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Lead in Paints

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1. POLLUTION MONITORING LABORATORY OF CSE

The Centre for Science and Environment (CSE), a non-governmental organization based in New Delhi, has set up the Pollution Monitoring Laboratory (PML) to monitor environmental pollution. PML is an ISO 9001:2000 certified laboratory accredited by SWISO, CH-5610, Wohlen, Switzerland, conducting Pollution Monitoring and Scientific Studies on Environmental Samples. The Lab has highly qualified and experienced staff that exercise Analytical Quality Control (AQC) and meticulously follow what is called Good Laboratory Practices (GLP). It is equipped with most sophisticated state-of-the-art equipments for monitoring and analysis of air, water and food contamination, including Gas Chromatograph with Mass Detector (GC-MS), Gas Chromatograph (GC) with ECD, NPD, FID and other detectors, High Performance Liquid Chromatograph (HPLC), Atomic Absorption Spectrometer (AAS), UV-VIS Spectrophotometer, Mercury Analyzer, Respirable Dust Sampler etc. Its main aim is to undertake scientific studies to generate public awareness about food, water and air contamination. It provides scientific services at nominal cost to communities that cannot obtain scientific evidence against polluters in their area. This is an effort to use science to achieve ecological security.

2. INTRODUCTION

Lead is a highly toxic metal found in small amounts in the earth's crust. Because of its abundance, low cost, and physical properties, lead and lead compounds have been used in a wide variety of products including paint, ceramics, pipes, gasoline, batteries, and cosmetics. In India, as in most developing countries the battery industry is the principle consumer of lead using an estimated 76% of the total primary and secondary lead produced annually.

Lead is taken up by humans by ingestion and inhalation. Eating lead bearing paints by children and drinking of lead contaminated water are important sources of non-industrial poisoning. Lead absorbed in course of occupational exposure is superimposed on lead absorbed from other means which leads to increased body burden of lead.

Exposure to lead can cause a variety of neurological disorders such as lack of muscular coordination, convulsions and coma. Lower levels of lead have been associated with measurable changes in children's mental development and behavior (*NAS 1993*). These include hyperactivity; deficits in fine motor function, hand-eye coordination, and reaction time; and lowered performance on intelligence tests. Chronic lead exposure in adults can result in increased blood pressure, decreased fertility, cataracts, nerve disorders, muscle and joint pain, and memory or concentration problems. http://www.niehs.nih.gov/health/topics/agents/lead/index.cfm

The effects of lead toxicity have been well established, with clear evidence of harm found in children whose blood lead levels are above 10 µg/dL and some evidence that harm may occur at lower levels (*U. S. CDC 1991; Lanphear et al. 2000; NAS 1993*).

A common source of lead exposure for children today is lead based paint and the contaminated dust and soil it generates (*Clark et al. 1991; Lanphear et al. 1995, 1998; Lanphear and Roghmann 1997; McElvaine et al. 1992; Rabinowitz et al. 1985; Shannon and Graef 1992*). A recent report of Toxics Link investigated a large number of paints available in India purchased in

November-December 2006 for their lead content and found that most of the oil based enamel paints contained lead at levels above 600 parts per million (ppm). More than 60% of enamel paints contained lead higher than 5,000 ppm and the maximum content of 140,000 ppm was found in yellow enamel paint (*Kumar, 2007*).

Ambient air concentration of lead during the operation of paint mixing, paint spraying (chrome yellow) may be at an average of 1.75 mg/m^3 and 3.9 mg/m^3 respectively (*Elkins, H.B., "The chemistry of Industrial Toxicology" John Willey and Sons, New York and Davis, W.E. & Associates "Emission Study of Industrial Sources of Lead Air Pollutants" Leawood, Kansas 1973*). Poisoning from lead-based paint has affected millions of children since this problem was first recognized more than 100 years ago (*Gibson 1904*). Some of the developed countries have established limits on the lead content of paint e.g. US regulation of the lead content in new paints is 600 ppm. In many countries however there are apparently still no regulations on lead content of either new paint or paints in houses. In India the maximum content of lead in paints is governed by Bureau of Indian Standards IS 15489:2004 – paints emulsion - Specification that is voluntary in nature. This leaves the paint industry virtually unregulated.

Therefore samples of enamel paints of different colours and brands available in Delhi markets were purchased and their lead content analyzed by Atomic Absorption Spectrometer.

3. PAINTS IN INDIA

Paint is any liquid, liquefiable, or mastic composition which after application to a substrate in a thin layer is converted to an opaque solid film. Paint is used to protect, decorate (such as adding color), or add functionality to an object or surface by covering it with a pigmented coating.

3.1 Composition of Paints

Paint is composed of two basic ingredients: pigment and a binder; a solvent (thinner) is generally added to change the application characteristics of the liquid. In paint, the combination of the binder and solvent is referred to as the paint "vehicle." Pigment and additives are dispersed within the vehicle. The amount of each constituent varies with the particular paint, but solvents traditionally make up about 60% of the total formulation. Typical solvents include toluene, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK). Binders account for 30%, pigments for 7% to 8%, and additives for 2% to 3%.

Pigments are insoluble solids, incorporated into the paint to contribute color, texture or some other characteristics. Opaque pigments give the paint its hiding or covering capacity and contribute other properties (white lead, zinc oxide, and titanium dioxide are examples). Color pigments give the paint its color. Pigments may be inorganic, such as chrome green, chrome yellow, and iron oxide, or organic, such as toluidine red and phthalocyanine blue. The major lead-containing pigments include white lead, red lead, leaded zinc oxide, chrome green, chrome yellow and chrome orange. Lead is present in these pigments as oxides, carbonates, hydroxides and chromates.

Transparent or extender pigments contribute bulk and also control the application properties, durability and resistance to abrasion of the coating. There are other special purpose pigments, such as those enabling paint to resist heat, control corrosion, or reflect light.

Vehicles or Binders of paint are the material holding the pigment together and causing paint to adhere to a surface. In general, paint durability is determined by the resistance of the binder to the exposure conditions. Linseed oil, the most common binder, has been replaced, mainly by the synthetic alkyl resins. These result from the reaction of glycerol phthalate and oil and may be made with almost any property desired. Other synthetic resins, used either by themselves or mixed with oil, include phenolic resin, vinyl, epoxy, urethane, polyester, and chlorinated rubber.

Solvents - thinners are used to adjust the consistency of the material so that it can be applied readily to the surface. The solvent evaporates, contributing nothing further to the film. Solvent most commonly used are naphtha or mineral spirits; turpentine is sometimes used but is very expensive.

In paint manufacture, lead is found in the waste solvent-based paint sludges which typically contain 27.5% pigment, 25% binders, and 47.5% organic solvents.

3.2. Market Structure

The Indian paint industry is a Rs. 112 billion sector. The demand for paints is relatively price elastic but is linked to the industrial and economical growth. The per capita consumption of paints in India is low at 0.5 kg per capita per annum compared with 4 kg in the South East Asian nations and 22 kg in developed countries. The global average per capita consumption is 15 kg per annum.

Indian paint industry can be classified into two sub segments - Decorative Paints and Industrial Paints.

Decorative Paints are acrylic emulsions used mostly in the metropolitan cities and cater to the housing sector. The medium range consists of enamels, is popular in smaller cities and towns. Distempers are economy products demanded in the suburban and rural markets. Nearly 20% of all decorative paints sold in India are distempers.

Industrial Paints include powder coatings, high performance coating, automotive and marine paints.

In India the decorative paint segment accounts for 75% of the paint market while the industrial paint segment accounts for 25% of paints sold in India. In most developed countries, the ratio of decorative paints vis-à-vis industrial paints is around 50:50.

The paint industry is further divided into organized and unorganized sector, the organised sector controls 65% of the total market with the remaining 35% being in the hands of nearly 2000 small-scale units. http://www.domainb.com/industry/paints/200012_paint_overview.html

3.3 Major Players

The leaders in the organised paint industry are Asian Paints (India) Ltd. (APIL), Goodlass Nerolac Paints Ltd. (GNPL), Berger Paints, Jenson & Nicholson Ltd. (J&N) and ICI (India) Ltd.

Asian Paints is the industry leader with an overall market share of 33% in the organised paint market and has the largest distribution network. The Berger group and ICI share the second position in the industry with market shares of 17% each. GNPL has a market share of 15% in the organised sector.

The demand for decorative paints is highly price-sensitive and also cyclical. Monsoon is a slack season while the peak business period is Diwali festival time, when most people repaint their houses. In the decorative segment, it is the distribution network that counts while in the industrial segment the deciding factors are technological superiority and tie-up with industrial users for assured business.

APIL dominates the decorative segment with a 38% market share. The company has more than 15,000 retail outlets and its brands *Tractor*, *Apcolite*, *Utsav*, *Apex* and *Ace* are entrenched in the market. GNPL, the number-two in the decorative segment, with a 14% market share too has now increased its distribution network to 10,700 outlets to compete with APIL effectively. Berger and ICI have 9% and 8% shares respectively in this segment followed by Shalimar and J&N with 6% and 1% shares.

The share of industrial paints in the total paint consumption of the nation is low compared to global standards. GNPL dominates the industrial paints segment with 41% market share. APIL, the leader in decorative paints, ranks second after Goodlass Nerolac in the industrial segment with a 15% market share. Berger and ICI are the other players in the sector with 10% and 9% shares respectively. Shalimar too, has an 8% share (*Table 1*).

Table 1: Market Share of Paint Industry

Decorative Paint		**Industrial Paint**	
Company	**Market share (%)**	**Company**	**Market share (%)**
Asian Paints (India) Ltd.	38	Goodlass Nerolac Paints Ltd.	41
Goodlass Nerolac Paints Ltd.	14	Asian Paints (India) Ltd.	15
Berger Paints (India) Ltd.	9	Berger Paints (India) Ltd.	10
ICI India (Ltd.)	8	ICI India (Ltd.)	9
Shalimar Paints Ltd.	6	Shalimar Paints Ltd.	8
Jenson & Nicholson Ltd.	1		

3.4 Technology Collaboration

All the paint majors have tie-ups with global paint leaders for technical know-how. Asian Paints has a joint venture with PPG Industries Inc to service the automotive original equipment manufacturers (OEMs). Berger Paints has a series of tie-ups for various purposes. It has a technical tie-up with Herbets Gmbh of Germany in addition to its joint venture with Becker Industrifag. With the agreement with Herbets ending in 2001, Berger has now allied with the Japanese major Nippon Paints to boost its OEM turnover since the Indian roads are being flooded with Japanese automobiles. It also has an agreement with Orica Australia Pvt. Ltd. to produce new generation protective coatings. For manufacturing heavy duty and powder coatings it has tie-ups with Valspar Corp and Teodur BV.

ICI makes paints with the technical support of Herbets, which has been recently acquired by E I Du Pont de Nemours of the US. Du Pont, which is a leader in automotive coatings in the US, has a technical tie-up with Goodlass Nerolac for the manufacture of sophisticated coatings for the automotive sector. Goodlass also has technical collaborations with Ashland Chemcials Inc, USA, a leader in the petrochemical industry, Nihon Tokushu Toryo Co and Oshima Kogyo Co Ltd, Japan. http://www.business-standard.com/common/news_article.php?tab=r&autono=321890&subLeft=6&leftnm=1

4. ABOUT LEAD

Lead is a transitional element with the symbol **Pb** (Latin: *plumbum*) belonging to group IV **A** of the periodic table, has the atomic number 82 and relative atomic mass 207.2. It is a soft, malleable metal, also considered to be one of the heavy metals with a density of 11.3 g/cm^3. Lead has a bluish white color when freshly cut, but tarnishes to a dull grayish color when it is exposed to air and is shiny chrome silver when melted into a liquid. Lead's low melting point (327^{0}C), ductility, malleability and weathering resistance enables its use without the need for more complex equipment required for other metals. Metallic lead does occur rarely in nature. It is usually found in ore with zinc, silver and (most abundantly) copper, and is extracted together with these metals. The main lead mineral is galena (PbS), which contains 86.6% lead. Other common varieties are cerussite ($PbCO_3$) and anglesite ($PbSO_4$). It is used in building construction, lead-acid batteries, bullets and shot, weights, and is part of solder, pewter, and fusible alloys. In the past, lead was added to petrol in the form of tetra-ethyl lead ($PbEt_4$) with an anti-knocking function; however, across the world this kind of petrol is currently being phased out for environmental and health reasons.

4.1 Lead in Paints

Lead-based paint is defined as any paint, varnish, stain, or other applied coating that has 1mg/cm^2 (5,000 µg/g by dry weight or 5,000 parts per million) or more of lead. http://www.fs.fed.us/eng/pubs/htmlpubs/htm96712353/index.htm

Lead-based paints have disappeared from consumer sales for residential use in developed countries because of toxicity concerns. However, paint containing lead is still being used for certain industrial painting requirements. Lead is added to paint to speed drying, increase durability, retain a fresh appearance, and resist moisture that causes corrosion. Lead is used as pigment, with lead (II) chromate ($PbCrO_4$, "chrome yellow") and lead (II) carbonate ($PbCO_3$, "white lead") being most common. Lead chromates are often used to produce yellow, orange, red, and green paints. White lead (basic lead carbonate) is a superior paint pigment, has a high affinity for paint vehicles and a tremendous hiding power, widely replaced by Titanium oxide and Barium-Zinc-Sulfur combinations. For color, lead pigments such as red lead (a lead oxide with 4 oxygens and bright orange color), and blue lead (lead sulfate with lead oxide, zinc oxide, and carbon) may be used industrially where corrosion protection and color on metal is needed. Lead flake still finds use as an exterior primer and lead oleate may be encountered as a drier in paints. http://www.lockport-ny.com/Allegheny/lead.htm

The George Foundation selected 24 paint samples from six paint companies purchased in stores in Bangalore and Chennai. Of the 24 samples analysed 17 had lead concentrations exceeding 0.5% lead by weight, 13 had lead concentrations exceeding 1% lead and 5 exceeded 10% lead. On the basis of a two coat paint thickness, the XRF determination of paint lead loading exceeded 1 mg/cm^2 in five of the samples. The lower Pb concentration paints are the white, blue and brown-red paints, while in order of increasing Pb concentrations are the green, red, orange and the yellow paints (*Van Alphen M, 1999*). Yellow paints showed highest lead levels as compared to others. Yellow paint pigments containing 200,000 ppm of lead were obtained as samples in paint manufacturing facilities and in an academic paint technology department. Yellow-derivative paints (green and brown) had the next highest amount of lead. After a third coat, the red paints also exceeded the given standard of 1.0 mg/cm^2 (*Clark et al 2005*).

Nineteen samples of locally manufactured paints purchased from the Nigerian market in February, 2005 were analysed for lead. The level of lead in the paints ranged from 17.5 µg g^{-1} to 515.9 µg g^{-1} with mean standard deviation of 62.2µg g^{-1} (115.1µg g^{-1}), while the median was 25.1µg g^{-1}. It was concluded that paints sold in Nigeria contain a substantial amount of lead with increased risk of exposure to children, for whom domestic sources of lead exposure is more important than exposure through leaded petrol (*Adebamowo et al 2006*).

From a total of 80 paint samples obtained from China, India, and Malaysia – 66% of new paint samples 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%. An examination of lead levels in paints of the same brands purchased in different countries showed 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. Some brands of paint marketed in two or more countries had lead based paint in one country and low lead based paints in the country that had a regulatory limit. They also reported that 100 percent (n=17) of paint samples from India had more than 600 ppm of lead concentration while 82% samples had more than 5000 ppm of lead contents (*Clark, et. al. 2006*).

Another study on lead levels of paints (5 colours) manufactured in Nigeria the lead was measured by flame-atomic absorption spectroscopy. It was found that 96% of the paints had higher than recommended levels of lead. The mean lead level of paints ranged from 84.8 to 50,000 ppm, with a mean of 14,500 ppm and median of 15,800 ppm. The main determinant of lead levels was the color of the paint. The study concluded that efforts need to be undertaken to assess the presence of high lead levels in existing housing and if detected, intervention programs for eliminating risk of exposure should be developed in addition to measures to increase awareness and enforce regulations leading to the elimination of lead based domestic paint (*Adebamowo, 2007*).

A survey was conducted by the South African Medical Research Council of the lead concentrations in paint samples collected from dwellings located in randomly selected Johannesburg suburbs. Of the 239 dwellings included in the survey, 20% had paint lead concentrations > 5,000 µg/g (the U.S. reference level). Paint with high lead levels was found in old as well as newly constructed dwellings (*Montgomery and Mathee 2005*).

Paint samples purchased from Johannesburg and Cape Town stores were analyzed for lead content. No lead was found in water-based or white shades of enamel paint, alarmingly high lead concentrations (up to 189,000 µg/g) were measured in samples of pigmented enamel paints. A total of 83% samples of pigmented enamel paints were lead based. High lead concentrations were found in popular as well as lesser-known brands of enamel paint, and only 2 out of 25 samples of lead-based paint displayed warnings of the high lead content. Similarly high lead concentrations (up to 145,000 µg/g) were found in paint removed from widely used children's toys (such as building blocks) that were purchased from 7 major toy, supermarket, and stationery chain stores as well as flea and craft markets. High lead levels were found in locally manufactured as well as imported toys (*Mathee et al 2007*).

A study on lead in paints in India conducted by Toxics Link and entitled "Brush with Toxics" studied different types of paints. Lead content was found to be high up to 140,000 ppm in many oil based enamel paints. Concentrations of lead in 83.87 % of the enamel paint samples were found to be more than 1000 ppm and 61.3% of samples had more than 5000 ppm. The colour of the paint was related to lead content. While yellow and orange coloured paints had the highest concentrations of lead, black and white showed the lowest concentrations (*Kumar, 2007*).

4.2 Exposure to Lead and Health Effects

Lead is dispersed throughout the environment primarily as the result of anthropogenic activities. In the air, lead is in the form of particles and is removed by rain or gravitational settling. The solubility of lead compounds in water is a function of pH, hardness, salinity, and the presence of humic material. Solubility is highest in soft, acidic water. The sink for lead is the soil and sediment. Because it is strongly adsorbed to soil, it is generally retained in the upper layers of soil and does not leach appreciably into the subsoil and groundwater. Lead compounds may be transformed in the environment to other lead compounds; however, lead is a metal and cannot be destroyed. Anthropogenic sources of lead include the mining and smelting of ore, manufacture of lead-containing products, combustion of coal and oil, and waste incineration. Many sources of lead, most notably leaded gasoline, solder in food cans, lead-arsenate pesticides, and shot and sinkers, have been eliminated or reduced due to lead's persistence and toxicity. Because lead does not degrade, these former uses leave their legacy as higher concentrations of lead in the environment. Plants and animals may bio-concentrate lead, but lead is not biomagnified in the aquatic or terrestrial food chain. The general population may be exposed to lead in ambient air, foods, drinking water, soil, and dust (*U. S. ATSDR, 2007*). Segments of the general population at the highest risk of health effects from lead exposure are preschool-age children and pregnant women and their fetuses. Occupational hazards (for example, those experienced by painters, maintenance/renovation, and abatement workers who use unsafe paint removal practices) are the leading cause of elevated blood lead levels in adults. Ingestion of lead-contaminated surface dust is the most common pathway of lead poisoning in children. Though lead exposure is harmful to both adults and children, children are more susceptible, to the neurobehavioral toxicity of lead exposure because their nervous system is still developing, their absorption rates are higher, they have higher likelihood of engaging in hand to mouth practices and frequently spend time on the floor and on soil areas so they are more likely to be exposed to lead from paint dust, soil and water in their domestic environment (*Bellinger, 2004*). Long term exposure to lead or its salts especially soluble salts or the strong oxidant PbO_2 can cause nephropathy and colic-like abdominal pains.

The most common metric of absorbed dose for lead is the concentration of lead in the blood (B-Pb), although other indices, such as lead in bone, hair, or teeth are also available The concentration of lead in blood reflects mainly the exposure history of the previous few months and does not necessarily reflect the larger burden and much slower elimination kinetics of lead in bone. Lead in bone is considered a biomarker of cumulative or long-term exposure to lead because lead accumulates in bone over the lifetime and most of the lead body burden resides in bone. For this reason, bone lead may be a better predictor than blood lead of some health effects.

Epidemiological studies consistently show that effects in children are associated with B-Pb levels of about 100–150 µg/L. There are indications that lead is harmful even at B-Pb concentrations considerably below 100 µg/L; there may be no threshold for these effects. In many areas there have been major decreases in B-Pb levels in recent decades, mainly because of the phasing out of leaded petrol but also because of reductions in other sources of exposure (*WHO/UNECE, 2007*).

The main target for lead toxicity is the nervous system, both in adults and children. Long term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production (*U.S. ATSDR, 2007*). Mortality in workers exposed to high levels of lead is increased, and adults who were poisoned by lead during childhood have increased blood pressure, which is a significant risk factor for cardiovascular diseases and mortality. Non-fatal mechanisms include renal effects; anemia owing to the inhibition of several enzymes involved in haem synthesis; acceleration of skeletal maturation; alteration of hormone levels and immunity parameters; and encephalopathy (at high exposure) and various other diseases of the nervous system, among which cognitive and neurobehavioral deficits in children at low levels of exposure are of great concern. The health effects of lead exposure are summarized, together with routes of exposure, affected population groups and critical lead levels (B-Pb), in Table 2.

4.3 Lead in Blood

Blood Lead Levels (BLL) is a measure of lead in the body. It is measured in micrograms of lead per deciliter of blood (µg/dL); 10 µg/dell is equivalent to 0.48 micromoles per liter (µmol/L). The Centers for Disease Control and Prevention (CDC) states that a BLL of 10 µg/dL or above is a cause for concern. However, lead can impair development even at BLLs below 10 µg/dL (*US CDC, 2007*).

In Australia, the acceptable level of lead in blood was lowered from 25 µg/dL to 10 µg/dL in 1992. In 1993 the National Health and Medical Research Council (NH & MRC) set a national target for 1998 for all Australians to have a BLL less than 15 µg/dL (except where they worked with lead), and strategies were put in place whereby 90% of pre-school children would have BLL below 15 µg/dL. In 1996 National Blood Lead Survey (the Donovan Survey) found 7.7% of children aged one to four were above 10 µg/dL, and 1.7% were above 15 µg/dL http://en.wikipedia.org/wiki/Blood_lead_level

Table 2: Main routes of lead exposure and critical effects identified with associated B-Pb levels for various population groups

Routes of Intake	Population Group (s)	Effects	Critical B-Pb Level (µg/l)
Placenta	Foetuses	Delays in neurological development	Probably no threshold
Mother's milk, inhaled air	Neonates and young children	- Inhibition of d-aminolevulinic acid dehydratase (ALAD) - Physical development	30-300 <70
Inhaled air, hand–mouth behaviour, ingestion	Children	- Decreased nerve conduction velocity - Cognitive development and intellectual performance - Hearing loss - Jaundice - Anaemia	200–300 <100 <100 350 >200
Inhaled air, food ingestion	Adults	- Decreased ALAD activity - Blood pressure - Damage to renal function - Sperm count	30–340 <20 20–100 400–500

Sources: ATSDR (2005); Scientific Committee on Toxicity, Ecotoxicity and the Environment (2000)

A cross-sectional study examined the association between blood lead levels and neuropsychological and behavioural problems of 533 schoolgirls (6 – 12 years of age) who attended public schools in Riyadh, Capital of Saudi Arabia. The mean blood lead level was 8.11±3.50 µg/dL in the range of 2.3 to 27.36 µg/dL. Standard scores and rank percentiles were inversely related to pupils with blood lead levels >9µg/dL. These findings attested an association between neuropsychological and behavioral impairment and lead exposure at blood lead levels in the range of 9.02 to 27.36 µg/dL (*Saleh et al, 2001*).

Another study by Department of Occupational Health & Environmental Health Science of China found that mean BLLs of Chinese children was 92.9 µg/L (37.2–254.2 µg/L), and 33.8% (9.6–80.5%) of the subjects had BLLs higher than 100 µg/L. Nine of the 27 provinces or cities reported had average BLLs ⩾100 µg/L. Boys' BLL was 96.4 µg/L, higher than girl's 89.4 µg/L (*P*<0.001). BLLs of children ⩽6 years increased with age. The mean BLLs of children living in industrial and urban areas were significantly higher than those of children in suburbs and rural areas. The results suggested that children's BLLs in China are higher than those of their counterparts in other countries due to its heavy lead pollution (*Wang and Zhang, 2006*).

In a study from Mangalore and Karnataka one hundred and seven school children were chosen on a random basis and their blood lead was analyzed. Of the cases analyzed, 10 students whose blood lead level was more than 40 µg/dL were investigated using a field portable X-Ray Fluorescence Analyzer. It was found that the 'likely' source of lead exposure could be determined in eight cases which was from the immediate environment of the children like 'lead-based' paint on surfaces in the house, on playground and other exterior equipment; lead storage batteries, contaminated dust and soil and other lead containing substances (*Kuruvilla et al 2004*). Lead based paint in older houses has long been associated with elevated blood lead in children residing within them (*Clark, et al., 1991*).

4.4 Mechanism of Toxic Action of Lead

Lead poisoning results from the interaction of the metal with biological electron-donor groups, such as the sulfhydryl groups, which interferes with a multitude of enzymatic processes. Lead also interacts with essential cations, particularly calcium, iron, and zinc; it interferes with the sodium-potassium-adenosine triphosphate (Na^+/K^+ - ATP) pump; and it alters cellular and mitochondrial membranes, thereby increasing cellular fragility. Additionally, lead inhibits pyrimidine-5'-nucleotidase and alters other nucleotide functions. Lead interferes with many enzyme systems of the body, thereby affecting the function of virtually every organ. Clinical manifestations of lead toxicity include symptoms referable to the central nervous system, the peripheral nervous system, the hematopoietic system, the renal system, and the gastrointestinal systems. Children exposed to lead may experience devastating consequences because of the effects of lead on the developing brain. Lead can interfere with the synthesis of heme, thereby altering the blood concentration of enzymes and intermediates in heme synthesis or their derivatives. Thus lead poisoning can lead to accumulation of nonheme iron and protoporphyrin – IX in red blood cells, an increase in delta-aminolevulinic acid (ALA) in blood and urine, an increase in urinary coproporphyrin, uroporphyrin and porphobilinogen, inhibition of blood ALA-dehydrase (ALA-D), and an increased proportion of immature red cells in the blood (reticulocytes and basophilic stippled cells).

5. REGULATIONS FOR LEAD IN PAINTS

5.1 *International* - The harmful effects of lead have been well known for over 100 years. Many countries investigated lead poisoning and recommended the substitution of non-lead pigments that were available. Countries that banned or restricted the use of white lead for paint include France, Belgium and Austria in 1909; Tunisia and Greece in 1922; Czechoslovakia in 1924; Great Britain, Sweden and Belgium in 1926; Poland in 1927; Spain and Yugoslavia in 1931; and Cuba in 1934 (*Markowitz, and Rosner, 2000*). In 1922 the third International Labour Conference of the League of Nations recommended the banning of white lead for interior use (*Hayhurst et al., 1923*).

USA- Lead based paint is defined by statute as paint with lead levels equal or exceeding 0.5% (5000 ppm) or 1.0 mg/cm^2 according to U.S. Environment Protection Agency (EPA) Standards (*40 CFR Part 745, 2001*).For paint and similar surface coatings, and certain consumer products, 16 CFR § 1303.1 specifies that the maximum allowable *total* lead content is 0.06% based on the total weight of the non-volatile portion of the paint (which is equivalent to 600 ppm). The lead limit in paint and surface coatings applies to (i) paint and other similar surface coatings; (ii) toys and other articles intended for use by children; and (iii) certain furniture articles that are not otherwise exempt under our regulations. As of August 14, 2009, the maximum allowable total lead content of such items will fall to 0.009% (which is equivalent to 90 ppm).

***Canada* -** Under the new regulations, published in Canada Gazette part II on May 4, 2005, the lead content limit has been reduced from 5000 mg/kg (0.5% by weight) to 600 mg/kg (0.06% by weight) for surface coating materials used in or around the home or other premises where children or pregnant women may become exposed, or on furniture, toys and other articles for children, as well as on pencils and artist's brushes.

***European Union* -** In 1988, an 8th amendment to the Marketing and Use Directive 76/769/EEC proposed a complete ban on the use of lead carbonate and sulphate pigments (white lead) in paints.

However, in September 1989, the European Parliament permitted derogation in the Marketing and Use Directive (89/677/EEC) allowing the use of leaded paints for works of art and historic buildings. The Directive stated that lead carbonates and sulphates "may not be used as substances or constituents of preparations intended for use as paints, except for the restoration and maintenance of works of art and historic buildings and their interiors, where member states wish to authorize this on their territory, in accordance with the provisions of ILO Convention 13 on the use of white lead in paint".

The 1999/45/EC of the European parliament and of the council of 31st may 1999 concerning the labeling of dangerous preparations states that "Labels of paints and varnishes containing lead in quantities exceeding 0.15% (expressed as weight of metal) of the total weight of the preparation as determined in accordance with ISO standard 6503/1984 must show the following particulars 'Contains lead. Should not be used on surfaces liable to be chewed or sucked by children'."

***Australia* -** The recommended amount of lead in domestic paints has declined from 50% before 1965, to 1% in 1965. In 1992 it was reduced to 0.25% and in 1997 it was reduced to 0.1% (*DEH 2001*).

Singapore - Singapore also has a standard for Lead Compounds in Paints in the List of Hazardous Substances controlled under Environment Protection and Management Act (EPMA) which states that the lead content should not be more than 0.06% (600ppm) by weight of the paint (*NEA, 2008*).

5.2 India - The paint industry is regulated by the Bureau of Indian Standards (which is voluntary) for the maximum content of lead in paint and is governed by IS 15489:2004 - Paints, Emulsion-Specification, superseding IS 5411 (Part 1): 1974 and IS 5411 (Part 2): 1972 (Bureau of Indian Standards, 2004). The Specific Requirements of Standard IS 15489 : 2004 in subsection 6.12.2.2 states that , *"The product shall not contain more than 0.1 percent by mass (as metal), of any toxic metals such as lead, cadmium, chromium (VI) and their compounds when tested by the relevant Atomic Absorption Spectrophotometric methods"*.

This standard also includes a scheme for labeling environment friendly product known as Eco Mark introduced by Ministry of Environment and Forests (MoEF) and is administered by the Bureau of Indian Standards (BIS) under the *BIS Act, 1986* as per the Resolution No. 71 dated 20th February, 1991 published in the Gazette of Government of India. As the requirement for lead to be below 0.1 percent (1000 ppm) comes under optional scheme of ECO-Mark, a paint product labeled ISI (thereby confirming to the BIS voluntary standards) may not contain lead below 1000 ppm unless it also has ECO Mark.

As the BIS standard is voluntary in nature (unlike certification), the paint manufacturers need not necessarily meet BIS specifications and the Indian paint industry is virtually unregulated for the lead content.

6. SUBSTITUTES OF LEAD IN PAINTS

Paint manufacturers replaced white lead with a less toxic substitute, titanium white (based on the pigment titanium dioxide) which was first used in paints in the 19th century. It is considered safe enough to be used as a food coloring and in toothpaste, and is a common ingredient in sunscreen. The titanium white used in most paints today is often coated with silicon or aluminum oxides for better durability.

7. OBJECTIVE OF THE STUDY

The main objective of this study was to determine the total lead (Pb) content of enamel paints (oil based) intended for residential use as earlier studies have shown very high concentration of lead in these paints which may lead to toxic effects in the population especially infants and unborn fetuses.

8. MATERIALS AND METHODS

8.1 Sampling Methodology

Twenty five enamel paint samples (5 colours of 5 brands) manufactured by the major players- Asian Paints (India) Ltd. (APIL), Goodlass Nerolac Paints Ltd. (GNPL), Berger Paints, Shalimar Paints Ltd, and ICI (India) Ltd were randomly purchased from various markets in Delhi during the months of November 2007- May 2008. On being informed that some paint manufacturers have removed lead from their paints, another set of eight samples-2 samples each manufactured by four major manufacturers Asian Paints (India) Ltd. (APIL), Kansai Nerolac Paints Ltd. (KNPL), Berger Paints and Shalimar Paints Ltd were again purchased from different markets of Delhi in May 2009. Details of the samples are given in Annexure I. The paint samples were purchased in the sizes of 50 ml, 100 ml, 200 ml, 500 ml and 1L depending upon the availability. None of the enamel paint samples selected had any warning on the labels as to the lead content or any guidance as to what uses of paints may or may not be hazardous. Only one brand, Dulux had a label stating, "No added lead, mercury, chromium compounds around a mark of green tree".

8.2 Equipments

Atomic Absorption Spectrometer (Thermo) Solar M-6 Series, Hot plate.

8.3 Chemicals

Lead Standard Solution (1000 mg/L) – Pb $(NO_3)_2$ in HNO_3 (0.5 mol/l), Nitric acid, Hydrogen peroxide (30%) were purchased from Merck India Ltd.

8.4 Glassware

Beaker, volumetric flask, funnel, pipettes, glass slides, watch glass, glass rod. All the glassware were cleaned with detergent and 10% nitric acid and rinsed thoroughly with distilled water before use.

8.5 Sample Preparation

Samples were prepared according to Standard Operating Procedures for Lead in Paints by Hot plate or Microwave-based Acid Digestions and Inductively Coupled Plasma Emission Spectrometry, EPA, PB92 – 114172 Sept. 1991; SW 846-740 (*USEPA, 2001*). Wet paint samples were applied onto individual clean glass slides using different glass rods for each sample to avoid any cross contamination. Samples, thus applied were left to dry for a minimum of 72 hours. After drying samples were scraped off from glass slides using sharp and clean scalpel and accurately weighed to the nearest 0.1 g into an acid washed 100 ml beaker. 3.0 ml of concentrated HNO_3 and 1.0 ml of H_2O_2 were added into beaker containing samples and then covered with watch glass. Reagent blank was also taken. Samples and reagent blank were then heated on a hot plate at 140^0 C until most of the acid was evaporated. These were then removed from hot plate and allowed to cool at room temperature. Two ml of HNO_3 and 1.0 ml 30% H_2O_2 were added into the beakers and dried on hot plate to dryness and then allowed to cool. This step was repeated once again. Watch glass and walls of beaker were rinsed with 5.0 ml of 1M HNO_3. Solution was evaporated gently to dryness on the hot plate and then cooled. 1.0 ml of concentrated HNO_3 was added to residue and samples were then swirled for a minute or so to dissolve soluble species. Samples were poured from beaker into 10 ml volumetric flasks and diluted to 10 ml by distilled water and mixed vigorously.

8.6 Sample Analysis

Digested samples and reagent blank were then analyzed for total lead (Pb) by Atomic Absorption Spectrometer using Air - Acetylene flame at the wavelength of 217 nm, band pass 0.5

nm, measurement time 4 second, background correction – D_2 (prescribed by AA Spectrometers Methods Manual of Thermo Electron Corporation). The calibration curve for lead was prepared by using five concentrations (2 to 10 µg/ml) from the lead stock standard solution (1000 µg/ml). A linear calibration graph of absorbance vs. solution concentration (µg/ml) was obtained. The absorbance of the blank and sample solutions was determined using AAS operated in the above said conditions. A standard was aspirated for every 10 samples to check the instrument drift. The sample solutions were diluted with distilled water by an appropriate factor in order to ensure that the measurements are taken within the linear calibration range. The lead content of the blank solution was determined and subtracted from the lead content of the samples. Recovery of lead from samples was estimated by adding known amounts of standards and processing of the samples by the same method. It was found to be more than 90% in each case.

8.8 Calculations

Lead concentration was calculated as follows:

$$\textbf{Pb (µg/g or ppm)} = \frac{\textbf{(µg/ml in sample solution) x total dilution}}{\textbf{Sample weight in grams}}$$

9. RESULTS AND DISCUSSION

Initially 25 samples of popular enamel paints were analyzed for lead with a widely and internationally used methodology based on United States Environment Protection Agency (USEPA) by AAS.

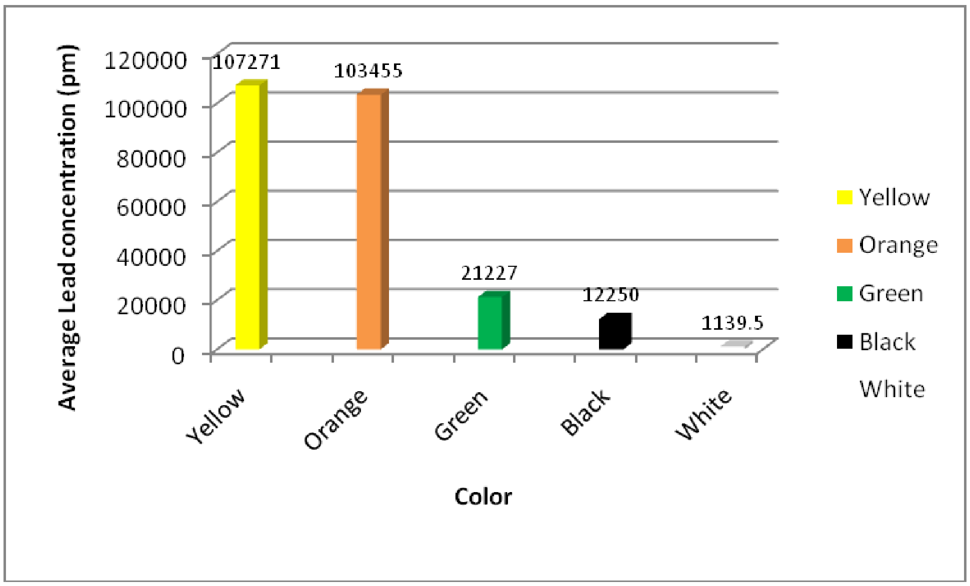
Lead was found in 23 out of 25 enamel paint samples tested. 72% (18/25) of the enamel paint samples did not meet the specification for lead content prescribed by BIS (IS 15489 : 2004) which is voluntary and does not prescribe the limit for any trace metal, whereas Ecomark scheme optional under the same voluntary standard says that product shall not contain more than 0.1% (i.e. 1000 ppm) by mass (as metal), of any toxic metals such as lead, cadmium, chromium (VI) and their compounds when tested by the relevant Atomic Absorption Spectrophotometric method. Lead content prescribed by US standard for new paints is 0.06% or 600 ppm. 28 percent (7/25) of the enamel paint samples were within the BIS limit and US limit for lead in paints, which includes 5 samples (golden yellow, deep orange, bus green, black and blazing white) of one brand Dulux which states “No lead, mercury or chromium added” on its label and two samples of white colour manufactured by Asian Paints India Ltd and Goodlass Nerolac Paint Ltd. (*Annexure II and III*)

The average concentration of lead in all the 25 enamel paint samples ranged from zero to 184,733 ppm. Highest concentration of lead (184,733) was detected in Superlac deep orange manufactured by Shalimar Paints Ltd, which is 185 times higher than the optional limit (1000 ppm) prescribed by BIS under voluntary IS 15489: 2004 standard and 308 times higher than the US limit for new paints (600 ppm) which is comparable to earlier reports of Clark *et al,* 2006 and Kumar, 2007. Lowest concentrations of lead were detected in Dulux brand of paints manufactured by ICI India Ltd. In case of golden yellow and deep orange colours no lead could be detected in Dulux brand and other colours of the same brand were also within the BIS limit and US limit for paints (*Annexure II*).

The average concentration of lead for yellow enamel paints of all the five brands was 107271 ppm followed by orange which was 103455 ppm, green 21227 ppm, black 12250 ppm and finally white enamel paint contained 1139.5 ppm (*Annexure IV and figure1*). The results indicate that main determinants of lead content were the colors. High levels of lead were detected in yellow color followed by orange and green (derivatives of yellow color) then black and finally white. White enamel paint had lowest levels of lead; 3 out of the 5 white enamel paints had lead content below the recommended level of BIS and US. The lead concentration in different colours of enamel paints in decreasing order is shown in figure 1 and was as follows:

Yellow > Orange > Green > Black > White

Figure1: Average lead content in enamel paints of various colours of different brands



The results also indicate that among the major Indian manufacturers only one manufacturer (ICI India Ltd) has removed lead pigments and other lead additives from all the products. Two manufacturers (Asians Paints and Nerolac) met the lead standards for only white enamel paint but lead levels exceeded several times in other colours (yellow, orange, black and green). The products of the other two manufacturers (Berger and Shalimar) had not met the lead standards for any colour (*Annexure II and III*).

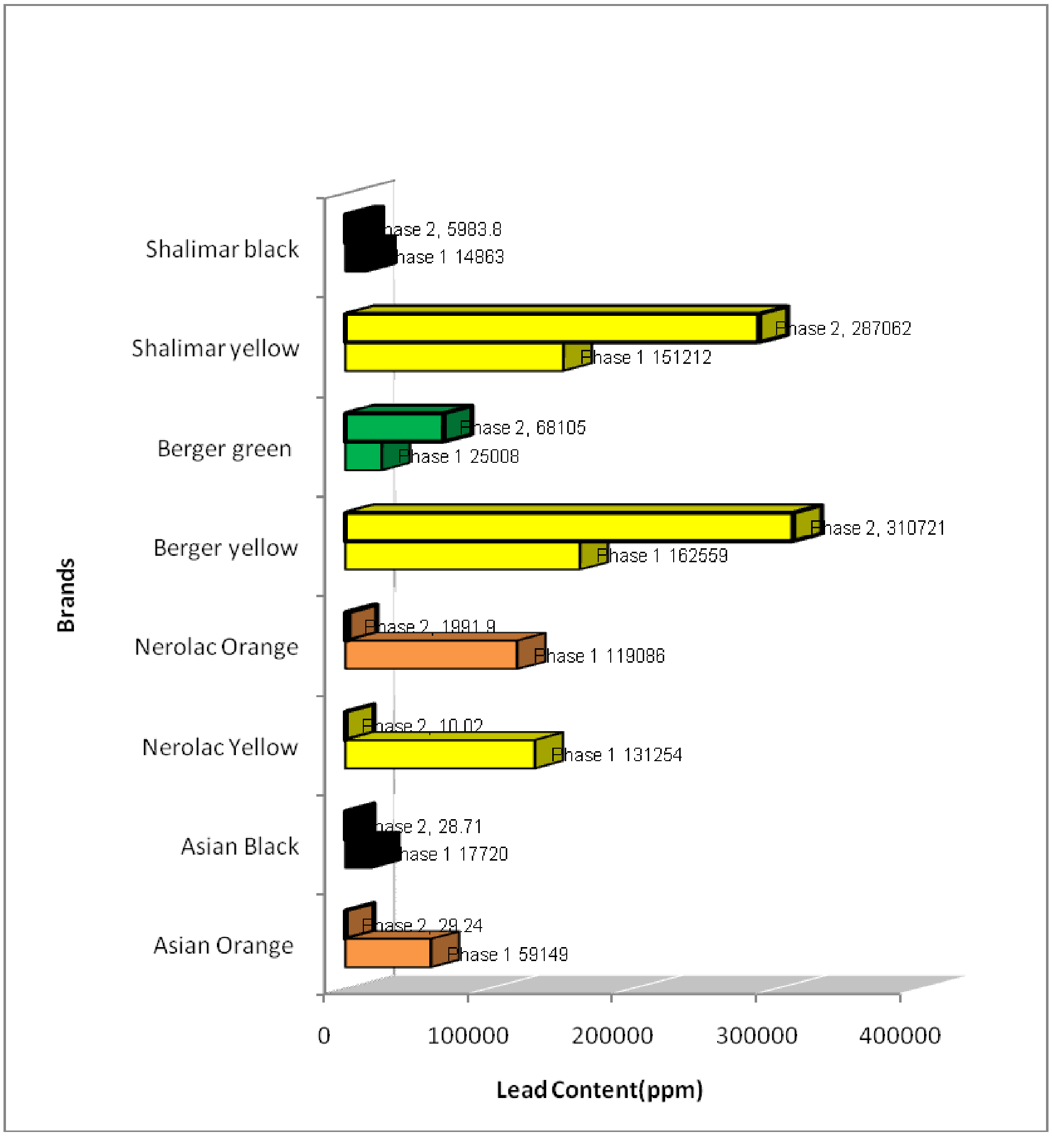
High levels of lead in paints are due to use of lead in paints for color, corrosion resistance etc. Lead chromate is added to produce yellow, orange, red, and green paints. Lead carbonate ($PbCO_3$) is used to produce white paint. Lead oxide (red lead), Lead sulfate with lead oxide, zinc oxide, and carbon (blue lead) are the other commonly used compounds in paint manufacturing. Lead is also added in paints to add the quality of speed drying, increase durability, retain a fresh appearance, and resist moisture that causes corrosion. Lead flake is used as an exterior primer and lead oleate may be encountered as a drier in paints.

Substitutes for lead pigments are available and are being used by one of the manufacturers. Lead is being replaced by Titanium oxide and Barium-Zinc-Sulfur combinations and their durability can be improved by adding Silicon or Aluminium oxides. The increase in cost resulting from the substitution is relatively small and cannot be compared with the harm caused to human beings due to continued exposure to lead.

As already stated the lead content found was quite high in most of the samples analysed except all colours of one brand and white colour of two brands. In view of the information that some manufacturers may have substituted lead in their products, a new set of eight paints of four different manufacturers (two of each manufacturer) were again procured and analysed. The results were as follows:

- In deep orange and black colour of Apcolite manufactured by Asian Paints Ltd. the lead content was 29.24 and 28.71 ppm respectively which was much lower as compared to the results obtained previously for the same colours and brand which were 59149 and 17720 ppm respectively (*Annexure III and figure 2*).
- The lead content in golden yellow and tractor orange of Nerolac manufactured by Kansai Nerolac Ltd. was found to be 10.02 and 1991.9 ppm respectively. These values are much less as compared to 131254 and 119086 ppm respectively found earlier in the paints of the same colours and brand (*Annexure III and figure 2*).
- Golden yellow and bus green colours of Luxol manufactured by Berger had lead 310721 and 68105 ppm respectively which was high showing that this particular manufacturer had not substituted lead (*Annexure III and figure 2*).
- The concentration of lead in golden yellow colour of Superlac manufactured by Shalimar was found to be 287062 ppm and the black colour of the same brand also contained high amounts of lead (5983.8 ppm) This also showed non-removal of lead from paints (*Annexure III and figure 2*).

Figure 2 Comparison of lead content in paints of different colors of different brands at two different time periods (Phase1and Phase 2)



Note:

BIS limit for Lead limit (IS 5489:2004) -1000 ppm

US New Paints Lead Limit - 600 ppm

10. CONCLUSIONS

- Twenty five samples of popular enamel paints were procured from Delhi markets and analyzed for lead content by US EPA methodology using Atomic Absorption Spectrometer in May - June 2008.
- The brands tested were Apcolite (Asian Paints Ltd.), Nerolac (Kansai Nerolac Paints Ltd.), Luxol (Berger Paints India Ltd.), Superlac (Shalimar Paints Ltd.) and Dulux (ICI India Ltd.) and the colours were yellow, orange, green, black and white (A*nnexure I*).
- Seventy two percent of these samples contained lead much higher than the BIS specification of 1000 ppm and only 28% had lead lesser than 100 ppm (A*nnexure II).*
- The lead concentration varied from zero to 184733 ppm, the highest amount being present in the deep orange paint of Superlac brand (A*nnexure II and III*).
- All the samples of Dulux brand (ICI) contained lead much below the specified limit of 1000 ppm (0.1%) (A*nnexure II and III*).
- In order of decreasing lead concentration the paint colours can be arranged as follows (A*nnexure IV*): **Yellow > Orange > Green > Black > White**
- In May 2009 eight more samples of four different brands (two of each) were procured and analysed. The results showed that deep orange and black paints of Apcolite brand (Asian Paints) contained 29.24 and 28.71 ppm lead as compared to 59149 and 17720 ppm respectively found earlier, thus showing substitution of lead (*Annexure III and figure 2*).
- In case of golden yellow and tractor orange of Nerolac brand the lead concentration was 10.02 and 1991.9 ppm respectively as compared to 131254 and 119086 ppm found earlier. Thus the manufacturer Kansai Nerolac also reduced lead content in at least these two colours (*Annexure III and figure 2*).
- The golden yellow and bus green of Luxol brand (Berger Paints) showed a lead concentration of 310721 and 68105 ppm. Similarly in case of golden yellow and black colours of Superlac brand (Shalimar Paints) the lead content was 287062 and 5983.8 ppm. It is thus seen that the Luxol brand of Berger Paints and Superlac brand of Shalimar Paints still continue to use lead in their paints (A*nnexure III and figure 2*).
- There is no regulation in India for labeling the contents of hazardous metals on paint containers.
- There is an urgent need to increase awareness of the harmful effects of lead especially in households due to lead based paints. Strict regulations for hazardous metal contents in paints are thus necessary.

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Annexure I: Enamel paints procured from Delhi

S. No.	Code No.	Brand Name	Color	Volume	Company	Manufacturer	Batch Number	Date of manufacture	Other information
Phase 1									
1	001	Apcolite	Golden Yellow	100 mL	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	J	Apr-07	
2	002	Nerolac	Golden Yellow	100 mL	Goodlass Nerolac	Goodlass Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	MAA	Jul-06	
3	003	Luxol	Golden Yellow	500 mL	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	1159	Jun-07	
4	004	Dulux	Golden Yellow	500 mL	ICI Paints	ICI India Ltd, Geetanjali Apartment, Ist Floor, 86 Middleton Street, Kolkata -700071	Bx M1099	May-07	The can states "No added lead, mercury and chromium compounds" around a mark of green tree
5	018	Superlac	Golden Yellow	200 mL	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	SL/1782	Aug-07	
6	005	Apcolite	Deep orange	500 mL	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	K 90	Jan-07	
7	006	Nerolac	Tractor orange	500 mL	Goodlass Nerolac	Goodlass Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	2-350	Jun-06	
8	007	Luxol	Deep orange	500 mL	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	6581	Feb-04	
9	008	Dulux	Deep orange	1 L	ICI Paints	ICI India Ltd, Geetanjali Apartment, Ist Floor, 86 Middleton Street, Kolkata -700071	Not clear	Not clear	The can states "No added lead, mercury and chromium compounds" around a mark of green tree
10	009	Superlac	Deep orange	200 mL	Shalimar	Shalimar Paints Ltd, 13, Camac street, Kolkata -	NL.3230	Oct-04	

						700017			
11	010	Apcolite	Bus Green	50 mL	Asian Paints	Asian Paints (India) Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	Y	Mar-06	
12	011	Nerolac	New Bus Green	100 mL	Goodlass Nerolac	Goodlass Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	JA	Mar-04	
13	012	Luxol	Bus Green	200 mL	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	6594	Nov-04	
14	013	Dulux	Bus Green	500 mL	ICI Paints	ICI India Ltd, Geetanjali Apartment, Ist Floor, 86 Middleton Street, Kolkata -700071	Bx M 1171	Oct-07	The can states "No added lead, mercury and chromium compounds" around a mark of green tree
15	014	Superlac	Bus Green	50 mL	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	PM 15242	Oct-04	
16	015	Apcolite	BLZ White	50 mL	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	J	May-06	
17	016	Nerolac	Brill White	500 mL	Kansai Nerolac Ltd	Kansai Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	JU	Sep-07	
18	019	Luxol	Snow White	200 mL	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	L157	Jul-07	
19	017	Dulux	Blazing white	500 mL	ICI Paints	ICI India Ltd, Geetanjali Apartment, Ist Floor, 86 Middleton Street, Kolkata -700071	BX M1612	Oct-07	The can states "No added lead, mercury and chromium compounds" around a mark of green tree
20	020	Superlac	Dazzling white	200 mL	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	SL-1817	Aug-07	
21	021	Apcolite	Black	100 mL	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	PGE	Jan-08	

22	022	Nerolac	Black	200 mL	Kansai Nerolac Ltd	Kansai Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	P/379	Mar-08	
23	023	Luxol	Black	200 mL	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	A/1536	Oct-07	
24	024	Dulux	Black	500 mL	ICI Paints	ICI India Ltd, Geetanjali Apartment, Ist Floor, 86 Middleton Street, Kolkata -700071	280122	Feb-08	The can states"No added lead, mercury and chromium compounds" around a mark of green tree
25	025	Superlac	Black	200 mL	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	SL0037	Apr- 2008	
Phase 2									
26	028	Apcolite	Deep orange	1 L	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	A 155	Apr-09	Purchased on May 2009
27	029	Apcolite	Black	500 mL	Asian Paints	Asian Paints Ltd., 6A, Shantinagar, Santacruz (E) Mumbai - 400055	K 796	May-09	Purchased on May 2009
28	030	Luxol	Golden Yellow	1 L	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	MS/9701 /03/09	Mar-09	Purchased on May 2009
29	031	Luxol	Bus Green	1 L	Berger	Berger Paints India Ltd, Berger House, 129, Park Street, Kolkata - 700017	JMS/993 9/03/09	Mar-09	Purchased on May 2009
30	032	Nerolac	Golden Yellow	1 L	Kansai Nerolac Ltd	Kansai Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	JA	Jan-09	Purchased on May 2009
31	033	Nerolac	Tractor orange	1 L	Kansai Nerolac Ltd	Kansai Nerolac Paints Ltd, Ganpatrao Kadam Marg, Lower Parel, Mumbai - 400013	JA	Apr-09	Purchased on May 2009
32	034	Superlac	Black	500 mL	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	SL 4440	Mar-09	Purchased on May 2009
33	035	Superlac	Golden Yellow	1 L	Shalimar	Shalimar Paints Ltd, 13, Camac Street, Kolkata - 700017	SL 3941	Jan-09	Purchased on May 2009

Annexure II: Concentration of lead in various enamel paints from Delhi analysed at two different periods of time

S.No.	Code No.	Brand Name	Colour	Company	Lead (ppm)	Lead (%)	No. of times of the BIS limit (IS 5489:2004) (1000 ppm)	No of times of the US New Paints Limit (600 ppm)
Phase 1: Paints analysed in May - June 2008								
1	001	Apcolite	Golden Yellow	Asian Paint	91327	9.13	91	152
2	005	Apcolite	Deep orange	Asian Paint	59149	5.91	59	99
3	010	Apcolite	Bus Green	Asian Paint	22182	2.22	22	37
4	015	Apcolite	BLZ White	Asian Paint	82.02	0.008	within limit	within limit
5	021	Apcolite	Black	Asian Paint	17720	1.77	18	30
6	002	Nerolac	Golden Yellow	Goodlass Nerolac	131254	13.13	131	219
7	006	Nerolac	Tractor orange	Goodlass Nerolac	119086	11.91	119	198
8	011	Nerolac	Bus Green	Goodlass Nerolac	23591	2.36	24	39
9	016	Nerolac	Brill White	Kansai Nerolac	11.65	0.001	within limit	within limit
10	022	Nerolac	Black	Kansai Nerolac	11141	1.11	11	19
11	003	Luxol	Golden Yellow	Berger	162559	16.26	163	271
12	007	Luxol	Deep orange	Berger	154306	15.43	154	257
13	012	Luxol	Bus Green	Berger	25008	2.50	25	42
14	019	Luxol	Snow White	Berger	2133.2	0.21	2	4
15	023	Luxol	Black	Berger	17488	1.75	17	29
16	004	Dulux	Golden Yellow	ICI	0.00	0.000	within limit	within limit
17	008	Dulux	Deep orange	ICI	0.00	0.000	within limit	within limit
18	013	Dulux	Bus Green	ICI	21.76	0.002	within limit	within limit
19	017	Dulux	Blazing white	ICI	9.44	0.001	within limit	within limit
20	024	Dulux	Black	ICI	36.25	0.004	within limit	within limit
21	018	Superlac	Golden Yellow	Shalimar	151212	15.12	151	252
22	009	Superlac	Deep orange	Shalimar	184733	18.47	185	308
23	014	Superlac	Bus Green	Shalimar	35330	3.53	35	59
24	020	Superlac	Dazzling White	Shalimar	3461.1	0.35	3	6
25	025	Superlac	Black	Shalimar	14863	1.49	15	25
Phase 2: Enamel paints analysed in June 2009								
1	028	Apcolite	Deep orange	Asian Paint	29.24	0.003	within limit	within limit
2	029	Apcolite	Black	Asian Paint	28.71	0.003	within limit	within limit
3	030	Luxol	Golden Yellow	Berger	310721	31.07	311	518
4	031	Luxol	Bus Green	Berger	68105	6.81	68	114
5	032	Nerolac	Golden Yellow	Kansai Nerolac	10.02	0.001	within limit	within limit
6	033	Nerolac	Tractor orange	Kansai Nerolac	1991.9	0.20	2	3
7	034	Superlac	Black	Shalimar	5983.8	0.60	6	10
8	035	Superlac	Golden Yellow	Shalimar	287062	28.71	287	478

Annexure III: Concentration of lead in enamel paints determined at two different periods of time arranged according to manufacturers

S. No.	Brand Name	Colour	Company	Lead (ppm)	
				Sampling Period*	
				Phase 1	Phase 2
1	Apcolite	Golden Yellow	Asian Paint	91327	
2	Apcolite	Deep orange	Asian Paint	59149	29.24
3	Apcolite	Bus Green	Asian Paint	22182	
4	Apcolite	BLZ White	Asian Paint	82.02	
5	Apcolite	Black	Asian Paint	17720	28.71
6	Nerolac	Golden Yellow	Goodlass Nerolac	131254	10.02**
7	Nerolac	Tractor orange	Goodlass Nerolac	119086	1991.9**
8	Nerolac	Bus Green	Goodlass Nerolac	23591	
9	Nerolac	Brill White	Kansai Nerolac	11.65	
10	Nerolac	Black	Kansai Nerolac	11141	
11	Luxol	Golden Yellow	Berger	162559	310721
12	Luxol	Deep orange	Berger	154306	
13	Luxol	Bus Green	Berger	25008	68105
14	Luxol	Snow White	Berger	2133.2	
15	Luxol	Black	Berger	17488	
16	Dulux	Golden Yellow	ICI	0.00	
17	Dulux	Deep orange	ICI	0.00	
18	Dulux	Bus Green	ICI	21.76	
19	Dulux	Blazing white	ICI	9.44	
20	Dulux	Black	ICI	36.25	
21	Superlac	Golden Yellow	Shalimar	151212	287062
22	Superlac	Deep orange	Shalimar	184733	
23	Superlac	Bus Green	Shalimar	35330	
24	Superlac	Dazzling White	Shalimar	3461.1	
25	Superlac	Black	Shalimar	14863	5983.8

***Sampling period:**

Phase 1 - May - June 2008

Phase 2 -May 2009

**** Manufactured by Kansai Nerolac Ltd. (Goodlass Nerolac is now Kansai Nerolac)**

Note: Each value is an average of three replicates and relative standard deviation was less than 10%

Annexure IV: Median and average values of lead in different colours of different brands of 25 enamel paints analysed in May-June 2008

S. No.	Code No.	Brand Name	Colour	Company	Lead (ppm)	Median (ppm)	Average (ppm)
1	001	Apcolite	Golden Yellow	Asian Paint	91327	131254	107271
2	002	Nerolac	Golden Yellow	Goodlass Nerolac	**131254**		
3	003	Luxol	Golden Yellow	Berger	162559		
4	004	Dulux	Golden Yellow	ICI	0.00		
5	018	Superlac	Golden Yellow	Shalimar	151212		
6	005	Apcolite	Deep orange	Asian Paint	59149	119086	103455
7	006	Nerolac	Tractor orange	Goodlass Nerolac	**119086**		
8	007	Luxol	Deep orange	Berger	154306		
9	008	Dulux	Deep orange	ICI	0.00		
10	009	Superlac	Deep orange	Shalimar	184733		
11	010	Apcolite	Bus Green	Asian Paint	22182	23591	21227
12	011	Nerolac	Bus Green	Goodlass Nerolac	**23591**		
13	012	Luxol	Bus Green	Berger	25008		
14	013	Dulux	Bus Green	ICI	21.76		
15	014	Superlac	Bus Green	Shalimar	35330		
16	021	Apcolite	Black	Asian Paint	17720	14863	12250
17	022	Nerolac	Black	Kansai Nerolac	11141		
18	023	Luxol	Black	Berger	17488		
19	024	Dulux	Black	ICI	36.25		
20	025	Superlac	Black	Shalimar	**14863**		
21	015	Apcolite	BLZ White	Asian Paint	**82.02**	82.02	1139.5
22	016	Nerolac	Brill White	Kansai Nerolac	11.65		
23	019	Luxol	Snow White	Berger	2133.2		
24	017	Dulux	Blazing white	ICI	9.44		
25	020	Superlac	Dazzling White	Shalimar	3461.1		

Annexure V: Median values of lead in different brands of 25 enamel paints analysed in Phase I -May-June 2008

S. No.	Code No.	Brand Name	Colour	Company	Lead (ppm)	Median (ppm)	Average (ppm)
1	001	Apcolite	Golden Yellow	Asian Paints	91327	22182	38092
2	005	Apcolite	Deep orange	Asian Paints	59149		
3	010	Apcolite	Bus Green	Asian Paints	**22182**		
4	015	Apcolite	BLZ White	Asian Paints	82.02		
5	021	Apcolite	Black	Asian Paints	17720		
6	002	Nerolac	Golden Yellow	Goodlass Nerolac	131254	23591	57017
7	006	Nerolac	Tractor orange	Goodlass Nerolac	119086		
8	011	Nerolac	Bus Green	Goodlass Nerolac	**23591**		
9	016	Nerolac	Brill White	Kansai Nerolac	11.65		
10	022	Nerolac	Black	Kansai Nerolac	11141		
11	003	Luxol	Golden Yellow	Berger	162559	25008	72299
12	007	Luxol	Deep orange	Berger	154306		
13	012	Luxol	Bus Green	Berger	**25008**		
14	019	Luxol	Snow white	Berger	2133.2		
15	023	Luxol	Black	Berger	17488		
16	004	Dulux	Golden Yellow	ICI	0.00	9.44	13.49
17	008	Dulux	Deep orange	ICI	0.00		
18	013	Dulux	Bus Green	ICI	21.76		
19	017	Dulux	Blazing white	ICI	**9.44**		
20	024	Dulux	Black	ICI	36.25		
21	018	Superlac	Golden Yellow	Shalimar	151212	35330	77920
22	009	Superlac	Deep orange	Shalimar	184733		
23	014	Superlac	Bus Green	Shalimar	**35330**		
24	020	Superlac	Dazzling White	Shalimar	3461.1		
25	025	Superlac	Black	Shalimar	14863		

Annexure VI: Median and average values of lead in different colours of different brands of all the 33 enamel paints analysed

S. No.	Code No.	Brand Name	Colour	Company	Lead (ppm)	Median (ppm)	Average (ppm)
1	001	Apcolite	Golden Yellow	Asian Paint	91327	141233	141768
2	002	Nerolac	Golden Yellow	Goodlass Nerolac	131254		
3	003	Luxol	Golden Yellow	Berger	162559		
4	004	Dulux	Golden Yellow	ICI	0.00		
5	018	Superlac	Golden Yellow	Shalimar	151212		
6	030	Luxol	Golden Yellow	Berger	310721		
7	032	Nerolac	Golden Yellow	Kansai Nerolac	10.02		
8	035	Superlac	Golden Yellow	Shalimar	287062		
9	005	Apcolite	Deep orange	Asian Paint	59149	59149	74185
10	006	Nerolac	Tractor orange	Goodlass Nerolac	119086		
11	007	Luxol	Deep orange	Berger	154306		
12	008	Dulux	Deep orange	ICI	0.00		
13	009	Superlac	Deep orange	Shalimar	184733		
14	028	Apcolite	Deep orange	Asian Paint	29.24		
15	033	Nerolac	Tractor orange	Kansai Nerolac	1991.9		
16	010	Apcolite	Bus Green	Asian Paint	22182	24300	29040
17	011	Nerolac	Bus Green	Goodlass Nerolac	23591		
18	012	Luxol	Bus Green	Berger	25008		
19	013	Dulux	Bus Green	ICI	21.76		
20	014	Superlac	Bus Green	Shalimar	35330		
21	031	Luxol	Bus Green	Berger	68105		
22	021	Apcolite	Black	Asian Paint	17720	11141	9608.7
23	022	Nerolac	Black	Kansai Nerolac	11141		
24	023	Luxol	Black	Berger	17488		
25	024	Dulux	Black	ICI	36.25		
26	025	Superlac	Black	Shalimar	14863		
27	029	Apcolite	Black	Asian Paint	28.71		
28	034	Superlac	Black	Shalimar	5983.8		
29	015	Apcolite	Blazing White	Asian Paint	82.02	82.02	1139.5
30	016	Nerolac	Brill White	Kansai Nerolac	11.65		
31	019	Luxol	Snow White	Berger	2133.2		
32	017	Dulux	Blazing white	ICI	9.44		
33	020	Superlac	Dazzling White	Shalimar	3461.1		

Annexure VII: Median values of lead in different brands of all the 33 enamel paints analysed

S.No.	Code No.	Brand Name	Colour	Company	Lead (ppm)	Median (ppm)
1	001	Apcolite	Golden Yellow	Asian Paints	91327	17720
2	005	Apcolite	Deep orange	Asian Paints	59149	
3	010	Apcolite	Bus Green	Asian Paints	22182	
4	015	Apcolite	BLZ White	Asian Paints	82.02	
5	021	Apcolite	Black	Asian Paints	**17720**	
6	028	Apcolite	Deep orange	Asian Paint	29.24	
7	029	Apcolite	Black	Asian Paint	28.71	
8	002	Nerolac	Golden Yellow	Goodlass Nerolac	131254	11141
9	006	Nerolac	Tractor orange	Goodlass Nerolac	119086	
10	011	Nerolac	Bus Green	Goodlass Nerolac	23591	
11	016	Nerolac	Brill White	Kansai Nerolac	11.65	
12	022	Nerolac	Black	Kansai Nerolac	**11141**	
13	032	Nerolac	Golden Yellow	Kansai Nerolac	10.02	
14	033	Nerolac	Tractor orange	Kansai Nerolac	1991.9	
15	003	Luxol	Golden Yellow	Berger	162559	68105
16	007	Luxol	Deep orange	Berger	154306	
17	012	Luxol	Bus Green	Berger	25008	
18	019	Luxol	Snow white	Berger	2133.2	
19	023	Luxol	Black	Berger	17488	
20	030	Luxol	Golden Yellow	Berger	310721	
21	031	Luxol	Bus Green	Berger	**68105**	
22	004	Dulux	Golden Yellow	ICI	0.00	9.44
23	008	Dulux	Deep orange	ICI	0.00	
24	013	Dulux	Bus Green	ICI	21.76	
25	017	Dulux	Blazing white	ICI	**9.44**	
26	024	Dulux	Black	ICI	36.25	
27	018	Superlac	Golden Yellow	Shalimar	151212	35330
28	009	Superlac	Deep orange	Shalimar	184733	
29	014	Superlac	Bus Green	Shalimar	**35330**	
30	020	Superlac	Dazzling White	Shalimar	3461.1	
31	025	Superlac	Black	Shalimar	14863	
32	034	Superlac	Black	Shalimar	5983.8	
33	035	Superlac	Golden Yellow	Shalimar	287062	