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Lead in Paint and Soil in Karnataka and Gujarat, India

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Blood lead surveys in several areas of India have found very high percentages of children with elevated blood lead levels. Fifty-three percent of children under 12 years of age in a seven-city screening had blood lead levels equal to or greater than 10 μg/dL, the level currently considered elevated by the U.S. Centers for Disease Control and Prevention (CDC). A number of these surveys focused on populations near lead smelters or in areas with high lead levels from combustion of lead-containing gasoline. There is little information available, however, on the levels of lead in paint in India and in soil. Field portable X-ray fluorescence analyzers were used to determine environmental lead levels in paint, dust, air, soil, and other bulk samples near several lead-using industries and in the residential environments of children with very high blood lead levels, at least four times as high as the CDC limit. Soils near industrial operations, such as secondary lead smelters, and battery dismantling units contained levels up to 100,000 ppm of lead. Four of 29 currently available paints from five manufacturers measured 1.0 mg/cm² or above—the current U.S. definition of lead-based paint in housing—after the application of a single coat; four others measured at least 1.0 after three coats, and three others likely reached this level after the application of an additional one or two coats. In 5 of 10 homes of the elevated blood lead children, three or more locations in or around the home were found to have lead paint levels of 1.0 mg/cm² or higher. Soil exceeding the U.S. standard for residential areas (400 ppm) was found at only one of the houses. Other sources of lead exposure, including traditional ayurvedic medicine tablets, were also observed. Similar surveys would be useful elsewhere in India and in other developing countries.

Keywords battery, India, lead paint, smelters, soil, XRF

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BACKGROUND

Blood lead surveys in several areas of India have found very high percentages of children with elevated blood lead levels (EBL). In a survey of 22,000 adults and children in seven cities in India conducted by The George Foundation,[1] 53% of children under 12 years of age had blood lead levels equal to or greater than 10 μg/dL, the level currently considered elevated by the U.S. Centers for Disease Control and Prevention.[2] A number of these surveys focused on populations near lead smelters or in areas with high lead levels from combustion of lead-containing gasoline prior to the phasing out of use of lead additives to gasoline that began in 1998.[3]

Lead smelters and the facilities involved in lead-storage battery recycling and manufacturing have long been recognized as potential sources of lead contamination of the environment and have shown to be a health hazard.[4–6] Many of the lead storage battery recycling and smelting operations are carried out in small facilities sometimes known as "backyard smelters." Because of the primitive nature of these operations and their enormous number, estimated to be in the tens of thousands, the control of contamination from them is a major challenge. Other potential sources of lead exposure could be certain ayurvedic, or traditional, medicines and automobile painting and body shops. Ayurvedic medicine pills formulated from nonstandardized recipes have often been found to contain lead and other heavy metals.[7]

A recent article[8] included lead-based paint as a major source of childhood lead poisoning in the United States, but not in its list of eight major sources of childhood lead poisoning worldwide: gasoline, lead-glazed ceramics, mining and smelting, battery repair and recycling, cottage industries, flour mills, medication and cosmetics, consumer products, and other. Yet, Chen[9] has recently found lead-based paints in the Chinatown and Little India neighborhoods of Singapore, which contain housing built before World War II. Although lead-based household paints were not available locally, they were available in a nearby country.[9] Singapore serves as a useful comparison as it is another South/Southeast Asian country that, in comparison with India, has a more highly developed regulatory system, and, more significantly, rigorous implementation of such laws.

There is little information available on the levels of lead in paint in India and in nearby soil; however, it has been reported that 10% of lead used in India is for paint.[10] This percentage corresponds to the amount of white lead used for paint in the year 1930 in the United States, a time when lead was still a common ingredient in household paint.[11] A study by Van Alphen[12] found that of 24 new paints applied to test surfaces and measured for lead, 17% had lead concentrations exceeding 0.5% lead by weight, 13% were higher than 1% lead, and 5% even exceeded 10% lead by weight. According to current standards in the United States and elsewhere, the nonvolatile or dry content of new paints marketed for residential use must contain less than 600 ppm of lead.[13] For existing paint in housing, any surface where the paint lead content is equal to or exceeds 5000 ppm or 1.0 mg/cm^2 is considered to be "lead-based" according to U.S. Environmental Protection Agency (EPA) standards.[14]

Health-based standards for lead in paint, soil, and dust in residential areas have been established in the United States.[13,14] In Singapore, a standard for lead in new paint has been established, but apparently none exists for soil and dust.[15] Guidelines for lead in soil are available in India, but there are no standards for paint.[16] These standards and guidelines are summarized in Table I.

A number of studies have shown that portable X-ray fluorescence (XRF) technology is useful for measuring lead in soil, paint, and dust.[17-19] The availability for the first time in India of field portable XRF analyzers in 2003 provided the opportunity to conduct surveys to identify possible sources of exposure. Testing was conducted in industrial and residential areas in two states in India (Karnataka and Gujarat). *In situ* paint lead levels were measured, and lead levels in paints available for purchase in local supply stores were determined.

In addition to testing likely industrial sources of lead contamination, the XRF analyzer was also used to examine the home environments of children known to have EBLs. A randomly selected group of 107 schoolchildren from Mangalore, Karnataka, participated in a blood lead screening program early in 2003 that was organized by the National Referral Center for Lead Poisoning in India (NRCLPI), a nonprofit institution founded by The George Foundation and St. John's National Academy of Health Sciences, and with support from the Karnataka State Pollution Control Board. Seventy-eight percent of the students had blood lead levels at or above 10 μg/dL, the level considered to be a health risk according to U.S. standards.[20] Of those tested, 11 students had blood lead levels at or above 40 μg/dL. This study served to complement the blood lead survey by examining the highest EBL children's home environments for possible sources of exposure to lead.

Objectives

The major research objectives were to determine (1) lead levels in soil at/near secondary lead smelters (Bangalore, Karnataka), paint manufacturers (Vallabh Vidyanagar, Gujarat), auto body shops and small-scale battery servicing and recycling operations (Bangalore and Vallabh Vidyanagar); (3) lead content in painted surfaces, soil, and dust in and around the home and play environments of children with elevated blood lead levels (Mangalore); and (2) lead content of currently available residential paints.

METHODS

Study sites were selected based on the types and accessibility of industries present in the geographic areas examined. In Bangalore, study sites were recommended by the NRCLPI.

Prior to the collection of composite soil samples, which would be sieved prior to examination, the XRF analyzers (Models XL-700 and XL-300; NITON Corp., Bedford, Mass.) were operated in the semiquantitative screening mode to determine locations of similar levels and to locate the high-lead areas. A map of estimated soil lead levels at the site could then be prepared in order to select areas of similar levels that could be included in the same composite soil sample, which contained about five subsamples. For these screening purposes, the XRF was placed directly on the surface of the soil using a protective shield known as a sled. This *in situ* soil screening, as

TABLE I. Standards and Guidelines for Lead in Paint, Soil, and Surface Dust

Media	Country	Level	Reference No.
Paint—existing housing	United States	<1.0 mg/cm^2 and <5000 ppm	14
Paint—new	United States	600 ppm	13
Paint—new/existing	India	No standard	—
Soil—bare play areas	United States	400 ppm	14
Soil—bare areas in rest of yard	United States	1200 ppm	14
Soil	India	100–300 ppm[A]	16
Soil	India	1000 ppm[B]	16
Dust—surface	United States	40 μg/ft^2[C]	14

[A]Guidance level: "may be tolerable."
[B]Guidance level: "contributes to child lead poisoning."
[C]Floor areas of housing.

well as all other readings taken with the XRF, were executed according to manufacturer's guidelines.

Bulk samples, consisting of about five subsamples, were collected and sieved for XRF analysis. A minimum of 20% of the samples was also analyzed later by atomic absorption at the University of Cincinnati, and excellent correlation was observed. Bulk soil samples were collected using a small metal spatula. Two to 4 cm^3 soil subsamples were collected from the top 1 cm of areas with similar lead concentrations as determined by the XRF in the screening phase. These subsamples were combined and mixed in a collection bag to make composite samples, which are referred to as such in the Results section. Dust wipes were collected according to U.S. EPA procedures on one-square-foot areas in locations of interest, such as floor areas of housing and lunchroom/table surfaces in workplaces and folded as prescribed by XRF manufacturer's procedures. In a laboratory, soil samples were sieved to <250 μm, placed in plastic sample cups with a Mylar cover, and lead levels measured at 60 nominal seconds, as per the manufacturer's guidelines.[21]

The types of samples analyzed consisted of paint (mg/sq ft), soil (ppm)—both *in situ* and laboratory prepared—dust wipes ($\mu g/ft^2$), bulk dust (ppm), and other solid substances such as traditional medicines and foodstuffs (ppm). The analytical method utilized was field portable XRF analysis (NITON XL-700 and XL-300 series models). Results were later confirmed by atomic absorption laboratory analyses in the hematology and environmental laboratories of the University of Cincinnati. The results reported below are atomic absorption values when available. Air samples were collected using personal air sampling pumps operating at 2 L/min to assess ambient lead levels at one of the paint manufacturing plants.

To examine potential sources of lead exposure among the group of EBL school children in Mangalore, the paint, soil, and dust in and around their home and play environments were tested with the XRF. Paint and soil screenings were taken on site, and bulk dust and composite soil samples were prepared for analysis. In addition to soil, dust, and painted surfaces, other areas tested included floor tiles, kitchen platforms, grinding stone, utensils, spice mixture additives, batteries, and medicines taken. Parents and other family members were also questioned regarding the child's possible exposure to activities such as battery recycling, as well as any use of traditional medicines and lead-containing kitchen items. The interviewing addressed the habits, hobbies of the child and family, and the child's general health to gain information on potential factors contributing to the child's elevated blood lead level. The home visit procedures were based on EBL child home investigation practices, with additions and adjustments made as appropriate to the local circumstances. The common use in India of traditional folk medicines that may contain lead and other metals, for example, prompted us to inquire about any tablets the EBL child might be taking.

To assess lead levels in residential paints currently available on the Indian market, wooden blocks were painted in three successive coats with paint purchased locally. A new brush was used for each paint, and coats were applied as uniformly and consistently as possible. A series of three measurements were taken with the XRF after each individual paint coat had dried. Readings were then averaged by coat for each individual paint.

RESULTS

Secondary Lead Smelters

Five composite soil samples from near the secondary smelter entrance (A) ranged between 711 and 182,000 ppm of lead (Table I) with the highest concentrations found adjacent to the facilities. The 711 ppm measurement was taken at a distance of 73 m from the smelter on a lane running alongside the plant. At 43 m from the smelter entrance, the soil concentration measured 3089 ppm of lead. At the front entrance to the facility, the soil lead level was 23,920 ppm. A soil sample taken on the edge of the scrap pile outside showed 182,000 ppm of lead. To provide an instructive comparison, the lead product itself—recovered from the batteries to be resmelted—measured 530,000 ppm of lead. Three dust wipes were taken in the office immediately adjacent to the smelting area, with results ranging from 7300 to 27,040 $\mu g/ft^2$. The surface of a worker's boot contained 22,330 $\mu g/ft^2$. Although the smelter was located in an industrial zone, children were observed coming to the work site and some lived in adjacent buildings.

Bulk samples that had previously been collected from another secondary smelter (B) by the Karnataka State Pollution Control Board were sieved and tested with the XRF analyzer. The product from this particular smelter showed 238,700 ppm of lead. Soil 2 m in front of the factory entrance at this smelter measured 107,000 ppm of lead. No dust wipes were taken. A summary of the results from the secondary lead smelters is presented in Table II.

Auto Body and Battery Servicing Shops

Lead testing with the XRF analyzer was conducted at two auto paint and repair shops in Bangalore. At Auto Body Shop A, dust wipes were taken on a car hood in the repair bay and on the office floor and measured 25 $\mu g/ft^2$ and 109 $\mu g/ft^2$, respectively. A soil sample taken from the walkway 1 m in front of the shop's entrance measured 48 ppm. Auto Body Shop B showed similar levels of soil and dust lead. The dust

TABLE II. Secondary Lead Smelters—Lead in Soil, Product, and Dust

Facility	Soil (ppm)[A]	Product (ppm)	Dust Wipe ($\mu g/ft^2$)
Smelter A	42,500 (711–182,000) n = 5	530,000	18,900 (7300–27,040) n = 3
Smelter B	107,000	238,700	None taken

[A]Composite samples.

wipe taken from a car hood in the scrapyard measured 31 μg/ft² of lead, and another in the repair bay measured 61 μg/ft². An office floor wipe contained 38 μg/ft² of lead. A dust wipe was also taken from the lunchroom table and showed 6 μg/ft². A bulk floor dust sample collected 1 m outside the office entrance measured 153 ppm of lead.

A retail battery store that performs maintenance was also inspected, although they do not dismantle batteries for lead recovery purposes at this site. The manager reported that this activity is done off site at licensed company facilities. A dust wipe on the actual service area floor contained a very high amount of lead, 5470 μg/ft², but the other surfaces screened in the office area, and soil screened 3 m in front of the entrance at the curb, showed negligible levels of lead, that is, less than the XRF detection limit of 100 ppm.

Lead levels measured in the auto body and battery servicing shops are summarized in Table III.

Small-Scale Battery Recycling

Soil samples collected from in and around two small-scale battery recycling sites showed dangerously high lead levels. As would be expected, the highest concentrations at both sites were found in the areas where the actual dismantling took place—3920 ppm at Battery Recycler Site A and 8970 ppm at Battery Recycler Site B, respectively. Lead levels steadily dropped as one moved away from the workstation yet remained high enough to be a cause for concern. Samples at Site A, located in a busy, mixed-use neighborhood, ranged from 463 to 8973 ppm of lead. The 463-ppm measurement was taken 25 m past the shop entrance on the sidewalk. Thirty-seven meters past the entrance, lead levels were actually higher, at 1640 ppm. Four meters in front of the shop at the curb, the soil measured 6233 ppm of lead. Testing at and around Site B revealed a narrower range of lead concentrations, from 602–3920 ppm. Bulk floor dust sampling also indicated high levels of lead contamination in and around the work sites. A sample collected from the workroom floor at Site A measured 21,200 ppm, and one from Site B measured 95,300 ppm. Dust wipe samples were taken only at Site A, on workroom surfaces, and ranged from 175–3550 μg/ft².

TABLE III. Auto Body and Battery Servicing Shops—Lead in Soil and Dust

Facility	Soil (ppm)[A]	Bulk Dust (ppm)	Dust Wipe (μg/ft²)
Auto shop A	48	None taken	25 (car hood) 109 (office floor)
Auto shop B	46	153	31 and 61 (car hood) 38 (office floor) 6 (lunch table)
Battery sales shop	None taken	<100 ppm	5470 (service area floor)

[A]Composite samples.

Paint Manufacturing Companies

The lead survey of paint companies in Gujarat focused on soil, dust, and air lead at manufacturing plants, as well as the lead content of actual pigments and paints. Air samples were collected only at Paint Company B; however, neither Company A nor B was operating at the time of the visits. Two composite soil samples at the plant entrance to Company A showed 139 and 468 ppm of lead, respectively. A bulk dust sample by the charging area on the work floor measured 3740 ppm, and another bulk sample by the mixing area measured 1620 ppm of lead. A dust wipe taken on the floor of the watchman's house within the factory compound gave a reading of 29.3 μg/ft². A dust wipe taken at the main entrance to the plant measured 293 μg/ft².

Results from composite soil samples from Company B were about nine times as high as those at Company A. Samples from Company B ranged from 37 to 3880 ppm of lead ($n = 9$). Dust wipes taken at Company B, ranging from 239–4583 μg/ft², were also many times higher. A dust wipe measuring 2010 μg/ft² was taken from the floor adjacent to a workers' rest area. Two dust wipes were taken in the areas where workers sit for lunch and measured 1000 μg/ft² and 3280 μg/ft² of lead, respectively. No bulk dust samples were obtained at Company B. Air lead levels were below the detection limit (<5 μg/m³). Results from the paint manufacturing companies and the small-scale battery recycling facilities are presented in Table IV.

Lead in Currently Available Paint Products

Twenty-nine paints were obtained from local suppliers, 10 in Bangalore and 19 in Gujarat, representing a total of five different brands of paint. The paint lead loadings from these samples, measured after application of the first, second, and third coats are presented in Figure 1. Three readings were usually taken after the application of each coat of paint. Values shown in the figure are the average of the readings taken of these readings.

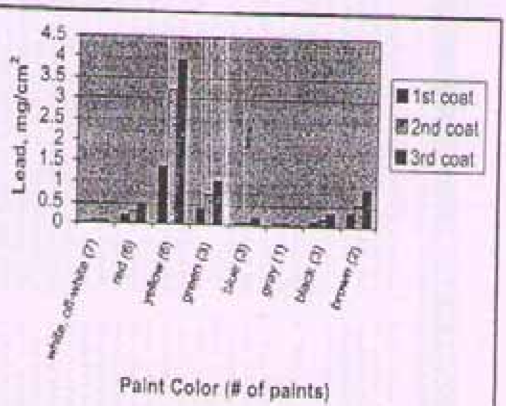

FIGURE 1. Comparison of lead levels in successive coats of new paint

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The lead content of currently available new residential paint in several Asian countries ☆

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Abstract

Worldwide prohibitions on lead gasoline additives were a major international public health accomplishment, the results of which are still being documented in parts of the world. Although the need to remove lead from paints has been recognized for over a century, evidence reported in this article indicates that lead-based paints for household use, some containing more than 10% lead, are readily available for purchase in some of the largest countries in the world. Sixty-six percent of new paint samples from China, India, and Malaysia were found to contain 5000 ppm (0.5%) or more of lead, the US definition of lead-based paint in existing housing, and 78% contained 600 ppm (0.06%) or more, the limit for new paints. In contrast, the comparable levels in a nearby developed country, Singapore, were 0% and 9%. In examining lead levels in paints of the same brands purchased in different countries, it was found that some brands had lead-based paints in one of the countries and paints meeting US limits in another; another had lead-free paint available in all countries where samples were obtained. Lead-based paints have already poisoned millions of children and likely will cause similar damage in the future as paint use increases as countries in Asia and elsewhere continue their rapid development. The ready availability of lead-based paints documented in this article provides stark evidence of the urgent need for efforts to accomplish an effective worldwide ban on the use of lead in paint.

Keywords: Lead-based paint; Housing; Childhood lead poisoning; Globalization and the environment; International public health

1. Introduction and background

The phasing out of lead from gasoline is regarded as a critical first step in reducing worldwide blood lead concentrations and is considered a major international public health achievement (Falk, 2003). The phase out has been accomplished by actions in many countries: Western countries such as the United States, countries in the former Soviet Union, in Asia (Michaelowa, 1997; Lovei, 1999), Africa (Montgomery and Mathee, 2005), and elsewhere. The percentage of children aged 1–5 years in the US with blood lead levels 10 μg/dL or higher has reduced from 77.8% to 4.4% from the period 1976–1980 to 1991–1994 and further reduced to 0.7% in the period 1999–2002 (MMWR, 2005). These dramatic reductions are due in part to the reduction of air lead and in part to efforts to control exposures from lead-based paints in older housing (Falk, 2003). The estimated number of US housing units containing lead-based paint was reduced from 64 million in 1990 to 24 million in 2000 through demolition, rehabilitation, lead hazard control, and other factors (Jacobs et al., 2002). Public health awareness of the dangers to the health of children and others from lead-based paint increased in the United States in the middle of the 20th century, although a US regulation of the lead content in new paint for residential use was not in effect until 1978 when a limit

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of 600 ppm became effective (US CPSC, 1977). For existing housing, US regulations now require that the paint contain less than 5000 ppm or 1.0 mg/cm² of lead (US HUD, 1995; US EPA, 2001a). Decades earlier the International Labour Organization promulgated a convention on the prohibition of the use of lead-based residential paint (ILO, 1921). Some other countries have established limits on the lead content of paint. Singapore, for example, has a limit of 600 ppm in new paints (Singapore NEA, 2004). In many countries, however, there are apparently still no regulations on the lead content of either new paint or paint in existing housing.

In many developing countries lead exposure from smelters and battery-recycling operations are considered to be major sources of lead poisoning for children and adults (Falk, 2003; Hashim et al., 2000; Nriagu et al., 1996; Shen et al., 1996). Little is known, however, about the lead content of paint in many developing countries and thus about exposures to children from lead-based paint. Reports on the paint lead levels in housing in Asia and Africa are very few. In China, painted surfaces of classroom desks, pencils and toys are reported to contain hazardous levels of lead (Shen et al., 1996). Over 60% of houses of a population of children in Venezuela with elevated blood lead were found to have paint lead levels above the regulatory limit (Rojas et al., 2000). Lead chromate has been reported to be unregulated in most African countries (Nriagu et al., 1996). In a recent report on lead paint levels in South Africa (Montgomery and Mathee, 2005), it was stated that a voluntary agreement has been in place among some industry stakeholders since the 1970s to limit the use of lead in paint but that a regulatory limit had not been established. In their survey of 239 homes, 20% were found to contain at least one surface with lead-based paint as defined by the US. Paint is considered to be a source of lead for children in Malaysia but levels of lead were not provided (Hashim et al., 2000). Lead-based paint was found in the homes of 7 of 10 children with blood leads of at least 40 μg/dL in India (Kuruvilla et al., 2004). Several years ago, an examination of samples of 24 new paints purchased in India (Van Alphen, 1999) revealed that 4 (17%) had a lead concentration exceeding 0.5% by weight, 3 (13%) were higher than 1% and 1 (5%) exceeded 10%. In a recent study of new paint in India, field-portable X-ray fluorescence (XRF) analyzers were used to determine the lead content (mg/cm²) of surfaces with a single coat of new paint and three coats of new paint. Three coats were used to simulate surfaces in older housing, which typically receive multiple coats over time; 14% of surfaces with one coat of paint and 28% of surfaces with three coats of new paint, respectively, had lead levels greater than or equal to the US limit of 1.0 mg/cm² for existing housing (Clark et al., 2005).

It is very important to know the content of lead in paint in existing housing so that the necessary poisoning prevention efforts can be implemented. Equally important for future generations is whether lead-based paints for domestic use are currently available and are continuing to be applied in housing. If lead-based paints are still available, then major action is needed to promote their effective banning to curb the growth of future cases of lead poisoning, an entirely preventable disease.

2. Objective and methods

In an effort to determine the extent to which lead-based paint is currently available for purchase in selected Asian countries, new paint samples were obtained in China, India, Malaysia, and Singapore. In each of the study countries, new paints were purchased from retail shops readily accessible to the public. Paints were selected with assistance of coauthors and others in the countries involved using two criteria: multiple brands and a variety of colors. The colors selected included those sampled earlier by Van Alphen (1999)—black, blue, green, orange, red, and white. To prepare each paint sample, the paint was stirred and applied by brush to individual wood blocks. Each stirring utensil and paintbrush was used only once. The paint was carefully removed from a premeasured area on the painted wood surface using a clean sharp paint scraper, using care not to remove portions of the wood. The scraping was done in the Hematology and Environmental Laboratory at the University of Cincinnati, which also analyzed the removed paint for lead. Paint scrapings were extracted using nitric acid and hydrogen peroxide according to the method: Standard Operating Procedures for Lead in Paint by Hotplate- or Microwave-based Acid Digestions and Atomic Absorption or Inductively Coupled Plasma Emission Spectroscopy, EPA PB92-114172, September 1991 (US EPA, 2001b). Extracts were analyzed by flame-atomic absorption spectroscopy using a Perkin-Elmer 3100 spectrometer. This laboratory is accredited by the American Industrial Hygiene Association as an industrial hygiene laboratory and an environmental lead laboratory under the National Lead Laboratory Accreditation Program. Consequently, the laboratory participates in the Proficiency Analytical Testing (PAT) and Environmental Lead Proficiency Analytical Testing (ELPAT) proficiency programs. Strict quality control procedures are maintained according to the accreditation guidelines. The laboratory is also a recognized facility through the National Environmental Laboratory Accreditation Conference and participates in the New York proficiency program for environmental sample analysis including lead.

3. Results

A total of 80 samples of paint were obtained from four countries: 9 were obtained in Shanghai, China; 17 were obtained in India from Vallabh Vidyanagar, Gujarat and in the Territory of Diu; 32 were from Johor Bahru and Kuala Lumpur, Malaysia; and 22 were from Singapore. A wide range of paint lead concentrations were observed (Fig. 1) with paints from China, India, and Malaysia generally having much higher concentrations of lead than those from Singapore. Concentrations of 10% and higher were found in some samples from India and Malaysia. The percentages of paint samples with lead concentrations exceeding the US limit of 600 ppm for new paints were 100%, 72%, 56% and 9% for India, Malaysia, China, and Singapore, respectively; and the percentages of which would be defined as lead-based paint in existing US housing (5000 ppm) were 82%, 62%, 44%, and 0% for India, Malaysia, China, and Singapore, respectively (Table 1). One of the new paints from Malaysia (143,000 ppm) had also recently been applied to an existing home; the label from this paint indicated that its producer was a Korean company.

Sixty-six percent of new paint samples from China, India, and Malaysia combined were found to contain 5000 ppm (0.5%) or more of lead and 78% contained 600 ppm (0.06%) or more. In contrast, the comparable levels in a nearby developed country, Singapore, were 0% and 9%.

Some brands of paint sampled were marketed in two or more countries (Table 2). In examining lead level, of the same brand in different countries, it was found that some of the paints were lead-based paints in one of the countries and not in another. Samples of one brand were obtained in India and Singapore: the samples from India contained from 1.10% to 15.9% lead while in the samples from Singapore the levels ranged from less than 0.005% lead to 0.04%. Paint samples of another brand contained 2.4–14.9% lead in Malaysia and about 0.004% in Singapore. A third brand of paint, for which the containers state that no lead was added, contained less than detectible levels of lead (less than 9 ppm (0.0009%)) in Malaysia and Singapore.

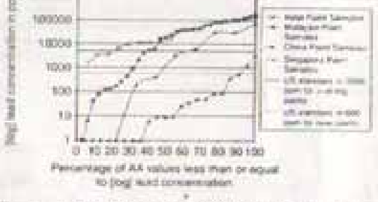

Fig. 1. Frequency distribution of lead concentrations by atomic absorption among new paint samples from China, Malaysia, Singapore, and India.

Table 1
Lead Concentration (ppm) in new household paints by country (analysis by atomic absorption)

Country	Number of paint samples	Median (ppm)	Maximum (ppm)	% (No.) Paints ≥600 ppm	% (#) Paints ≥5000 ppm
China	9	3280	73,400	56 (5)	44 (4)
India	17	16,720	167,300	100 (17)	82 (14)
Malaysia	32	21,300	143,000	72 (23)	62 (20)
China, India, and Malaysia combined	58	17,370	167,300	78 (45)	66 (38)
Singapore	22	9	3500	9 (2)	8 (0)

4. Discussion and conclusions

In the first known study of the lead levels in new paints in several Asian countries, the lead levels in the three countries which did not have regulatory limits greatly exceeded levels in the regulations in place in the US and elsewhere. In the fourth country where paint samples were collected, and which had a regulatory limit, concentrations were markedly lower. Some brands of paint marketed in two or more countries had lead-based paint in one country and low-lead paint in the country that had a regulatory limit. One of the brands of yellow paint analyzed in this study, marketed with a label statement that it contains no added lead, contained a low level of lead, <9 ppm, in the country that contained a regulatory limit (Singapore) and in one that did not (Malaysia). In a third country (India) the level of lead in yellow paint from this brand was found, by XRF analysis in a previous study (Clark et al., 2005), to contain 0.00 mg/cm². In unpublished data from new paint

Table 2
Comparisons of lead levels in new paints by color, brand, and country (ppm)[a]

Color	Brand	India	Malaysia	Singapore
Yellow	A	159,200[b]	—	408
Green	A	39,200	—	33
Brown	A	10,980	—	50
Yellow	B	—	149,100	47[c]
Green	B	—	34,200	33
Yellow	C	[d]	<9	<9

[a] Paint lead levels determined by atomic absorption.
[b] Average of two samples (187,200 and 131,300 ppm).
[c] Average of two samples (88.8 and <9 ppm).
[d] As described under Discussion and conclusions, using unpublished data, the yellow paint in India from brand C was estimated to contain less than or equal to 1328 ppm lead.

samples analyzed first by XRF and then by atomic absorption (AA), of 28 paint samples measured by XRF as 0.00 mg/cm², the corresponding AA values ranged from <9 to 1328 ppm. Thus it is likely that the brand marketed in India as having no added lead, and measured as 0.00 mg/cm² by XRF, contained less than or equal to 1328 ppm lead. One of the countries where high lead levels were frequently found (Malaysia) is adjacent to the country with low lead levels and a regulatory limit: Singapore. In general, it appears that the lead levels of many brands of paint depend on whether an enforceable regulatory limit exists in the specific country where the paint is marketed.

Lead-based paint was readily available for purchase in three of the four countries where samples were obtained. It is also possible that these lead-based paints could be exported to other countries, including the United States, as it has on jewelry, miniblinds, and other consumer products. As paint use in housing increases in these countries, a very likely result of increasing development, it is only a matter of time before childhood lead poisoning becomes an even greater public health issue. Substitutes for lead pigments have been available for many years and are indeed used in at least one paint brand marketed in three Asia countries where samples were obtained. Therefore, preventing future poisonings of children and others exposed to paint is a clearly achievable public health goal. This goal urgently calls for worldwide action, similar to that which occurred for gasoline lead additives. With the increased attention being given to globalization issues, including the environmental conditions of workers and families involved, consideration should be given to the inclusion in agreements and treaties of bans on the use of lead in paints so that this preventable disease does not increase.

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References

Clark, C.S., Thuppil, V., Clark, R., Sinha, S., Menezes, G., D'Souza, H., Nayak, N., Kuruvilla, A., Law, T., Dave, P., Shah, S., 2005. Lead in paint and soil in Karnataka and Gujarat India. J. Occup. Environ. Hyg. 2, 38–44.
Falk, H., 2003. International environmental health for the pediatrician: case study of lead poisoning. Pediatrics 112, 259–264.
Hashim, J.H., Hashim, Z., Omar, A., Shamsudin, S.B., 2000. Blood lead levels of urban and rural Malaysian primary school children. Asian Pacific J. Public Health 12 (2), 65–70.
International Labour Office (ILO), 1921. Convention 13 concerning the use of white lead in painting. ILO Publication No. 13. ILO Publications, Geneva.
Jacobs, D.E., Clickner, R.P., Zhou, J.Y., Viet, S.M., Marker, D.A., Rogers, J.W., Zeldin, D.C., Broene, P., Friedman, W., 2002. The prevalence of lead-based paint hazards in U.S. housing. Environ. Health Perspect. 110, A599–A606.
Kuruvilla, A., Pillay, V.V., Venkatesh, T., et al., 2004. Portable lead analyzer to locate source of lead. Indian J. Pediatr. 41, 495–499.
Lovei, M., 1999. Eliminating a silent threat: world bank support for the global phaseout of lead from gasoline. In: George, A.M. (Ed.), Proceedings of the International Conference on Lead Poisoning Prevention and Treatment: Implementing a National Program in Developing Countries, February 8–10, 1999. The George Foundation, Bangalore, India, pp. 87–94.
Michaelowa, A., 1997. Phasing out lead in gasoline: how developing countries can learn from the experiences of the industrialized world. In: Fairclough, A. (Ed.), World Development and Even Venture Finance 1997/1998. London, pp. 268–272.
Montgomery, M., Mathee, A., 2005. A preliminary study of residential paint lead concentrations in Johannesburg. Environ. Res. 98, 279–283.
Morbidity and Mortality Weekly Report (MMWR), 2005. Blood lead levels—United States, 1999–2002. 54(20) 513–516, May 27, 2005.
Nriagu, J.O., Blankson, M.L., Ocran, K., 1996. Childhood lead poisoning in Africa: a growing public health problem. Sci. Total Environ. 181, 93–100.
Rojas, M., Squillante, G., Medina, E., De Rojas, O., Sarmiento, A., 2000. Environmental factors associated with blood lead levels in Venezuelan children. Vet. Hum. Toxicol. 42, 174–177.
Shen, X., Rosen, J.F., Guo, D., Wu, S., 1996. Childhood lead poisoning in China. Sci. Total Environ. 181, 101–109.
Singapore National Environmental Agency (Singapore NEA), 2004. List of controlled hazardous substances. [on line] Available at: http://app.nea.gov.sg/cms/htdocs/article.asp?pid=1429 (accessed June 18, 2004).
US Consumer Products Safety Commission (US CPSC), 1977. Notice reducing allowable levels of lead. Final Rule. Fed. Register 42 (1 September 1977), 44199pp.
US Department of Housing and Urban Development (US HUD), 1995. Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing. HUD Office of Lead-based Paint Abatement and Poisoning Prevention, Washington, DC.
US Environmental Protection Agency (US EPA), 2001a. Lead: identification of dangerous levels of lead. Final Rule. Washington DC.
US Environmental Protection Agency (US EPA), 2001b. Standard Operating Procedures for Lead in Paint by Hotplate- or Microwave-based Acid Digestions and Atomic Absorption or Inductively Coupled Plasma Emission Spectroscopy. EPA, PB92-114172, September 1991.
Van Alphen, M., 1999. Lead in paints and water in India. In: George, A.M. (Ed.), Proceedings of the International Conference on Lead Poisoning Prevention & Treatment: Implementing a National Program in Developing Countries, February 8–10, 1999. The George Foundation, Bangalore, India, pp. 265–272.