Impact of blood lead level on haemoglobin and intelligence among school children living near lead based industries

Bhima Uma Maheswari[1], Rajagopalan Vijayaraghavan[2] and Thuppil Venkatesh[3]
[1]Padmashree Institute of Nursing, Bengaluru, India
[2]Saveetha University, Chennai, India
[3]St. John's Medical College, Bengaluru, India

Abstract: Blood lead level and its impact on haemoglobin and intelligence among school children near lead based industries, and to supplement them with a nutritious food for its effect, were studied. Blood was withdrawn from 120 children (9-12 years) and lead was estimated by Lead Care Analyzer Kit and haemoglobin by auto analyser. Culture Fair Non-verbal Test was used to assess the Intelligence Quotient. After pre-test, the experimental group (n = 60) were given nutritional supplementation for 3 months and education on hygiene measures, while the control group (n = 60) did not receive them. Food supplementation and education significantly decreased the lead level in the experimental group (8.8±0.5 to 6.9±0.4, µg/dL, mean ± SE) but not in the control group. The intelligence score improved in the experimental group but not in the control group. A negative correlation was observed between the lead level and intelligence. No improvement was observed in the haemoglobin. This study shows that the blood lead level in children near lead based industries is high and is negatively correlated with intelligence. Supplementation of nutritious food and education on hygiene measures have decreased the lead level and increased the intelligence score.

Keywords: Blood lead, haemoglobin, intelligence, nutritional supplementation, hygiene measures.

INTRODUCTION

Many heavy metals in our environment are toxic to humans and animals. Heavy metals like iron and zinc play an important role in our body, but many have no beneficial effect on our health. One among them is lead and its toxic effects are well known (Burke *et al*., 2011). Lead is very common in the environment and ubiquitously used in several products viz., pipes; batteries; paints; glazes; vinyl products; weights, ammunitions, cable covers and radiation shielding (Vishwanath *et al*, 2012). Mining, smelting, occupational exposures and traditional medicines used in some countries also increase the lead burden and cause neurotoxicity (Gilani *et al*. 2015).

Children are vulnerable to lead exposure, because of their developmental and behavioral differences (Landrigan, 1999; Bellinger, 2008). They are more susceptible than adults to the toxic effects, since lead is considerably absorbed from the gut mucosa in children (Bao *et al*., 2009). In Adults, the absorbed lead is almost excreted, but in children significantly large amount is retained leading to accumulation (Legget, 1993; Gordon *et al*., 2002). In children with nutritional deficiencies like iron deficiency, lead is absorbed appreciably (Bradman *et al*., 2001; Ahamed *et al*., 2007; Vishwanath *et al*., 2008; Kordos, 2010). The lead levels in children in urban settings are generally higher when compared to rural settings due to environmental pollution. Though, they may be asymptomatic, sudden symptoms may occur at a later stage (Kishore Kumar and Kesaree, 1999).

The developing nervous system is more vulnerable to the toxic effects of lead and can cause permanent damage to the brain (Hou *et al*., 2013). Lead can interfere with the growth of children, and in their ability to think and concentrate. It is directly associated with lower Intelligence Quotient (IQ) (Lidsky and Schneider, 2003). Many reports are available that the level of blood lead in children varies from small amounts to very large amounts (Ajumobi *et al*., 2014). Present scientific evidence has shown that in children there is no acceptable safe lead level (Liu *et al*., 2013; Dapul and Laraque, 2014). Even low concentrations of lead have been shown to interfere with biochemical pathways and at higher levels of 10 µg/dL biochemical and neurobehavioral effects have been shown. Higher lead levels can cause anaemia, hearing loss, and can affect kidneys, heart and brain. At extremely high levels of lead exposure, ataxia, cerebral edema, paralysis, coma and death may result (Goyer, 1993).

The aim of the present study is (i) to evaluate the lead levels of children living in the vicinity of lead based industries and to correlate it with haemoglobin and IQ, and (ii) to study the effect on the level of lead and haemoglobin by providing the children with nutritional supplementation, and teaching on general hygiene to reduce the lead contamination.

**Corresponding author:* e-mail: jai_vijay@hotmail.com

MATERIALS AND METHODS

Participants: One hundred and twenty children of both sexes in the age group of 9 to 12 years living in the vicinity of industries with particular reference to lead based industries like battery industries (< 2 km) were included for this study. The children were selected from two schools from Peenya (Bengaluru, India) after obtaining permission from the authorities and randomly assigned as control and experimental groups. A sample size of 120 was taken based on power analysis. Including a 10% for drop outs, the sample size was estimated as 60 for control and 60 for experimental group. From each age group 15 children were selected randomly in the control and experimental groups. Informed consent was obtained from the mothers of children for their participation in the study and the children were also informed about the study. This study has the approval of the Institutional Human Ethics Committee of Saveetha University (002/10/2012/IEC/SU). This study was carried out from September to December 2014.

***Inclusion and exclusion criteria*:** Children of both sexes whose mothers agreed to the participation of their children were included. Children who were irregular in their morning breakfast and who were suffering from bleeding disorders were excluded.

***Pre-test phase*:** On the first day, 2 mL of venous blood from the ante-cubital vein was collected from all the 120 children (control and experimental groups) in an EDTA vacutainer. It was labelled with child's name, age, sex and a serial number. Lead estimation was carried out using "Lead Care II Blood Lead Test Kit" at St. John's Medical College, Bengaluru. Haemoglobin was estimated by using Automated Haematology Analyser (Sysmex 1800) at Padmashree Diagnostic Centre, Bengaluru as per the instrument manufacturer's method.

During-test phase: On the same day, after withdrawing the blood, the experimental group children were given a cereal powder (36 g) to be mixed with 250mL of milk as a supplementary health food. A commercial product (FDA approved) comprising of malted barley (40%), wheat flour (27%), milk solids (14%), sugar, calcium, vitamin C, iron, zinc, magnesium and selenium to fight against lead toxicity in the body was used. The supplementary health food was provided for 3 months duration (excluding Sundays) in the morning after the school prayer. A responsible person from the school supervised and ensured that the children take the supplementary health food in the morning. There were not much absentees and if absent that day, the supplementary health food was omitted. On the 4th day, non-verbal intelligence test was administered to all 120 children (control and experimental) in their school premises by using Culture Fair Intelligence Test (Rao and Singh, 2013). The test comprised of 4 sub-tests (Test 1 - series with 12 items, Test 2 -classification with 14 items, Test 3 - matrices with 12 items, Test 4 – conditions with 8 items; total 46 items). The IQ test used was non-verbal pictorial intelligence test. The IQ test papers were distributed to all the children (control and experimental groups on separate days). The instructions about filling the test paper with examples were explained by one investigator. After the completion of the IQ test by the children the papers were received by the second investigator and scored them as per the guidelines given in the procedure. The scores were handed over to the first investigator. On the 7th day for the experimental group, structured teaching program was given on the impact of lead among children, with PowerPoint presentation for 45 minutes duration. Handout was distributed in English and regional language (Kannada) to all the mothers for future reference. Between 10 to 14 days the experimental group children were demonstrated general hygiene measures, including hand washing technique with soap solution, and advised to follow before eating.

***Post-test phase*:** After 3 months, post-test was carried out similar to the pre-test on all the 120 children (control and experimental groups) by withdrawing 2 mL of blood and administering the IQ test.

The control group children were not given the nutritional supplementation and the education on general hygiene measures during the study. However, after the completion of the study, the control group children were also provided the supplementary health food for 1 month period. Structured teaching was administered regarding the impact of lead and its prevention. Handouts were distributed to all the mothers. The control group children were also demonstrated general hygiene measures.

STATISTICS ANALYSIS

The data were expressed as mean ± SE, and as frequency distribution. Paired and unpaired 't' test, χ^2 test and Pearson's correlation coefficient were used. For χ^2 test the blood lead level was categorised as <10 µg/dL (acceptable level) and >10µg/dL (high level), haemoglobin as <11 g/dL (anaemic) and > 11 g/dL (normal), and intelligence score as <110 (average) and >110 (above average). The analysis and the plotting of graphs were carried out using SigmaPlot 13 (Systat, USA).

RESULTS

The blood lead and haemoglobin levels, and the intelligence score of control and experimental group in the pre-test and post-test is given in table 1. The control and experimental group blood lead and haemoglobin levels, and the intelligence score in the pre-test were not significant. But, the blood lead level in the experimental group in the post-test was significantly lower than the control group. The haemoglobin level and the intelligence score of the experimental and control group in the post test was not significant.

The blood lead level of the control in the pre-test and post-test was not significant (paired' test). But, in the experimental group the post-test blood lead level was significantly lower than the pre-test level (table 1). The mean lead level of the experimental group was significantly lower than the control group in the post test ($p < 0.05$). In the control group the maximum lead level observed was 21.7 µg/dL in the pre-test and at post-test it was 29 µg/dL. In the experimental group the maximum lead level observed was 20.8µg/dL in the pre-test and at post-test it was 16.2µg/dL. In the control and experimental group the haemoglobin was lower in the post-test compared to the pre-test level (paired 't' test). The difference was small and the level was within the normal level. No significant difference was observed in the intelligence score between the control and the experimental groups in the pre-test, while in the post test the score was higher in experimental group compared to the control group but the difference was not statistically significant ($P = 0.061$). The pre-test and post-test scores of the control group was not significant by paired 't' test, while in the experimental group the pre-test and post-test scores were statistically significant.

No association was observed in the blood lead and haemoglobin levels in the control and experimental groups in the pre-test and post-test (table 2). A significant association was observed in the intelligence in the control and experimental groups in the pre-test and post-test ($\chi 2 = 5.637$; $P<0.05$). The correlation studies of blood lead, haemoglobin and intelligence of control and experimental groups in pre-test and post-test is given in table 3. None of the variables were correlated, except the blood lead and intelligence in the control post-test was negatively correlated ($r = -0.340$; $P=0.011$). The overall correlation of blood lead, haemoglobin and intelligence of all the samples (two times measurement of 120 children, n = 240) is shown in fig. 1. The blood lead and haemoglobin was not significantly correlated. But, the blood lead and intelligence was negatively correlated ($r = - 0.159$; $P = 0.014$), while haemoglobin and intelligence was not significantly correlated.

DISCUSSION

Lead is a toxic heavy metal and there is no safe level of its exposure. Lead levels in blood greater than 5µg/dL are considered as higher (Yabe *et al*., 2014). Studies in Indonesia showed lead levels of 6.8 and 5.9 µg/dL for male and female respectively (Iriani *et al*., 2012). In Chinese preschool children mean blood lead levels at 6.4 µg/dL, were associated with behavioural problems (Liu *et al*., 2014). Levels more than 20 µg/dL are reported in India near industrial areas (Ahamed *et al*., 2005; Roy *et al*., 2009; Palaniappan *et al*., 2011) and also in several countries viz., China (Liu *et al*., 2011), Mexico (Garcia-Vargas *et al*., 2014), Nigeria (Ugwuja *et al*., 2014), and Palestine Sawalha *et al*., 2013). Very high levels of more than 300 µg/dL are reported from Nigeria (Ajumobi *et al*., 2014). In the present study, the lead level was 8.7±0.3 (mean ± SE) µg/dL with a maximum of 21.7 µg/dL. Many parents and caregivers are not aware of sources of lead, risks of lead poisoning, its impact on children and the measures to prevent lead exposure. Public health staff should be given instructions and blood test of children for lead level living near lead based industries should be made a necessary.

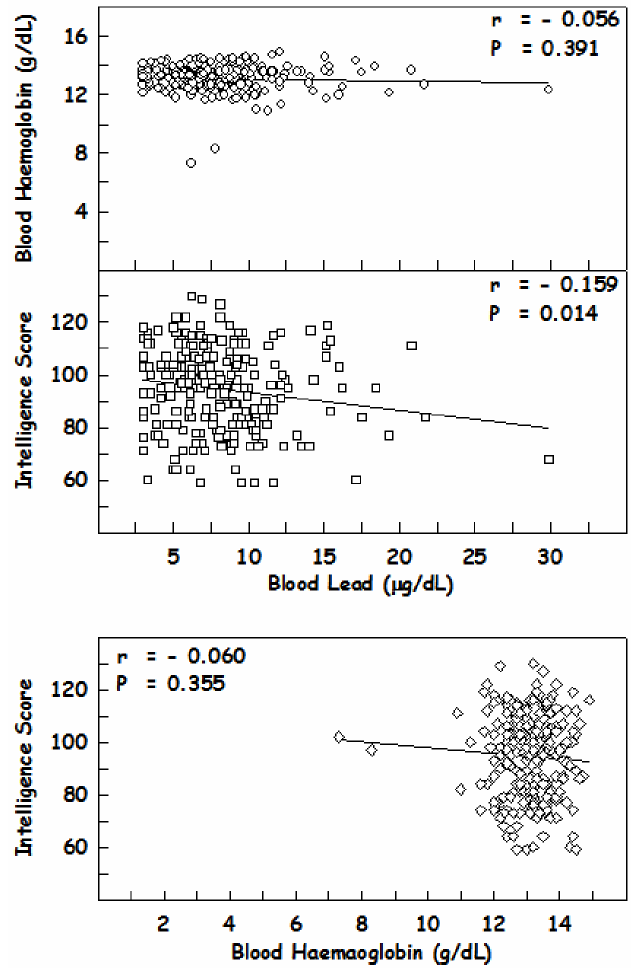

Fig. 1: Correlation of blood lead, haemoglobin and intelligence in children (n = 240).

Lead exposure leads to abnormal neurobehavioral and cognitive development in children (Ahamed *et al*., 2005). Children living near lead based industries in China showed higher blood lead levels and their Intelligence Quotient was low (Wang *et al*., 1989). High lead levels due to electrical waste exposure with temperament changes were observed in Chinese children (Liu *et al*.,

Table 1 : Blood lead, haemoglobin and intelligence of control and experimental groups in the pre-test and post-test.

S. No.	Parameter	Group	mean ± SE	Significance Unpaired 't' test		Significance Paired 't' test	
				Con-Exp Pre-test	Con-Exp Post-test	Control Pre - Post	Experimental Pre - Post
1	Blood Lead (µg/dL)	Control Pre-test	8.7 ± 0.4	t = 0.281 P = 0.779	t = 2.075 P = 0.04	t = 1.286 P = 0.204	t = 9.068 P < 0.001
		Control Post-test	8.3 ± 0.5				
		Experimental Pre-test	8.8 ± 0.5				
		Experimental Post-test	6.9 ± 0.4				
2	Haemoglobin (g/dL)	Control Pre-test	13.1 ± 0.1	t = 1.907 P = 0.059	t = 1.272 P = 0.206	t = 3.697 P < 0.001	t = 6.252 P < 0.001
		Control Post-test	12.9 ± 0.1				
		Experimental Pre-test	13.4± 0.1				
		Experimental Post-test	13.1 ± 0.1				
3	Intelligence Score	Control Pre-test	92.4 ± 1.9	t = 1.400 P = 0.613	t =1.891 P = 0.061	t = 1.575 P = 0.121	t = 3.474 P< 0.001
		Control Post-test	95.1 ± 2.1				
		Experimental Pre-test	91.0 ±2.0				
		Experimental Post-test	100.5 ± 2.0				
Values are mean ± SE (n = 60)/ Con = Control/ Exp = Experimental							

Table 2: Association of blood lead, haemoglobin and intelligence of control and experimental groups in pre-test and post test.

S. No.	Parameter	Group	Con Pre-test	Con Post-test	Exp Pre-test	Exp Post-test	Control		Experimental	
							χ^2	P	χ^2	P
1	Blood Lead	< 10 µg/dL	44	52	44	51	2.552	0.110	1.819	0.177
		> 10 µg/dL	16	8	16	9				
2	Haemoglobin	< 11 g/dL	1	1	0	0	0.508	0.476	0	1
		> 11 g/dL	59	59	60	60				
3	Intelligence Score	< 110	52	45	52	40	1.936	0.164	5.637	0.018
		> 110	8	15	8	20				

Table 3: Correlation of blood lead, haemoglobin and intelligence of control and experimental groups in pre-test and post test

Variable	Pre-test					
	Control			Experimental		
	Blood lead	Haemoglobin	Intelligence	Blood lead	Haemoglobin	Intelligence
Blood lead	-	r = - 0.121 P = 0.358	r = - 0.167 P = 0.203	-	r = - 0.052 P = 0.695	r = - 0.081 P = 0.543
Haemoglobin	-	-	r = - 0.028 P = 0.872	-	-	r = 0.094 P = 0.475
	Post-test					
	Control			Experimental		
Blood lead	-	r = - 0.004 P = 0.979	r = - 0.340 P = 0.011	-	r = - 0.097 P = 0.482	r = 0.108 P = 0.434
Haemoglobin	-	-	r = - 0.130 P = 0.320	-	-	r = - 0.019 P = 0.886
n = 60			n = 60			

2011). Studies conducted in Australia showed lead levels of 10 to 30µg/dL and a reduction in IQ in children (Baghurst *et al.*, 1992). Reduced intelligence quotient and academic performance occur at levels even below 10 µg/dL. Blood lead concentrations even below 10µg/dL were associated with increased risk of behavioural and developmental problems and negative impact on cognitive development in children (Liu *et al.*, 2014).

A detailed analysis was done in the present study of the changes in blood lead levels, haemoglobin, and intelligence. The children were initially assessed and a supplementary health food was given for a period of 3 months. The parents and children were also given instructions to avoid exposure to polluting materials including lead. Supplementation of micronutrients and hygiene measures are very effective in reducing the blood lead levels (Rhoads *et al.*, 1999; Jordan *et al.*, 2003). Iron fortified food was shown to significantly decrease the blood lead levels in children (Zimmermann *et al.*, 2006).

Several studies have shown that haemoglobin is negatively correlated with blood lead level in children (Shah *et al.*, 2010; Counter *et al.*, 2012). In the present study, a negative correlation was observed between blood lead level and haemoglobin, but it was not statistically significant. The maximum blood lead level observed in the present study was about 30µg/dL, where as low haemoglobin levels have been reported, when the blood lead level was more than 50µg/dL.

To reduce the body burden of lead, where very high blood lead levels are observed, chelation therapy is recommended with EDTA (ethylene diaminetetraacetic acid) or DMSA (dimercapto succinic acid), but further contamination has to be reduced by way of teaching (Hryhorczuk *et al*., 1985; Flora, 2002).When the blood lead level is very high with symptoms, chelation therapy should be considered along with environmental, nutritional and educational interventions (Koike, 1997; Campbell and Osterhoudt, 2000). High lead level may require drug treatment, but they are not readily available and supplementation and avoidance is the better solution. Lead accumulation in the body takes a longer time following exposure and hence longer time of avoidance and supplementation are required. Health workers can focus on the problems and educate the public but government and non-government agencies should work for reducing the lead exposure (Carlisle, 2009).

CONCLUSION

This study shows that the blood lead level in children near lead based industries is high and is negatively correlated with intelligence. Supplementation of nutritious food and education on hygiene measures have decreased the lead level and increased the intelligence score.

ACKNOWLEDGEMENT

The authors are thankful to the authorities of Rajeev Gandhi Memorial School and Aswini Public School, Bengaluru for giving permission to carry out the study.

REFERENCES

Ahamed M, Verma S, Kumar A and Siddiqui MK (2005). Environmental exposure to lead and its correlation with biochemical indices in children. *Sci. Total Environ*., **346**: 48-55.

Ahamed M, Singh S, Behari JR, Kumar A and Siddiqui MK (2007). Interaction of Lead with some essential trace metals in the blood of anaemic children from Lucknow, India. *Clin. Chim. Acta*., **377**: 92-97.

Ajumobi OO, Tsofo A, Yango M, Aworh MK, Anagbogu IN, Mohammed A, Umar-Tsafe N, Mohammed S, Abdullahi M, Davis L, Idris S, Poggensee G, Nguku P, Gitta S and Nsubuga P (2014). High concentration of blood lead levels among young children in Bagega community, Zamfara Nigeria and the potential risk factor. *Pan Afr. Med. J*., **21**: 14.

Baghurst PA, Mc Michael AJ, Wigg NR, Vimpani GV, Robertson EF, Roberts RJ, Psych Mc and Tong SL (1992). Environmental Exposure to Lead and Children's Intelligence at the Age of Seven Years - The Port Pirie Cohort Study. *N. Engl. J. Med*., **327**: 1279-1284.

Bao QS, Lu CY, Song H, Wang M, Ling W, Chen WQ, Deng XQ, Hao YT and Rao S (2009). Behavioural development of school-aged children who live around a multi-metal sulphide mine in Guangdong province, China: a cross-sectional study. *BMC Public Health*, **9**: 217.

Bellinger DC (2008). Very low lead exposures and children’s neurodevelopment. *Current Opinion in Pediatrics*., **20**: 172-177.

Bradman A, Eskenzi B, Sutton P, Asthana Soulis M and Goldman LR (2001). Iron deficiency associated with higher blood lead in children living in contaminated environments. *Environ. Health Perspect*., **109**: 1079-1084.

Burke MG and Miller MD (2011). Practical guidelines for evaluating lead exposure in children with mental health conditions: Molecular effects and clinical implications. *Postgrad. Med*., **123**: 160-168.

Campbell C and Osterhoudt KC (2000). Prevention of childhood lead poisoning. *Curr. Opin. Pediatr*., **12**: 428-437.

Carlisle JC, Dowling KC, Siegel DM and Alexeeff GV (2009). A blood lead benchmark for assessing risks from childhood lead exposure. *J. Environ. Sci. Health A Tox. Hazard Subst. Environ. Eng*., **44**: 1200-1208.

Counter SA, Buchanan LH and Ortega F (2012). Association of hemoglobin levels and brainstem auditory evoked responses in ead-exposed children. *Clin. Biochem*., **45**: 1197-1201.

Dapul H and Laraque D (2014). Lead poisoning in children. *Adv. Pediatr*., **61**: 313-333.

Flora SJ (2002). Lead exposure: Health effects, prevention and treatment. *J. Environ. Biol*., **23**: 25-41.

Garcia-Vargas GG, Rothenberg SJ, Silbergeld EK, Weaver V, Zamoiski R, Resnick C, Rubio-Andrade M, Parsons PJ, Steuerwald A, Navas-Acién A and Guallar E (2014). Spatial clustering of toxic trace elements in adolescents around the Torreón, Mexico lead-zinc smelter. *J. Expo. Sci. Environ. Epidemiol*., **24**: 634-642.

Gilani SR, Zaidi SR, Batool M, Bhatti AA, Durrani AI and Mahmood Z (2015). Report: Central nervous system (CNS) toxicity caused by metal poisoning: Brain as a target organ. *Pak. J. Pharm. Sci*., **28**: 1417-1423.

Gordon JN, Taylor A and Bennett PN (2002). Lead poisoning: case studies. *Br. J. Clin. Pharmacol*., **53**: 451-458.

Goyer RA (1993). Lead toxicity: Current concerns. *Environ. Heath Perspect*., **100**: 177-187.

Hou S, Yuan L, Jin P, Ding B, Qin N, Li L, Liu X, Wu Z, Zhao, G and Deng YA (2013). Clinical study of the effects of lead poisoning on the intelligence and neurobehavioral abilities of children. *Theor. Biol. Med. Model*, **10**: 13. Hryhorczuk DO, Rabinowitz MB, Hessl SM, Hoffman D, Hogan MM, Mallin K, Finch H, Orris P and Berman E (1985). Elimination kinetics of blood lead in workers with chronic lead intoxication. *Am. J. Ind. Med*., **8**: 33-42.

Iriani DU, Matsukawa T, Tadjudin MK, Itoh H and Yokoyama K (2012). Cross-sectional study on the effects of socioeconomic factors on lead exposure in children by gender in Serpong, Indonesia. *Int. J. Environ.Res. Public Health*, **9**: 4135-4149.

Jordan CM, Yust BL, Robison LL, Hannan P and Deinard AS (2003). A randomized trial of education to prevent Lead burden in children at high risk for Lead exposure: Efficacy as measured by blood Lead monitoring. *Environ. Health Perspect*., **111**: 1947-1951.

Kishore Kumar R and Kesaree N (1999). Blood Lead Levels Urban and Rural Indian Children. *Indian Pediatrics*, **36**: 303-306.

Koike S (1997). Low-level lead exposure and children's intelligence from recent epidemiological studies in the U.S.A. and other countries to progress in reducing lead exposure and screening in the USA *Nihon Eiseigaku Zasshi.*, **52**: 552-561.

Kordas K (2010). Iron, Lead, and Children's Behavior and Cognition. *Annu. Rev. Nutr*., **30**: 123-148.

Landrigan PJ (1999). Risk assessment for children and other sensitive populations. *Ann. N. Y. Acad. Sci*., **895**: 1-9.

Leggett RW (1993). An age-specific kinetic model of lead metabolism in humans. *Environ. Health Perspect*., **101**: 598-616.

Lidsky T and Schneider JS (2003). Lead neurotoxicity in children: basic mechanisms and clinical correlates. *Brain.*, **126**: 5-19.

Liu J, Li L, Wang Y, Yan C and Liu X (2013). Impact of low blood lead concentrations on IQ and school performance in Chinese children. *PLoS One*, **8**: e65230.

Liu J, Liu X, Wang W, Mc Cauley L, Pinto-Martin J, Wang Y,Li L, Yan C and Rogan WJ (2014). Blood lead concentrations and children's behavioral and emotional problems: A cohort study. *JAMA Pediatr*., **168**: 737-745.

Liu J, Xu X, Wu K, Piao Z, Huang J, Guo Y, Li W, Zhang Y, Chen A and Huo X (2011). Association between lead exposure from electronic waste recycling and child temperament alterations. *Neurotoxicology*, **32**: 458-464.

Palaniappan K, Roy A, Balakrishnan K, Gopalakrishnan L, Mukherjee B, Hu H and Bellinger DC (2011). Lead exposure and visual-motor abilities in children from Chennai, India. *Neurotoxicology*, **32**: 465-470.

Rao S and Singh RN (2013). NTL-160 Culture Fair Intelligence Test (a measure of ‘g’), scale 2, Forms A and B, NLEPT, Catalogue of tests, NCERT, New Delhi, India.

Rhoads GG, Ettinger AS, Weisel CP, Buckley TJ, Goldman KD, Adgate J and Lioy PJ (1999). The effect of dust Lead control on blood lead in toddlers: A randomized trial. *Pediatrics*, **103**: 551-555.

Roy A, Bellinger D, Hu H, Schwartz J, Ettinger AS, Wright RO, Bouchard M, Palaniappan K and Balakrishnan K (2009). Lead exposure and behavior among young children in Chennai, India. *Environ. Health Perspect*., **117**: 1607 - 1611.

Sawalha AF, Wright RO, Bellinger DC, Amarasiriwardean C, Abu-Taha AS and Sweileh WM (2013). Blood lead level among Palestinian schoolchildren: a pilot study. *East Mediterr. Health J*., **19**: 151-155.

Shah F, Kazi TG, Afridi HI, Baig JA, Khan S, Kolachi NF, Wadhwa SK and Shah AQ (2010). Environmental exposure of lead and iron deficit anemia in children age ranged 1-5 years: A cross sectional study. *Sci. Total Environ*., **408**: 5325-5330.

Ugwuja EI, Ogbu IS, Umeaku EA and Otuu FC (2014). Blood lead levels in children attending a tertiary teaching hospital in Enugu, south-eastern Nigeria. *Paediatr. Int. Child Health*, **34**: 216-219.

Vishwanath P, Akila P, Devanand D, Nayak N, D’souza V and Venkatesh T (2008). Screening of school children for blood lead levels and attempts to reduce them by nonpharmacolocical means in a coastal city in India. *Indian J. Med. Sci*., **62**: 185-192.

Vishwanath P, Devegowda D, Prashant A, Nayak N, D'souza V, Venkatesh T and Scott C (2012). Environmental lead levels in a coastal city of India: the lead burden continues. *Indian J. Med. Sci.*, **66**: 260-266.

Wang L, Xu SE, Zhang GD and Wang WY (1989). Study of lead absorption and its effect on children’s development. *Biomed. Environ. Sci*., **2**: 325-330.

Yabe J, Nakayama SM, Ikenaka Y, Yohannes YB, Bortey-Sam N, Oroszlany B, Muzandu K, Choongo K, Kabalo AN, Ntapisha J, Mweene A, Umemura T and Ishizuka M (2014). Lead poisoning in children from townships in the vicinity of a lead-zinc mine in Kabwe, Zambia. *Chemosphere*, **119**: 941-947.

Zimmermann MB, Muthayya S, Moretti D, Kurpad A and Hurrell RF (2006). Iron fortification reduces blood lead levels in children in Bangalore, India. *Pediatrics*, **117**: 2014-2021.