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Predictors of environmental lead exposure among pregnant women – a prospective cohort study in Poland

Kinga Polańska[1], Wojciech Hanke[1], Wojciech Sobala[1], Małgorzata Trzcinka-Ochocka[2], Danuta Ligocka[2], Halina Strugała-Stawik[3], Per Magnus[4]

Nofer Institute of Occupational Medicine, Department of Environmental Epidemiology, Łódź, Poland
Nofer Institute of Occupational Medicine, Department of Toxicology and Carcinogenesis, Łódź, Poland
The Foundation for Children from Copper Basin, Legnica, Poland
Norwegian Institute of Public Health, Division of Epidemiology, Oslo, Norway

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Abstract

Blood lead levels (BLL) in women of child-bearing age have been decreasing in recent decades, but still remains a concern for long-term effects of child psychomotor development. The aim of the study was to characterize lead exposure among Polish pregnant women and assess the relationship between BLL and selected socio-demographic, economic and lifestyle factors. The study population consisted of 594 pregnant women who had been the subjects of the prospective Polish Mother and Child Cohort Study (REPRO_PL). The women were interviewed three times during pregnancy (once in each trimester). Lead concentration in the blood collected during the second trimester of pregnancy was analyzed using graphite furnace atomic absorption spectrometry (GF-AAS), or inductively coupled plasma mass spectrometry (ICP-MS). Active and passive smoking was analyzed by the cotinine level in saliva using liquid chromatography with tandem mass spectrometry (LC-MS/MS). The lead level in the blood ranged from 0.3 – 5.7 μg/dL, with a geometric mean (GM) of 1.1 μg/dL (GSD ±0.2 μg/dL). Statistically significant associations were found between BLL and factors such as maternal age (β=0.01; p=0.02), education (β=0.08; p=0.04) and prepregnancy BMI (β=0.1; p=0.001). Additionally, BLL increased with increasing cotinine level in saliva (β=0.02; p=0.06) and decreased with the increasing distance from the copper smelter (β=-0.1; p=0.009). Public health interventions, especially in regions with a higher level of exposure to lead, among women with lower SES and among smokers, are still reasonable.

Key words

Blood lead level, pregnancy, distance from smelter, cotinine

INTRODUCTION

Lead in one of the well-established environmental toxicants, and its negative effects, particularly in children as the most vulnerable group, continues to be a major public health issue worldwide [1, 2, 3, 4, 5]. It is well known that prenatal and postnatal lead exposure is associated with cognitive impairment and correlates with decreased IQ scores, impaired attention and behavioural problems. For effective prevention it is important to know the level of exposure and predictive factors for BLL.

Thanks to public health and regulatory activities, including restrictions on the use of tetraethyl lead as a petrol additive, a significant reduction of lead emission has been observed with more than 90% decrement in 24 countries in the EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe) region between 1990 – 2003 [6, 7]. As another example, in pre-school children in the USA, the lead level in blood dropped from 15 μg/dL, noted in the 1970s, to 1.9 μg/dL at the beginning of this century [3]. In Poland, analyses of BLL in children from the Legnica-Głogów Copper Basin and in Upper Silesia have been conducted [8, 9, 10, 11]. Based on the analyses performed by The Foundation for Children From The Copper Basin, the BLL in children decreased from 10 μg/dL in 1991 to 4 μg/dL in 2009 [11]. Although the magnitude of the socio-economic disparities has declined, higher BLL are still noted more frequently in a minority of children, children in low-income families and in those living closer to the source of emission (such as copper smelters).

The governmental agencies, including the Environmental Protection Agency (EPA) and the Centres for Disease Control and Prevention (CDC), continue to use the value of 10 μg/dL in whole blood samples as the criterion for concern in public health advise. However, no safe threshold for BLL has been identified. Significant poorer cognitive performance and behavioural problems have been identified in children with BLL less than 10 μg/dL, and even as low as 5 μg/dL. Additionally, the rate of decline in IQ scores might be greater at BLL below 10 μg/dL than it is at levels above 10 μg/dL [3, 12].

The aim of the presented study was to characterize lead exposure among Polish pregnant women and assess the relationship between BLL and selected socio-demographic, economic and lifestyle factors.

Address for correspondence: Kinga Polańska, Nofer Institute of Occupational Medicine, Department of Environmental Epidemiology, Teresy od Dzieciątka Jezus 8, 91-348, Łódź, Poland
e-mail: kinga@imp.lodz.pl

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MATERIALS AND METHODS

Study design and population. The current analysis is based on 594 pregnant women who participated in the prospective Polish Mother and Child Cohort Study (REPRO_PL; www.repropl.com). The complete description of the cohort has been published elsewhere [13, 14]. Briefly, pregnant women were recruited and followed up between 2007 – 2011 in maternity units or clinics from the following regions of Poland: Legnica (n=124), Łódż (400) and Silesia (70). The enrolment included only women in single pregnancies up to 12 weeks of gestation. Women whose pregnancies were assisted by reproductive technologies or pregnancies expected to be finished as spontaneous abortion, as well as women with chronic diseases as specified in the study protocol, were excluded from the study.

Questionnaires. Upon enrolment (up to 12 weeks of pregnancy), a detailed questionnaire was administered to each subject to collect socio-demographic data (age, marital status, number of children, educational level and employment status), medical and reproductive history, information about occupational exposure, and lifestyle factors (active and passive smoking, alcohol consumption and diet). Such information was updated twice during the pregnancy (in the 2nd and 3rd trimesters). Because the lead level was analyzed in blood collected during the 2nd trimester of pregnancy, the relevant questionnaire data were chosen from the same period and supplemented with information collected in 1st and 3rd trimester of pregnancy, when appropriate.

Analysis of questionnaire data was restricted to factors that potentially contribute to the lead exposure, including socio-demographic variables, smoking status verified by cotinine level in saliva, and subjective perception of traffic intensity close to the place of residence. Income was divided into 3 categories (low, medium and high), based on the following variables: type of housing (independent living), size of the apartment and the women's opinion regarding their financial status. Financial status of the family was described based on the following question: 'What is the financial status of your family?' Women who declared that they have sufficient money for current expenses and that it is possible for them to put a substantial sum aside, and those with an independent apartment bigger than 37m^2 were allocated into the high income category. These who indicated sufficient money for current expenses, with possibility to put aside some money, with or without an independent apartment bigger than 37 m^2, were allocated into the medium income category. Subjects who declared insufficient money for current expenses and living in an apartment smaller than 37m^2 were allocated into the low income category.

The data about medications (supplements) containing calcium and/or iron was based on information filled by the gynecologist (such information included: name of medication, dosage and frequency). Additionally, based on data from a food frequency questionnaire, information about the frequency (times a week) of consumption of following food: 1) calcium-rich food (such as milk, yogurt, cheese), 2) iron-rich food (such as red meats, iron-fortified cereals, prunes, raisins, dark leafy green vegetables), and 3) food as a major contributor to lead exposure (such as grains and grain-based products, potatoes or leafy vegetables) was identified. For each of the food groups (calcium-, iron-rich food and food as a major contributor to lead exposure) the sum of frequency (times a week) of consumption of selected food products, was calculated. For the subpopulation of pregnant women from the districts where copper smelters are located, such as the Legnica-Głogow copper district (Głogów Copper Smelter and Refinery and the Legnica Copper Smelter and Refinery), or from the Silesia district, the exact distances (in km) of place of residence (based on address) from the smelters were calculated. The potential lead exposure of each smelter was checked. 33 smelters (28 of which were in operation at time of the women's enrolment to the study) were taken into account. The distance to the closest smelter was assigned for each women. Of 194 pregnant women from the Legnica and Silesia regions, the exact address (place of residence) for 193 women (necessary for calculation of the distance from the smelter) was available, and these women were included in the analysis of the association between the distance of place of residence from the copper smelter, and the BLL.

Blood sample collection and analysis. During the 2nd trimester of pregnancy, a blood sample was collected from each pregnant women by venipuncture using S-Monovette with Lithium Heparin as anticoagulant, and frozen at -20 °C until analysis. Blood lead levels were analyzed in 2 laboratories: the laboratory at the Nofer Institute of Occupational Medicine (NIOM) in Łódż (n=427) and the laboratory at The Foundation for Children from the Copper Basin in Legnica (n=167).

At NIOM, blood lead concentrations were determined following the method of Stoeppler and Brandt (1978) with the Razniewska and Trzcinka-Ochocka (1995) modification [15]. The method based on deproteinisation of blood samples (400 µl) by addition of 5% nitric acid (1600 µl) was regularly checked by using reference materials (Seronorm, ClinCheck, BCR), and by participation in the UK National External Quality Assessment Schemes UK NEQAS (Wolfson EQA Laboratory, PO Box 3909 Birmingham, B15 2UE, UK) and in the German External Quality Control (G-EQUAS), according to Guidelines of the German Federal Medical Council. For these analyses, the technique of graphite furnace atomic absorption spectrometry (GF-AAS) (Perkin Elmer 4100ZL, AAnalyst 600) and inductively coupled plasma mass spectrometry (ICP-MS) (Perkin Elmer Elan – DRCe) was used. The laboratory is accredited (No. PCA, AB 215) according to PN/EN ISO/IEC 17025 to perform the analysis of lead and cadmium levels in blood in the fields of occupational medicine and environmental health. At the Foundation for Children from the Copper Basin in Legnica, the blood lead levels were analyzed using the GF-AAS method, as described above.

For 20 randomly selected samples, a cross-laboratory analysis was performed. The geometric mean was 30% lower for the NIOM laboratory, compared to the analysis performed at the laboratory at The Foundation for Children from the Copper Basin in Legnica (1.3 µg/dL vs. 1.7 µg/dL). The correlation was 0.83 (95% CI 0.62–0.93). All statistical analyses were adjusted for laboratory differences and the method used for lead level assessment (GF-AAS or ICP-MS).

Exposure to active and passive smoking. The cotinine level in saliva was analyzed at the Environmental Organic Pollutants Monitoring Laboratory, at NIOM using high performance liquid chromatography, coupled with tandem mass spectrometry/positive electrospray ionisation (LC-MS/MS-ESI$^+$) and isotope dilution method [16]. This procedure has been validated under ISO 17025 criteria and accredited by the Polish Centre for Accreditation (Certificate AB215). Briefly, a 0.25 ml of saliva was extracted with the SPE method on OASIS HLB 96-well Plate, and analysed on an XTerraC18 MS, 3.5 µm, 150×2.1 mm column (Waters) using Alliance High Performance Liquid Chromatograph (Waters). Quantitative analysis was made by a Quattro Micro API tandem mass spectrometer equipped with electrospray probe (Micromass/Waters) with MRM mode. The calibration curve was based on the peak area ratio of native cotinine and deuterium-labelled surrogate (internal standard). To ensure the highest quality of results, every series of analyses included QC samples, such as: repeated samples (already analysed), blank, in-house reference material, and calibration control samples (2 levels of concentrations).

Statistical analysis. Statistical inference was based on two-sided tests and a standard significance level of 0.05. Linear regression was used. Univariate and multivariate analyses were performed to identify the predictors of BLL. All variables at the level of significance p<0.1 (except the distance from smelter) identified in univariate analysis were included in the multivariate method. Analyses of the distance from smelter were conducted for a subset of observations (n=193), but the results were adjusted for all variables selected for multivariate analysis. The 3 variables: BLL, cotinine level and distance from copper smelter were log transformed. All variables were adjusted for methods of BLL analysis, including the 2 laboratories where the analysis were performed, and 2 method of assessment of BLL (GF-AAS or ICP-MS). The following variables were categorized into 2 categories: marital status (married-ref., unmarried), maternal education (>12 years of education-ref., ≤12 years of education), maternal employment (unemployed-ref., employed), number of children (no children prior to current pregnancy-ref., ≥1child), income (high-ref, low and medium), prepregnancy BMI (<25kg/m^2-ref., ≥25kg/m^2), traffic intensity in the area of residence (low-ref., high), and medications containing calcium and iron (no-ref., yes). Maternal age, consumption of calcium- and iron-rich food and food groups as the major contributors to lead exposure were analyzed as continuous variables.

Statistical analysis was performed using R software version 2.15.1 (R Core Team (2012) [17].

RESULTS

Socio-demographic characteristics of the study population. Table 1 presents descriptive statistics of the study population. 67% of the pregnant women were in the age category 20–30 years of age and one third (31%) of the study population were older than 30. More than 75% of the women were married and 63% had no children prior to the current pregnancy. About 61% of women had more than 12 years of education and 85% were employed. More than 60% of the subjects were allocated into the medium income category and 16% into low income according to the created subgroups described in the Method section. More than 35% of the study subjects reported road traffic close to their place of residence. Based on cotinine levels in saliva (>10 ng/ml), 16% of the pregnant women could be identified as smokers. 20% of the women were categorized as overweight or obese, based on prepregnancy BMI. About 40% of the women declared consumption of supplements containing calcium, and 50% of them supplements containing iron. Based on data from the food frequency questionnaire, the women consumed calcium-rich food on average 12 times a week (SD±5) and iron-rich food 8 times a week (SD±4). The women declared consumption of food groups identified as the major contributors to lead exposure 11 times a week (SD±3). For the subpopulation of the study sample (193 women) who lived in the region where copper smelters were located, the mean distance from the smelter was about 6 km (SD±4 km).

Level of lead exposure during pregnancy. On average, the BLL measured during the 2nd trimester of pregnancy was low (GM=1.1 µg/dL; GSD±0.2) and none of the women had levels above 6.0 µg/dL (range 0.3–5.7 µg/dL) (Tab. 1).

In univariate analysis, the BLL increased significantly with the age of the pregnant women (β=0.01; p=0.002) (Tab. 2). Overweight and obese women had a significantly higher BLL compared to those with normal weight (β=0.15; p<0.001). Marital status, employment, income and subjective perception of road traffic did not have a significant impact on BLL (p≥0.1). Neither the consumption of medications containing calcium and/or iron, nor the calcium and iron-rich food, as well as food groups identified as the contributors to lead exposure, had any statistically significant impact on BLL (p>0.1). The following factors: maternal education, number of children, smoking status and distance from copper smelter, were at the level of significance <0.1, and were finally included in the multivariable analysis.

Multivariable adjusted predictors of lead exposure. Multivariable analysis confirmed that significantly higher BLL was observed among older women (β=0.01; p=0.02), those with less years of education (β=0.08; p=0.04) and among those with prepregnancy BMI≥25kg/m^2 (β=0.14; p=0.001) (Tab. 3). The cotinine level in saliva was positively correlated with BLL (β=0.02; p=0.06). With increasing distance from the place of residence to the copper smelter, the BLL were significantly decreasing (β=-0.1; p=0.009). The number of children was not a statistically significant predictor of BLL (p>0.05).

DISCUSSION

Blood lead levels in women of child-bearing age have been decreasing in recent decades, but still remain a concern.

In the presented study, the BLL measured during the 2nd trimester of pregnancy was low (GM=1.1 µg/dL; SD±0.2), and all measurements showed levels below 6 µg/dL, which is below the CDC level currently considered to be benchmark for intervention (10 µg/dL). The National Health and Nutrition Examination Survey (NHANES) data from 1999 – 2002 indicate that women aged 20–59 have a mean level of 1.2 µg/dL, and that 0.3% of women have BLL above 10 µg/dL [18]. Analysis based on the Kraków cohort of pregnant women also showed low levels, although a little higher than in the presented study, GM for BLL (1.7µg/dL) [19]. On the other hand, none of the women from Kraków had levels above 4 µg/dL, which is lower than the maximum level

Table 1. Descriptive statistics of the study population

Variables	No. of women	%
Age (years); N=590		
≤ 20	10	1.7
20–30	394	66.8
≥ 31	186	31.5
Marital status; N=592		
Married	451	76.2
Unmarried	141	23.8
No. of children; N=592		
0	376	63.5
1	193	32.6
≥2	23	3.9
Education (years of education); N=593		
≤12	231	39.0
>12	362	61.0
Employment status; N=594		
Employed	503	84.7
Unemployed	91	15.3
Income; N=588		
High	140	23.8
Medium	356	60.5
Low	92	15.7
Prepregnancy BMI (kg/m^2); N=592		
<25	474	80.1
25-29.9	96	16.2
≥ 30	22	3.7
Cotinine level; N=552		
≤ 10 ng/ml	463	83.9
> 10 ng/ml	89	16.1
Traffic intensity in residence area; N=592		
Low	378	63.9
High	214	36.1
Medications containing calcium N=594		
No	350	58.9
Yes	244	41.1
Medications containing iron; N=594		
No	289	48.7
Yes	305	51.3
Calcium-rich food (frequency; times a week); N=536 Mean ± SD	11.6 ± 5.1	
Iron-rich food (frequency; times a week); N=530 Mean ± SD	7.5 ± 4.0	
Food groups as major contributors to lead exposure (frequency; times a week); N=536 Mean ± SD	11.4 ± 3.2	
Lead in maternal blood (μg/dL); N=594		
Mean	1.2	
SD	±0.6	
Geometric mean	1.1	
GSD	±0.2	
Min	0.3	
Max	5.7	
Distance from copper smelter (km); N=193		
Mean ± SD	6.1±4.1	

SD – standard deviation, GSD – geometric standard deviation

Table 2. Univariable analysis of log concentrations of maternal BLL related to potential predictor variables

Variables*	Beta coefficient	SE	p
Maternal age (per year)	0.01	0.004	0.002
Marital status (unmarried vs. married)	0.02	0.04	0.7
No. of children (≥1child vs. no child)	0.06	0.03	0.08
Maternal education (≤12 years vs. > 12 years of education)	0.06	0.03	0.08
Maternal employment (employed vs. unemployed)	0.08	0.05	0.1
Income (low and medium vs. high)	0.05	0.04	0.2
BMI (≥25 kg/m^2 vs. <25 kg/m^2)	0.15	0.04	<0.001
Cotinine level (ng/ml) (log transformed)	0.02	0.01	0.06
Traffic intensity in residence area (high vs. low)	0.02	0.03	0.7
Medications containing calcium (yes vs. no)	0.02	0.03	0.6
Medications containing iron (yes vs. no)	0.02	0.03	0.5
Calcium-rich food (frequency)	-0.001	0.003	0.8
Iron-rich food (frequency)	-0.001	0.004	0.7
Food groups as major contributors to lead exposure (frequency)	-0.005	0.005	0.3
Distance from copper smelter (log transformed)	-0.08	0.04	0.07

*All variables were adjusted for methods of BLL analysis

Table 3. Multivariable analysis of log concentrations of maternal BLL related to potential predictor variables

Variables*	Beta coefficient	SE	p
Maternal age (per year)	0.01	0.005	0.02
No. of children (≥1child vs. no child)	0.03	0.04	0.5
Maternal education (≤12 years vs. > 12 years of education)	0.08	0.04	0.04
BMI (≥25 kg/m^2 vs. <25 kg/m^2)	0.14	0.04	0.001
Cotinine level (ng/ml) (log transformed)	0.02	0.01	0.06
Distance from copper smelter (log transformed)**	-0.1	0.04	0.009

*All variables were adjusted for methods of BLL analysis
** model based on population from districts where smelters (as the potential source of lead exposure) exist (adjusted for other variables in the Table)

observed in the current analysis. The recruitment of pregnant women into the Kraków cohort was performed about 6 years earlier than for the presented REPRO_PL cohort. Additionally, in the previous cohort, the study participants were selected only from the city of Kraków (with less diversity of exposure), whereas in REPRO_PL the study participants were selected from different (more diverse) regions of Poland (from suburban as well as urban areas, and from the Legnica district where copper smelters as the potential source of lead exposure are located).

Previous epidemiological studies have indicated a few predictors of BLL such as: age, education, income, age of housing, living in urban areas and smoking [20].

The presented study confirmed the positive correlation of BLL with the age of pregnant women. The same association was observed in the analysis performed on the Kraków cohort [19]. The association with age could be explained, on one hand, by the fact that the older women might have been exposed to higher environmental lead in the past than the younger ones, and on the other hand, it could be the result of the accumulation of lead over time and/or remobilization of this heavy metal from bone stores during pregnancy [21].

Consistent with other studies, in the presented analysis, women with a few years of education had higher BLL than those who were more educated [3, 20]. This can be related to higher standards of environmental hygiene among the more educated women [21]. Other factors which can be proxies of socio-economic status (SES), such as employment and income, did not correlate with BLL in the presented study.

The income variable was categorized based on 3 selected variables (described in Methods), not by monthly income per family member, so that the educational level seems to be a more accurate estimate of SES. The employment category can be understood as the measure of SES, on one hand, but on the other, it can be identified as the source of exposure (especially in the regions where smelters exist).

In the current study, the association between cotinine level in saliva and BLL was on the border of significance (p=0.06), even after differences in educational level were controlled for. Additional adjustment for income and employments status (not shown) did not change the results. These findings are in agreement with earlier published results showing that active and even passive tobacco smokers have higher BLL than nonsmokers not exposed to environmental tobacco smoke [19, 20, 22]. As an example, the analysis performed on US women of reproductive age (20–49 year old) who were the subjects of NHANES III, indicated that smokers had 4.5 times higher odds ratio for high BLL (>4.0 µg/dL) than nonsmokers (p<0.001) [20] after controlling for socio-demographic variables. Additional analysis on US adults who participated in the above survey indicated BLL of 3.5 µg/dL in current smokers, 2.9 µg/dL in former smokers and 2.3 µg/dL in never smokers with high cotinine levels, and 1.8 µg/dL in those with no detectable cotinine. The adjusted linear model showed that geometric mean BLL were 30% higher (95% CI 24%-36%) in adults with high cotinine levels than they were in nonsmokers not exposed to environmental tobacco smoke [22].

Cigarette smoke may contain lead and other heavy metals, such as cadmium and mercury, which have been shown to be synergistic in experimental animals [21]. The estimates from Canada indicate that from 1968 – 1988 the levels of lead inhaled by smokers declined by about 62% as the consequence of decreasing the level of lead in ambient air [23]. The Massachusetts Benchmark Study estimated that mainstream tobacco smoke contains 60 ng of lead per cigarette, and that side-stream smoke contains 5–10 ng of lead per cigarette [24]. This level of lead is likely to be associated with the particulate fraction of tobacco smoke and absorbed through the respiratory system [22]. The mean lead levels in the indoor air of homes in which smoking occurs (21.8 ng/m^3) was higher compared with levels in homes where no smoking occurs (7.8 ng/m^3) [25]. Additionally, lead in particulate fraction could settle onto surfaces and food where it has the potential to re-expose people through the gastrointestinal route or the respiratory system [22].

Epidemiological data indicate that calcium and iron supplementation, consumption of calcium and iron-rich food may reduce BLL and foetal exposure to lead. In experimental studies of adults, absorption of a single dose of lead (100–300 µg lead chloride) was lower when the lead was ingested together with calcium carbonate (0.2–1 g calcium carbonate) than when the lead was ingested without additional calcium [21]. Also, based on experimental animal models, absorption of lead from the gastrointestinal tract has been shown to be enhanced by dietary calcium depletion or administration of vitamin D [21]. Iron deficiency may result in higher absorption of lead or, possibly, other changes in lead biokinetics that would contribute to BLL. Evidence for the effect of iron deficiency on lead absorption has been provided from animal studies. As the example, in rats, iron deficiency increases the gastrointestinal absorption of lead, possibly by enhancing binding of lead to iron binding proteins in the intestine [21]. In the presented analysis, neither the consumption of medications containing calcium and/or iron, nor the calcium and iron-rich food, as well as food groups identified as the contributors to lead exposure, had a statistically significant impact on BLL.

With the low levels of lead exposure observed in the current study and the lack of lead in the petrol used for vehicles, the diet need not necessarily be identified as the predictor of lead exposure. The Scientific Report of the European Food Safety Authority (EFSA), indicated that more than a half of the food tested had levels of lead at less than detection or quantification limits, and that adult exposure was estimated at 0.50 µg/kg body weight per day [26].

The study confirmed positive correlation between prepregnancy BMI and BLL after controlling for environmental, lifestyle and socio-demographic factors. The same result was observed in analysis on pregnant women from Kraków region [19]. This could be determined by the total caloric or dietary fat intake. Based on a study performed on preschool children, Lucas et al. speculated that bile secreted into the gastrointestinal to aid in the digestion and absorption of fat, may increase lead absorption [21, 27]. On the other hand, the influence of the total caloric intake may reflect increased intake of lead through food.

There were no statistically significant association between BLL and subjective traffic intensity in the place of residence. In the case of the elimination of tetraethyl lead as a petrol addictive, the traffic profile and intensity seems not to be a significant predictor of lead exposure. Although the possibility of misclassification exists (as this variable is based on subjective information from pregnant women and not actual traffic density), it seems to be less important. The environmental data monitoring carried out in 2010 by the Chief Inspectorate of Environmental Protection, demonstrated that there were no regions in Poland which exceeded the 0.5 µg/m^3 annual limit value for lead for the protection of human health [28, 29].

The results of the presented study indicate that BLL decreases with increasing distance from smelters as the source of lead exposure. The results were significant after controlling for socio-demographic and lifestyle factors (such as age, educational level, number of children, BMI and cotinine level). Additional adjustment for income and employments status (not shown) did not have an impact on the results. Thus, socio-economic status and related environmental hygiene standards should not have an impact on the association between distance from the smelter and BLL. The systematic biomonitoring of BLL in children from the Legnica-Głogów Copper Basin has been conducted by the Foundation for Children from the Copper Basin. Based on the analyses performed between 1991 – 2009, the mean BLL in children decreased over the years (from 10 µg/dL in 1991 to 4 µg/dL in 2009) [11]. Additionally, in agreement with the presented results, higher BLL were observed at a shorter distance from a copper smelter (BLL decreased with increasing distance from the smelter).

SUMMARY

In summary, the presented study conducted among Polish pregnant women showed low BLL. This is an example of the success of the public health intervention mostly aimed at eliminating lead from petrol. Although poor pregnancy outcomes were noted at maternal BLL higher than 15 µg/dL for birth weight, and above 30 µg/dL for spontaneous abortion or preterm delivery, which are much higher levels than observed nowadays, there is still concern about the impact of relatively low levels on child psychomotor development. The majority of the studies confirm the neuro-developmental (including cognitive and intellectual) effect of BLL above 10 µg/dL. These include reduced intelligence, behavioural problems and diminished school performance [3, 4, 12]. Many of the studies also confirmed the existence of an adverse effect below such levels, and additionally indicate that the rate of decline in IQ scores might be greater at BLL below 10 µg/dL than it is at levels above 10 µg/dL. It is important to note that still higher BLL was observed among older, less educated women, those who smoke cigarettes and lived close to a copper smelter. Taking this into account, there is still good reason to perform some programmes and interventions, especially in the regions with higher levels of exposure to lead, among women with lower SES and among smokers.

CONCLUSIONS

The blood lead levels observed in pregnant women did not exceed 6ug/ml. Statistically significant associations were found between BLL and factors such as maternal age, education and prepregnancy BMI. Additionally, BLL increased with increasing cotinine level in saliva and decreased with the increasing distance from a copper smelter.

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