Dusty Toxics
A Study on Lead in Household Dust in Delhi

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Foreword

The current study is the fifth in the series of evidence- based work to determine the presence of lead in our everyday lives, carried out by Toxics Link over the period of the past few years. The studies related to the presence of heavy metals (including lead) in vegetables through air, in vegetables through irrigation water, lead in toys, and lead in household paints. Other similar studies relating to mercury have also been carried out by us and are all- available on our website (www.toxicslink.org).

The presence of lead (and of cadmium and mercury) seems to be ubiquitous in our lives, and can lead to high exposures. This of course is completely avoidable. There is well- established medical evidence that exposure to lead and some other heavy metals cause significant and irreversible harm to human health. Children are most vulnerable and most at risk. This has been fully recognized by the World Health Organization (WHO) and other authoritative agencies.

It is therefore surprising that in India, where there has been a growing concern about harms to human health caused by chemical exposures, there has been very little attention given to heavy metals like lead, even when safer alternatives are easily available. In the developed world, many lead- containing products have been banned for more than a half- century, and sources of lead emissions to the environment are heavily regulated. In recent years, there has been important international progress in phasing-out lead from petrol, but the international community has given little attention to other major sources of lead exposure. Recently, the United Nations Environment Program (UNEP) has begun to debate international action on heavy metals, but only the context of their possible long- range transport across international borders. While understandably, developed countries act in self- interest to protect their own populations from such exposures, we in India have done too little.

India, having recently removed lead from petrol, seems to believe that the task is done and over with. However, as our studies show, this is far from the case. In all our studies, we have found an alarmingly high level of lead in everyday environments and products. However India does not regulate lead-containing products with mandatory standards that manufacturers must follow. Some manufactures appear to be making products that meet the lead contents standards of international markets whilst supplying lead laden products in India. This clearly reflects the duality of the approach, and the lack of government policy or public awareness.

This study of lead in household dust was undertaken to examine an important source of exposure. Lead in dust is often ingested by children and harms their health. It affects the brain, decreases lifelong intelligence, and causes behavior disorders. Dust is present in our homes and all around us. When household dust contains lead, children are exposed. We need an urgent response, since most major sources of lead are replaceable by much safer alternatives. This has been known for decades by the industry and by scientists. Not to take action, is criminal.

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About Toxics Link

Toxics Link is an information outreach and environmental advocacy organization set up in 1996. It has a special emphasis on reaching out to grassroots groups and community based organization. The areas of its engagements include research, outreach and policy advocacy on issues of communities and urban waste, toxics free healthcare, hazardous waste and pesticides.

Toxics Link works closely with all stakeholders working on similar issues and has been conducive to the formation of several common platforms for them. It also networks internationally and is part of international networks working on similar issues.

The mission of the organization is to:

"Working together for environmental justice and freedom from toxics. We have taken upon ourselves to collect and share both information about the sources and dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and rest of the world"

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The idea to do this study was mooted by Jack Weinberg of the International POPs Elimination Network (IPEN). He has also been helpful in reviewing the draft of the report. I am, therefore, indeed indebted to him. Thanks are due to my colleagues at Toxics Link for helping this project carry forward. I take this opportunity to express my gratitude to Prof. Scott Clark, University of Cincinnati and Perry Gottesfeld, Director, OK International for providing sampling kits and helping me understand the sampling protocol. Comments and suggestions received from them were very helpful in finalizing the report. I am grateful to Ravi Agarwal and Satish Sinha, Associate Director, Toxics Link for providing important inputs during the entire course of this project. I also wish to thank all who allowed me to collect samples from their respective homes. Without their support this work could not have been completed.

Abhay Kumar

Summary and Conclusion

The study analyzed 99 samples of dust taken from floors in Delhi houses for lead content. It also analyzed 49 samples of dust taken from windowsills. The findings were then compared with standards that have been set by the United States Environmental Protection Agency (USEPA). Under the USEPA standards, a hazard exists, and a house is not considered to be clean enough to be occupied by children, when there are 40 or more micrograms of lead in dust per square foot on its floors; or when there are 250 or more micrograms of lead in dust per square foot on its interior windowsills.

The study found that 31% of the floor dust samples collected from Delhi houses that it analyzed exceeded the USEPA standard; and that 14% of the of the window sill dust samples in analyzed exceeded the USEPA standard. This suggests that the lead content of the dust in many Delhi homes is at a level that poses a hazard to children.

More studies are needed to further document the lead content of dust in houses in Delhi and in other parts of India. However, it is likely that the levels we found in Delhi houses are typical of will be found in urban areas across the country. Toxics Link therefore concludes from this study that action is needed to further control sources of lead dust in India.

The phase-out of lead from petrol in India was a good first step. However, mandatory government regulations are now urgently needed to phase-out and ban other sources of lead in the environment starting with lead-containing paints. Additional work is needed to identify other major sources of lead contamination in India and to develop the regulations needed to bring them too under control.

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INTRODUCTION

Household dust intake is a significant pathway of human exposure of many contaminants including microorganisms, toxic flame-retardants (Jones-Otazo et al., 2005), synthetic organic contaminants and allergens. Household dust is also a very important pathway of heavy metals, particularly lead. Lead (Pb) in household dust is especially dangerous to children who are especially sensitive and who ingest lead from playing close to the ground and having frequent hand-to-mouth contact.

Because of widespread and diverse use of lead, its content in dust is dependent upon many factors. The previous use of lead based gasoline (which has now been phased out in India) was probably the largest single source of lead in the general environment, and lead from this source continues to circulate. Important sources that are mainly local include the manufacturing and recycling of lead batteries; lead smelting and lead mining industries; abandoned lead smelters and old mines; garages that work on car radiators; hazardous waste sites; and others.

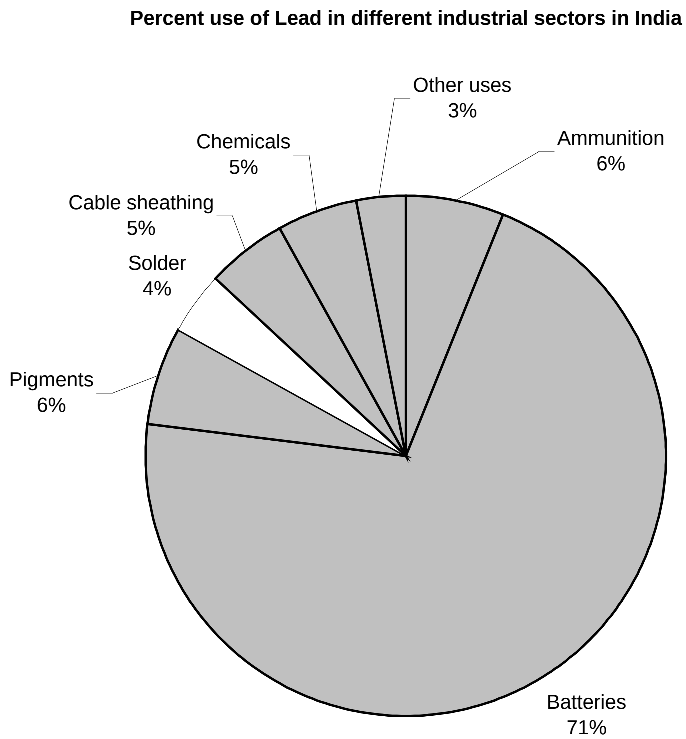
Additionally, when lead based paints are used in and around homes, this contributes directly to the contamination of household dust with lead. The paint on interior walls degrades when it is exposed to sunlight and its lead content becomes part of the house dust. Paint can also crack or blister and release paint chips that then crumble. When building exteriors are coated with lead paint, lead contamination in the soil surrounding the structure is common.

The above-mentioned factors can all contribute to the lead content of household dust. The occupations of residents, the age and location of the house, its proximity to environmental sources of lead, and other considerations all play a role.

Household dust is a major source of childhood lead exposure. Although children are known to eat paint chips, contaminated dust and soil are often the most significant sources of exposure for children. Significant exposure may also occur from lead paint when smaller particles become airborne during sanding and scrapping while repainting and remodeling. In addition, damaged paint and the weathering of paints on the exterior of buildings also contribute to lead in soil and exterior dust making contaminated soil another significant source of exposure to children. Ingestion of interior and exterior dust, lead based paint chips and contaminated soil are all-important sources of lead exposure in infants and young children.

Source apportionment of lead in house dust has been conducted by using automated scanning electron microscopy (Hunt, A. et al., 1992; Hunt, A. et. al., 1993) and by performing mass balance analyses (Adgate, J. L. et al., 1998). In these studies, the exterior sources (street dust/soil) and lead based paint appeared to be major contributors to contamination of the residential environment. The extent of the lead absorption form these sources depends on the duration and intensity of exposure, age, hand- to- mouth behaviour, the consumption of nonfood substances (pica), socioeconomic status, diet and cultural practices.

The following pie chart (Fig- 1) represents the percentage usage of lead in different industrial sectors in India in 1999- 2000 (Tandon, S.K., 1999)



The domestic demand for lead in India is approximately 170000 t/y while the total primary smelting capacity in the country is 89000 t/y. This gap in demand and supply creates the need for India to import lead, mainly from China, Korea and Australia. Production of lead concentrates in India is given in table- 1.

Table- 1 Production of lead concentrates in India.

States	2002- 03 (in tones)	2003- 04 (in tones)	2004- 05 (in tones)
AP	3153	-	-
Rajasthan	55806	72958	81601
Sikkim	148	111	34
Total	59107	73069	81635

Source: Unstarred question number 2534, answered on 14th March 2006 in the Lok Sabha (Lower House) of Indian Parliament

Worldwide USA, China, Japan, the European Union and India are the major consumers of lead. Lead supply in world is controlled by Australia and China.

Household dust and Human Exposure Pathways

Many studies have been conducted in the past to examine the relationship between lead levels in soil and household dust and blood-lead levels of children residing in the home (Brunekreef et al., 1981; Charney et al., 1980; Diemel et. al., 1981; Milar and Cooney, 1982; Roels et al., 1980; Galke at al., 2001; Lanphear et al., 1998). There have been several reports on the correlation of hand lead to blood lead to support the hand-in-mouth route of lead ingestion (Charney et al., 1980; Duggan, 1980; Roels et al., 1980). An impressive research effort has focused on the role of lead contaminated dust in contributing to children's blood lead levels over the last three decades. Nonetheless, there is still debate about sources of the lead in dust although leaded gasoline and lead-based paints appear to be major contributors.

Some argue that lead-based paint is the most important source of lead exposure and that it is a major contributor to lead in soil and dust. In the Unites States much of the lead contaminated dust comes from painted surfaces or from automotive or industrial pollution fallout (Clark et. al., 1985). Several studies have shown that the elevated lead levels in blood (B-Pb) of preschool children were strongly associated with elevated lead levels in house dust (D-Pb) (Charney et al., 1983; Bornschein et al., 1986; Thornton et al., 1990; Davies et al., 1990; Clark et al., 1991; Cambra and Alonso, 1995; Lanphear et al., 1996; Rhoads et al., 1999). This association between B-Pb and D-Pb has been attributed to dust ingestion from the frequent hand-to-mouth behaviour of young children (HUD, 1995).

Other studies have identified flaking lead-based paint, road dust, garden soil, and airborne lead-bearing particles as major sources of lead in household dust (Yiin et al., 2000). Mielke and Reagan (1997) concluded in their review paper that leaded gasoline showed greater importance compared to lead-based paint as a source of exposure. However, we also know that homes with lead paint on the interior and/or exterior are more likely to have lead contaminated soil and dust. Most studies concur that lead contaminated dust and soil resulting from leaded gasoline and the presence of lead-based paint is a more significant pathway of human lead exposure than the presence of only lead-based paint. Once a country phases out the use of leaded gasoline, its contribution to household dust declines over time, and other sources become more important.

Lead based paint in older houses has long been associated with elevated blood lead in children residing within them (Clark, et al., 1985). In one of the first studies on lead in paints and soil in India, Clark, et. al., (2005) concluded that lead paint should be considered a significant potential source of lead poisoning in the country. They tested the lead content of 29 paint samples collected from Gujarat and Karnataka in India and reported that 11 of them were either equal or exceeded 1.0 mg/cm^3. In one of the studies to investigate the sources of lead in environment in children with elevated blood lead concentrations with the help of Field Portable X-Ray Fluorescence Analyzer, Kuruvilla A., et. al., (2004) attributed high blood lead levels in three of ten children to be likely due to lead-based paint: in one child with the brightly coloured swings painted with lead based paint in an area where he routinely played. In another case high blood lead level was associated with a railing coated with lead based yellow paint where the child played. The third child with high blood lead level attributed to lead-based paint had the habit of licking the painted surface (pica) leading to ingestion of lead.

In one of the recent studies done by this author on lead content in household paints it was found that about 84 percent of samples of new enamel paint available in the Indian market contained lead at levels more than 600 ppm (Kumar A, 2007). Another study done by Clark, et. al., (2005), found 78 percent of new paint samples purchased from China, India and Malaysia containing lead at levels of 600 ppm or more. The authors point out that the lead content in paints depended upon the regulations and the same brand has different contents of lead in different countries depending upon whether any regulation existed or not (Clark, et. al., 2006). They also reported that 100 percent (n=17) of paint samples from India had more than 600 ppm of lead concentration.

In a study conducted before the complete phase-out of lead from gasoline to estimate the blood lead level and prevalence of lead toxicity in school children and children residing in urban slums in Delhi, it was found that the mean blood-lead level was 7.8 µg/dl and the proportion of children having blood lead levels greater than 10 µg/dl of blood-lead was 18.4 percent (Kalra, V., et al., 2003). It also suggested that distance of the residence or school from a main road appeared to be associated with higher blood lead concentrations, but these differences were not statistically significant.

Health Impacts of Lead

Childhood lead exposure adversely affects cognitive and behavioural development. No level of lead in blood is considered safe. Studies are finding adverse affects of lead at lower and lower levels. In the United States, health authorities recommend a public health intervention when a child is found to have a blood lead level of 10 µg/dl or more. However, the US Center for Disease Control (CDC) which established this recommendation, also states that 10 µg/dl should not be seen as defining a threshold level for harmful effects (CDC, 1991). The World Health Organization (WHO) suggests that IQ loss can be expected from blood lead levels as low as 5 µg/dl (Lanphear et. al., 2000). Some researchers now argue that public health interventions should be triggered when a child's blood level is above 2 µg/dl (Gilbert, S. G. and Weiss, B. 2006).

In the 1960's, the accepted action level of lead in blood was 60 µg /dl. This was brought down to 30 µg/dl in 1970s and further revised in 1990s to the current level (Kumar, A. and Pastore, P., 2007). The current level is considered by many to be out of date as it fails to account for research conducted in the past ten years which finds neurological deficiencies in children at blood lead levels of 5 µg/dl (Needleman & Gatsonis, 1990; Canfield et al., 2003). Other recent studies have found that children's math and reading scores showed reductions correlating to blood lead levels at concentrations lower than 5 µg/dl ((Lanphear et. al., 2000).

The disturbing fact is that exposure to extremely small amounts of lead can have long- term and measurable effects in children while at the same time causing no distinctive and readily detectable symptoms. Once lead is absorbed into the blood stream, some of it is filtered out and excreted, but the rest gets distributed to the liver, brain, kidneys and bones, with the latter containing the bulk of the body's lead burden. The following table (Table–2) summarizes the range of symptoms that are generally observed at different blood lead levels in both children and adults.

Table 2. Symptoms associated with Blood Lead Levels in Children and Adults

Effect in Children	Pb- Blood (μg/dl)	Effect in adults
Mortality	150	
	100	Encephalopathy
Encephalopathy		
Nephropathy		Anemia
Anemia		
Abdominal pain		
	50	Decrease in hemoglobin synthesis
Decrease in hemoglobin synthesis	40	Infertility (men) Nephropathy
Diminished Vitamin D metabolism	30	Hearing loss
Diminished nerve conduction	20	
Erthropoietic protoporphyria	10	Hypertension
Hearing loss		Miscarriages
Reduced growth		

Source: Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Case Studies in Environmental Medicine, No. 1.

Children and pregnant women are particularly susceptible to lead poisoning. Children's digestive system absorbs up to 50% of the lead they ingest (NRCLPI, 2008) The high retention occurs from birth to age 6 when the brain is developing and lead interferes with its development. By the time physical symptoms are evident - headache, lethargy or hyperactivity, nausea, stomach aches, vomiting, and constipation - significant brain damage has already occurred. The fetuses of pregnant women are gravely affected by lead exposure since lead can pass through the placenta directly into the baby. This problem is compounded by the lead released from the bones of pregnant women to provide the body with calcium and other minerals. High lead exposures can also result in birth defects and fetal death.

Dust wipes sampling

Although different techniques to sample house dust for lead contamination have been used, U.S. regulatory standards rely on dust wipe sampling. Wipe sampling techniques for floors and windowsills have been widely studied. This test measures lead loading on surfaces and not the lead concentration of the dust. It is also reflective of children's normal hand-to-mouth behaviour wherein a child while playing on ground touches the dust and then puts their hands into the mouth. What is important is not the total lead concentration (by weight) in dust but the lead quantity, which is ingested by a child. The lead concentration, multiplied by the dust loading on a surface, gives a lead loading value (µg/g x g/ft^2 = µg/ft^2) and is commonly expressed as micrograms of lead per unit area (µg/m^2 or µg/fl^2) [EPA, 1995]. Davies, et. al., (1990) states that for a given lead loading value, the lead concentration can range from high where there is little dust to, conversely, low where there is a large volume of dust. So, a situation may arise where a house may have low lead concentration but due to high dust loading on floor may contain high lead load values. Sterling, et. al., (1999) in their study on evaluation of vacuum and wipe methods for determining exposure to lead-contaminated household dust found that wipe method significantly correlated with blood lead levels and that regression analysis indicated that a blood lead level of 10 µg/dl corresponded to a carpet wipe sampling geometric mean of 68 µg/ft^2.

Dust Load Standards

Few countries have any standards for lead content in household dust. The U.S. Environmental Protection Agency (USEPA) and the USA Department of Housing and Urban development have developed a standard to determine if a home is sufficiently clean to be occupied by children following a lead abatement project.

Under the current USEPA standards, lead is considered a hazard when equal to or exceeding 40 micrograms of lead in dust per square foot on floors; 250 micrograms of lead in dust per square foot on interior window sills, In addition, the regulated soil lead levels for residential properties are 400 parts per million (ppm) in children's play areas and 1200 ppm average in the rest of the yard.

Only exposed areas of soil without vegetation are considered a hazard. The dust standards also specify a wipe method for collection of the samples.

STUDY OBJECTIVES AND METHODOLOGY

Objectives

The primary objective of the present study was to quantitatively analyse lead (Pb) loading in samples of settled household dust collected from various locations in Delhi using the wipe sampling method. The results can be useful for predicting the extent of children's blood lead levels that come from this pathway. This was done to follow up on previous study of lead paint showing a high prevalence of lead in paint at levels exceeding US regulatory levels and this study was done to investigate a potential exposure pathway that can result from the presence of lead based paint. This study, done by Toxics Link (Brush with Toxics: An investigation on Lead in household paints in India), found 84 percent of enamel paint samples containing more than 600 ppm of lead. 61 percent of samples had lead concentration more than 5000 ppm. 38 percent of all samples, including plastic and enamel types, contained lead at levels above 600 ppm, an international standard formulated by the US EPA.

Study Site

Delhi is the capital city of India spread over an area of 1483 Km^2. The river Yamuna, a tributary of Ganga, forms the eastern boundary of the city. It is also bounded by the Thar desert of Rajasthan in the west and hot plains of central India in the south. Delhi is situated between 28^0.25' and 28^0.53' N and 76^0.50' and 77^0.22' E. Delhi ridge forms the most important geographical region of this city as it not only protects the city from the sweltering heat of Thar in the west but also inhabits many important fauna and flora. Delhi ridge originates from the Aravali range in the south and encircles the west, north and northwest parts of the city. Delhi has a sub- tropical climate with extremely hot summer and moderately cold winters. Its climate is influenced by the Himalayas in North and Thar Desert in the West. The rainfall in this region is generally erratic.

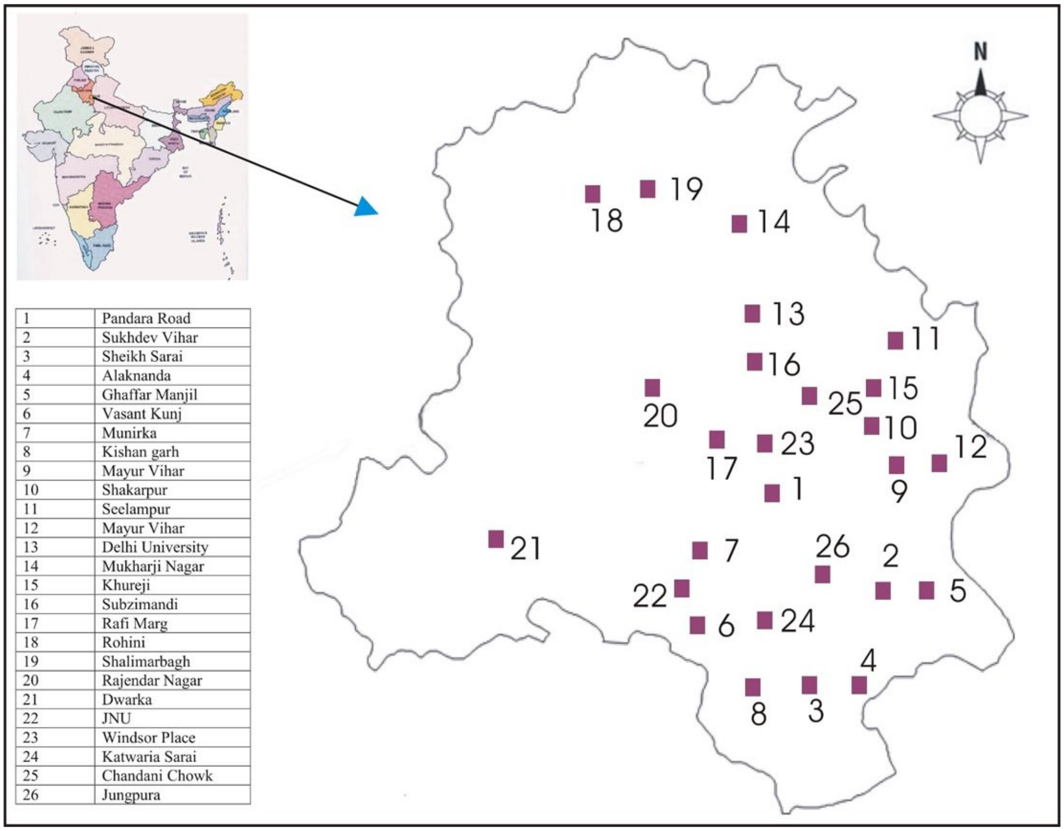
According to the 2001 census, the population of Delhi was 13,782,976. The corresponding population density was 9,294 persons per km², with a ratio of 821 women per 1000 men, and a literacy rate of 81.82%. In 2001, the total workforce in all government (union and state) and quasi government sector was 620,000. In comparison, organised private sector employed 219,000. In 2001, the manufacturing sector employed 1,440,000 workers while the number of industrial units was 129,000. Delhi's vehicular population increased from 1.9 million in 1990 to 3.6 million in 2001 (an increase of almost 87 percent). During the same time the road length in Delhi has increased by 14 percent from 22,000 Km to 25,000 Km.

Sampling

Wipe samples for settled dust were collected from both floors and interior windowsills from 33 single or joint family homes during the winter of November- December 2007 following USEPA's method. A total of 155 dust wipe samples were collected (which including field blanks) from these homes located in six parts of Delhi, viz., North Delhi, South Delhi, South- West Delhi, West Delhi, East Delhi and Central Delhi. Sampling locations are depicted in figure 2 and its details are given in table 3 (Annexure I). In this table, house code instead of actual address has been assigned. On an average 4- 5 samples were collected from each home. Random selection of houses was not possible as only those homes were sampled where permission was granted. However, houses were selected to be representative of all socioeconomic sectors of society. 25 samples from 5- 6 houses were planned to be collected from each zone. The actual number of houses sampled in each zone is given in Table 4.

Table 4. Number of houses sampled in each zone

Sampling Zone	No of Houses
North Delhi	6
South Delhi	11
East Delhi	5
West Delhi	3
Central Delhi	5
South-West Delhi	3
Total	33



1	Pandara Road
2	Sukhdev Vihar
3	Sheikh Sarai
4	Alaknanda
5	Ghaffar Manjil
6	Vasant Kunj
7	Munirka
8	Kishan garh
9	Mayur Vihar
10	Shakarpur
11	Seelampur
12	Mayur Vihar
13	Delhi University
14	Mukharji Nagar
15	Khureji
16	Subzimandi
17	Rafi Marg
18	Rohini
19	Shalimarbagh
20	Rajendar Nagar
21	Dwarka
22	JNU
23	Windsor Place
24	Katwaria Sarai
25	Chandani Chowk
26	Jungpura

Figure 2. Map of Delhi showing sampling locations

Sampling required following materials.

i) Disposable wipes- Lead-free lead dust sampling wipes which met ASTM standard E1792 were used. Wipes were manufactured by Lynx Products, P.O. Box 29, Thorofare, NJ 08086

ii) Disposable gloves were used to prevent cross-sample contamination from hands.

iii) Centrifuge tubes (50 ml) were used primarily to keep sampled dust wipes.

iv) Disposable plastic templates was used to mark the area to be sampled

v) Permanent marker

vi) Measuring tape

vii) Trash bag

viii) Dust sample collection forms

Wipe sampling Procedure

Floors: First a representative area to be wiped was identified and a template of 1 ft^2 of dimension was placed on the surface. Care was taken to ensure that area to be wiped was not touched, except by the wipe during the sampling process.

Windowsills: Similar procedure was adopted in case of windowsills except that in this case adhesive tapes were used to mark the measured surface area.

With new gloves the moist wipe was placed in a corner of the surface to be wiped. With fingers together, the wipe was grasped between the thumb and palm and pressed down firmly. Care was taken to avoid any touching the building surface with the thumb or other fingers. Then the entire surface was wiped side- to- side with as many 'S' –like motions as necessary to completely cover the wipe area. Then the wipe was folded in half with the contaminated side facing inward. Once folded, the wipe was placed in the top corner of the wipe area and pressed down firmly with the palm and fingers. Wiping of the surface was repeated with as many 'S' –like motions as necessary. This time wiping was done in a top- to-bottom direction to collect all visible dust. If required, more than one wipe was used in collecting dust. After wiping was over, the wipe was folded with the contaminated side facing inward again and inserted into centrifuge tubes and was marked. In case of windowsill after collecting the samples, wiped area was measured. Blank wipes were also kept in the centrifuge tubes and were given unique sample identification numbers before being submitted for laboratory analysis.

Sampling forms were filled with all information regarding the nature of surface, type of room, location of the sampling, and an assigned sample number, etc. After sampling, templates, tapes, gloves etc were kept in a trash bag, which was disposed outside the dwelling unit.

Laboratory Methods

Laboratory analysis was done as per the ASTM ES 30- 94. The details of the protocol are discussed below. All laboratory works were done in Delhi Test House, Azadpur, New Delhi, a NABL accredited laboratory.

Process

Wipe samples were digested in closed digestion assembly in the presence of Oxy-acid (Suprapur grade Nitric Acid) and Hydrogen peroxide and after making a fixed volume, lead content is determined by Graphite furnace Atomic Absorption Spectrometer.

Chemicals and Glassware

i) 1000 mg/l Pb, Lead standard solution traceable to SRM from NIST certified Pb $(NO_3)_2$ in HNO_3 0.5 mol/l. (MERCK)
ii) Nitric Acid (Lead free suprapur ® MERCK)
iii) Hydrogen Peroxide (Lead free MERCK)
iv) Digestion Assembly (Closed Reflux)
v) Volumetric flask
vi) Auto- Pipette (200µl- 1000µl)
vii) Auto- Pipette (50µl- 200µl)

Equipment

i) Closed Digestion Assembly (Closed Refluxed)
ii) Atomic Absorption Spectrometer with Graphite Furnace
Make – GBC, Model – 932 Plus.

Sample Preparation

Dust wipes were weighed and placed into different flasks. Then 10 ml HNO_3 (Suprapur) and 5 ml H_2O_2 and 35 ml double distilled water were added into each flask and digestion was performed for 8 hours, including a sample blank with each set of 12 digestion flasks. Sample and sample-blank were made to final volume and then analysed on GF-AAS. Calibration curve for the standards was also performed.

Recovery Study

Recovery was between (90-110) percent for different lots of digestions.

Results And Discussion

Results

The average lead loading for floor samples is 36.24 µg/ft^2. The average lead loading values for windowsill samples is 129.48 µg/ft^2. The range of values for floor dust samples range from 0 to 221.57 µg/ft^2, while for windowsill dust samples the range is 3.88 µg/ft^2 to 558.48 µg/ft^2. Table 5 and 6 (Annexure II) give the lead loading values (µg/ft^2) of floor dust samples and interior windowsill samples respectively. A summary of the results is presented in Table 7.

Table 7 Common statistical parameters related to the data set on Lead loading in dust samples

	Number of samples	Arithmetic mean	Geometric mean	Max	Min	Std Dev
Floors	99	36.24	19.66	221.57	0	43.81
Windows	49	129.48	75.46	558.48	3.88	140.17

Graphical representations of table 5 and 6 are shown in figure 3 and 4. Table 8 shows the prevalence of lead contaminated dust samples above or lower than the EPA standards among the housing units.

Table 8: Prevalence of lead contaminated dust samples above or lower than the EPA standards among the housing units.

Number of housing units which had only floor samples, one or more exceeding the EPA standards of 40 µg/ft^2	10
Number of housing units which had only windowsill samples, one or more exceeding the EPA standards of 250 µg/ft^2	0
Number of housing units which had both floor and window samples exceeding the EPA standards of 40 µg/ft^2 and 250 µg/ft^2 respectively	7
Number of housing units which had none of the samples exceeding the EPA standards for floor or window dust samples	16

16 housing units had no sample exceeding the EPA standards. 10 housing units had only floor samples exceeding the EPA standards while none of the housing unit reported only windowsill sample exceeding EPA standards. There were 7 housing units, which had both floor and window samples exceeding the EPA standards.

Out of 99- floor dust samples that were analysed for lead loading, 31 showed (31 percent) exceeded the USEPA standard of 40µg/ft^2. Out of 49 interior windowsill dust samples that were analysed for lead loading 7 samples (14 percent) exceeded the US EPA standard of 250 µg/ft^2. A total of 26 percent of the samples collected exceeded the EPA standards of lead loading in household dust. Table 9 shows the percentage of samples that exceeded the EPA standards in each sampling zone.

Table 9. Percentage of samples exceeding EPA standards in the each sampling zone (Figures in parenthesis is the total number of samples in the zone)

Sampling zone	Floor dust percentage	Window dust percentage
North Delhi	59 (n =17)	25 (n = 12)
South Delhi	31 (n = 29)	17 (n = 12)
South West Delhi	31 (n = 12)	33 (n = 3)
East Delhi	19 (n = 16)	11 (n = 9)
Central Delhi	19 (n = 16)	- (n = 9)
West Delhi	11 (n = 9)	- (n = 4)
Overall Average	31	14

Total percentage of samples (including floor and window sill) exceeding EPA standards --- 26 %
(n) denotes the sample size in that particular zone)

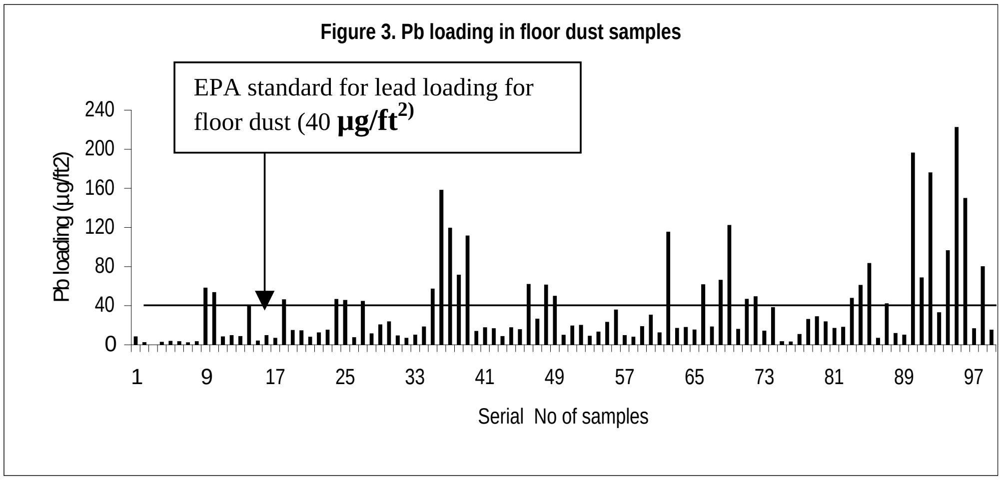


Figure 3. Pb loading in floor dust samples
EPA standard for lead loading for floor dust (40 µg/ft2)
240
200
160
120
80
40
0
Pb loading (µg/ft2)
1
9
17
25
33
41
49
57
65
73
81
89
97
Serial No of samples

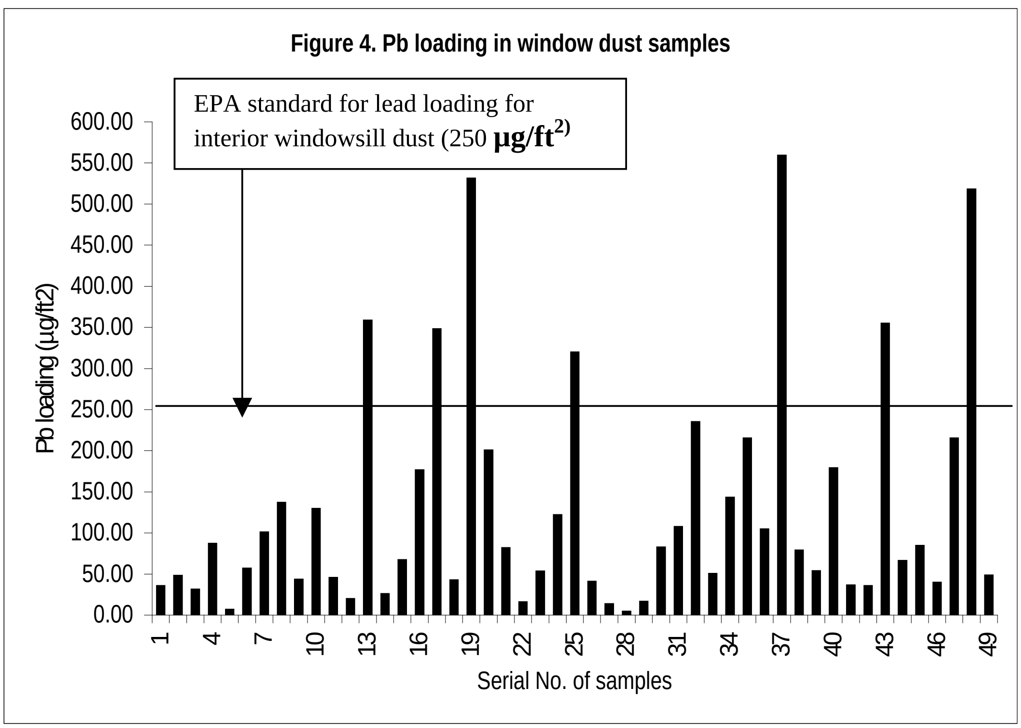


Figure 4. Pb loading in window dust samples
EPA standard for lead loading for interior windowsill dust (250 µg/ft2)
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Pb loading (µg/ft2)
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
Serial No. of samples

Discussion

The geometric mean of dust lead loading for floor and interior window samples is 19.66 µg/ft^2 and 75.46 µg/ft^2 respectively in a cross-section of housing in Delhi. This study assumes significance if compared with the study done by Galke et al., (2001), which reported dust lead loading in high-risk housing of a number of cities in USA. They found the geometric mean of dust lead loading for floor samples to be 34 µg/ft^2, which declined to 12 µg/ft^2 immediately after the lead abatement interventions. Similarly, for windowsill samples the geometric mean of lead loading declined from 340 µg/ft^2 to 19µg/ft^2 after lead abatement interventions. Galke et al., (2001) also reports the blood lead levels of children residing in these homes. The blood lead level of these children ranged from 2 to 48 µg/dl with a median of 10 µg/dl. Thus one half of the kids had levels above the CDC level levels of concern. Sterling et. al. (1999) has reported that a blood lead level of 10 µg/dl corresponded to a carpet wipe sampling geometric mean of 68 µg/ft^2. Therefore, although the geometric mean of lead dust loading for floor samples in Delhi is lower than the one reported by Galke el al., (2001) for US cities, it still suggests blood lead levels higher than 10 µg/dl in significant number of children in these homes in Delhi. This is particularly significant because the housing in Delhi was thought to represent a cross-section of housing conditions and not focused on high-risk housing, as was the Galke et al study.

Lead was found in all but one sample in varying surface loading levels. As discussed earlier lead in household dust may primarily come from following sources: a) Industrial sources; b) Lead-based gasoline; c) Paints. Industrial sources range from lead smelters to recycling of lead acid batteries in unorganized sector. Battery assemblers in unorganized sector are spread all over Delhi. They are located in the areas like Narela, Jangpura, Karol Bagh, Pahar Ganj, Mayapuri, Gokhale Market, Sadar Bazar, Mandoli, Motiakhan, Turkmann Gate, Ballabh Garh, Old Silampur, Gokhale market Mandoli. Most of these areas are located in North, North-West or East Delhi. Those homes, which showed high lead loading in dust samples, were typically middle class homes with paint coatings on walls in different conditions. Given the scope of the present study it is not possible to locate the precise source of lead in household dust. It appears that small-scale industries in unorganized sector, which use or recycle lead and the household paints are the most likely primary contributors for lead contamination of household dust. Soils, which get contaminated by paints and other lead-materials in and around the houses, may also contribute to lead loading of household dust. A more elaborate study, which can take into account various factors contributing to lead contamination in dust, is recommended.

CONCLUSION

1. Almost all samples showed lead loading in varying amount.
2. A total of 38 samples (26 percent) showed high lead loading exceeding the EPA standards.
3. 31 percent of floor samples and 14 percent of windowsill dust samples exceeded the EPA standards.
4. These levels were only 15 percent lower than those in a large US study where one half of the children had blood lead levels above 10 µg/dl, the CDC level of concern and where the focus was on high risk housing rather than a cross- section of housing selected in Delhi.
5. Household paints and small- scale industries in unorganized sector, especially lead- acid battery assemblers are the most likely primary contributors for lead contamination of household dust.
6. Soils, which get contaminated by paints in and around the houses, may also contribute to lead loading of household dust.

Annexure I

Table 3. Sample description

SAMPLE NO	SURFACE SAMPLED	SAMPLE LOCATION	ROOM	AREA OF SURFACE SAMPLED
1	Blank	Blank		Blank
2	Floor	House of A, Pandara Road, Central Delhi	Drawing room	1 ft^2
3	Floor	House of A, Pandara Road, Central Delhi	Bed room	1 ft^2
4	Floor	House of A, Pandara Road, Central Delhi	Bed room	1 ft^2
5	Window sill	House of A, Pandara Road, Central Delhi	Drawing room	38" x 2"
6	Floor	House of B, Sukhdeovihar, South Delhi	Drawing room	1 ft^2
7	Floor	House of B, Sukhdeovihar, South Delhi	Dining room	1 ft^2
8	Floor	House of B, Sukhdeovihar, South Delhi	Bed room	1 ft^2
9	Window sill	House of B, Sukhdeovihar, South Delhi	Bed room	39" x 2"
10	Floor	House of C, Sheikh Sarai, Ph-II, South Delhi	Drawing room	1 ft^2
11	Floor	House of C, Sheikh Sarai, Ph-II, South Delhi	Drawing room	1 ft^2
12	Window sill	House of C, Sheikh Sarai, Ph-II, South Delhi	Bed room	23" x 2.5"
13	Floor	House of C, Sheikh Sarai, Ph-II, South Delhi	Play room	1 ft^2
14	Floor	House of D, Alaknanada Apts, South Delhi	Drawing room	1 ft^2
15	Floor	House of D, Alaknanada Apts, South Delhi	Bed room	1 ft^2
16	Window sill	House of D, Alaknanada Apts, South Delhi	Drawing room	45" x 2"
17	Floor	House of D, Alaknanada Apts, South Delhi	Bed room	1 ft^2
18	Floor	House of E, Jamia Nagar, South Delhi	Drawing room	1 ft^2
19	Floor	House of E, Jamia Nagar, South Delhi	Bed room	1 ft^2
20	Window sill	House of E, Jamia Nagar, South Delhi	Bed room	30" x 5.5"
21	Window sill	House of F, Vasant Kunj, South Delhi	Drawing room	69" x 2"
22	Floor	House of F, Vasant Kunj, South Delhi	Drawing room	1 ft^2
23	Floor	House of F, Vasant Kunj, South Delhi	Bed room	1 ft^2
24	Floor	House of F, Vasant Kunj, South Delhi	Dining room	1 ft^2
25	Floor	House of F, Vasant Kunj, South Delhi	Drawing room	1 ft^2

26	Floor	House of G, Munirka, South Delhi	Drawing room	1 ft^2
27	Window sill	House of G, Munirka, South Delhi	Drawing room	5.5" x 22"
28	Floor	House of H, Kishan agrh, South Delhi	Drawing room	1 ft^2
29	Window sill	House of H, Kishan agrh, South Delhi	Drawing room	59" x 2"
30	Blank	Blank		Blank
31	Floor	House of I, Mayur Vihar, Phase-1, East Delhi	Drawing room	1 ft^2
32	Floor	House of I, Mayur Vihar, Phase-1, East Delhi	Drawing room	1 ft^2
33	Floor	House of I, Mayur Vihar, Phase-1, East Delhi	Bed room	1 ft^2
34	Window sill	House of I, Mayur Vihar, Phase-1, East Delhi	Drawing room	24" x 3"
35	Floor	House of J, Shakarpur, East Delhi	Drawing room	1 ft^2
36	Window sill	House of J, Shakarpur, East Delhi	Drawing room 1st floor	31" x 4.5"
37	Floor	House of J, Shakarpur, East Delhi	Drawing room 1st floor	1 ft^2
38	Floor	House of J, Shakarpur, East Delhi	Bed room g. floor	1 ft^2
39	Window sill	House of J, Shakarpur, East Delhi	Bed room g. floor	31" x 4.5"
40	Floor	House of K, Seelampur, East Delhi	Drawing room	1 ft^2
41	Window sill	House of K, Seelampur, East Delhi	Drawing room 1st floor	58" x 6"
42	Floor	House of K, Seelampur, East Delhi	Bed room 1st floor	1 ft^2
43	Floor	House of K, Seelampur, East Delhi	Bed room 2nd floor	1 ft^2
44	Window sill	House of K, Seelampur, East Delhi	Bed room 2nd floor	29" x 1.25"
45	Floor	House of K, Seelampur, East Delhi	Bed room 2nd floor	1 ft^2
46	Floor	House of L, Mayur Vihar-Ph-1, East Delhi	Drawing room 3rd floor	1 ft^2
47	Window sill	House of L, Mayur Vihar-Ph-1, East Delhi	Drawing room 3rd floor	38" x 2.25"
48	Floor	House of L, Mayur Vihar-Ph-1, East Delhi	Bed room-1 3rd floor	1 ft^2
49	Floor	House of L, Mayur Vihar-Ph-1, East Delhi	Bed room-2 3rd floor	1 ft^2
50	Window sill	House of L, Mayur Vihar-Ph-1, East Delhi	Bed room-1 3rd floor	16" x 3"
51	Floor	House of M, DU, North campus, North Delhi	Drawing room	1 ft^2
52	Window sill	House of M, DU, North campus, North Delhi	Drawing room	44" x 3.5"
53	Floor	House of M, DU, North campus, North Delhi	Bed room 1st floor	1 ft^2
54	Window sill	House of M, DU, North campus, North Delhi	Bed room 1st floor	48" x 3.5"

55	Window sill	House of M, DU, North campus, North Delhi	Lobby	34" x 8.5"
56	Floor	House of N, Mukherjee Nagar, North Delhi	Drawing room	1 ft^2
57	Floor	House of N, Mukherjee Nagar, North Delhi	Bed room	1 ft^2
58	Floor	House of N, Mukherjee Nagar, North Delhi	Kitchen	1 ft^2
59	Floor	House of N, Mukherjee Nagar, North Delhi	Store room	1 ft^2
60	Window sill	House of N, Mukherjee Nagar, North Delhi	Drawing room	32" x 2.5"
61	Floor	House of O, Khuraiji, East Delhi	Drawing room	1 ft^2
62	Blank	Blank		Blank
63	Floor	House of O, Khuraiji, East Delhi	Bed room	1 ft^2
64	Window sill	House of O, Khuraiji, East Delhi	Bed room	31" x 1.5"
65	Window sill	House of O, Khuraiji, East Delhi	Drawing room	29" x 1.7"
66	Floor	House of O, Khuraiji, East Delhi	Bed room	1 ft^2
67	Floor	House of P, Sabzimandi, North Delhi	Drawing room	1 ft^2
68	Floor	House of P, Sabzimandi, North Delhi	Bed room	1 ft^2
69	Window sill	House of P, Sabzimandi, North Delhi	Bed room	36" x 12"
70	Window sill	House of P, Sabzimandi, North Delhi	Drawing room	22"x 8"
71	Floor	House of Q, Sabzimandi, North Delhi	Drawing room	1 ft^2
72	Window sill	House of Q, Sabzimandi, North Delhi	Drawing room	22" x 3"
73	Floor	House of Q, Sabzimandi, North Delhi	Drawing room 1st floor	1 ft^2
74	Window sill	House of Q, Sabzimandi, North Delhi	Drawing room 1st floor	23" x 10.5"
75	Window sill	House of Q, Sabzimandi, North Delhi	Drawing room 1st floor	40" x 4"
76	Floor	House of Q, Sabzimandi, North Delhi	Bed room 1st floor	1 ft^2
77	Floor	House of R, Sabzimandi, North Delhi	Drawing room	1 ft^2
78	Window sill	House of R, Sabzimandi, North Delhi	Drawing room	42" x 9"
79	Floor	House of R, Sabzimandi, North Delhi	Kitchen	1 ft^2
80	Floor	House of R, Sabzimandi, North Delhi	Bed room	1 ft^2
81	Window sill	House of R, Sabzimandi, North Delhi	Bed room	36" x 9"
82	Floor	House of S, Rafi Marg, Central Delhi	Drawing room	1 ft^2
83	Floor	House of S, Rafi Marg, Central Delhi	Kitchen	1 ft^2
84	Window sill	House of S, Rafi Marg, Central Delhi	Bed room	39" x 3"

85	Floor	House of S, Rafi Marg, Central Delhi	Bed room	1 ft^2
86	Window sill	House of S, Rafi Marg, Central Delhi i	Bed room	36" x 2"
87	Floor	House of T, Rohini, West Delhi	Drawing room	1 ft^2
88	Floor	House of T, Rohini, West Delhi	Drawing room	1 ft^2
89	Window sill	House of T, Rohini, West Delhi	Drawing room	34" x 3"
90	Floor	House of T, Rohini, West Delhi	Bed room	1 ft^2
91	Window sill	House of T, Rohini, West Delhi	Bed room	36" x3"
92	Blank	Balnk		Blank
93	Floor	House of U, Rohini, West Delhi	Drawing room	1 ft^2
94	Floor	House of U, Rohini, West Delhi	Bed room	1 ft^2
95	Window sill	House of U, Rohini, West Delhi	Bed room	72" x 3.5"
96	Floor	House of V, Shalimar Bagh, West Delhi	Drawing room	1 ft^2
97	Floor	House of V, Shalimar Bagh, West Delhi	Bed room-1	1 ft^2
98	Floor	House of V, Shalimar Bagh, West Delhi	Bed room-2	1 ft^2
99	Floor	House of V, Shalimar Bagh, West Delhi	Drawing room	1 ft^2
100	Window sill	House of V, Shalimar Bagh, West Delhi	Bed room-1	18" x 4.5"
101	Floor	House of W, Old Rajednra Nagar, Central Delhi	Drawing room	1 ft^2
102	Floor	House of W, Old Rajednra Nagar, Central Delhi	Bed room	1 ft^2
103	Window sill	House of W, Old Rajednra Nagar, Central Delhi	Drawing room	33" x 4.2"
104	Floor	House of W, Old Rajednra Nagar, Central Delhi	Bed room	1 ft^2
105	Window sill	House of W, Old Rajednra Nagar, Central Delhi	Bed room	30"x 3"
106	Floor	House of X, Dwarka, Soth-West Delhi	Drawing room	1 ft^2
107	Floor	House of X, Dwarka, Soth-West Delhi	Drawing room	1 ft^2
108	Window sill	House of X, Dwarka, Soth-West Delhi	Drawing room	39"x2"
109	Floor	House of X, Dwarka, Soth-West Delhi	Bed room	1 ft^2
110	Floor	House of X, Dwarka, Soth-West Delhi	Bed room-2	1 ft^2
111	Floor	House of Y, Dwarka, Soth-West Delhi	Drawing room	1 ft^2
112	Floor	House of Y, Dwarka, Soth-West Delhi	Bed room	1 ft^2
113	Floor	House of Y, Dwarka, Soth-West Delhi	Bed room	1 ft^2
114	Floor	House of Y, Dwarka, Soth-West Delhi	Dining room	1 ft^2
115	Floor	House of Y, Dwarka, Soth-West Delhi	Balcony	1 ft^2
116	Floor	House of Z, Dwarka, Soth-West Delhi	Drawing room	1 ft^2

117	Window sill	House of Z, Dwarka, Soth-West Delhi	Drawing room	31" x 3"
118	Floor	House of Z, Dwarka, Soth-West Delhi	Bed room	1 ft^2
119	Floor	House of Z, Dwarka, Soth-West Delhi	Bed room	1 ft^2
120	Window sill	House of Z, Dwarka, Soth-West Delhi	Bed room	42" x 3"
121	Floor	House of AS, JNU, South Delhi	Bed room	1 ft^2
122	Window sill	House of AS, JNU, South Delhi	Bed room	40.5" x 2.5"
123	Floor	House of BP, JNU, South Delhi	Bed room	1 ft^2
124	Floor	House of BP, JNU, South Delhi	Bed room	1 ft^2
125	Blank	Blank		Blank
126	Floor	House of CC, , Rafi Marg, Central Delhi	Drawing room	1 ft^2
127	Window sill	House of CC, , Rafi Marg, Central Delhi	Drawing room	40" x 3"
128	Floor	House of CC, , Rafi Marg, Central Delhi	Drawing room-ext	1 ft^2
129	Floor	House of CC, , Rafi Marg, Central Delhi i	Bed room	1 ft^2
130	Window sill	House of CC, , Rafi Marg, Central Delhi	Bed room	40" x 2"
131	Floor	House of DA, Katwaria Sarai, South Delhi	Drawing room	1 ft^2
132	Window sill	House of DA, Katwaria Sarai, South Delhi	Drawing room	22"x2.25"
133	Floor	House of DA, Katwaria Sarai, South Delhi	Bed room	1 ft^2
134	Window sill	House of DA, Katwaria Sarai, South Delhi	Bed room	34"x2"
135	Floor	House of DA, Katwaria Sarai, South Delhi	Bed room-2	1 ft^2
136	Blank	Blank		Blank
137	Floor	House of EC, Janpath, Central Delhi	Drawing room	1 ft^2
138	Floor	House of EC, Janpath, Central Delhi	Bed room-1	1 ft^2
139	Window sill	House of EC, Janpath, Central Delhi	Bed room-1	43"x8"
140	Floor	House of EC, Janpath, Central Delhi	Bed room-I-ext	1 ft^2
141	Window sill	House of EC, Janpath, Central Delhi	Drawing room	22.5"x8"
142	Floor	House of EC, Janpath, Central Delhi	Drawing room	1 ft^2
143	Floor	House of FS, Chandani Chowk, Central Delhi	Drawing room	1 ft^2
144	Floor	House of FS, Chandani Chowk, Central Delhi	Drawing room	1 ft^2
145	Window sill	House of FS, Chandani Chowk, Central Delhi	Kitchen	26"x2"
146	Floor	House of FS, Chandani Chowk, Central Delhi	Kitchen	1 ft^2

147	Floor	House of GO, Jungpura Ext, South Delhi	Bed room-1 1st floor	1 ft^2
148	Window sill	House of GO, Jungpura Ext, South Delhi	Bed room-1 1st floor	29.5"x5.5"
149	Floor	House of GO, Jungpura Ext, South Delhi	Bed room-2 1st floor	1 ft^2
150	Floor	House of GO, Jungpura Ext, South Delhi	Bed room g. floor	1 ft^2
151	Window sill	House of GO, Jungpura Ext, South Delhi	Bed room g. floor	33.5"x2.5"
152	Floor	House of GO, Jungpura Ext, South Delhi	Drawing room basement	1 ft^2
153	Floor	House of GO, Jungpura Ext, South Delhi	Drawing room g. floor	1 ft^2
154	Floor	House of GO, Jungpura Ext, South Delhi	Drawing room basement	1 ft^2
155	Blank	Blank		Blank

Annexure II

Table 5 Lead loading of floor dust samples

Sample No	Pb loading (µg/ft²)
2	7.48
3	1.53
4	ND
6	1.99
7	2.64
8	2.51
10	1.34
11	2.59
13	57.17
14	52.74
15	7.41
17	8.76
18	7.56
19	38.39
22	2.98
23	8.66
24	5.84
25	45.13
26	13.84
28	13.57
31	6.99
32	11.26
33	14.3
35	45.46
37	44.52
38	6.58
40	43.84
42	10.45
43	19.56
45	22.86
46	8.39
48	5.72
49	9.28
51	17.68
53	56.29
56	157.29
57	118.54
58	70.5
59	110.49
61	13.03
63	16.63
66	15.72
67	7.69
68	16.49
71	14.92
73	60.78
76	25.5
77	60.35
79	49.05
80	8.89
82	18.59
83	18.96
85	7.89
87	12.25
88	22.05
90	34.84
93	8.61
94	7.23
96	17.9
97	29.59
98	11.26
99	114.61
101	16.1
102	17.02
104	14.41
106	60.76
107	17.61
109	65.31
110	121.31
111	15.1
112	45.72
113	48.37

114	13.15
115	37.31
116	2.41
118	2.19
119	9.78
121	25.11
123	27.93
124	22.66
126	15.91
128	17.1
129	46.66
131	60.13
133	82.38
135	5.76
137	41.26
138	10.81
140	9.16
142	195.48
143	67.59
144	174.97
146	32.09
147	95.32
149	221.57
150	148.9
152	15.57
153	79.08
154	14.29

Table 6 Lead loading of window sill dust samples

Sample No	Pb loading (μg/ft^2)
5	35.24
9	47.74
12	30.93
16	86.544
20	6.17
21	56.51
27	100.44
29	136.31
34	43.06
36	128.87
39	45.03
41	19.32
44	357.95
47	25.15
50	66.75
52	175.84
54	347.53
55	42.32
60	530.73
64	200.18
65	81.20
69	15.27
70	52.72
72	121.31
74	319.32
75	40.41
78	13.04
81	3.88
84	16.23
86	82.02
89	107.08
91	234.52
95	49.99
100	142.74
103	214.77
105	104
108	558.48
117	78.44
120	53.01
122	178.53
127	36.06
130	35.30
132	354.47
134	65.67
139	84.01
141	39.2
145	214.67
148	517.44
151	48.1

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