Blood Lead Concentration and Working Memory Ability on Primary School Children in Urban and Rural Area of Malacca

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Asia Pacific Environmental and Occupational Health Journal (ISSN 2462 -2214), Vol 3(1): 1 – 8, 2017

Blood Lead Concentration and Working Memory Ability on Primary School Children in Urban and Rural Area of Malacca

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ABSTRACT

Introduction: Most of the lead concentrations in the environment come from human activities such as burning fossil fuels, mining and manufacturing. Once lead enters into environment, it does not break down, but lead compounds were changed by sunlight, air and water. The main target for lead toxicity is nervous system. A child’s mental and physical growth can be affected even at low levels of exposure.

Objective: This study determined the relationship between blood lead concentration and working memory ability among primary school children in urban and rural area of Melaka.

Method: This study recruited 111 respondents from urban (N = 37) and rural area (N = 74). Lead exposure was measured through blood samples and analyzed with Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) model Perkin Elmer AAnalyst 600. The Working Memory Index (WMI), Digit Span Forward (auditory short-term memory) and Digit Span Backward (auditory working memory) were applied. Results were analysed with statistical software.

Result: The mean±SD of blood lead concentration for urban children was significantly higher (8.51±3.61µg/dL) compared to the rural children (6.86±4.63µg/dL) (t=2.061 and p=0.042). The WMI score for the urban children was significantly lower (82.03±12.55) than the rural children (87.30±13.88) (t=-2.012, p=0.048). The WMI scores were inversely correlated with the blood lead level but not with socio-demographic background of the respondents. This indicate, a reduction of the WMI scores were expected to be obtained with the increased of lead level.

Conclusion: The working memory ability of the children in urban area was low and this phenomenon was not significantly due to their socio-demographic differences but significantly correlated with the blood lead concentration.

Keywords: *blood lead, working memory ability, urban and rural, children*

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1. Introduction

Lead (Pb) is a highly toxic metal. This element occurs naturally in bluish-gray metal at small amounts in the earth’s crust (15 – 20 mg/kg). Lead are very soft, highly malleable, ductile and relatively poor conductor of electricity. It is also very resistant to corrosion but tarnishes upon exposure to air. Native lead is rare in nature. Lead is usually found in ore with zinc, silver and copper and it was extracted together with these metals. Lead is found in a form of mineral in galena (PbS) and in deposited of mined cerrussite (PbSO4) and anglesite (PbCO3) (ATSDR, 2011). However, most lead concentrations in the environment come from human activities such as fossil fuels burning, mining and manufacturing.

Lead does not break down in the environment. It was changed by sunlight, air and water. It may travel long distance before settling to the ground as tiny particles. Lead in air, formed as fine particle with diameter less than 1 µm (Agius, 2012). It has been estimated that some 0.33×10^9 kg of lead per year are directly emitted into the (WHO, 2015). Pb is sticks strongly to the soil particles and remains in the upper layer of soil. the type of lead compound, and the physical and chemical characteristics of the soil influence the movement of Pb from soil to groundwater (ATSDR, 2011).

Lead poisoning occurs when it builds up in the human body that enters through ingestion, inhalation and dermal contact. The adverse health effects of lead are same whether it enters the body through breathing or swallowing. Once lead absorb in the body, it will circulate through blood circulatory system and distribute to organs and soft tissues. For adults and children, the main target for lead toxicity is the central nervous system. Long term exposure of lead to adults at work has resulted in decreased performance in some tests that measure nervous system functions (Agius, 2012). A child’s mental and physical growth can be affected even at low levels of exposure (ATSDR, 2011). Most findings reported that blood lead has an inverse relationship with mental development and there is a reduction in intellectual quotient (IQ) when blood lead concentration exceeds 10 µg/dL (CDC, 2014). At high levels of exposure, lead can severely damage the brain in adults and children and ultimately cause death.

Children exposed to lead all through their live are more vulnerable to lead poisoning than adults. They can be exposed to lead in the womb if their mothers have lead in their bodies (Ashley-Martin et al., 2015; Thomas et al., 2015; Shamsul et al., 2003). Babies can swallow lead when they breast feed, eat foods and drink water that contains lead. In addition, babies and children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground.

Children are more sensitive to the health effects of lead than adults especially on the nervous system. No safe blood lead level in children has been determined so far (ATSDR, 2011). However, the permissible value of blood lead concentrations for children should below 10µg/dL (CDC, 2014). Childhood lead poisoning continue to be a major public health problem for certain groups of children, such as in low income country, urban area (Kordas et al., 2015; Hashim et al., 2000; Shamsul et al., 2003), and rural mining area (Ona et al., 2006). In developing countries like Malaysia, lead poisoning is one of the public health issues especially in the urban area. One of the concerns is due to high lead concentration in the air (five times greater) in the urban area compared to the rural (Hashim et al., 2000; Zailina et al., 2008). Lead is generated mainly from exhaust mobile due to high traffic density, urbanization development and human activities.

Melaka is located in the southern region of the Peninsular Malaysia, next to the Straits of Malacca. The main economy activity in this area is tourism and industrial manufacturing. The state has been proclaimed as the developed state by the Organization for Economic Co-operation and Development in 2010 which is expecting to bring more development in every corner of Melaka. Living in highly urbanized area of Melaka, may be a significant risk of lead exposure to the children especially from the increased number of traffic in the town. There have been no local studies conducted among the population to study this problem. Objective of this study was to examine level of lead exposure by examining the level in the blood and the potential relationship with the working memory ability (WMI) of the school children in urban and rural area of Melaka. This study is needed to identify gaps in the environmental monitoring and to further promote strict control or mitigating measure to reduce the exposure that can be used by the respective agencies in the town planning.

2. Materials and Method

This cross-sectional study was conducted on February to June 2015 of the urban and rural area in Melaka. Melaka is a state located in the southern region of the Peninsula Malaysia (2°12′N 102°15′E) with a total area of 1,664 km^2. The urban area located at Padang Temu, Banda Hilir and the main activities here were mainly tourism and industrial manufacturing. Meanwhile, Kuala Linggi, Kuala Sungai Baru represented the rural area and it is fishing villages near to the Straits of Malacca (Fig.1). These two areas were selected based on the factors of location, economic activities and environment factors. Selection of school-base respondents by stratified random sampling. The inclusive criteria of study sample unit were Malay ethnic group, aged 10 to 11 years old and local residents of study location not less than 10 years. Any children who were diagnosed with any type of mental illnesses or brain injury were excluded from this study. The final number of 111 respondents participated in this study represents 37 from urban area and 74 from rural area. The samples selection selected among those school children who were voluntary and get consent from parent to be respondents of this study.

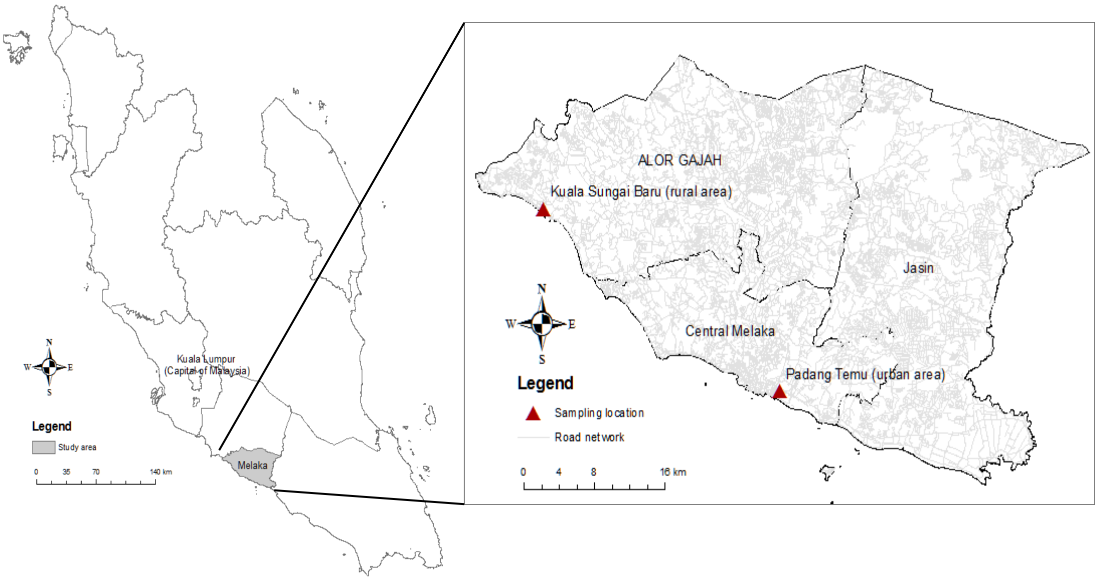

Figure 1. The study location of Melaka, situated in Peninsular Malaysia. Sampling was done in Padang Temu (urban area) and Kuala Sungai Baru (rural area).

2.1. Questionnaire

A set of questionnaire was used to gather the demographic and socioeconomic information of each respondent. The questionnaire comprised of three parts; socioeconomic status, background information and health status of the respondents. The questionnaire was pre-tested to ensure the questions were suitable and understandable. The research procedures and process was explained to the respondents and parents before they get involved in this study.

2.2. Blood lead analysis

The biological indicator for lead exposure was blood sample. The blood sample was collected from capillary from each of the respondents using finger prick method by a registered medical assistant. The hygienic and strict cleaning procedure was practiced. The materials used were antibacterial soap, distilled water, alcohol swab, disposable glove, disposable lancet, capillary tube 100 µL, applicator and Becton Dickinson pink-top microtainer tube contain of 500µL matrix modifier. Blood samples were stored in a cool box and the temperature was maintained at 2°C until 8°C before further analysis. Blood lead concentration was analyzed with Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) model Perkin Elmer AAnalyst 600 with WinLab 32 Software Version 6.5. The method and procedure to operate the GFAAS was based on the manual provided by manufacturer and incorporated with standard method. The temperature of pyrolisis and atomization were 850ºC and 1600ºC respectively (Zailina et al., 2008).

2.3. Working Memory Index (WMI)

The Wechsler Intelligence Scale for Children version IV (WISC-IV) consists of four indexes which comprise seven subtests. The indexes are called Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI) and Processing Speed Index (PSI). However, only WMI was used in this study. WMI requires working memory processes to manipulate orally presented verbal sequences or to simply recall orally presented sequential information. WMI consist of Digit Span as a subtest which comprise of Digit Span Forward (auditory short-term memory) and Digit Span Backward (auditory working memory).

3. Results

The total sample size after exclusion of those who did not met the inclusive criteria were 111 respondents from which 37 (33.3%) of them were urban children and other 74 (66.7%) were rural children. The mean and standard deviation (SD) of age for the study population was 10.69±0.46, where 58 (52.3%) of them are male and 53 (47.7%) are female.

The mean of blood lead concentration for urban children was significantly higher (8.51 ± 3.61 µg/dL) than the rural children (6.86 ± 4.63 µg/dL) (t=2.061, p=0.042). Figure 2 and 3 show the distribution of the blood lead concentration in both study areas. The lead distributions for urban children were more in normal shape with a narrow range (3.32 µg/dL to 19.36 µg/dL). But the data was skewed to the left for the rural children with wider range (1.89µg/dL to 22.08 µg/dL). 27% of urban children and 20.3% of rural children were exceeded 10 µg/dL.

The mean of WMI score for urban children was 82.03±12.55 and ranged between 55 to 115 (Figure 4). Meanwhile, for rural children the mean score of WMI was 87.30±13.88 and ranged between 15 to 125 (Figure 5). Table 1 showed 91.9% of urban children and 83.8% of rural children were in the category below the average level of WMI score.

The WMI score for rural children (87.30 ± 13.88) was significantly higher than the urban children (82.03 ± 12.55) at t=-2.012 and p=0.048. The Digit Span Backward of rural children also were significantly higher (4.70±1.68) compared to the urban children (4.00±1.58) at t=-2.162 and p=0.034). However, no significant difference was obtained for the Digit Span Forward (t=-1.807, p=0.075) between these two groups (Table 2).

Table 3 showed there was significant inversely correlation of WMI score with blood lead concentration among urban (r=-0.417, p=0.010) and rural (r=-0.369, p=0.001) children. Table 4 showed there was no association of socio-economic variables with the WMI score among urban and rural children.

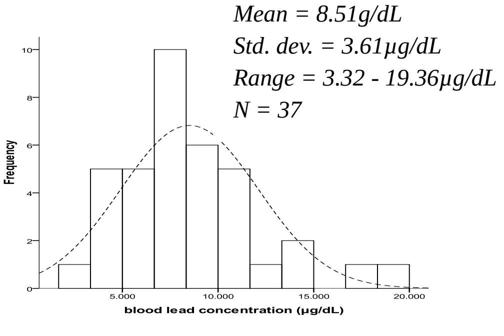

Figure 2. Distribution of blood lead concentration (µg/dL) among urban children

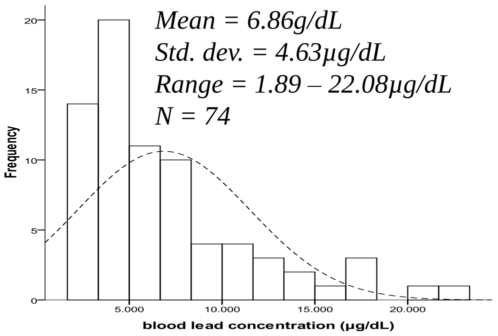

Figure 3. Distribution of blood lead concentration (µg/dL) among rural children

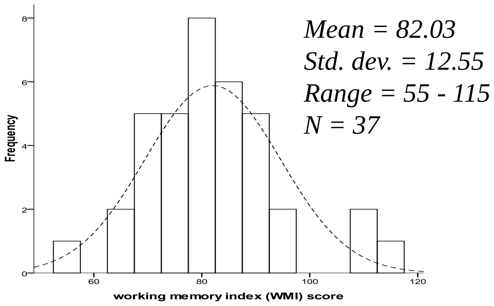

Figure 4. Distribution of working memory index (WMI) among urban children

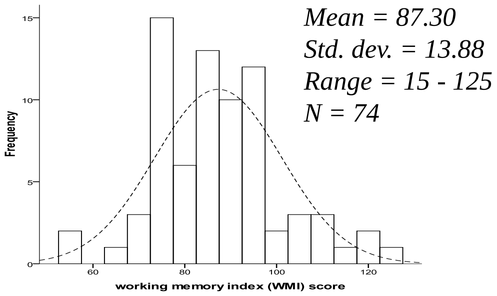

Figure 5. Distribution of working memory index (WMI) among rural children

Table 1. The WMI score among urban and rural children (N = 111)

WMI Score	Urban (n = 37)	Rural (n = 74)
	Frequency (%)	Frequency (%)
125 – 129 (Superior)	0 (0.0)	1 (1.4)
115 – 124 (High Superior)	1 (2.7)	3 (4.1)
100 – 114 (Average)	2 (5.4)	8 (10.8)
85 – 99 (Low Average)	13 (35.1)	35 (47.3)
70 – 84 (Borderline)	21 (56.8)	27 (36.5)

Table 2. The difference of working memory score among respondents

Variables	Mean ± SD		t value
	Urban n = 37	Rural n = 74	
Working Memory Score	82.03 ± 12.55	87.30 ± 13.88	2.012*
Digit Span Forward	5.92 ± 1.82	6.58 ± 1.83	1.807
Digit Span Backward	4.00 ± 1.58	4.70 ± 1.68	2.162*

Table 3. Relationship of blood lead concentration and WMI score

Variables	Blood Lead Concentration (μg/dL)	
	Urban n = 37	Rural n = 74
	r	*r*
Working Memory Score	- 0.417 **	- 0.369**
Digit Span Forward	- 0.407 *	- 0.283*
Digit Span Backward	- 0.178	- 0.326**

*N = 111, ** Significant at p ≤ 0.01, * Significant at p ≤ 0.05*

Table 4. The difference of working memory score among respondents

Variables	Working Memory Index (WMI) Score			
	Urban n = 37		Rural n = 74	
	r value	p value	r value	p value
Age	0.173	0.307	- 0.141	0.229
Household Income (RM)	0.156	0.358	- 0.046	0.700
Parents Education (years)				
- Mother	0.177	0.294	- 0.082	0.488
- Father	0.234	0.163	0.024	0.838
Body Mass Index (kg/m2)	- 0.021	0.904	- 0.155	0.188
Pre-school Education (years)	0.067	0.695	0.119	0.312
Number of Sibling	- 0.100	0.555	0.209	0.074
Outdoor Activities (hours)	- 0.313	0.059	0.050	0.671

4. Discussion

Lead is an element with unknown physiologic function in humans but adversely affects a variety of fundamental biochemical process. Lead poisoning is a substantial problem in developing countries (Zailina et al., 2008). The permissible value of blood lead concentrations for children was below 10μg/dL (CDC, 2014). Majority of the children reported a normal or lower than the allowable standard blood lead concentrations. This study found that 10 children in urban (27 %) and 15 from rural (20.3 %) have blood lead concentrations higher than 10μg/dL.

The Centers for Disease Control has defined an elevated blood lead level in children as more than 10μg/dL on the basis of neurologic toxicity (CDC, 2014). This value is extremely important because policy makers and public health officials generally have acted to remove sources of lead only after the Centers of Disease Control level of concern had been exceeded. Although the CDC’s current definition is 10μg/dL, lead levels below 10μg/dL have recently been associated with neurocognitive deficits in children (Bellinger, 2013; Even et al., 2015) and no “safe” level has yet been established (Shamsul et al., 2003).

Blood lead concentration is the most widely used and considered to be the most reliable biomarker for general clinical use and public health surveillance. Currently, blood lead measurement is the screening test of choice to identify children with elevated blood lead level. In children, blood lead concentration between 10µg/dL and 14µg/dL should trigger community-wide childhood lead poisoning prevention activities (CDC, 2014). Since the elimination half-time of lead in blood is approximately 30 days, blood lead generally reflect relatively recent exposure and cannot be used to distinguish between low-level intermediate or chronic exposure and high level acute exposure. A blood lead level will tell if a child has been exposed to lead in the last 3 to 4 months.

Urban children in this study had higher blood lead concentration compared to the rural children. This is possibly due to the construction of a new academic building at the school (Sekolah Kebangsaan Padang Temu) that may indirectly cause the children to inhale lead-containing dust from the construction area higher than usual. Besides, high traffic density in this area also may contribute to high lead from deposited particulate matter in the air and soil. Previous study had shown high lead concentration in soil (2,000 ppm) was detected within 25 meters of major roadways. These concentrations fall of exponentially with distance. In urban soils, the lead found is a mixture of powdered paint and atmospheric fallout of lead particles (Mazumdar et al., 2011).

Similar results were also reported in Zailina et al., (2008). A significant different of respirable lead was detected in urban and rural area in Malaysia (Zailina et al., 2008). Data on respirable lead and blood lead of 346 school children were obtained from Kuala Lumpur (urban), Kemaman (semi-urban) and Setiu (rural). Respirable lead and blood lead were the highest for Kuala Lumpur (95ng/m^3 and 5.26µg/dL) followed by Kemaman (27ng/m^3 and 2.81µg/dL) and Setiu (15ng/m^3 and 2.49µg/dL). Regression analysis shows that urban children are at higher risk of exhibiting excessive blood lead levels. Kuala Lumpur's school children have a 25 times greater risk of having excessive blood lead levels when compared to Kemaman's and Setiu's school children. The respirable lead comes from deposited dust in the air produced from heavy traffic. Other study also states that mean blood lead concentration was higher in the urban area (8.3µg/dL) than in suburban area (6.9µg/dL) (Mazumdar et al., 2011).

The Working Memory Index (WMI) was derived from the Digit Span subtest. This subtest basically measured the attention and concentration of the respondent. Our findings showed that most of the urban (91.9%) and rural children (83.8%) have low WMI score (below than average of 100±15). The urban children (82.03±12.55) have lower WMI score compared to the rural children (87.30±13.88). The Digit Span text shows that the urban children were easily distracted during the test and were not performed well. This possibly explained why they have low WMI score compared to the children in rural area. Low WMI score also possibly related to high blood lead concentration of these children.

One of the serious outcomes of lead exposure is a decline in cognitive functioning (memory, attention, language, concept formation, problem solving, executive and visuospatial functions) which also has an impact on school performance (Surkan et al., 2007). Lead toxicity has detrimental effects to the nervous system and the brain, thus impairing the memory abilities of a person. Higher blood lead levels were associated not just with lower scores on tests of neuropsychological domains, but also with lower scores on tests of academic achievement (Surkan et al., 2007).

Previous study also reported higher mean cognitive score (102.55) of the children from the industrial area compared to the urban children ($p<0.001$). The McCarthy Scales of Children Abilities (MSCA) test also showed the mean General Cognitive Score or the IQ of the children in the industrial estate (102.55±12.41) was significantly higher than the children in the urban area (95.09 ± 13.98) (Zailina et al., 2008).

The blood lead concentration in this study were inversely correlated with the working memory ability scores (WMI). This indicates a reduction trend in working memory ability of the children with the increase of blood lead concentration. However, due to small sample size and the possible influence of other factors such as socio demographic and environmental factors produced weak correlation. This finding was consistent with Zailina et al., (2008) where significant inverse relationship between blood lead concentrations and cognitive scores for the children who lives in the urban and industrialized area. The blood lead level of 4.30µg/dL could affect the cognitive development of children (Zailina et al., 2008). Blood lead levels between 5-10 µg/dL were associated with decreased attention and working memory. Hisham et al., (2000) indicates a significant association between lead exposure and neurobehavioral tests results. This result reflect the attention and short-term memory where it appeared to be low at high level of blood lead.

Numerous studies also reported that the cognitive score (IQ) of children were affected by blood lead concentrations higher than 10µg/dL (0.483µmol/L). For example, higher blood lead level was associated with measures of intellectual functioning and social-behavioral conduct (Shamsul at al., 2003). It was estimated an IQ loss by 4.6 points for each increase in the blood lead concentration of 10µg/dL. For every 1µg/dL increase in blood lead concentration, there was a 0.7 point decrement in mean arithmetic scores, an approximately point decrement in mean reading scores, a 0.1 point decrement in mean scores on a measure of nonverbal reasoning, and a 0.5 point decrement in mean scores on a measure of short-term memory (Shamsul et al., 2003). Overall, the analyses support prior research that children's blood lead levels less than 10µg/dL are related to compromised cognition and highlight that these may especially be related to academic achievement (Zailina et al., 2002).

Mostafa et al., (2009) stated that children with cognitive dysfunction had higher blood lead levels than those with normal cognitive function. Poor scholastic achievement was reported in 33% of the children, of whom 87.9% had cognitive dysfunction and 90.9% had blood lead levels more than 10µg/dL. The frequency of poor scholastic achievement was significantly higher in children with cognitive dysfunction than those who were without. Similarly, the frequency of poor scholastic achievement was significantly higher in children with blood lead levels more than 10µg/dL than those with levels less than 10µg/dL. Blood lead level more than 10µg/dL was the most significant independent predictor of cognitive dysfunction followed by the degree of lead exposure in a logistic regression analysis in the children. There was a consistent finding in this study that deficits were found on only four subtests of the verbal and performance IQ (digit span, arithmetic, digit symbol and block design). These tests are used in a clinical setting to show abilities in working memory attention (digit span and arithmetic), processing speed (digit symbol) and perceptual reasoning (block design).

Other factors such as age, household income, parent's education, body mass index, pre-school education, number of sibling and duration of outdoor activities did not have significant association with working memory ability. In short, working memory ability among urban and rural children was associated with blood lead concentration even after considered other factors.

5. Conclusion

In conclusion, the blood lead concentration among urban was significantly higher than the rural children. The urban children showed lower score for the working memory ability compared to the rural children. There was inversely significant correlation between blood lead concentration and working memory ability among these children and no association was determined with their socio-demographic background.

Ethical Clearance

The methodology of this study was approved by Ethics Committee of Faculty of Medicine and Health Science, Universiti Putra Malaysia. Written permission was obtained from the Ministry of Education, Malaysia, Department of State Education, Melaka, and selected schools. Parents who agreed of the involvement of their children in this study had signed the consent letter and understood that they were permitted to withdraw from the study anytime as they wish. Furthermore, the consent form was aimed to inform them that all the effects that they will get from the study were the responsibility of the researcher. Individual data are confidential. The reports of the study will be sent to Ministry of Education and selected schools.

Conflict of interest

The authors declare that there is no conflict of interest in the publication of this research

References

Agius R. (2012). Lead in the environment and health. http://www.agius.com/hew/resource/lead.htm (visited 24/12/2015).

Ashley-Martin. J., Dodds, L., Arbuckle, T. E., Ettinger, A. S., Shapiro, G. D., Fisher, M., Taback, S., Bouchard, M. F., Monnier, P., Dallaire, R., & Fraser, W. D. (2015). Maternal blood metal levels and fetal markers of metabolic function. *Environ Res.* 2015 Jan, 136, 27-34.

ATSDR - Agency for Toxic Substances and Disease Registry. 2011. Lead.http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=22 (visited 22/02/2016).

Bellinger D. C. (2013). Prenatal Exposures to Environmental Chemicals and Children's Neurodevelopment: An Update. *Saf Health Work*, 4(1), 1-11.

CDC – Centers for Disease Control and Prevention (2014). Blood Lead Levels in Children. http://www.cdc.gov/nceh/lead/ACCLPP/blood_lead_levels.htm (visited 20/02/2016).

Evens, A., Hryhorczuk, D., Lanphear. B. P., Rankin, K. M., Lewis, D. A., Forst, L., & Rosenberg, D. (2015). The impact of low-level lead toxicity on school performance among children in the Chicago Public Schools: a population-based retrospective cohort study. *Environ Health*, 7, 14:21.

Hashim, J. H., Hashim, Z., Omar, A., & Shamsudin, S. B. (2000). Blood lead levels of urban and rural Malaysian primary school children. *Asia Pac J Public Health*,12(2), 65-70.

Kordas, K., Ardoino, G., Coffman, D. L., Queirolo, E. I. , Ciccariello, D., Mañay, N., & Ettinger, A. S. (2015). Patterns of exposure to multiple metals and associations with neurodevelopment of preschool children from Montevideo, Uruguay. *J Environ Public Health*, 2015:493471.

Mazumdar, M., Bellinger, D. C., Gregas, M., Abanilla, K., Bacic, J., & Needleman, H. L. (2011). Low-level environmental lead exposure in childhood and adult intellectual function: a follow-up study. *Environ Health*, 30, 10:24.

Mostafa, G. A., El-Shahawi, H. H., & Mokhtar, A. (2009). Blood lead levels in Egyptian children from high and low lead-polluted areas: impact on cognitive function. *Acta Neurol Scand*, 120(1), 30-7

Ona, L. F., Alberto, A. M., Prudente, J. A., Sigua, G. C. (2006). Levels of lead in urban soils from selected cities in a central region of the Philippines. *Environ Sci Pollut Res Int.*, 13(3), 177-83.

Shamsul, B. S, Jamal, H. H., Nik Nasri, N. I. & Abdul Rahman, A. J. (2003). Blood lead concentration during pregnancy and the health implication to the mothers and their babies. *Epidemiology*, 14(5) Suppl. 2003.

Surkan, P. J., Zhang, A., Trachtenberg, F., & Daniel, D. B., McKinlay, S., & Bellinger, D. C. (2007). Neuropsychological function in children with blood lead levels <10 microg/dL. *Neurotoxicology*, 28(6), 1170-7.

Thomas, S., Arbuckle, T. E., Fisher, M., Fraser, W. D., Ettinger, A, & King, W. (2015). Metals exposure and risk of small-for-gestational age birth in a Canadian birth cohort: The MIREC study. *Environ Res*, 140, 430-9.

WHO – World Health Organization (2015). Lead poisoning and health. http://www.who.int/mediacentre/factsheets/fs379/en/ (visited 10/01/2016).

Zailina, H., Junidah, R., Josephine, Y., Jamal, H. H. & Shamsul, B. S. (2008). The influence of low blood lead concentrations on the cognitive and physical development of primary school children in Malaysia. *Asia Pac J Public Health*. 20(4), 317-26.

Zailina, H., Josephine ,Y., Shamsul, B. S., Jamal, H. H., & Ariffin, O. (2002). McCarthy Score and Academic Performance Among Primary School Children In Kuala Lumpur, Malaysia. *Malaysian J of Public Health Medicine*, 2(1), 6-12.