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ORIGINAL ARTICLE

Blood Lead Levels among School Children after Phasing-Out of Leaded Petrol in Delhi, India

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Abstract
Objectives The use of leaded petrol was prohibited in the Delhi city by the end of 1998. To determine the impact of use of unleaded petrol, this cross-sectional study was conducted to determine blood lead levels in primary school children.
Methods Blood lead levels were estimated in 300 school children aged 6 to 10 y. The data regarding clinical features and putative risk factors for high blood lead levels was also collected.
Results Of the 300 children, 36 (12 %) had high blood lead levels. Of the 36 children, 32 had blood lead levels between 10 and 19 μg/dl, 4 had 20–44 μg/dl and none had levels >45 μg/dl. Factors such as exposure to peeling paint, recent renovation of housing and near-distance of house to main road were significantly associated with high blood lead levels.
Conclusions There is significant prevalence of high blood lead levels in school children in Delhi, even after with prohibition of use of leaded petrol.

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Keywords Blood lead level · Delhi · Lead pollution

Introduction

Worldwide, lead has been used industrially in the production of petrol, paints, batteries, metal alloys, lead pipes, soldered cans and ceramic products [1]. In past, emissions from vehicles that burn leaded petrol were the major source of lead pollution [1, 2]. According to the guidelines of the Centers for Disease Control and Prevention (CDC), blood lead levels (BLLs) ≥10 μg/dl considered as high lead levels [3]. It has been observed that even low-level lead exposure has an association with intellectual impairment in children [4].

Delhi, capital of India has a central urban population of approximately 16 million. In the earlier study (source: Central Pollution Control Board website) conducted in school children aged 6 to 10 y hailing from low and high ambient air lead levels in Delhi, showed that 55.6 % and 72.3 % children respectively had high (≥ 10 μg/dl) blood lead levels [5]. The study was conducted in 1997, before the phasing-out of leaded petrol was done. Another study, conducted by George foundation in 1997, found that 54.1 % of the 451 children aged <12 y in Delhi had BLLs ≥ 10 μg/dl and 18.6 % children had BLLs ≥ 20 μg/dl [6]. The use of leaded petrol was prohibited in the city by the end of 1998. Introduction of lead free petrol has shown a reduction in ambient lead concentration in Delhi as monitored by Central Pollution Control Board [5]. Eight years after phase–out of leaded petrol in Delhi, the effect of unleaded petrol use should logically be reflected in the blood lead level. Hence, this study was conducted to measure prevalence of high BLLs in Delhi school children. The study also envisaged to investigate potential risk factors associated with high BLLs.

Material and Methods

The study design included estimation of blood lead levels in school children aged 6 to 10 y (Class I to V) studying in the two Shahpur Jat schools (earlier low ambient air lead level zone) and the one Daryaganj school (earlier high ambient air lead level zone) of the Municipal Corporation of Delhi. The study duration extended from January 2006 through December 2006. School children aged 6 to 10 y were selected because they represent an age group that is considered high risk for lead exposure. The schools selection was based on lowest and highest lead air level area according to data by Central Pollution Control Board. Identified schools were visited. Awareness and sensitization material about hazards of lead pollution was prepared and pasted in schools. Talks were held in school during parent and teacher meetings. Individual parents were given leaflets in vernacular language. The purpose and procedures of the study were explained to the parents of first hundred children according to the roll card and they were requested to participate in the study. Written informed consent was obtained from the parent or legal guardian of each patient. Consenting parents/guardians were required to complete a questionnaire designed to determine parental education status, child's behavior, and potential sources of lead exposure in the environment (Table 1). Questionnaires were administered through personal interview by research associate. The study design was approved by the institute ethics committee.

Two milliliter blood sample was collected from each child in a metal-free tube (BD vacutainer EDTA; K3 EDTA) for BLL and hemoglobin estimation. The site of veni-puncture of each child was made lead free by cleaning with solution acid I ethanol (20 g/L). A portable Lead Care analyzer (ESA Inc.,Chelmsford,MA,USA) was used for determining the blood lead levels by a process called 'Anode Stripping Voltametry'. The instrument was calibrated against high and low controls (provided by the manufacturer) in every blood test session to provide internal quality assurance. Anemia was diagnosed when hemoglobin was less than 11 g/dl for children of 5–6 y age and 12 g/dl for more than 6 y age (WHO criteria) [7].

Parents of children diagnosed with high BLLs were informed and children were treated with iron, calcium and zinc supplements.

The SPSS version 17.0 software (SPSS, Chicago, IL) was used for data analysis. Frequencies and means were calculated by descriptive analysis. The Chi-squared test was used for comparing categorical variables, and unpaired *t*-test was used for comparing continuous variables. All of the reported *p* values were two-sided and $p<0.05$ was considered as significant. Logistic regression analysis was performed to explore the relationship of high BLLs with various predictors.

Results

BLLs of 300 school children were tested. It included 100 children of Daryaganj school and 200 children of Shahpur Jat schools. The mean age of children was 8.4 ±1.8 y. A total of 36 (12 %) school children had high BLLs (≥10 μg/dl). Of the 36 children, 32 had blood lead levels between 10 and 19 μg/dl, 4 had 20–44 μg/dl and none had levels >45 μg/dl. Of the 36 children, 25 were from Daryaganj school (earlier high ambient air lead level zone) and 11 were from Shahpur Jat school (earlier low ambient air lead level zone). Higher mean BLL (7.6±4.1SD μg/dl) was observed in Daryaganj school children, in comparison with Shahpur Jat school children (mean BLL of 4.1±3.2SD μg/dl, $p=<0.05$) (Table 1).

Table 2 depicts various clinical features among subjects with high BLLs. It revealed clinical symptoms like tiredness, headache, behavorial symptoms (destructive activities, frequently fights and irritable behavior) were significantly more common in children with high BLL. Amongst gastrointestinal symptoms decreased appetite was significantly more common in children with high BLLs. Hemoglobin was estimated in 273 children. Anemia was more common in children with high BLL, but difference (77.7 % *vs*. 54.5 %) was not statistical significant ($p=0.083$).

Table 3 depicts the association of potential factors with BLLs in school children. High BLLs were found significantly associated with anemia, peeling paint, renovation of housing in last 2 y and distance of house to main road. In

Table 1 Blood lead levels in school children

Areas	Number of children with high BLLs (%) according to CDC				
	Class I <10μg/dl	Class II 10–19 μg/dl	Class III 20–44 μg/dl	Class IV >45 μg/dl	Mean (SD) μg/dl
Shahpur Jat ($n=200$) (low ambient air lead area)	189 (94.5)	9 (4.5 %)	2 (1 %)	0	4.1(3.2)
Daryaganj ($n=100$) (high ambient air lead area)	75 (75 %)	23 (23 %)	2 (2 %)	0	7.6(4.1)
Total ($n=300$)	264 (88 %)	32 (10.6 %)	4 (1.3 %)	0	5.3(3.2)

Table 2 Clinical features in children with high blood lead level

Clinical feature	High BLL (≥10μg/dl) (*N*=36)	Low BLL (BLL<10 μg/dl) (*N*=264)	*P* value
Mean BLL in μg/dl (SD)	14.0 (4.6)	4.1(2.3)	NS
Somatic symptoms			
Tiredness (%)	17 (47.2)	59 (22.3)	0.003
Headache (%)	10 (27.8)	47 (17.8)	0.071
Decreased play activity (%)	7 (19.4)	41 (15.5)	NS
Decreased appetite (%)	23 (63.9)	108 (40.9)	0.004
Abdominal pain (%)	16 (44.4)	95 (36)	NS
Pica (%)	2 (5.6)	5 (1.9)	NS
Behavioral symptoms			
Restless (%)	2 (5.6)	8 (3.0)	NS
Destructive activities (%)	5 (13.9)	9 (3.4)	0.017
Frequently fights (%)	16 (44.4)	49 (18.6)	0.001
Irritable (%)	17 (47.2)	77 (29.2)	0.035
Steals/tell lies (%)	6 (16.7)	27 (10.2)	NS
Bullies classmates (%)	3 (8.3)	16 (6.1)	NS
Anemia (%)	14/18 (77.8)	139/255 (54.5)	0.083

logistic regression analysis, exposure to peeling paint, renovation and distance of house to main road were strong predictors of high BLLs after adjustment for age, sex, parental education, anemia and surma application.

Discussion

The study has important observations, which are of public health importance. The authors observed 12 %

Table 3 Factors associated with BLLs in school children

Characteristics	High BLL No. (%)	Normal BLL No. (%)	*P* value	Unadjusted ODD's ratio	Adjusted ODD's ratio
Mean age in years (SD)	7.7(1.6)	8.4(1.9)	NS	0.81(0.65–0.98)	
Sex			0.38	1.38(0.66–2.88)	
Male	12(33.3)	108(40.9)			
Female	24(66.6)	156(59.0)			
Parental education			0.42	0.75(0.37–1.51)	
Secondary	20(55.5)	165(62.5)			
Higher than secondary	16(44.4)	99(37.5)			
Anemia			0.083	2.92(0.94–9.11)	
No anemia	4(22.2)	116(45.5)			
Anemia	14(77.8)	139(54.5)			
Peeling paint			0.001	20.9(8.25–52.8)	7.67(2.40–24.4)
No peeling paint	6(16.7)	213(80.7)			
Peeling paint	30(83.3)	51(19.3)			
Renovation			0.001	4.19(2.33–10.32)	6.29(2.04–19.40)
No renovation	20(55.6)	227(86.0)			
Renovation	16(44.4)	37(14)			
Distance of house to main road			0.023	16.3(7.15–37.2)	3.74(1.20–11.63)
<100 m	9(25)	223(84.5)			
>100 m	27(75)	41(15.5)			
Surma application			0.15	1.86(0.78–4.42)	
No surma application	28(77.8)	229(86.7)			
Surma application	8(22.2)	35(13.2)			

prevalence of high BLLs in studied primary school children of Delhi. Children from high ambient air lead zone had significantly high mean BLLs, in comparison with children from low ambient air lead zone. Furthermore, tiredness, decreased appetite and behavioral symptoms (destructive activities, frequently fights and irritable behavior) were significantly more common in children with high BLLs. Factors like exposure to peeling paint, recent renovation of housing and near-distance of house to main road were potential risk factors for high blood lead levels.

The observed number of children with high BLLs was significantly lower than previously observed 55.4 % (low ambient air lead level zone) and 72.3 % (high ambient air lead level zone) in the same geographical area, prior to unleading of petrol (5). The previous study was conducted in 1997 and unleading of petrol was introduced from Sept 1998. It is believed that the reduction effect on BLLs by ceasing leaded petrol use would be thoroughly reflected in the present study. In addition, during the observation period, there was no additional strategy done for environmental lead exposure. Accordingly, the magnitude of reduction of BLLs in the present study could almost all be attributed to the effect of ceasing leaded petrol use.

Exposure to high BLLs in early childhood has been reported to be associated with higher rate of behavioral problems including attention-deficit and later criminality [8, 9]. The present study showed that behavorial symptoms comprising destructive activities; frequent fights and irritable behavior were significantly more common in children with high BLLs. In present study, a near significant (p=0.083) greater proportion of children with high BLLs (77.7 %) had anemia as compared with low BLLs (54.5 %). Similarly, Jain and colleagues reported anemia more common in children with high BLLs (75.3 % *vs*. 67.4 %) in a study on children below 3 y of age [10]. Lead causes anemia by impairment of heme synthesis and an increased rate of red blood cell destruction. On the other hand, it is also possible that iron deficiency, which is a proven cause of anemia, leads to increased absorption of lead in the body, resulting in high BLLs.

There is scarce data on risk factors of high BLLs in India [10–13]. In present study, a significant association of exposure to peeling paint and recent renovation of house with children with high BLLs was found. A study from Karnataka and Gujarat revealed that four of 29 currently available paints from five manufacturers measured lead levels 1.0 mg/cm^2 or above [12]. In a recent study, it was found that lead content of the dust in Delhi homes is at high level which poses a hazard to children [13].

Surma (kohl) is a potential source for lead exposure [14]. It is available as fine powder or heavy crystals of lead sulphide and contains 16–80 % lead. Eye rubbing and finger licking could further enhance the absorption of lead, causing elevated BLLs in surma exposed children. In the index study, children who were exposed to surma application (at least twice a week) had 1.86 (0.78–4.42) higher odds for high BLLs.

The present study had few inadvertent limitations. It has inherent limitations of one-point prevalence study. Also, the authors did not investigate intellectual function in children.

To conclude, the present study reports significant prevalence of BLLs in studied primary school children of Delhi. Although data suggests, a decline in prevalence of BLLs after unleading, there is enough evidence of the continuing exposure of lead from the environment. The evidence also shows the need for appropriate interventions in reducing the lead burden due to other factors and increasing community awareness.

Conflict of Interest None.

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