Journal of Pediatric Sciences

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Journal of Pediatric Sciences 2011;3(3):e92

How to cite this article:

Ahmed S, Nasrin S, Kabir ARML, Zakaria ABM, Seraji MSI, Rahman M, Alauddin M. Blood lead levels of secondary school students in Dhaka, Bangladesh after the elimination of leaded gasoline and phase-out of two-stroke vehicles: study on one hundred children. Journal of Pediatric Sciences. 2011;3(3):e92

ORIGINAL ARTICLE

Blood lead levels of secondary school students in Dhaka, Bangladesh after the elimination of leaded gasoline and phase-out of two-stroke vehicles: study on one hundred children

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Abstract:
Background: Lead (Pb) is a proven environmental toxicant throughout the world. Elevated blood lead level (BLL) adversely affects the neuro-cognitive and behavioral development of children. Considering the worst source of lead pollution, the government of Bangladesh banned leaded petrol and phased out two-stroked vehicles from Dhaka city—the capital of Bangladesh—in late 1999. In 2000, on the verge of introducing unleaded gasoline, a baseline survey showed high mean value of BLLs (15 µg/dL) in school children of Dhaka—much higher than the CDC's permissible level of 10 µgm/dL. Methods: This cross sectional, follow-up study was conducted to see the current status of BLLs in school children of Dhaka city. Total 100 students from two schools, 50 girls and 50 boys from grade six through ten, were randomly selected and their finger-pricked bloods were analyzed for Pb levels. Results: The mean (±SD) BLLs was 15.31±5.81 µgm/dL; and the majority (84%) of the students tested had BLLs higher than 10µg/dL. The BLLs was found significantly higher among the students who used to play outside house premises in a dusty environment (p=0.03) and among the frequent users of a traditional eye cosmetics "surma" (p= 0.032). No significant associations were noted between BLLs and the gender of the study subjects, their housing status, and the distance of the houses from the school. Conclusion: The mean BLL is still alarmingly high in the studied school children that have not declined significantly despite taking several visibly effective measures. Recommendation: The possible causes and source(s) of such persistently higher BLLs in children need priority exploration, since this important environmental health issue is of crucial importance so far the health and wellbeing of the future generations of the country are concern.

Keywords: blood lead level, school children, Bangladesh, leaded petrol, surma
Received: 24/12/2010; **Accepted:** 06/06/2011

Introduction

Lead (Pb) is an established environmental pollutant and a major developmental neurotoxicant in children throughout the world. Many studies around the globe have already confirmed that elevated blood lead level (BLL) is associated with retarded physical growth and impairment of cognitive, motor, and psycho-behavioral development of children [1,2,3].

Each µg/dL increment of BLL has been found to be associated with 3.32 point decline in cognitive functions of the children aged 6 months to 3 years [4]. Studies have also identified positive association with high BLL and childhood attention deficit hyperactive disorders (ADHD) [5, 6]. Increased lead exposure in childhood has also been identified as a risk factor for future anti-social behavior and criminal arrest for violent offenses [7]. The neuro-anatomical basis for these functional impairments in terms of cognition, executive functions, social behaviors and motor abilities has been supported by volumetric analysis of whole brain by Magnetic Resonance Imaging (MRI) [8]. Considering the harmful effects of high BLLs in children, in 1991, the United States Centers for Disease Control and Prevention (CDC) established 10 µg/dL as the lowest level of concern for children's BLL [9]. A growing body of evidences, however, reveals that even BLLs below 10µg/dL may impair neuro-behavioral development in children [10 11]; and strong arguments are increasingly being accumulated to reduce the acceptable BLLs further down to a level of 2µg/dL [12, 13].

Children can get exposed to environmental lead pollution through various ways. Dust and soil are the final resting place for the airborne lead from gasoline and dust form paint and contribute to elevated blood lead concentrations in children who play on bare, contaminated soil [14]. In some parts of the world including South-East Asia, Africa and the Middle East, some traditional herbal medicines and eye cosmetics (kohl or surma) are considered to be a pervasive source of environmental lead exposure in those areas [15, 16, 17, 18].

Until 1999, a very high level of lead was detected in the air of Dhaka—the capital of Bangladesh. During 1994-1998, about 50 tons of lead dispersion occurred through leaded gasoline in Dhaka. The scientists of the Bangladesh Atomic Energy Commission (BAEC) detected 463 nanogram of lead per cubic mm of air over Dhaka during the dry months (November to January) of 1996—designated Dhaka as one of the highest lead-polluted city in the world at that time. [19, 20]. In, 1998, five children having physical and mental developmental delay were screened for blood lead level at the child neurology unit of Dhaka shishu (meaning children) hospital. The result yielded very high levels of lead (80-180µg/dL) [21]. The vehicular emissions, especially from the two-stroked auto rickshaws (which were considered to contribute more than 80% of total air pollution in Dhaka) were identified as the main source of this neurotoxin in Dhaka's air. After adopting the amendment of the "Bangladesh Environment Conservation Rules" in 1997, the government banned the import and use of leaded gasoline from July 1999 onwards (The first batch of lead free fuel, about 19,000 tons, was imported in July 1999 and became available in the market in late August). Later on, as a further initiative to reduce air pollution level, about 50,000 two-stroke engine auto rickshaws were phased out from the capital city. The process took effect from 1st January, 2003 and by late 2003, almost all of the polluting two-stroke engines had been replaced by the CNG-powered ones [22]. After enforcing these measures, follow up estimation of the quality of air in Dhaka by the Department of Environment revealed significant decrease in the overall pollutant level, and lead level has fallen by about two-third of the previous high levels [23].

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In February 2000, just few months after implementing the elimination of leaded gasoline, the Bangladesh Ministry of Health and CDC jointly conducted a base-line survey on BLLs among 779 primary-school students (4-12 years of age) from five primary schools in different regions of Dhaka city. The result showed that 87.4% of the students had BLLs more than CDC's recommended level for children; the mean value was 15.0µg/dL [24]. After the progressive price hiking of petrol, octane and diesel over past few years, a substantial change has taken place in the consumption of transport fuel in Bangladesh. From 2001, the government liberally allowed and encouraged establishment of compressed natural gas (CNG) vending stations and conversion workshops in and around the capital city, which made a breakthrough in the transport sector. The vehicle owners happily started using CNG instead of gasoline, and by 2008, >95% of all kinds of vehicles, be it private, government or company-owned, that run on the roads of Dhaka city now use CNG as fuel [source: Media and Communication Wing, Bangladesh Road Transport Authority (BRTA)-personal communication]. Now a day, use of petrols/octanes is limited to those of high-priced brand new luxury cars / jeeps owned by the wealthy persons.

In this backdrop, the present study was aimed at to follow up the BLLs in school children of Dhaka, after taking these measures to reduce the environmental lead pollution.

Material and methods

This cross-sectional study was conducted in two secondary-level schools of Dhaka city, the capital of Bangladesh, during the first week of July, 2009. The schools are located one in the Sayedabad and the other in the Jatrabari areas of the town—the former bordering a bus terminal and the later beside a traffic-congested highway. The schools are situated within approximately two kilometers of Khilgaon & Nawabpur schools—two out of five primary schools where 2000's study was conducted. Children mainly from the lower middle class families study in these schools. The schools were purposively selected considering the cooperation of the school management committees, convenient locations to manage and store the blood samples, and to some extent constraint of the research fund.

The students were enrolled by convenient sampling procedure. Initially, we sensitized the parents, the teachers, and the members of the school management committee about the rationale and the objectives of our study. They were briefed about the harmful effects of high lead concentration on the cognitive development of children. Later on, we shared our aims and procedures with the available school students.

Each of the two selected secondary schools accommodates approximately 350 students—around 70 in each grade (six to ten). The motivated and willing students were requested to submit their identification numbers (IDs) to the class teachers. We sampled 100 students—50 from each school (25 girls and 25 boys) by random selection (using a computer-generated random table) from the pool of submitted IDs of the agreed students. We included five boys and five girls from each grade (six through ten). The participated students represented slightly over 14% of the total number of students eligible to participate in the study. The enrolled students were handed over a consent paper and a pre-tested questionnaire, both written in mother tongue, to be completed and signed by the parents.

The questionnaire was designed to extract data regarding socio-demographic variables, status of housing and play ground, use of paint in living rooms, distance and mode of transport from home to school, period of living in present house and study in present school, knowledge about the harmful effects of lead, and use of "surma" (a kind of traditional eye-cosmetic that contains very high concentration of black Pb). The school teachers and in few cases the researchers helped to complete the questionnaire if any parent required assistance.

Collection and analysis of blood samples: The Center for Disease Control, Atlanta (USA) approved protocols were followed in collecting and analyzing for blood lead level in school children. All the reagents and supplies were obtained from the USA. Blood samples were taken by finger pricking. Immediately before sampling, all the children were ensured through hand wash using commercial liquid soap. Finally the finger was wiped with an alcohol swab. The fingers were pricked with a one-time-use lancet. The first droplet of blood was discarded and later 50 µl blood was collected into a capillary tube (ESA Inc., Chelmsford, MA, USA) form where, the blood was pushed by a plunger into the vial containing lead testing reagent. Each vial was labeled with and identification number matching the roll number of the children. All blood samples were preserved in the refrigerator till collection of all samples was complete. All collected samples were transferred to the testing lab (Exonics Technology Center, Dhaka, Bangladesh) within two hours of collection and samples were analyzed the same day. Blood lead levels were measured using LeadCare (ESA Inc., USA). The system has an analytical range of 3.3 – 65 µg/dL. The analysis results were obtained in about 3 minutes and all data were tabulated. 'Low' in the display window indicated a blood lead test result <3.3 µg/dL; 'high' indicated greater than 65 µg/dL. The kits were well-within expiration date, and

Table 1. Details the demographic characteristics of the studied subjects.

Socio-demographic parameters	Number of students (n=100)
Religion of the students	
Muslim	91 (91.0%)
Hindu	09 (9.0%)
Occupation of the fathers	
Small trader	46 (46.0%)
Motor vehicle driver	24 (24.0%)
Job in govt./non-govt. office	22 (22.0%)
Undefined, fleeting professions	08 (8.0%)
Occupation of the mothers	
House wife	82 (82.0%)
Garments worker	04 (4.0%)
Undetermined professions	04 (4.0%)
Distance to school from home	
< 2 kilometre	06 (6.0%)
2-4 kilometre	05 (5.0%)
> 4 kilometre	89 (89.0%)
House occupancy status	
Rented house	86 (86.0%)
Own house	14 (14.0%)
Duration of living in present house	
Since birth (all in owned house)	14 (14.0%)
≤ 5 years	41 (41.0%)
> 5 years	45 (45.0%)
Duration of study in this school	
<3 years	43 (43.0%)
3-6 years	46 (46.0%)
> 6 years	11 (11.0%)
Transportation to school	
Walks to school	99 (99.0%)
Non-motorized van ("Rickshaw")	01 (1.0%)

proper calibration of the analyzer was ensured. The daily quality assurance was carried out with controls provided by the instrument manufacturer. In addition, the Exonics Technology Center laboratory is a CDC (Atlanta, USA) blood lead laboratory reference system (BLLRS) participant and carries out analysis of control samples provided by the CDC every year.

Ethical Consideration: The study obtained ethical clearance from the Ethical Review Board of the Institute of Child and Mother Health, Dhaka, Bangladesh. The study was completed in compliance with the Helsinki Declaration. The data were treated with highest possible confidentiality.

Data analysis: Data was analyzed using SPSS for windows, version 15.0. Blood lead levels of the children were categorized into: <5µg/dL, 5-10µg/dL, 10-15µg/dL, 15-20µg/dL, and >20µg/dL. The frequency of the variables was calculated and the categorical variables of children with normal and elevated BLLs were compared by Chi-square test. A probability level (p value) of ≤0.05 was considered to be statistically significant.

Results

The mean (±SD) age of the children studied was 13.44±1.36 years (range 11-17 years), median being 13.00 years. The mean (±SD) weight was 42.15±9.19 Kg (Table I).

The overall geometric mean of BLLs was 15.31 µg/dL (range 5.92 µg/dL to 33 µg/dL); the median value was 13.95µg/dL. Eighty four percent of the children had BLLs above CDCs permissible level of 10µg/dL for children (Figure-1&2).

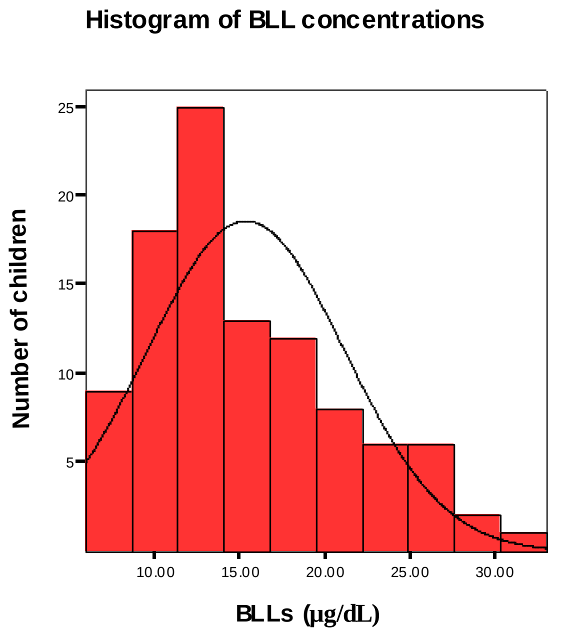

Figure 1. Histogram of the BLL distribution

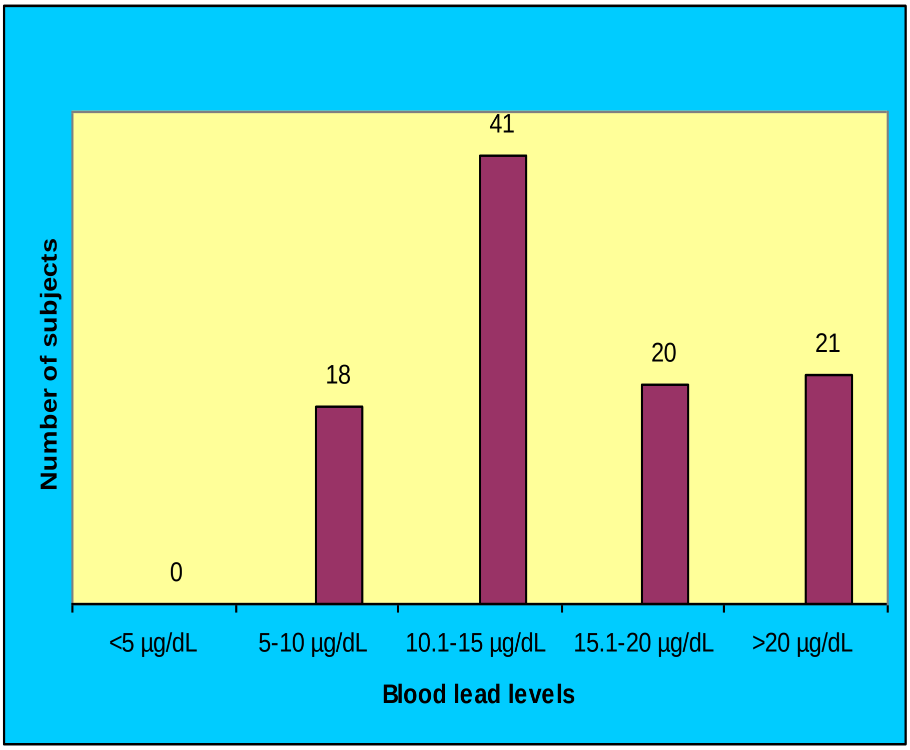

Figure 2. Distribution of the students according to BLLs.

Table II. Distribution of BLLs by gender and age-groups.

BLLs (µg/dL)	Gender				Age groups (years)			
	Male		Female		11-13		13.1-17	
	n	%	n	%	n	%	n	%
5.1-10	7	14.0	11	22.0	9	17.0	9	19.1
10.1-15	23	46.0	18	36.0	23	43.4	18	38.3
15.1-20	12	24.0	8	16.0	12	22.6	8	17.0
>20	8	16.0	13	26.0	9	17.0	12	25.5
Total	50	100.0	50	100.0	53	100.0	47	100.0

The geometric means BLLs of the girls and that of the boys were 15.27µg/dL and 15-28µg/dL respectively. Older students and girls represented a greater proportion of the group having BLL concentrations > 20 µg/dL (Table-2).

In 76% of the houses, the walls of the living rooms were 'painted'; although on further enquiry, it revealed that some respondents wrongly meant chalk-dust concentrates as 'paint'). The premises of living houses were dusty in 72% cases. However, neither

Table III. The relationship of some environmental parameters and the observed BLLs.

Parameters	BLLs < 10 (µgm/dL)	BLLs ≥ 10 (µgm/dL)	*p*
Painted wall (n=100):			0.46; (df=1)
Yes (n=76)	11 (14.5%)	65 (85.5%)	
No (n=24)	5 (20.8%);	19 (79.2%)	
House premises (n=100):			0.77; (df=1)
Dusty (n=72)	12 (16.7%)	60 (83.3)	
Not dusty (n=28)	4 (14.4%)	24 (85.7%)	
Place of play (n=85):			0.004; (df=2)
Outside house (n=43)	1 (02.3%)	42 (97.7%)	
House compound (n=14)	4 (28.6%)	10 (71.4%)	
Inside house room (n=28)	8 (28.6%)	20 (71.4%)	
Use of 'Surma' (n=24):			0.004; (df=2)
1-2 times a year (n=9)	1 (11.1%)	8 (88.9%)	
3-4 times a year (n=13)	1 (07.7%)	12 (92.3%)	
≥ 5 times a year (n=2)	2 (100%)	0 (00.00%)	

the painted walls nor the dusty house-premises were found to have statistically significant association with elevated blood lead concentrations. A significant association was noted between BLLs above 10 µg/dL and playground outside home and use of surma (Table-3).

All 'surma' users (16 boys and 8 girls) were Muslim by religion. They used to apply "surma" around the eye-lid margins during different social and religious occasions. Among them, 15 (62.5%) were in the age range of 13-16 years and 9 (37.5%) were in 11-13 years' range. All surma user girls had BLLs >20 µg/dL.

Discussion

It goes beyond saying that elevated BLL significantly impairs the cognitive functions of the school children—the future socio-political nerve and spine of any country. After discontinuing use of leaded gasoline, the BLLs have declined significantly in many countries of the world [25, 26, 27, 28]. However, many years are required for such go down [29]; for example, BLLs fell down significantly in the Canadian population 30 years after unleaded gasoline was introduced [30].

When a decade has elapsed since the era of leaded gasoline is over in Bangladesh, it is sensible to evaluate the effectiveness of the steps taken to reduce environmental lead pollution by periodical monitoring of the BLLs. Our study has yielded slightly higher mean value of BLLs than the baseline study in 2000 (15.31µg/L and 15.0µg/L respectively) [24]. This observation can be judged from two angles. The students in the current study were older than the students in the earlier baseline study.

In some studies, older age has been recognized as a risk factor for elevated BLLs among children [24, 31]; because the older the child, the more the time to get exposed to lead in the environment. If we evaluate our result in this light, the obtained mean value is a decrease from the previous level; because these older children had been exposed to lead longer and should have had higher BLLs than the younger students in the previous study had there been no positive impacts of the steps taken to reduce environmental lead.

On the other hand, reports from the United States and Australia showed consistently higher BLLs for younger children (1-5 years) than for older children [32, 33]. If we evaluate this data in our perspective, the current value of BLLs in older school children is definitely much higher than expected.

Whatever are the circumstances, our study has at least partly exposed the fact that the BLLs in our school children are still higher than the permissible limit. While the developed countries are expressing their growing concerns and demands of further lowering the 'safe' BLLs from 10 to 2 μg/dL [10], our achievement in this regard is still not reasonable. The reasons may be manifolds. Firstly, it is well-known that lead in environment does not degrade easily. After a substantial accumulation of lead in the dust, it takes many years for its removal; since the lead has a very long residence time in surface soil. So its past use continues to contribute to human exposure [34, 35]. For children, the route is from air to soil to dust to a child's hand to a child's mouth [14].

Elevated lead concentration has been identified in the soil dust of Dhaka city [36].

Recently, analysis of street surface dusts collected from some traffic area and residential areas of Dhaka city shows higher level of lead in the former (389±10 ppm of dust) than in the later (76±2 ppm of dust) [M Alauddin and M. Bhattacharjee. Exonics Technology Center, Dhaka; unpublished data obtained through personal communication]. Scientific study has revealed strong positive correlation between exposure to lead-contaminated soils and BLL levels—generally for every 1000 ppm increase of lead in soil or dust, the BLLs rises by 3-7 μg/dL [37]. The significant relationship of higher BLLs and the dusty playgrounds observed in our study is easily explainable by these facts and figures. Moreover, the students spent about 5 hours in schools which are located beside dusty traffic areas.

Secondly, the lead-based paint is another important source of lead in dust and soil [38, 39]. A recent study conducted by Environment and Social Development Organization (ESDO), Bangladesh shows dangerously high level of lead (1420 ppm, which is 2,366.66 times higher than the permissible level of 600 ppm by WHO and U.S. Code of Federal Regulations) in some non-branded paints sold in Bangladeshi markets[40].

Thirdly, extensive use and recycling of lead-acid batteries are rampant especially in the old town of Dhaka (the studied schools are located in the nearby area), which might be a significant source of continued environmental lead pollution [41]. A recently published article in 2009 also discloses a significantly higher mean BLL (24.58±10.32) in children working and living in an industrial area of Dhaka city [42]. In addition, lead weights are used on tires to balance the wheels. When these are thrown off and crushed in traffic (a very common practice in Bangladesh), it also becomes a significant source of lead in environment. [43].

Lastly, use of once popular 'surma' as an eye cosmetic is not an uncommon practice in Bangladesh and frequent users of this lead-laden substance suffer from lead toxicity, as is evident in our study and in other's [15 -18].

Conclusion

The story of environmental lead pollution in Bangladesh is still an unfinished one. There is a substantial amount of accumulated lead in dust from earlier depositions, and lead is still being used in an uncontrolled and un-regulatory manner in paints, batteries and other industrial works contributing to persistently high environmental lead levels whose worst victims are the future 'hopes' of this ever-struggling country. It is, therefore, essential to continue the fight for lowering lead level in environment by imposing legislative measures, ensuring ongoing monitoring and public health interventions. Health education and media campaign against the century-old custom of using surma as eye-cosmetics can be fruitful. The results of our study and earlier studies can be utilized for future surveying and testing a similarly aged cohort of students from the same area to track the future trends of BLLs of school children in Dhaka city.

Limitation of the study: Limited institutional funding was the major step-limiting factor responsible for yielding some avoidable biases in the study. In addition, selection of two different schools (rather than choosing the schools studied in 2000) and small, less-representative sample size may logically be blamed for methodological flaws and sampling biases. It could have been more valid to strengthen the findings if the lead in air and dust of the study area were analyzed simultaneously. The cognitive and the behavioral aspects of the studied children should have been evaluated.

Acknowledgement: We acknowledge the co-operation of the management committee, the teachers, the students, the parents and the supporting staffs of the school.

The supportive center for this research work is "Institute of Child and Mother Health", Mautail, Dhaka-1362, Bangladesh. Website: www.icmhbd.org

The work was partially supported by a grant from Wagner College, New York, USA. Bulk funding came from personal contributions.

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