica are used by backyard recyclers or by small battery repair shops (where the lead is frequently smelted) scattered throughout the island.* Because the social and economic conditions that encourage residential lead smelting (and other lead-related cottage industries) are found in other developing countries, clinicians and public health workers should be alert to the risk of both childhood and occupational lead poisoning from such activities elsewhere.

VIII. RECOMMENDATIONS

The following recommendations are made to assist the MOH in developing and implementing a specific intervention plan to prevent lead poisoning in the Red Pond Road community.

1. Because backyard lead smelting is a livelihood for some Red Pond residents, preventing lead poisoning will be difficult. The owners of the established smelter were considering relocating their facility to a more secure location in an industrial park near Kingston. This would remove both a source of lead emissions and a supply of lead scrap from the Red Pond area and may greatly

*A. Elliot, unpublished report.

curtail operations of the backyard smelters which have proliferated in this community. In the interim, until the smelter relocates, the grounds surrounding this facility should be additionally secured to reduce theft of lead-containing material.

2. If the established smelter does not relocate, the level of current airborne lead emissions from the stack should be assessed during smelter operations. Recommended procedures for conducting a community survey to measure air lead levels near the smelter were described in an interim letter to the Ministry of Health dated February 11, 1988. Based on such a survey, the adequacy of emission controls at the smelter could be evaluated and upgraded, if necessary.

3. Hazards from existing contamination, particularly localized collections of lead scrap, dross, and highly lead-contaminated soil, should be abated on a priority basis. First, local collections of lead scrap at backyard lead smelting sites, and the heavily contaminated soil underlying these areas, must be removed to a safe disposal site. Second, soil in the most heavily contaminated yards should be either removed or covered. Given the drainage problems present in some areas of the Red Pond Road community, soil removal may not be acceptable to residents. Thus, covering yards with uncontaminated soil may be the more feasible approach, providing that suitable drainage is maintained away from inhabited areas.

   Ideally, abatement of the lead in soil should be based on additional soil lead testing throughout the Red Pond community, but the expense may make the plan infeasible. Based on this survey most yards with clearly hazardous soil lead levels could be identified by a history of smelting and visually observing lead containing debris, dross, etc. A reasonable approach would be to concentrate initial soil lead abatement on yards where such a history is obtained and young children live.

4. While data collected by NIOSH investigators did not find house dust to be the main source of absorbed lead, such contamination is more easily controlled than soil dust. Therefore, it is prudent to instruct parents of young children with high PbB levels to regularly wet mop household floors.

5. This evaluation included only a sample of households in the Red Pond community, thus additional efforts will be needed to identify other high risk children and to target sites for abatement efforts. The most efficient way to accomplish this is through organized mass screening efforts focusing on children less than

six years of age. After children with elevated PbB levels ($\geq$ 25 ug/dl) have been identified, interviewing household members may reveal a history indicating that soil lead contamination in a yard is likely. Soil and house dust lead abatement could be accomplished without further environmental testing, except in cases where no apparent source could be identified. Periodic screening activities could be designed to assess the effect of community-wide interventions.

6. Educational efforts, unaccompanied by environmental hazard abatement, have not been successful in preventing lead poisoning in the Red Pond community to date. However, community education may be helpful as part of an overall intervention program. First, residents need to be informed of the overall findings of this survey, including the fact that backyard smelting and soil contamination play an important role in causing lead poisoning in the community. Education of parents of children with lead poisoning should be focused on the chronicity of the problem even after symptoms have been treated. Parents should be enlisted as participants in hazard abatement activities such as dust control, creating "clean" play areas, and planting grass or other ground cover, where possible, to reduce the large areas of bare dirt observed in many Red Pond yards. Iron supplementation should also be provided to reduce lead absorption in iron deficient children with high PbB levels, although this is not a substitute for hazard abatement. Finally, although NIOSH investigators did not demonstrate an effect of consumption of local foods on PbB levels, it is prudent to recommend thorough washing of local fruits, vegetables, and cooking utensils to remove possible lead dust contamination before preparing meals.

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XI. 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.

EXPLANATIONS OF FOOTNOTES USED IN FIGURES 1, 2 and 3

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Figure 1: Map of Area Soil Lead Levels at Survey Households

ppm = parts per million
Pbs-area = concentration of lead in area soil samples
BYLS = backyard lead smelter
NNW = north by northwest
WNW = west by northwest
SW = southwest
E = east

Figure 2: Distribution of Blood Lead Levels in Survey Households

RP = Red Pond Households
EV = Ebony Vale Households
BYLS = Backyard lead smelter
ug/dl = micrograms of lead per deciliter of whole blood
* $p < 0.05$
+ $p > 0.0005$

Figure 3: Relationship Between Area Soil Lead and Blood Lead Among Children

ug/dl = micrograms of lead per deciliter of whole blood
ppm = parts per million

FIGURE 1

Map of Area Soil Lead Levels At Survey Household Yards
Saint Catherine Parish, Jamaica, October 1987
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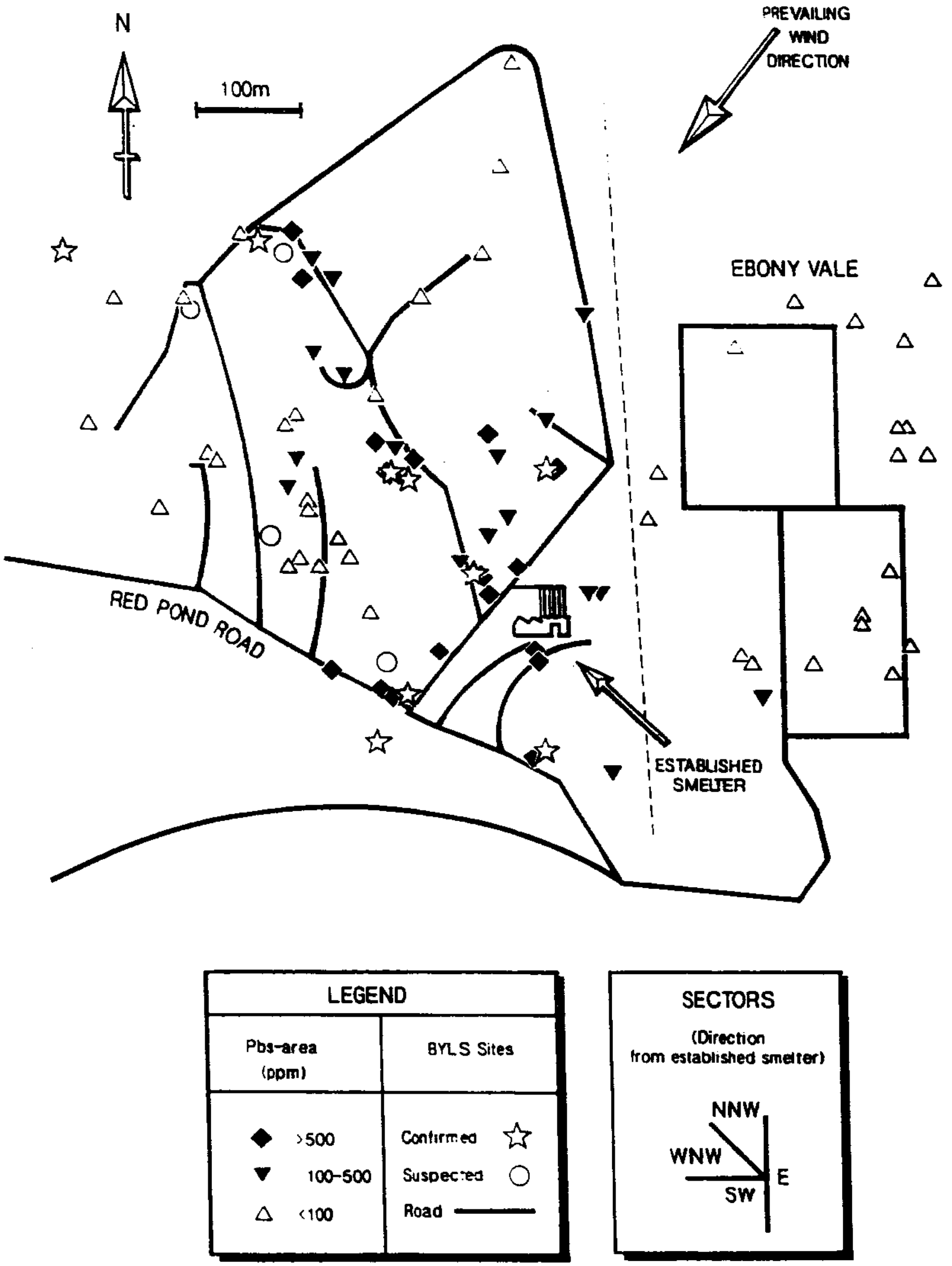

FIGURE 2

Distribution of Blood Lead Levels in Survey Households
Saint Catherine Parish, Jamaica October 1987

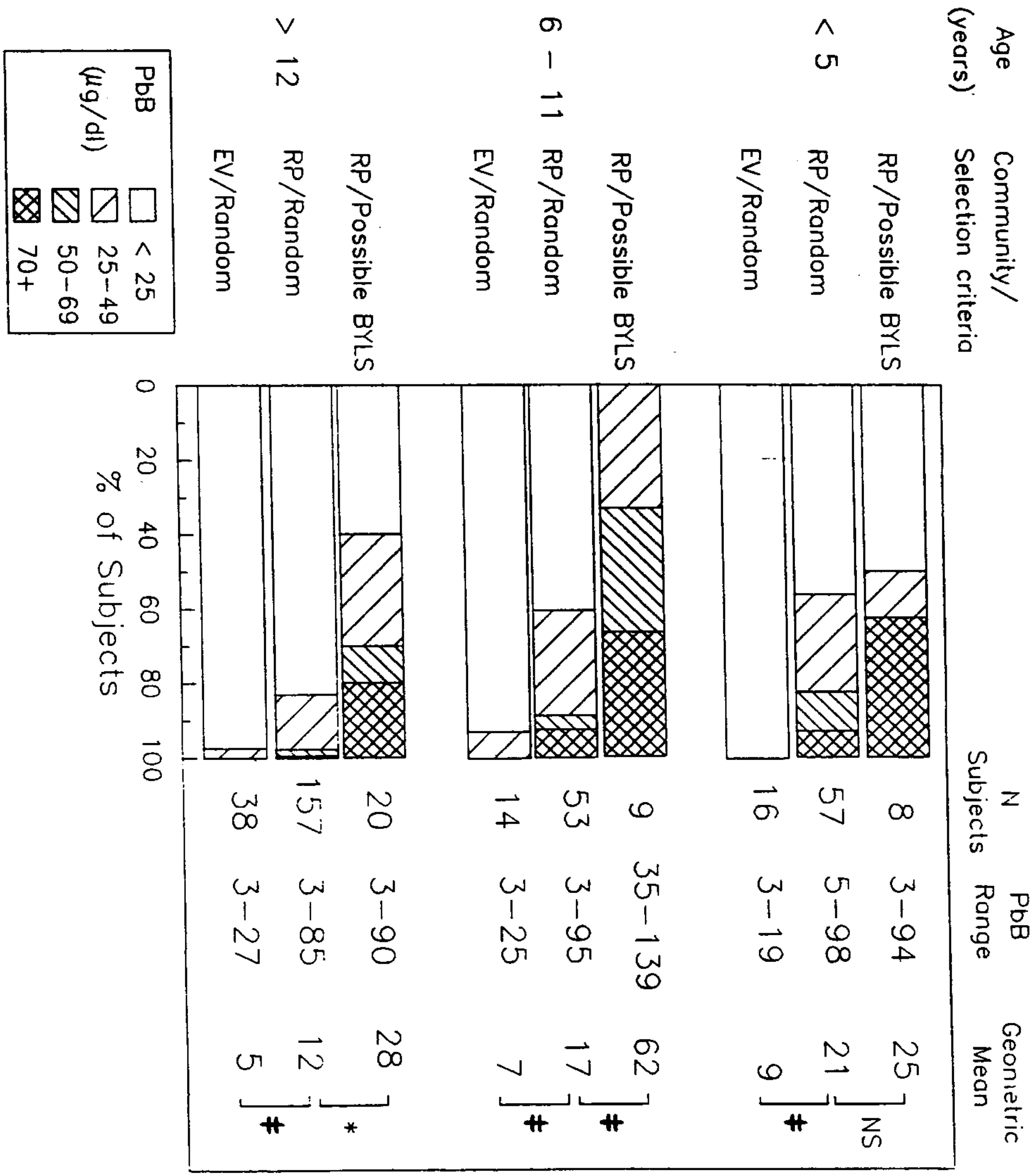

FIGURE 3

Relationship Between Area Soil Lead and Blood Lead Levels
Among Children Less Than Six Years of Age in Red Pond

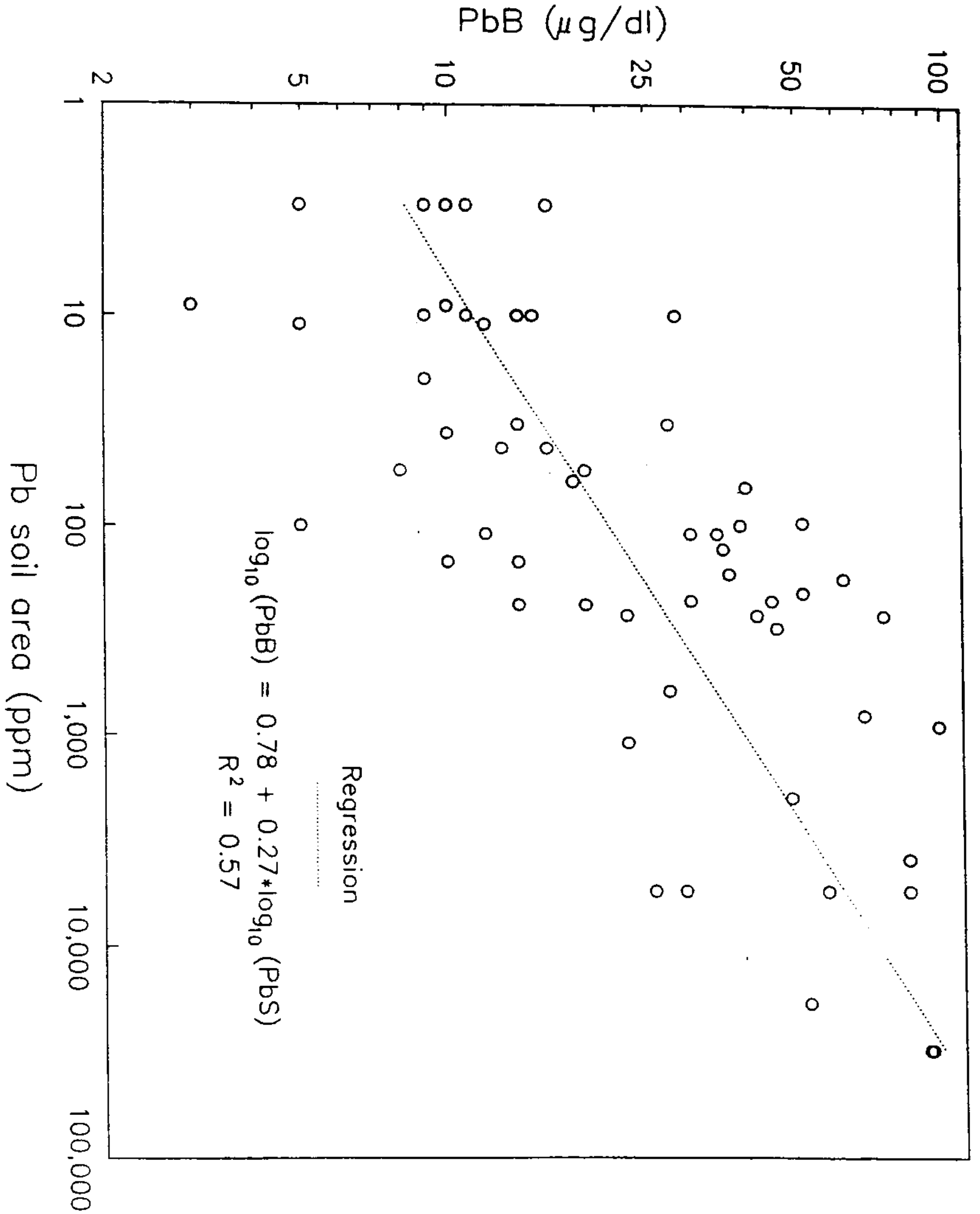

Table 1 - Household and subject selection, community lead survey, Saint Catherine Parish, Jamaica, October 1987

Selection criteria:	Community: Red Pond — Possible Backyard smelter	Red Pond — Random Sample	Ebony Vale — Random Sample
Households			
Number surveyed (% of eligible households)	9 (100)	49 (86)	21 (68)
Mean household size	5.3	7.6	4.4
Mean household income (US $/week)	32	42	93
Subjects tested for blood lead (% of those eligible)			
By Age:			
6 months - 5 years	8 (100)	57 (93)	16 (84)
6-11 years	9 (90)	53 (88)	14 (82)
≥ 12 years	20 (69)	157 (64)	38 (67)

Table 2 - Environmental lead (Pb) levels at survey households, Saint Catherine Parish, Jamaica, October 1987

		Community		
		Red Pond		Ebony Vale
	Selection criteria:	Possible Backyard smelter	Random Sample	Random Sample
Pb soil-area (ppm)	N households	8	46	20
	Geometric mean	1089*	133‡	6
	Range	9-31,000	3-18,600	3-150
Pb soil-peak (ppm)	N households	9	49	21
	Geometric mean	7691†	221‡	7
	Range	9-320,000	3-520,000	3-150
Pb dust ($\mu g/m^2$)	N households	9	46	20
	Geometric mean	2790*	690‡	100
	Range	100-109,180	50-294,680	20-338

P values for differences in geometric means, possible backyard smelter compared with randomly-selected Red Pond households and randomly-selected Red Pond households compared with Ebony Vale households:

* $p < 0.05$

† $p < 0.005$

‡ $p < 0.0005$

Table 3 - Study variable definitions for multivariate analyses.

Saint Catherine Parish, Jamaica, October 1987

Household characteristics

Variable Name	Definition	Units/transformations or Categories
Pb soil-area	Lead in soil, central yard area	$\log_{10}$(ppm)
Pb soil-peak	Lead in soil, maximum found in yard	$\log_{10}$(ppm)
Pb dust	Lead in housedust	$\log_{10}(\mu g/m^2)$
Backyard smelter distance	Distance to nearest confirmed backyard lead smelter site	$\sqrt{\text{meters}}$
Stack distance	Distance to established smelter stack	$\sqrt{\text{meters}}$
Sector	Direction from smelter stack (four categories, three dummy variables)	north-northwest, east, southeast, west-northwest*
Lead waste	Contamination of yard by solid lead waste by smelting, dross landfill, or lead-oxide storage drum fencing	yes,no*
Pb-paint	Lead level in peeling house paint (three categories, two dummy variables)	$\geq$1%, <1%, no peeling paint*
Dirt cover	Proportion of yard area covered by exposed dirt	%
Worker house	Smelter worker in household (three categories, two dummy variables)	established smelter worker, backyard worker, not smelter worker*

Table 3 (cont.)

Variable Name	Definition	Units/transformations or Categories
Smelter site	Household located at, or adjacent to, confirmed backyard smelter site, based on observations and/or questionnaires (three categories, two dummy variables)	Confirmed, suspected, non-backyard smelter*
Income	Weekly household income	≥ $36 US ($200 Jamaican), < $36*

Individual characteristics

Variable Name	Definition	Units/transformations or Categories
PbB	Whole blood lead	$\log_{10}\mu g/dl$
Sex		male, female*
Age	Three year age group among children under age six	≤ 2 years, 3-5 years*
Occupation	Works at lead smelting (three categories, two variables)	established smelter worker, backyard worker, not smelter worker*
Smelter play	Plays at backyard smelter at least weekly	yes, no*
Pica	Dirt eating reported by guardian	yes, no*
Unattended	Proportion of day unattended by adult	≥ 50%, < 50%*
Smoking	Current cigarette smoker	yes, no*

* Referent category.

Table 4 - Correlation coefficients (r) between environmental lead, distances to smelters, and blood lead levels in the Red Pond community, Saint Catherine Parish, Jamaica, October 1987

	Pb soil-area[a]	Pb soil-peak[a]	Pb dust[a]
N Households:	54	58	55
Backyard smelter distance[b]	-0.77‡	-0.74‡	-0.63‡
Stack distance[b]	-0.58‡	-0.45‡	-0.28*
Blood lead levels[a], by age (N subjects)[c]			
$\leq$ 5 years (N=62)	0.75‡	0.74‡	0.57‡
6 - 11 years (N=52)	0.71‡	0.69‡	0.37
$\geq$ 12 years (N=156)	0.56‡	0.59†	0.42†

a log-transformed

b square-root transformed

c only includes subjects in households with no missing environmental levels

P values for correlation coefficients:

* $p < 0.05$

† $p < 0.005$

‡ $p < 0.0005$

Table 5 - Multivariate models of environmental lead levels in the Red Pond community, Saint Catherine Parish, Jamaica, October 1987

Dependant variables:	Pb soil-area (log_{10}ppm)		Pb soil-peak (log_{10}ppm)		Pb dust (log_{10}µg/dl)	
Model characteristics						
N households	54		58		51	
Variance explained (r^2)	0.82		0.75		0.59	
Y intercept	3.37		3.71		1.66	
Beta and (se) of variables in final models[a]						
Backyard smelter distance ($\sqrt{meters}$)	-0.10	(0.02)	-0.10	(0.03)	NS	
Stack distance ($\sqrt{meters}$)	-0.05	(0.003)	-0.07	(0.02)	NS	
Lead waste (referent = no)	0.43	(0.16)	1.15	(0.25)	NS	
Pb soil-area (log_{10}ppm)	NA		NA		0.52	(0.08)
Sector (referent = west-northwest)						
north-northwest	0.65	(0.14)	0.70	(0.22)	0.25	(0.16)
east	0.49	(0.20)	0.30	(0.33)	-0.09	(0.21)
southwest	1.11	(0.22)	0.76	(0.34)	-0.72	(0.26)

Table 5 (cont.)

NS = not significant, dropped by backwards elimination.

NA = not applicable or not assessed in model.

a Models include variables which remained after backwards elimination of variables not significant at $p < 0.05$ level. All starting models included backyard smelter distance, stack distance, sector, lead waste, Pb paint, worker house. Starting model for Pb dust also included Pb soil-area, Pb soil-peak, dirt cover.

Table 6 - Multivariate models of blood lead (PbB) by age in Red Pond, Saint Catherine Parish, Jamaica, October 1987

Dependant variable- PbB ($log_{10}\mu g/dl$) by age (years):	≤ 5		6-11		≥ 12	
Model characteristics						
Number of subjects	62		52		156	
Variance explained (r^2)	0.68		0.51		0.35	
Y intercept	0.63		0.58		1.38	
Beta and (se) of variables in final models[a]						
Pb soil-area ($log_{10}ppm$)	0.27	(0.03)	0.31	(0.03)	NS	
Dirt cover (%)	0.0025	(0.0005)	NS		NS	
Backyard smelter distance ($\sqrt{meters}$)	NS		NS		-0.04	(0.01)
Sex (referent = female)	NS		NS		0.14	(0.05)
Sector (referent = west-northwest)						
north-northwest	0.16	(0.08)	NS		NS	
east	0.20	(0.08)				
southwest	-0.12	(0.08)				
Occupation (referent = not a smelter worker)						
established smelter worker	NA		NA		0.29	(0.06)
backyard smelter worker					0.06	(0.10)

Table 6 (cont.)

NS = not significant, dropped by backwards elimination.

NA = not applicable or not assessed in model.

a Models include variables which remained after backwards elimination of variables not significant at $p < 0.05$ level. All starting models included backyard smelter distance, stack distance, sector, lead waste, smelter site, worker house, Pb paint, Pb soil-area, Pb soil-peak, Pb dust, dirt cover, sex, income. According to age group, starting models also included: occupation and smoking for subjects 12 and older; smelter play for subjects 6-11; smelter play, pica, unattended, and age for subjects 5 and under.