Lead and cadmium in soft plastic toys

Abhay Kumar* and Prashant Pastore

Toxics Link, H2, Ground Floor, Jungpura Extension, New Delhi 110 014, India

It is widely accepted that no level of lead or cadmium in the blood should be considered safe for children and hence every effort should be made to ensure that their environment remains free from any such toxic metals. Toys made of polyvinyl chloride (PVC) are potentially toxic to children as PVC contains both lead and cadmium. Lead or cadmium compounds act as stabilizers but they readily leach out. Moreover, they can also be used in pigments to impart bright colours to toys in order to attract children. Chewing and swallowing behaviour of children is a common source of lead and cadmium exposure. The present study was undertaken to ascertain the levels of total lead and cadmium in soft plastic toys. A total of 111 non-branded toy samples, purchased randomly from three metropolitan cities of Delhi, Mumbai and Chennai, were analysed for levels of lead and cadmium. Lead and cadmium were found to be present in all tested samples in varying concentrations.

Keywords: Polyvinyl chloride, risk, standards, toys, toxicity.

TOYS are an integral part of a child's developmental processes. Children play with toys and learn about the world. *Wikipedia* defines a toy as something used in play by children, adults or pets[1]. A toy may mean different things to children of different age groups and hence exposure pathways also differ accordingly. A child below 3 years of age may handle a toy in a completely different manner from a child 3–6 years of age. Toys can broadly be categorized as mechanical, electrical and soft toys. According to available figures, the global toy market presently is of the order of US$ 105.0 billion. USA is the world's biggest importer of toys (imports worth US$ 35.0 billion)[2] having a market share of approximately 30%.

Toys may also inflict accidental injuries to children. Sharp edges of toys or other electrical, mechanical or flammable characteristics may cause accidents. Chemical exposure to children, especially from toys, is an emerging concern. Metals in materials and paints are loosely bound to the surface and can leach easily. The chewing, licking and swallowing behaviour of children is a common source of lead and cadmium exposure[3]. Children and pregnant women are particularly susceptible to lead poisoning. The digestive system of children absorbs up to 50% of the lead they ingest[4]. In fact, physicians and scientists agree that no level of lead in blood is safe or normal[4]. It is important to understand that what constituted 'safe' yesterday is no longer 'safe' today, and what is 'safe' today may not be 'safe' tomorrow. The present 'safe' limit[5] of 10 μg/dl of lead in blood was actually 60 μg/dl in 1960s and then it was brought down to 30 μg/dl in 1970s, which was again revised in 1985 to 25 μg/dl and in 1991 to 10 μg/dl. Similarly, cadmium when released as fine airborne particles reacts almost immediately with oxygen to form respirable cadmium oxide, which is a carcinogen. Cadmium dust (cadmium oxide, CdO) is another source of cancer in human beings[6]. Polyvinyl chloride (PVC) also releases its metal stabilizers as dust on its surface, which may contain lead or cadmium.

Toys made of PVC (CH_2=CHCl) are a potential source of risk to children. PVC has a special problem of auto-digestion since free chlorine radicals in the structure react with free hydrogen radicals forming hydrochloric acid (HCl) leading to the digestion of PVC, which causes a chain reaction and proceeds rapidly to completely weaken the structure (causing damage to the manufacturing equipment as well). Lead or cadmium is hence added to PVC as stabilizers to prevent the free chlorine radicals from reacting with hydrogen radicals to form HCl[7]. Lead compounds are the most common stabilizers in PVC. Some of them are basic lead carbonate, lead stearate, basic lead stearate, tribasic lead stearate, basic (dibasic) lead stearate and basic lead phthalate. Other metals have also been used when lead came under regulatory scrutiny, including Cd, Zn, organotins, etc. Lead and cadmium are also added to PVC or other plastic products as colouring agents in the form of organo-metallic compounds.

Lead and cadmium are known poisons, being neurotoxins and nephrotoxins respectively. Although numerous epidemiological studies have been carried out on the health impacts of lead on children in India, little has been done to ascertain its source in children's environment in the country[8–10]. Lead as a source has mostly been studied in aerosols, the atmosphere or in paints[11–14]. Toys, particularly soft toys, which are intimately linked to children's environment, have not been investigated as one of the possible sources of lead, cadmium and other heavy metals. Moreover, India now produces and imports a wide range of toys. The unorganized sector dominates the toy manufacturing industry. It is estimated that the industry volume is US$ 1.0 billion in the organized sector and about US$ 1.5 billion in the unorganized sector[2]. Soft toys account

*For correspondence. (e-mail: abhay@toxicslink.org)

for 35% of India's total production of toys[2]. The absence of any study on lead and cadmium content in toys coupled with the fact that soft toys dominate the toy industry, we decided to work on non-branded and cheap soft plastic toys probably used by the bulk of the children here, with the sole objective to ascertain the total contents of lead and cadmium in the sampled toys collected from three metropolitan cities of Delhi, Chennai and Mumbai. In the present work risk assessment has not been done. The toy samples were collected from the above-mentioned three metropolitan cities as they are one of India's largest manufacturers and supply centres for unbranded toys to their surrounding sub-urban and rural areas. Mumbai and Delhi account for nearly 95% of the toy output in India[2]. The difference in number of samples from the three cities roughly reflects the share of toy market that these cities have. All the samples from Delhi, Mumbai and Chennai were brought to one place (Toxics Link Head Office) in Delhi. These samples were then codified based on their place of purchase (Table 1). A total of 111 toy samples were purchased: 60 from Delhi, 30 from Mumbai and 21 from Chennai.

Materials and methods

All toy samples were tested at Delhi Test House, a National Accreditation Board for Testing and Calibration Laboratories (NABL), Department of Science and Technology accredited laboratory in Delhi.

The toy samples were first subjected to an indicative test for PVC using the Beilstein test. This is not a confirmatory test for PVC. The Beilstein test is based on the principle that copper halides vapourize readily, giving-off a blue-green coloured flame owing to the presence of copper[15]. To perform this test, copper wire (18–20 gauge) inserted into a cork (which served as an insulated handle) was heated in a blue Bunsen burner. The hot wire was placed on an inconspicuous part of the plastic toy to be tested in order to melt some of the polymer onto the wire; then the wire was re-heated in the flame. A blue-green coloured flame, which persisted only a few seconds, indicated the presence of a halogen (excluding fluorine) and suggested that the polymer might be PVC. All toy samples which tested positive for Beilstein test were further tested for total contents of lead and cadmium. A few toy samples which gave negative test for Beilstein test were also tested for the total content of lead and cadmium. A total of 88 samples (77 tested positive for Beilstein test and 11 tested negative for the test) were analysed for lead and cadmium. The methodology included subjecting samples first to ashing to breakdown the PVC and then digesting in accordance with EPA SW-846 3050 (digestion with nitric acid and hydrogen peroxide)[16]. Individual samples were broken into several pieces in a large silica crucible and charred on a hot plate till the fume ceased to exist, followed by complete ashing in muffle furnace at 480°C. The crucible was then taken out of the furnace and kept in desiccators for cooling. After cooling, the samples were powdered and homogenized in the silica crucible. Then 2 g of the sample was taken in separate silica crucible for acid digestion. Supra pure-Merck (lead and cadmium-free) nitric acid and hydrogen peroxide were used for digestion in an open vessel. After complete digestion the samples were transferred to 100 ml Tarson bottles and the volumes were made 100 ml. Blank samples were also prepared similarly. Standards were prepared with serial dilution technique within the range of 10–30 ppb for lead and 10–50 ppb for cadmium. The stock solutions of standards were National Institute of Standards and Technology (NIST)-certified and provided by Merck. The final processed samples were quantitatively analysed using AAS (GBC 932 plus) with graphite furnace. The instrument was first calibrated with standards prepared from stock solution provided by Merck. The final processed samples were quantitatively analysed using AAS (GBC 932 plus) with graphite furnace. The instrument was first calibrated with standards prepared from stock solution provided by Merck. After every ten samples analysed using AAS, the first sample was repeated for quality check. Only when the results were within 10% of earlier readings did the analysis proceed further.

Results and discussion

The average, range and standard deviation of Pb and Cd concentration are presented in Table 2. Column diagram of the same data is presented in Figure 1 *a* and *b* respecti-

Table 1. Catalogue of samples

Sample no.	Description of toys and market from where they were purchased
D-1 to D-10	Purchased from Chandni Chowk, New Delhi
D-12 to D-32	Purchased from Sadar Bazar, Delhi
D-34, D-37, D-38	Purchased from road-side vendors, Jungpura, New Delhi
D-40 and D-48	Purchased from Tigri resettlement area, New Delhi
D-49 to D-60	Purchased from Munirka, New Delhi
C-1, C-2, C-4 to C-6, C-8, C-15, C-16, C-19, C-20	Purchased from Chennai
M-2 to M-30	Purchased from Mumbai

Table 2. Average, range and standard deviation of data related to Pb and Cd concentration (ppm) in toy samples

	Average	Maximum	Minimum	Standard deviation
Delhi				
Pb	27.8	121.8	0.65	23.49
Cd	26.53	188	0.016	48.98
Chennai				
Pb	20.67	51.3	4.9	13.88
Cd	3.10	14.5	0.16	4.48
Mumbai				
Pb	278.73	2104	1.68	512.03
Cd	2.61	11.6	0.03	2.76
All				
Pb	112.51	2104	0.65	319.64
Cd	15.71	188	0.016	37.98

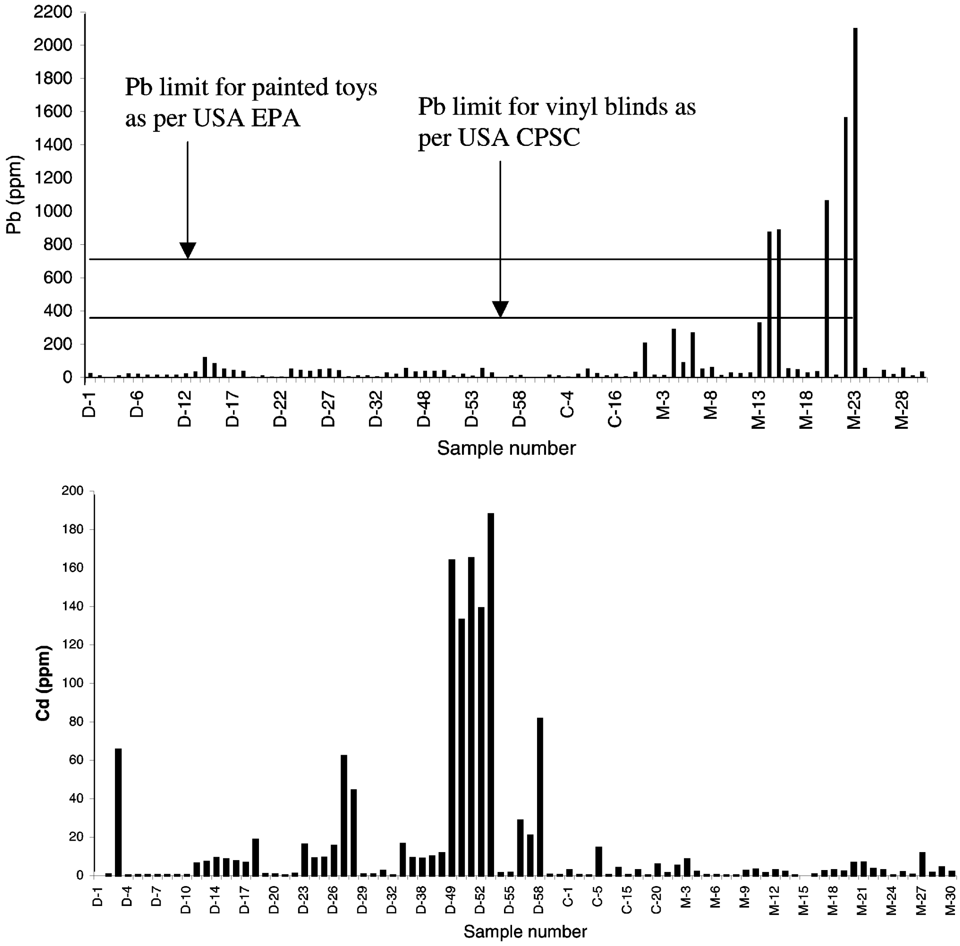

Figure 1. Pb (***a***) and Cd (***b***) concentrations in toy samples across the regions.

vely. Pb and Cd were found in all tested samples in varying concentrations. Among the 111 toy samples tested, 77 indicated the presence of halides and hence may be considered to be made up of PVC materials, while 34 samples showed absence of halides and hence may considered to be made up of non-PVC plastic materials. Among 77 such samples, 43 were from Delhi, 30 from Mumbai and 4 from Chennai.

The average concentration of Pb was found to be least in the toys from Chennai (3.10 ppm). It may be due to fewer toy samples (n = 11) being analysed for Pb and Cd in comparison to those of Delhi and Mumbai. Cd concen-

Table 3. The Indian standard

Toy material	Element (ppm)							
	Sb	As	Ba	Cd	Cr	Pb	Hg	Se
Any toy material given in clause 1, except modelling clay and finger paint	60	25	1000	75	60	90	60	500
Modelling clay and finger paint	60	25	250	50	25	90	25	500

Source: Indian Standard SAFETY REQUIREMENTS FOR TOYS Part 3. Migration of certain elements (First revision) IS 9873 (Part 3): 1999, Bureau of Indian Standards, 1999.

tration was generally lower than that of Pb in toys across the region. However, concentration of Cd was generally high in samples from Delhi. In fact, the maximum for Cd (188 ppm) was higher than that of Pb (121.8 ppm). It was also observed in Delhi samples that cadmium concentration was higher in those which had lower Pb concentration. If lead was high then cadmium was low and vice-versa. Although the correlation coefficient between Pb and Cd in Delhi samples was not statistically significant (–0.0378), it may still be argued that it was either Pb or Cd, which was used as stabilizer in toys or a combination of pigments and poor quality control. Similar but even weaker correlation was found between Pb and Cd in the Mumbai samples (correlation coefficient = –0.01385). The weak negative correlation may be due to other sources of lead and cadmium in toys, that is, from the surface coatings of paints. Overall Pb seems to be largely in use as stablizer in PVC toy-manufacturing. Cd concentration was found to be low in the samples brought from Mumbai and Chennai. However, this requires a further study of the manufacturing processes to confirm the heterogeneity in lead and cadmium concentrations in toys across the country.

Concentration of lead was high in some of the Mumbai samples. In fact, Mumbai average (278.3 ppm) was higher than that of the national average (112.51 ppm). It is crucial to note that out of 30 samples analysed for total concentration of Pb and Cd in toys brought from Mumbai, eight showed concentration higher than 200 ppm, which is the limit proposed by the US Consumer Product Safety Commission in vinyl blinds[17]. In fact, five samples (close to 20% of Mumbai samples analysed) showed very high lead concentration (from 878.6 to 2104 ppm) even exceeding US EPA limit of 600 ppm in painted toys (Figure 1 *a*). Such high quantities of lead in toys pose a threat to children's health. It must be noted that exposure from lead is in addition to that of cadmium. Hence children playing with toys having both lead and cadmium are exposed to both toxic metals. This is an important concern and any regulatory mechanism must take this into account.

Uncertainties related to standards

Defining standards is a first step in any regulatory mechanism and prevention is the key to safe environmental health. Unfortunately India does not have an enforceable standard for the total content of lead, cadmium and other toxic metals in toys. Whatever standard India has in this regard is with respect to migratory elements from toy materials, which has been adopted from European Union safety requirements (BS EN 71-3:1995) and International Standards (International Organization for Standardization, ISO 8124-3:1997 Migration of Certain Elements; Table 3). This is only voluntary in nature. A standard which is voluntary in nature cannot be termed as 'standard'. Authors' own inquiries have revealed that not a single toy manufacturer in India has applied to the Bureau of Indian Standards even for this voluntary standard. It is rather perturbing that an important policy feature relating to crucial implications for children's health has not been given due consideration as yet.

A crucial shortcoming of these standards is the absence of any correlation between the bioavailable elements and their total content in toys. The scientific community is still grappling with this and there seems to be no agreement.

Conclusion

Lead and cadmium were found in varying concentrations in all toy samples. Eight samples showed concentration higher than 200 ppm. Five samples (close to 20% of the Mumbai samples analysed) showed high lead concentration (from 878.6 to 2104 ppm) even exceeding the US EPA limit of 600 ppm in painted toys; this poses a threat to children exposed to such toys. The fact that these toys were made to look attractive to children is even more sinister. In the absence of any leaching studies it is difficult to ascertain the levels of exposure that unbranded toys available in India can cause to children. However, with all toy samples containing lead and cadmium in varying concentrations and some even showing high lead concentration, it does indicate that Indian toys pose a worrying and potential risk to children's health. A lack of any enforceable mechanism makes this even worse.

1. http://en.wikipedia.org/wiki/Toy (accessed in August 2006).
2. Project Brief of Trust Fund Agreement between The United Nations Industrial Development Organisation and Ministry of Small Scale Industries and Agro and Rural Industries, Government of India, July 2000.

3. Kelley, M., Watson, P., Thorton, D. and Halpin, T. J., Lead intoxication associated with chewing plastic wire coating. *Morbidity Mortality Wkly Rep.*, 1993, **42**, 465–467.
4. National Referral Centre for Lead Poisoning in India, http://www.tgfworld.org/lead.html (accessed in June 2006).
5. Joseph, Di Gangi, Lead and cadmium in children's vinyl products. A Greenpeace Study, 1996; http://composite.about.com/gi/dynamic/offsite.htm?site=http://www.greenpeaceusa.org (accessed in June 2006).
6. Urgent intelligence bulletin 42 cadmium (Cd). http://www.cdc.gov/niosh/84116_42.html; 27 September 1984 (accessed in June 2006).
7. Tuczai, E. and Cortolano, F., Reformulating PVC to eliminate heavy metals and protect performance. *Mod. Plast.*, 1992, 123–124.
8. Sharma, M., Maheshwari, M. and Morisawa, S., Dietary and inhalation intake of lead and estimation of blood lead levels in adults and children in Kanpur, India. *Risk Anal.*, 2005, **25**, 00–00.
9. Krishnamurti, C. R. and Vishwanathan, P. (eds), Lead in the Indian environment and its human health implications. In *Toxic Metals in the Indian Environment*, Tata McGraw-Hill, New Delhi, 1991.
10. Basu, K., Mondal, R. K. and Banerjee, D. P., Epidemiological aspects of acute childhood poisoning among patients attending a hospital at Kolkata. *Indian J. Public Health*, 2005, **49**, 00–00.
11. Tripathi, R. M., Raghunath, R. and Krishnamoorthy, T. M., Dietary intake of heavy metals in Bombay city, India. *Sci. Tot. Environ.*, 1997, **208**, 149–159.
12. Malviya, R. and Wagela, D. K., Studies on lead concentration in ambient air, roadside dust and its influence on the healthy traffic police personnel at Indore city. *Pollut. Res.*, 2001, **20**, 635–638.
13. Sharma, M. and Maloo, S., Assessment of ambient air PM10 and PM2.5 and characterization of PM10 in the city of Kanpur, India. *Atmos. Environ.*, 2005, **39**, 6015–6026.
14. Clark, C. S., Rampal, K. G., Thuppil, V., Chen, C. K., Clark, R. and Roda, S., The lead content of currently available new residential paint in several Asian countries. *Environ. Res.*, 2006, **102**, 9–12.
15. Mohrig, J. R., Hammond, C. N., Morrill, T. C. and Neckers, D. C., *Experimental Organic Chemistry*, W. H. Freeman and Company, New York, 1998, pp. 535–536.
16. http://www.epa.gov/epaoswer/hazwaste/test/pdfs/3050b.pdf
17. US Consumer Product Safety Commission, Memo from A. Schoem, Office of Compliance to P. Rush, Executive Director, Window Covering Safety Council, 16 July 1996.

ACKNOWLEDGEMENTS. This study was conducted as a part of Toxics Link's investigation into the use of heavy metals in everyday products and food. We thank Dr Joseph Di Gangi, IPEN for providing vital insights, which proved crucial for the completion of this work. We also thank the Toxics Link team for collecting samples from Delhi, Mumbai and Chennai. Ravi Agarwal, Director, Toxics Link and Satish Sinha, Associate Director – Program, Toxics Link provided valuable guidance in detailing methodology and refining the discussions.

Received 15 September 2006; revised accepted 3 August 2007