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The effect of illegal lead processing on blood lead levels in children living in the mining area

Uticaj nezakonite prerade olova na nivo olova u krvi dece u rudarskoj zoni

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Abstract

Background/Aim. The northern part of Kosovo was one of the largest lead and zinc production industries in Europe. Special attention has been paid to the landfill sites of these metals remained after past industrial activities. The inhabitants of Roma camps in this area are collecting led waste they process by crushing and melting in their shacks in primitively organized working environments. Because of all the aforementioned it was necessary to examine the concentration of blood lead level (BLL) in the children aged less than 6 years inhabiting this area, especially taking care of blood analysis of children living in Roma camps. **Methods.** The study was conducted in the municipality of Leposavić, Province Kosovo and Metohija, Serbia. Totally 78 subjects participated in the study. All the subjects were divided into two groups: the group I consisting of 42 children who lived in the Romas camp, and the group II with 36 children from a city kindergarten. Based on the mathematical model WRPLOT we found out that both groups of patients were in the low risk zone for industrial contamination exposure. Blood analysis was done according to the protocol provided by ESA Lead Care. **Results.** The average age of participants in the study was 4.60 ± 1.63 years. The mean BBL in the children from the group 1 was 19.11 μg/dL and from the group 2 4.87 μg/dL. There was a statistically significant difference in the mean values of BBL between the groups (U = 39, $p < 0.001$). All of the children from the group 1 had BBL greater than 5 μg/dL in comparison to 38.9% of the children from the group 2 ($\chi^2 = 35.75$, $p < 0.001$). **Conclusion.** Although both groups were located outside the zone of direct spread of pollution, the results indicate high concentrations of lead in blood of all the examined children. The concentration was higher in the children who lived in the area in which illegal processing of lead waste took place.

Key words:
lead poisoning; child, preschool; serbia; environmental pollutants; blood chemical analysis.

Apstrakt

Uvod/Cilj. Na području severnog Kosova nalazila se jedna od najvećih industrija za proizvodnju olova i cinka u Evropi. Poseban akcenat se stavlja na deponije zaostale nakon ove industrijske proizvodnje. Na ovom području stanovnici u romskim kampovima bave se prikupljanjem olovnog otpada koji prerađuju – drobe i tope, u svojim barakama u primitivno organizovanim radnim sredinama. Zbog svega navedenog, bilo je neophodno ispitati koncentraciju olova u krvi dece mlađe od šest godina koja žive u ovom području, sa posebnim akcentom na analizu krvi dece koja žive u romskim kampovima. **Metode.** Naše istraživanje sprovedeno je na području opšine Leposavić, Kosovo i Metohija, Srbija, uključujući 78 ispitanika podeljenih u dve grupe: grupa I od 42 dece iz romskog kampa, i grupa II od 36 dece iz gradskog vrtića. Na osnovu matematičkog modela WRPLOT dobili smo podatak da se obe grupe ispitanika nalaze u zoni niskog rizika od izloženosti industrijskom zagađenju. Krv za nalizu uzimali smo iz prsta dece. Analiza krvi vršena je prema protokolu predviđenom od ESA *Biosciences Lead Care*. **Rezultati.** Prosečna starost ispitanika iznosila je 4,60 ± 1,63 godine. Prosečna koncentracija olova u krvi u grupi I bila je 19,11 μg/dL, a u grupi II 4.87 μg/dL. Postoji statistički visokoznačajna razlika u pogledu koncentracije olova u krvi

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između ispitivanih grupa (U = 39; $p < 0,001$). Sva deca (100%) iz grupe I imali su koncentracije olova u krvi veće od 5 μg/dL, a iz grupe II ($\chi^2 = 35,75$; $p < 0,001$) njih 38,9%. **Zaključak.** Iako su obe grupe bile locirane van zone direktnog širenja zagađenja, rezultati ukazuju na visoke koncentracije olova u krvi sve ispitivane dece. Koncentracija je veća kod dece koja žive u sredini u kojoj se odvija ilegalna prerada olovnog otpada.

Ključne reči:
trovanje olovom; deca, predškolska; srbija; životna sredina, zagađivači; krv, hemijske analize.

Introduction

The presence of substantial increases in lead (Pb) levels in the environment leads to increased risk of increased blood lead level (BLL) in people [1, 2]. Children under 6 years of age are at a particular risk of environmental lead [3]. Lead gets into a child's body by ingesting or inhaling lead dust. As a consequence of industrial pollution, lead particles fall out of the air to the ground and stick to soil dust, exposing the children to inhaling dust while playing outdoors. Children may also be exposed to lead by eating food contaminated by secondary transfer of lead from soil to plants and animals.

The absorption of lead from the gastrointestinal tract in children is significantly greater than in adults (according to literature data children absorb lead five times more efficiently than adults), and the food intake per unit body weight is more than that of adults [4, 5]. Also, heavy metals are metabolized faster in children than in adults. Children are particularly vulnerable to the toxic effects of lead because of their ongoing growth and development and not fully matured bodies [6]. So far there has been no medical treatment that permanently reverses the neurodevelopmental effects of lead exposure [7]. Evidence suggests BLL ≤ 5 μg/dL are associated with cognitive deficits [8]. Apart from this, exposure to lead may affect a child's IQ [9, 10]. These effects are long-lasting and persist into adulthood even after lead exposure has been reduced or eliminated [11, 12]. Further lead exposure in children, even in low concentrations, may cause slow growth, anemia, hearing and hyperactivity disorders [13–16]. Some authors describe a proof of concept gene-environment interaction studies of early life Pb^{2+} exposure in mice expressing the human mutant form of the disrupted in schizophrenia 1 (DISC-1) gene, a gene that is strongly associated with schizophrenia and allied mental disorders [17].

In 2012, the Centres for Disease Control and Prevention (CDC) changed the "actionable" reference BLL from 10 μg/dL to 5 μg/dL [18].

The northern part of the province of Kosovo was one of the largest lead and zinc production industries in Europe, which caused a legacy of widespread environmental pollution with heavy metals [19–23]. Special attention has been paid to the landfill sites of these metals remained after past industrial activities. The Roma population of this region from the camps collects waste material, including lead. They process the collected lead waste – crush and melt in their barracks in primitively organized workplaces. After waste processing and blending into lead ingots, they are still illegaly sold.

Earlier studies have showed increased BLL in the population of northern part of Kosovo [24]. The World Health Organization Regional Office for Europe (WHO-EURO) assessed in 2004 that 25% of children aged 2–3 years in the general population in the area had elevated (≥ 10 μg/dL) BLL, according to WHO unpublished data. However, new studies have not been conducted so far.

Due to all of these reasons, it was necessary to analyze the BLL in children of this region, especially in Roma children living in the camps where their families are suspected of informal lead smelting activities.

The aim of the paper was to determine BLL in all the subjects and identify the differences in BLL between the children living in Roma camps where informal and unsafe lead processing has been practiced and the children living outside the camps. All the children were from the municipality of Leposavić in northern Kosovo, Serbia.

Methods

The study was conducted in the municipality of Leposavić in northern Kosovo (Figure 1), known for lead and zinc mines and processing and industrial landfill sites that are the

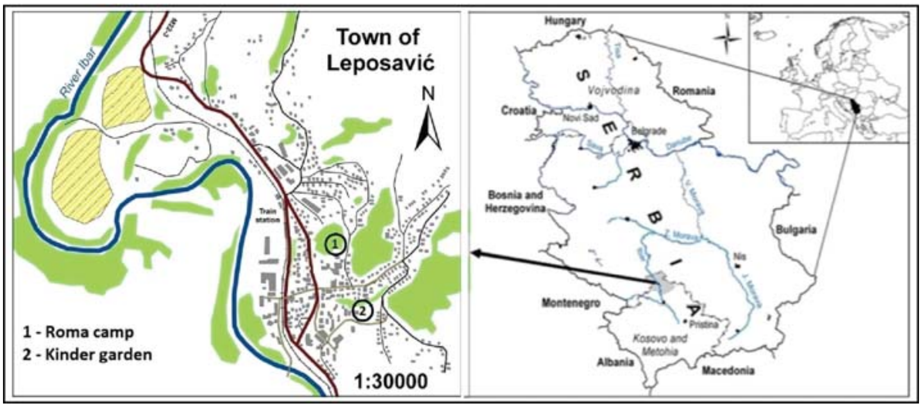

Fig. 1 – Geographical location of the area near Leposavić where blood samples were taken.

major cause of environmental contamination. There is also a Roma camp with illegal and primitive lead waste processing.

The study was conducted in cooperation with Roma people living in the camps aiming at better control of overall health conditions and improvement of their quality of life. The Standard of Good Practice have been applied in the study. The parents of the children had been informed on the procedure of blood sampling and the importance of the study. An informed consent was given to each parent by the doctors involved in the study to be signed on voluntary basis.

Totally 78 subjects participated in the study (47 males and 31 females). All the subjects were divided into 2 groups. One group consisted of children who lived in the Roma camp, the group I of 42 participants, and the group II of children from the kindergarten, the group II of 36 participants. Blood sampling was performed in this institution for faster and more efficient study performance. The average age of the subjects was 4.56 ± 1.52 years.

A difference in pollution diffusion caused by industrial waste depots between the industrial and residential zones was determined by the mathematical model provided in the WRPLOT view TM 7.0.0. software (Figure 2). The children from both groups lived in the zones with lower levels of industrial contamination, but the children from the Roma camps were additionally exposed to lead due to lead waste processing in the camp.

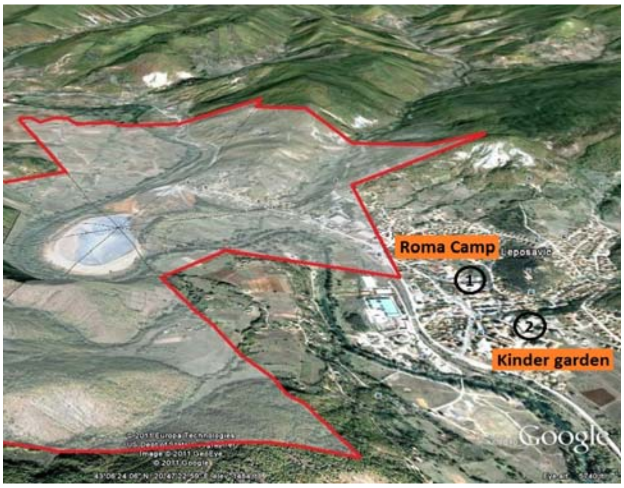

Fig. 2 - Presentation of the zones of propagation of industrial pollution from landfills (shaded – zone of a greater risk from industrial pollution; unshaded – zone of lower risk from industrial pollution; black circle with the number – places of residence of the study children).

In our study, capillary blood samples were collected from fingertips. Children's fingers were prepared by alcohol wipe according to the CDC guidelines and samples were collected into capillary tubes following a finger prick. Capillary whole blood was collected in to metal-free phlebotomy tubes by a registered medical doctor. The sampling was done in one day, in the period from 7 h to 18 h. The process of sampling was made by ensuring there was no lead contamination from the surrounding environment.

Blood analysis in our study was done according to the protocol provided by ESA Biosciences Lead Care [25].This device has been used in some previous studies as well [24, 26, 27]. The maximum BLLs detection limit for the instrument was 65 µg/dL. The ESA lead care instrument was calibrated after the testing of every 48 samples. In order to control the impact of temperature on the BLLs analysis, the samples were analyzed immediately after the sample collection. All blood samples were analyzed at room temperature at the Public Health Institute in Kosovska Mitrovica.

Statistical analysis

The descriptive statistical method, statistical hypothesis testing and dependency testing were used in the study for the analysis of the primary data. The distribution of the sample data was assessed using the Kolmogorov-Smirnov normality test. The descriptive statistical methods included determination of the central tendency (mean, median), measures of variability (standard deviation) and relative numbers (data structure). To test statistical hypotheses, the Mann-Whitney U-test and the χ^2 test were used. The statistical hypotheses were tested for statistical significance at the level $p < 0.05$.

Results

Out of the total number of children involved in the study, 47 (57.7%) were males and 31 (42.5%) females. There was no significant difference according to gender between the groups ($\chi^2 = 0.368$; $p = 0.544$).

The average age in the group II was 5.06 ± 4.26, and in the group I it was 4.14 ± 1.60. There was no statistically significant difference by age between the groups (U = 502.5; $p < 0.001$) (Table 1).

The results obtained using WRPLOT model showed both groups within low-risk areas regarding industrial pollution exposure. We want to emphasize the fact that both groups were within the same risk zone (Figure 2).

The mean BLL value of the children included in the study was 12.54 ± 9.63 µg/dL. The lowest value was 1.1 µg/dL, and the highest one 41.8 µg/dL. The mean BLL in the children from the group II was 4.87 µg/dL (range 1.1–16.6 µg/dL), and the

Table 1

Sociodemographic characteristics of children

Characteristics	Roma camp (Group 1)	Kindergarden (Group 2)	*p*
Age (years), x̄ ± SD	4.14 ± 2.60	5.06 ± 1.26	< 0.001
Gender, n (%)			
male	24 (57.1)	23 (63.9)	< 0.001
female	18 (42.9)	13 (36.1)	

x̄ – arithmetic mean; SD – standard deviation.

mean BLL in the children from the group I was 19.11 μg/dL (range 6.8–41.8 μg/dL). There was a statistically significant difference in the mean values of lead concentration between the study groups (U = 39; $p < 0.001$). The children from the Roma camp (group I) had significantly higher BLL values than the children from the kindergarten.

Out of a total number of 78 children, 50% had concentrations of lead above 10 μg/dL. In the group II, even 85.7% of children were registered with BLL greater than 10 μg/dL, while in the group I the values of BLL greater than 10 μg/dL were noted in significantly lower percentage (8.3%). The difference was statistically significant ($\chi^2 = 46.43$; $p < 0.001$).

On the other hand, our results show that all the children from the group I had BLL greater than 5 μg/dL in comparison to 38.9% children from the group II. This difference was also statistically significant ($\chi^2 = 35.75$; $p < 0.001$) Table 2.

The distribution of capillary BLL in the children from both groups is shown in Figure 3.

The Regional Office of the WHO-EURO estimated that 25.0% of children, aged 2–3 years, in this area had increased BLL (≥ 10 μg/dL) in 2004 [24].

A study conducted in 1978 and 1980 aimed at determining the concentrations of BLL population near lead smelter in the town of Kosovska Mitrovica [28] showed increased concentration of lead in blood of the subjects (mean BLL value 23.4 ± 15.6 μg / dL, range 1.7–65.0 μg/dL). A recent study conducted in the Kosovska Mitrovica in 2009, 30 km south of Leposavić, was aimed at monitoring the concentrations of lead in blood of internally displaced Roma, Ashkali and Egyptian's children [29]. In this study the average BLL in the subjects was 18.8 μg/dL, in the range 5.9–41.8 μg/dL. Unfortunately, the results have not improved since this research was performed. So, in our sample even 71.8% of children had BLL higher than acceptable 5 μg/dL, which is certainly an alarming data. What is particularly important to note is that even 38.9% of children in the control group had

Table 2

Capillary blood lead levels (BLLs) in children

Characteristics	Roma camp (Group 1)	Kinder garden (Group 2)	*p*
BLL (μg/dL)			
median (range)	18.8 (6.8 –41.8)	4.1 (1.1–16.6)	< 0.001
x̄ ± SD	19.11 ± 8.4	4.8 ± 3.1	
BLL > 10 μg/dL, n (%)			
below	6 (14.3)	33 (91.7)	< 0.001
above	36 (85.7)	3 (8.3)	
BLL > 5 μg/dL, n (%)			
below	0 (0)	22 (61.1)	< 0.001
above	42 (100)	14 (38.9)	

n (%) – number (%) of children; x̄ – arithmetic mean, SD – standard deviation.

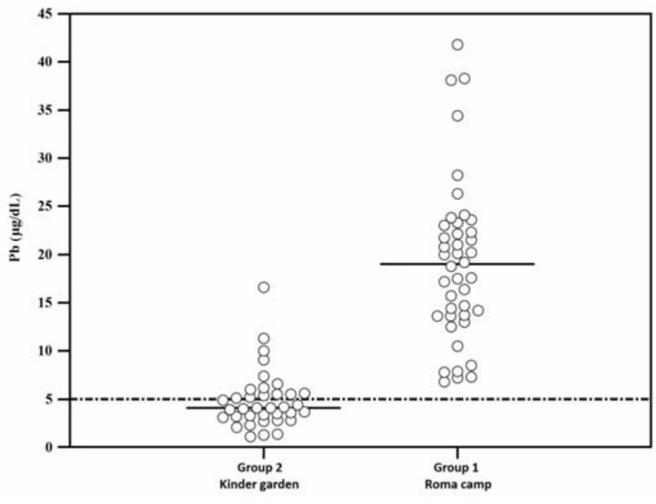

Fig. 3 – Distribution of the concentration of lead in capillary blood of the children from the kindergarden and the Roma camp.

Discussion

The toxicity of environmental lead is one of the most serious health threats to the children worldwide.

Our results show worryingly high BLL in the overall sample. The previous studies show similar results, too. lead levels above the acceptable limits. These data, along with the data from the mentioned studies, clearly indicate the presence of increased concentration of environmental lead which then enters the body. We have already mentioned that children are particularly vulnerable and exposed to this type of poisoning. Despite the fact that mining and ore processing have greatly been reduced at the region of testing, the main source of pollution are still landfills created after many years of industrial production, that cause pollutants spreading and contamination of the surrounding grounds by erosion of the land surface by wind-blown dust and land degradation caused by rainfalls. Pollutants enter the human body either directly or indirectly by contaminated plants and animals [30]. It is worth mentioning that many studies conducted worldwide have proved that increased BLL are the consequence of increases in lead levels in the environment [31, 32].

There was a statistically significant difference in BLL between the examined groups, indicating that children who live in Roma camps are additionally exposed due to increased concentrations of lead in their immediate environment. Our results show the alarmed concentration of lead in blood of the children (Table 2). Namely, in all the children BLL was found to be higher than the referential value. If we take into account that the average age of children in this portion of the sample was 4.14 ± 1.6 years, we come to the conclusion that health of these children at their earliest age is at serious risk. Additionally, even 85.7% children from this group had BLL greater than 10 μg/dL. Unfortunately, there are no previously conducted studies concerning children from this region to compare our results with.

Limitations of the study

We did not measure the concentration of lead in the environment because we did not have the permission from the people living in the Roma camp.

Children were not clinically examined.

According to "Brief guide to analytical methods for measuring lead in blood", limitations of a portable andic skipping voltammetry (ASV) are: not as accurate as other methods, can determine levels only up to 65 μg/dL.

Conclusion

Although both groups were located outside the zone of direct spread of pollution, the results indicate high concentrations of lead in blood of all the examined children. The concentration is higher in children who live in an environment in which illegal processing of lead waste takes place. As toxic effects of lead on children's health are numerous and extremely dangerous, we can conclude that health of children who live in this area is at extremely high risk. We can assume that health in some of these respondents has already been threatened.

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