STUDIA UBB AMBIENTUM, LX, 1-2, 2015, pp. 31-38
(RECOMMENDED CITATION)

CHILDREN'S EXPOSURE TO LEAD AND CADMIUM IN BAIA MARE AREA, ROMANIA

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ABSTRACT. The objective of this study was to assess children's exposure to lead and cadmium in the Baia Mare area, a place known for its heavy metal contamination resulted from the mining activities carried out in the past. Blood and urine samples were collected from 33 children ages between 2 years and 8 months to 14 years. The parents of all 33 children completed a questionnaire; the questionnaire provided information on the demographic characteristics, playground activities and health data in particular. Urinary cadmium was measured with the help of atomic absorption spectrometers with a graphite furnace, and the lead in the blood was determined with the help of anodic stripping voltammetry. The median values of the biomarkers were of 0.99 µg/L (ranging between 0.40-2.66 µg/L) for urinary cadmium and 3.3 µg/dL (ranging between 1.3-13 µg/dL) for lead in the blood, both being below the general reference levels of the population. A positive association was found between urinary cadmium and the age of the participants: the concentration of the cadmium levels in the urine increased with age ($p = 0.026$). Statistically significant differences were found between blood lead levels and children playing in the sand ($p = 0.018$). Although such an approach requires substantial resources in order to develop scientific models to analyze the environment-health relationship, it is very important to expand this pilot study to a larger population, children representing the group of population with an increased susceptibility to lead and cadmium exposures.

Key words: *urinary cadmium, blood lead levels, children, exposure*

INTRODUCTION

Children are more susceptible to chemical contaminants compared to adults because their systems and organs grow and consume more food, more fluids and breathe more air than adults, related on their body weight. Also, they spend more time on the ground than adults, and explore the environment they live using their hands and mouth, so they are more exposed and can ingest larger amounts of chemical contaminants found in the soil (Getaneh et al., 2014).

Lead is naturally found in the Earth's crust and also in the human body. Lead and its compounds are released into the environment though mining activities like smelting, processing and recycling (WHO, 2002). Lead poisoning in children occurs from many sources: paint containing lead, ceramic pots, soil contaminated with lead, leaded gasoline, medicines (natural remedies), beverages contaminated with lead, water contaminated with lead because of the distribution network, foods containing lead. (Bellinger, 2008) The effects of lead exposure are mainly related to neonatal morbidity and mortality, abortion and sterility, and they are dependent on the age at which the exposure occurs and the level of exposure. The maximum risk of exposure is found in young children because their central nervous system is going through a full process of development, making children extremely sensitive. (Papanikolaou et al., 2005; ATSDR, 2000) Exposure to lead can affect the hematopoiesis system, as well as the kidneys and blood pressure (Lanphear et al., 2005). Chronic exposure to lead may delay the normal development of children with approximately two years (Chiodo et al., 2004).

Cadmium is naturally found in the environment. It is present in copper ores, lead and zinc in the form of copper sulfide. Cadmium can reach the environment during mining and refining processes, fossil fuel combustion, and waste incineration and during the production of phosphate fertilizers. Cadmium has a tendency to accumulate in tobacco leaves and leafy vegetables (ATSDR, 2012). Long-term exposure to cadmium produces renal dysfunctions (Gonick, 2008). Following ingestion of foods with high cadmium levels, the main symptoms are vomiting, diarrhea, fever accompanied by headaches, coughing, difficulty breathing (Rong et al., 2014).

The purpose of this paper is to determine the concentrations of urine cadmium and blood lead in children ages from 2 years and 8 months to 14 years in Baia Mare, and creating links between demographic characteristics and exposure.

MATERIALS AND METHODS

The study participants were selected from an area with high levels of lead and cadmium in the environment as a result of mining activities there. The study is conducted in Baia Mare, Maramures County, with a population of about 136.000 inhabitants. The participants in the study were identified while taking into account their increased susceptibility; as a result, children ages 2 years and 8 months to 14 years were monitored.

This study was conducted in May 2010 over the course of two days. The investigated sample included 33 children who were recruited with the help of family physicians. They were applied questionnaires and the exposure biomarkers were determined. The families were informed of the purpose of the study and also on the procedures to be performed, thus consent was obtained for the collection of blood and urine. The questionnaire was completed by the parents in the presence of an investigator of the study that was able to provide further information on the questions. As a result of the data provided by the parents of each of the children part in the study, information on exposure to metals and other potential risk factors (i.e. demographic factors - gender, age, socio-economic factors - education of parents etc.) were found, and they were used as new variables in the database. Some of the data was analyzed in Excel 2007, with the creation of tables and graphs in various forms, which were then interpreted using statistical methods and the Kruskal-Wallis test. Continuous variables such as age and the play activities embraced by children were spread into groups based on the tertile distribution. The statistically significant differences were identified by two-tailed p-value <0.05.

Blood and urine samples were collected by a qualified nurse and analyzed at the Environment Health Center in Cluj-Napoca.

The urine was collected in polyethylene containers early in the morning, then the samples were labeled, refrigerated, and transported into the laboratory. Urine cadmium levels were measured using atomic absorption spectrometry with graphite furnace (unit: Zeenit 700p) with a limit detection of 0.02 mg/l. For urinary cadmium, the measurement device was calibrated with a standard addition method to eliminate possible array errors. Urine samples were diluted at a ratio of 1: 5 and then placed in an auto sampling vial and injected into the graphite furnace in the presence of modifier matrices, 1% palladium nitrate and 0.5% ammonium nitrate. The cadmium concentration expressed in mg/l was read directly from the calibration curve.

The technique used to determine blood lead levels is the striped anodic voltammetry with a sensitivity of 0.1 ug/dl and an accuracy of 99% for three minutes. The device used is a Lead Care System, manufactured in 2000; similar devices are being used in the US for screening and community risk assessment of lead exposure and they are approved for use in the healthcare system in Romania by the Ministry of Health. The reading is conducted in 50 µl capillary blood in order to provide immediate results over the course of 3 minutes.

RESULTS AND DISCUSSION

The investigated sample included 33 males and females (19 males representing 57.6% and 14 females representing 42.4%), ages between 2 years and 8 months and to 14 years, residing in Baia Mare.

Table 1. *Urinary cadmium levels and blood lead levels in children (µg/l / µg/dl)*

Biomarkers	n	Mean (SD)	Median	Range
Blood lead (µg/dl)	33	4.0 (2.09)	3.3	1.3-13
Urinary cadmium (µg/L)	33	1.16 (0.40)	0.99	0.40-2.66

Table 1 presents the results of the biological measurements in children who participated in the study. Of the 33 children, the median blood lead concentration was of 3.3 µg/dl with an average of 4 µg/dl and the median levels of cadmium in urine was 0.99 µg/l, with an average of 1.16 µg/l.

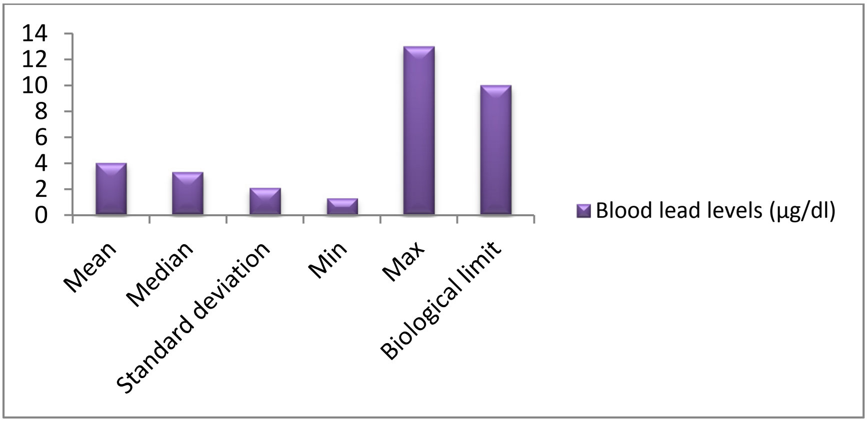

Fig. 1. *Blood lead levels (normal values or ≤ 10 µg/dl according to CDC, Center for Diseases Control)*

Blood lead levels determined in the investigated sample ranged between 1.3-13 µg/dl, with an average value of 4 µg/dl and a standard deviation of 2.09 µg/dl. All of the measured values, except for one, the maximum of 13 µg/dl, stood below 10 µg/dl, the biological limit set by CDC (figure 1).

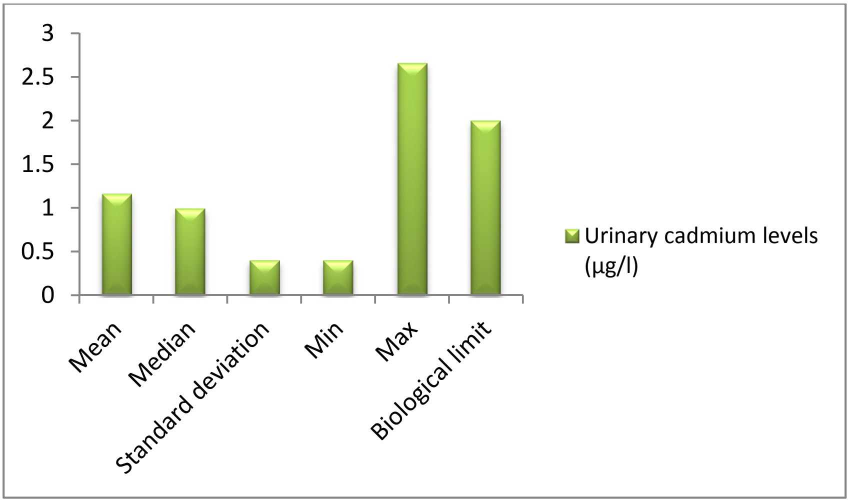

Fig. 2. *Urinary cadmium levels (benchmarks < 2 µg/l)*

Figure 2 shows that the value for Cadmium in urine discovered in the investigated sample ranged between 0.40-2.66 µg/l with an average of 1.16 µg/l and a standard deviation of 0.40 µg/l. Two of the measured values were above the reference limit of 2 µg/l.

Table 2. *Urinary cadmium levels and blood lead levels in the study participants by gender and age (µg/l / µg/dl)*

Demographic characteristics	Urinary cadmium (µg/l)			Blood lead levels (µg/dl)		
	n	**Mean (SD)**	**Median**	**n**	**Mean (SD)**	**Median**
Gender						
Males	33	1.06 (0.22)	0.99	33	3.7 (1.5)	3.2
Females	33	1.3 (0.55)	0.99	33	4.3 (2.8)	2.2
P value[b]	0.071			0.813		
Age (years)[a]						
2.8 to 3.9	6	1.07 (0.19)	0.99	6	2.9 (0.6)	3
4 to 5.8	13	0.99 (0)	0.99	13	4 (1.8)	3
6.2 to 14.1	14	1.35 (0.56)	0.99	14	4.4 (2.8)	3.8
P value[b]	**0.026**			0.389		

[a] *Categorized in groups based on the tertile distribution in the study participants;*
[b] *Differences in levels of biomarkers among groups were assessed using the Kruskal-Wallis test.*
SD *- Standard deviation.*

Table 2 shows the distributions of cadmium levels in urine and blood lead levels by gender and age. Despite of the upward trend observed for urinary cadmium concentrations, no differences between boys and girls were observed; no correspondence between blood lead levels and gender were determined either.

Cadmium levels in urine increased with age (p = 0.026). The urinary concentration average for children aged between 6.2-14.1 years (1.35 µg/l) was almost two times higher than the levels recorded in children ages between 2.8-3.9 years (1.07 µg/l) and between 4-5.8 years (1.35 µg/l). The explanation for this positive association that was found is found in the fact that, as they grow, children make contact with the soil more often when playing, thus they are submitted to higher exposure to cadmium. Regarding the blood lead levels, no relationship between age and blood lead concentration was found.

Table 3 shows the distribution of urinary cadmium concentrations and blood lead levels in relation with playing habits. We found a positive association between blood lead and playing with sand; the blood lead level was higher in children playing with sand (p = 0.018), with the median concentration being twice as high for children playing with sand (6.6 mg / dL) than for those did not play with sand (3.2 mg / dL). No similar differences were observed in the concentration of urinary cadmium depending on playtime in the sand, with an equally recorded median concentration in both cases (0.99 mg / L).

Table 3. *Urinary cadmium levels and blood lead levels in the study participants by playing habits (µg/l / µg/dl)*

Risk factors	Cadmiu din urină (µg/L)			Plumbemie (µg/dL)		
	n	**Medie (SD)**	**Mediană**	**n**	**Medie (SD)**	**Mediană**
Playing with soil						
Yes	26	1.18 (0.44)	0.99	26	3.7 (1.5)	3.3
No	7	1.07 (0.18)	0.99	7	4.9 (3.8)	3.3
P value[b]	0.782			0.877		
Playing outside (hours)[a]						
< 4	14	1.18 (0.49)	0.99	14	4.2 (3.0)	2.9
4 to 6	10	1.08 (0.18)	0.99	10	3.6 (1.2)	3.4
> 6	9	1.22 (0.46)	0.99	9	3.9 (1.3)	3.5
P value[b]	0.951			0.749		
Playing with sand						
Yes	4	1.01 (0.04)	0.99	4	7.4 (4.1)	6.6
No	29	1.18 (0.43)	0.99	29	3.5 (1.3)	3.2
Valoarea p[b]	0.969			**0.018**		

[a] *Categorized in groups based on the tertile distribution in the study participants;*
[b] *Differences in levels of biomarkers among groups were assessed using the Kruskal-Wallis test.*
***SD** - Standard deviation.*

Regarding outdoor playing activities and the ones involving sand, no differences were found between the levels of heavy metals in fluids influenced by these potential risk factors.

CONCLUSION

The determined values in blood or urine biomarkers for heavy metal exposure - blood lead, cadmium - in the investigated sample in the study area resulted in normal values. Except for a single subject (with blood lead levels of 13 µg/dl), the subjects in the investigated sample (97%) had blood lead values within normal limits (below 10 µg/dl).

Regarding the levels of cadmium in the urine, for the vast majority of investigated subjects, the values were below the reference limit of 2 µg/l except for 2 subjects (2.11 µg/l and 2.66 µg/l, the highest measured value). Connections between between the level of cadmium in the urine and the age of the subjects ($p = 0.026$) and between blood lead levels and playing with sand habits ($p = 0.018$) were identified.

The Baia Mare area is not singular in terms of human lead and cadmium poisoning from mining activities. Following a study analyzing children ages between 6 months to 6 years in the Yatağan region in 2002, exceeded average blood lead levels were identified in 95.7% of the investigated samples (Yapici et al., 2006). Another study performed in an old mining area in the United States has identified an average of 6.25 µg/dl blood lead concentration (Murgueytio et al., 1998; Paoliello et al., 2002). Lower values were found in two communities in Sweden that were characterized by historical pollution, with medians of 3 μg/dl (Bjerre et al., 1993) and 1.9 μg/dl (Berglund et al., 2000). Carvalho et al. (1985) found blood lead concentrations equal to 58.7 μg/dL in children aged between 1 to 9 years in Brazil in an area with a lead refining facility that has been active for many decades. Ten years later, the same authors have identified similar concentrations (58.9 μg/dL) in the same populations (Silvany-Neto et al., 1996).

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