Paint lead levels in Singapore

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ABSTRACT

The lead content of paint in Singapore was determined using field portable X-ray Fluorescence Analysers (NITON Corp, Billerica, MA, USA) in existing housing of various ages and in currently available paints. These instruments are widely used for lead determinations in paint, dust, soil and other media in the United States, Europe and elsewhere but had not previously been used for paint analyses in Singapore. Units of paint lead measurement are in mg Pb/cm^2 in the paint mode and ppm Pb in the bulk mode. In the United States, lead-based paint poisoning is still considered a major environmental health hazard and many efforts are underway to reduce the exposure to young children who are particularly susceptible to the harmful effects of lead. In Singapore, the maximum allowable level for lead in residential paint is 600 ppm. In the United States, the standard is also 600 ppm for new paints. Lead-based paint in existing US housing is defined as levels greater than or equal to a surface level of 1.0 mg/cm^2 or a mass concentration of 5000 ppm. In two groups of old housing in Singapore, the average lead content was found to be 2.5 mg/cm^2 in one group (exterior and interior surfaces) and 0.4 mg/cm^2 in another (exterior only). This compares to 3.3 and 6.2 mg/cm^2 on interior and exterior areas, respectively, in a recent study of older housing in the United States. In a group of newer homes from various areas of Singapore, none of the surfaces were found to exceed 1.0 mg/cm^2 except for plastic plumbing where the lead was thought to be incorporated into the plastic material itself. Of 22 new Singapore paints tested, all had surface levels of less than 1.0 when applied in three layers. The highest level was 0.09 mg/cm^2 with only two having average levels above 0.01 mg/cm^2. A scraping of the paint with 0.09 mg/cm^2 was found in the bulk mode to contain about 3000 ppm lead, five times the Singapore limit of 600 ppm. One paint with a level of 0.02 mg/cm^2 contained 1200 ppm lead, twice the allowable limit. Lead-based paints were frequently used in street markings and were readily available in a nearby country.

INDEX TERMS

Lead-based paints; Lead blood level; Microgram per deciliter

INTRODUCTION

Lead is widely used in the manufacture of paints, batteries, ammunition and glazed potteries. Until recently, it was used as an anti-knock additive in gasoline. The toxic nature of lead (Agency for Toxic Substances and Disease Registry, 1999) is well documented. It affects the central nervous system, the blood, the reproductive organs, cardiovascular systems and other bodily functions in varying degrees, depending upon their levels of exposure. Death and coma may occur when there are prolonged elevated blood lead levels (BBL) >80 μg/dl. When workers' BBL approach 40–50 μg/dl, they may experience fatigue, irritability, headaches, insomnia and a subtle drop in intelligence and mental alertness (Mantere *et al.*, 1984). Local paralysis known as 'wrist drop' or 'foot drop' (Feldman *et al.*, 1977) may occur when exposure is more than twice the PEL of 50 μg/m^3 while symptoms of fatigue and irritability

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are seen at lower levels. Lead is absorbed into the body through the lungs and digestive system. It accumulates in the bones and may be released into the blood many years later, re-exposing the bodily system to lead poisoning even though the original exposure may have been a long time ago (Mushak *et al*., 1989). Children are particularly vulnerable because their growing bodies absorb lead in a higher percentage than adults. Studies by Needleman (2004) and Battacharya *et al*. (1995) showed adverse effects on children.

In the United States, lead-based paint was widely used in the 1940s and continued to be used until the mid-1970s. As the buildings aged, lead exposures come from paint chips that break down into floor dust, from frictional abrasions between painted windows and frames and painted doors. Very young children are generally more at risk because they play on the floor more often and children at this age are also more prone towards hand to mouth activities (Bornschein *et al.*, 1986). Adult exposures come from renovation work on old buildings, bridges or on other surfaces coated with lead-based paints. In response to the public health problem of lead-based paint in housing, the United States' Congress passed the Residential Lead-Based Paint Hazard Reduction Act of 1992 (also known as Title X) to protect children from exposure to lead in paint, dust and soil.

In the United States, the Occupational Safety and Health Administration (OSHA) set the PEL on airborne inorganic lead at 50 $\mu g/m^3$ on an 8-h TWA. The OSHA general industry lead standard (29CFR1910.1025) requires the lowering of PEL for work shifts longer than 8 h and for workers whose exposures are $\geq$30 $\mu g/m^3$, medical monitoring is required. For workers whose BLL is 50 μg/dl, medical removal is imposed with pay retention. Units of paint lead measurement are in mg Pb/cm^2 in the paint mode and ppm Pb in the bulk mode. In Singapore, the maximum allowable level for lead in residential paint is 600 ppm. In the United States, the standard is also 600 ppm for new paints. Lead-based paint in existing US housing is defined as levels greater than or equal to a surface level of 1.0 mg/cm^2 or a mass concentration of 5000 ppm.

In Singapore, a comparison of the amount of lead used in paint was performed between sites having older buildings (Chinatown and Little India) and modern housing estates. The objective of this study was to determine the amount of lead used in paint in older housing compared with the more modern buildings.

METHODS

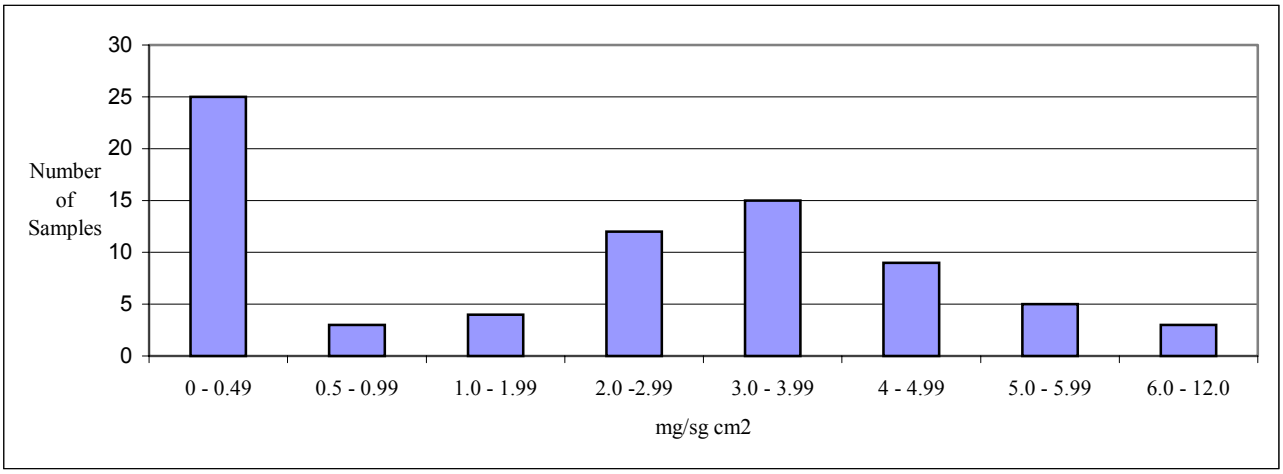
The lead content of paint in Singapore was determined using field portable X-ray Fluorescence Analysers. XRF equipment works on the principle that when a sample is irradiated with X-rays, the X-ray is either absorbed by the sample or scattered through the material. The process in which an X-ray is absorbed by the atom by transferring all of its energy to an innermost electron is called the 'photoelectric effect'. During this process, if the X-ray had sufficient energy, electrons are ejected from the inner shells, creating vacancies. These vacancies present an unstable condition for the atom. As the atom returns to its stable condition, electrons from the outer shells are transferred to the inner shells and in the process give off a characteristic X-ray whose energy is the difference between the two binding energies of the corresponding shells. Because each an element has a unique set of energy levels, each element produces X-rays at a unique set of energies, allowing one to non-destructively measure the elemental composition of a sample. The process of emissions of characteristic X-rays is called 'X-ray Fluorescence', or XRF. The XRF equipment that is calibrated for lead measurement will measure feedback of photon intensity or energy peaks from the lead sample. In most cases the innermost K and L shells are involved in XRF detection. The radiation feedback intensity of each sample is proportional to the amount of lead in the paint.

In the selection of old buildings for sampling, Singapore's Ministry of Manpower (MOM) and Urban Redevelopment Authority (URA) were approached and informed of the project. They informed the investigator that the two sites suitable for sampling were Chinatown and Little India. They also disclosed that some Chinatown houses were undergoing renovation works and provided names of contractors involved in the renovation works to the investigator. Some of the buildings undergoing renovation in Chinatown were in a condition where it was unsafe for the investigators to enter for sampling. All the contractors were contacted and where there was possibility for safe entry into the buildings, access was granted. As for Little India, these are accommodation units, restaurants and shop houses. Access into the buildings was quite problematic. Decision was made to take XRF readings of paintworks on the exterior of these buildings.

RESULTS

A total of 231 XRF readings were taken from various sections of the older housing in Chinatown. These are three-story buildings built in the 1940s and occupied mainly by Chinese immigrants who came to Singapore from China to seek a living. The ground floors were normally used for businesses and served as sleeping quarters at night. The second and third floors were each subdivided into seven or eight single room lodging areas (about 3 m × 3 m) and these were let out to tenants who shared a common toilet and kitchen. Readings were taken from walls, doors, door frames, windows, window frames, stairs located in the living room, bedrooms, halls, balcony, bathroom, kitchens and exteriors. The average mean reading was 2.54 mg/cm^2, with a range of 0–11.8 mg/cm^2. Chinatown's results indicated that many of the painted surfaces in this older housing site contained a measurable amount of lead. About 64% of the surfaces contained at least 1.0 mg/cm^2 of lead (one of the US standards for lead-based paint); 75% contained at least 0.1 mg/cm^2 of paint and the maximum was 11.8 mg/cm^2. Results of the readings are graphically represented in Figure 1.

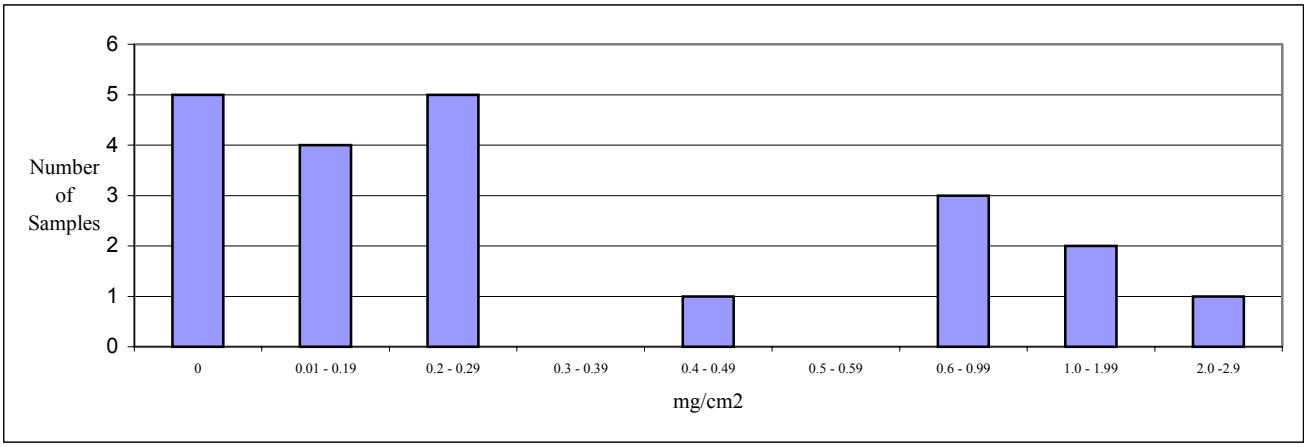
Figure 1 Paint lead readings in old Chinatown.



Little India is located at Serangoon Road, Singapore. It is one of the tourist sites in Singapore with history dating back to the 1900s. It still has many Indian temples, cafes, shops and restaurants. Buildings we visited were built in the 1940s or earlier. The investigator was unable to get timely access into the buildings, so the XRF measurements were taken on the exterior of the building, namely the doors, door frames, windows, window frames, wall, etc. A total of 42 XRF readings were taken. The average XRF reading was 0.413 mg/cm^2 with a range of 0–2.15 mg/cm^2. The results indicated that 14% of the painted surfaces contained lead-based paint by the US definition of ≥1.0 mg/cm^2. Figure 2 shows the lead-based paint

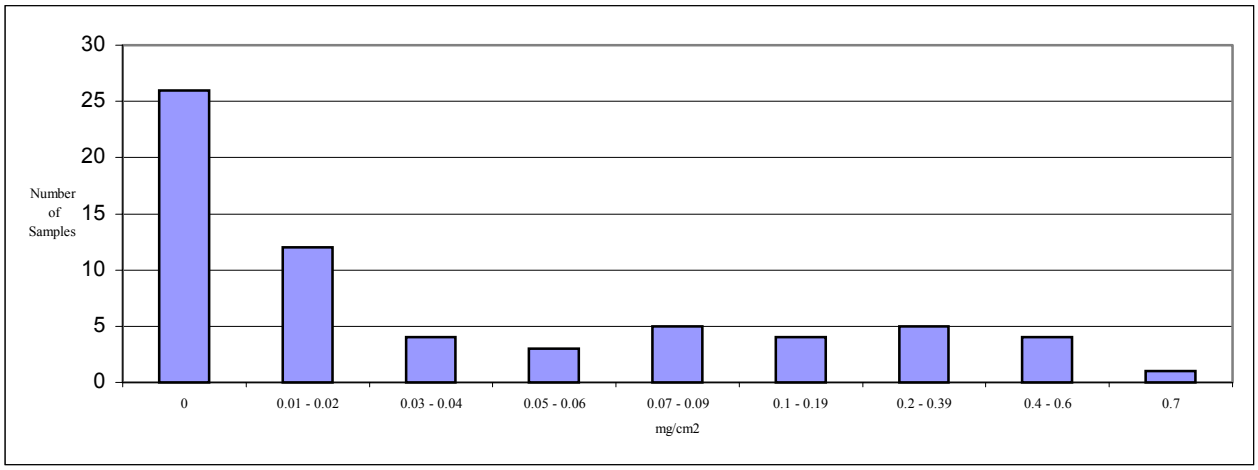
readings for buildings in Little India. Because of the limited sample size, results must be treated with caution. However, even with the limited sample size, some surfaces were found to contain lead-based paint.

Figure 2 Lead paint readings for Little India.



In the 'modern housing', a total of 201 XRF readings for lead were taken from nine houses. These houses belonged to friends and relatives of the investigator. Locations of these dwellings were Bishan, Hougang, Serangoon North, Woodlands, Clementi, Pasir Ris, Upper Changi and Toa Payoh. The average reading was 0.27 mg/cm^2 with a range of 0–0.7 mg/cm^2 (Figure 3). Four readings that are above 1 mg/cm^2 are not reflected in Figure 3. These high readings came from plastic pipes. It is understood that lead is used as a stabilizer in the production of plastics. Other than plastics, the results indicated that paint used in newer housing in Singapore did not exceed US lead-based paint standards of ≥1.0 mg/cm^2. However, at one of the new houses, paint scrapings from equipment from a play area were found to contain 3420 ppm of lead, which is above the Singapore standard of 600 ppm.

Figure 3 Lead paint readings in modern housing.



An investigative study was also conducted on paints bought from various parts in Singapore. Twenty-two cans of paint of different colours and different manufacturers were bought for the study. Each paint was applied to clean boards in three layers with XRF measurements made after each layer was applied. Investigation showed that all the 22 cans of paint bought in Singapore had little or no lead (≤0.09 mg/cm^2) in them. The average XRF reading for lead was 0.0073 mg/cm^2. The lowest XRF reading for lead was zero for three

coats of paint, while the highest reading for lead was 0.09 mg/cm^2 for three coats of paint. A scraping of the paint with 0.09 mg/cm^2 was found in the bulk mode to contain about 3000 ppm lead, five times the Singapore limit of 600 ppm. One paint with a level of 0.02 mg/cm^2 contained 1200 ppm lead, twice the allowable limit.

DISCUSSION

XRF readings in Chinatown showed that 64% of the sampled surfaces had paint lead levels above 1 mg/cm^2. In Little India, the XRF readings exceeded 1 mg/cm^2 for 14% of the sampled surfaces. However, the data collected from Little India came from the exterior of the building, since the investigator was unable to get access inside the houses to determine the interior XRF values. Modern housing from the various housing estates in Singapore did not have any lead-based paint exceeding 1 mg/cm^2 except for one isolated case.

The investigation of paints bought from various parts of Singapore showed that these paints did not have lead above 1 mg/cm^2. However, measurements made in the bulk mode demonstrated that the lead content may be at least two times higher than the 600 ppm standard.

CONCLUSIONS AND IMPLICATIONS

The conclusions drawn from XRF sampling data showed that paints used in older housing (built 1940s or earlier) in Chinatown and Little India generally had paint lead levels exceeding 1 mg/cm^2. In contrast, the paint lead levels in modern housing from the various Singapore housing estates showed that the lead level in paints did not exceed this limit. Paint lead levels in 22 cans of paints bought at random from various parts of Singapore and from different manufacturers also showed they were well below the 1 mg/cm^2 upon investigations.

The implications that can be concluded here is that paint manufacturers, in present day context, are fully aware of the toxicity of lead and had made conscious efforts to reduce its quantity in paint. It also implied that occupants of modern housing should not be unduly worried about house paints and their associated lead hazards.

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