Short Communication

Blood Lead Concentrations in Children from Industrial Areas in Southwestern Poland in 1995 and 2007

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Abstract

The Legnica-Głogów Copper Mining District has been the site of metal mining for more than 50 years. Intensive environmental actions have, more recently, been aimed at reducing emissions of harmful substances in the region. We compared the blood lead concentrations of children resident in the copper smelting district in southwestern Poland in 1995 and 2007.

The sample included 1,405 children, 7-15 years of age, resident in the same communities in the Legnica-Głogów Copper Mining District in 1995 (432 boys, 403 girls) and 2007 (279 boys, 291 girls). Blood samples were drawn (venipuncture) and analyzed for lead levels (Pb-B) with the same protocol in both years (atomic absorption spectrometry in a graphite furnace). Analysis of covariance, with age and age squared as covariates, was used to compare blood lead levels between years, regions (Głogów and Legnica), and genders. The prevalence of children with blood lead levels >6 μg/dl was compared between years, regions, and genders, and was compared with the chi square statistic (χ^2).

Blood lead level was significantly higher in 1995 (7.52±0.12 μg/dL) compared to 2007 (4.80±0.16 μg/dL), a decline of 2.72±0.19 μg/dL over the 12-year interval. Blood lead levels were higher in boys than in girls in each year, and declined between 1995 and 2007 in each gender, 8.61±0.16 μg/dL and 5.31±0.23 μg/dL, respectively, in boys, and 6.43±0.17 μg/dL and 4.29±0.22 μg/dL, respectively, in girls. Percentages of high blood lead levels (>6 μg/dL) were significantly higher in boys than girls in both years (1995: 77.5% and 51.9%, respectively; 2007: 32.6% and 16.5%, respectively), and declined significantly between 1995 and 2007 in both genders.

Blood lead levels decreased over the interval of 12 years in school children resident in the Legnica-Głogów Copper Mining District.

Keywords: youth, lead, pollution, copper industry

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Introduction

Lead is a relatively common heavy metal, occurring naturally at an average of 70 ppm in the Earth's crust. Adverse effects of lead were noted as early as Roman times, and probably earlier. Adult lead intoxication is a health hazard, but lead exposure affect children much more profoundly than adults. Physical growth and sexual maturation are significantly delayed. In addition, elevated blood lead levels are associated with irreversible mental and fine motor developmental deficits [1-4].

Increased blood lead levels are associated with environmental pollution caused by engine exhaust, lead plumbing, and lead smelter emissions. Children absorb lead more readily than adults because they are growing and increase cell numbers rather than replacing them. Children resident in areas with high concentrations of vehicular traffic and industrial pollution are thus more at risk for potentially negative consequences compared to adults [5, 6].

The Legnica-Głogów Copper Mining District in southwestern Poland has been the site of mining for 50 years, or almost two generations or more. Recent intensive environmental actions have functioned to reduce emissions of harmful substances in such areas with potential health-related benefits for the population resident in or close to industrial zones [7]. It is thus relevant to periodically evaluate blood lead levels and the growth and functional status of children in areas with a history of lead pollution.

In a survey conducted in 1995, blood lead levels and the growth and physical fitness of school children resident in several communities in the Legnica-Głogów Copper Mining District were evaluated [8-10]. Elevated blood lead was related to reduced height and weight, and especially to reduced leg and arm lengths [9], but did not directly influence several measures of physical fitness. Rather, elevated lead influenced physical fitness through its effect on physical growth [10].

The mines, plants, and smelting works in Legnica and Głogów generate large amounts of industrial waste, including heavy metals that contaminate soils and plants [11, 12]. Soils and crops near the smelting works had lead concentrations in the early 1990s that exceeded permissible levels compared with other regions of Poland [12, 13], but by 1995 average soil lead concentrations in four of the communities were 23 to 45 ppm and within acceptable limits [14]. The level of lead in cereals was also higher than permissible [12, 13]. The burden of lead in the atmosphere is an additional concern; it is higher compared to levels in food and water [15].

There have been recent efforts to reduce the emission of lead and other pollutants in the Legnica-Głogów Copper Mining District, but specific data for the region are limited [7]. A report from the company operating the smelters (KGHM Polska Miedź S.A.) indicated a reduction in lead emissions by 99% between 1985 and 2007 [16]. Particulate emissions in the Legnica-Głogów region were >3,000 tons per year in 1995, 1996, and 1997, and varied about 2,000 tons per year from 2002 through 2006, 1,400 tons per year in 2007, and 1,300 tons in 2008 [17-19].

National data for Poland, including the southwestern region, noted an increase in lead levels from 1990 to 1993, a rapid decline to 1998, and subsequently a slight decline to 2007. Lead emissions in Poland have declined from 647.5 tons/year in 2000 to 573.4 tons/year in 2007 [19]. The outflow of lead through rivers to the Baltic Sea was also reduced from 124.7 tons per year in 1995 to 68.9 tons per year in 2007 [19]. Although emissions have seemingly declined, it should be noted that lead and other heavy metals (Cu, Cd) and toxic compounds that have been emitted in the past remained in the soil and plants, and that the soil self-cleansing process takes many years in contrast relatively short self-cleansing times of the air (few days) and water (few years).

Given the apparent improvement in technology and associated reductions in emissions of lead and other pollutants since our initial study in 1995, the purpose of this study is to compare blood lead levels in school children in 2007 with those observed in the 1995 survey in the region. The study specifically compared blood lead levels in school children 7-15 years of age resident in six communities in the Legnica-Głogów Copper Mining District in 1995 and 2007.

Materials and Methods

The 1995 and 2007 surveys included school children 7-15 years of age from six communities, four in the vicinity of Głogów and two in the vicinity of Legnica. Both projects were approved by the Committee for Scientific Research Ethics of the University School of Physical Education in Wrocław (28. 04. 2007), by local administrators and school authorities in each community, and by parents. The four Głogów communities and respective population sizes in 1995 and 2007 were Brzeg Głogowski (495, 500), Kotla (1,424, 1,400), Kromolin (337, ~300), and Nielubia 563, ~300). The two Legnica communities and respective population sizes in 1995 and 2007 were Rosochata (793, 750), and Rzeszotary (775, 960). One community surveyed in 1995 (Pielgrzymka) and another surveyed in 2007 (Spalona) were excluded for this comparison of blood lead levels.

Blood samples were collected from 1,405 children 7 through 15 years of age in the six communities, 835 in 1995 (432 boys, 403 girls) and 570 in 2000 (279 boys, 291 girls). Sample sizes by community and region in each year are indicated in the results. The protocol for collecting and analyzing blood samples were identical in both years. Samples were collected in the office of the school nurse at the respective community schools by qualified personnel. Blood samples were drawn by venipuncture and vacutainer tube, and tested for lead by electrothermal atomic absorption spectrometry [20] in Hitachi Z-8200 a graphite furnace with a Zeeman correction for background and established laboratory practices. Analyses were done at the nationally accredited Laboratory of Heavy Metals (Legnica, Poland) using appropriate reference standards (Nycomed, Sweden). The minimum detectable level for lead was <0.1 μg/dL in the

Table 1. Sample sizes, means (M), and standard deviations (SD) for blood lead levels by region, community, year, and gender in school children 7-15 years of age.

Community	Boys						Girls					
	1995			2007			1995			2007		
	n	M	SD	n	M	SD	n	M	SD	n	M	SD
Głogów	328	8.98	3.38	227	5.71	2.38	298	7.06	2.42	235	4.57	1.68
Brzeg Głogowski	71	9.41	3.03	31	5.88	2.93	49	7.53	2.73	20	5.18	1.66
Kotla	135	8.18	2.99	109	5.16	2.01	145	6.41	2.1	109	4.23	1.51
Kromolin	67	9.89	3.97	20	6.31	2.24	56	8.08	2.41	14	5.09	1.58
Nielubia	55	9.29	3.59	67	6.34	2.52	48	7.33	2.5	92	4.75	1.83
Legnica	104	8.23	4.07	52	4.89	2.1	105	5.79	4.78	56	4.02	1.81
Rosochata	32	8.27	3.56	33	5.11	2.37	25	5.74	1.92	37	4.32	1.93
Rzeszotary	72	8.21	4.3	19	4.49	1.52	80	5.8	5.38	19	3.44	1.39
Total	432	8.8	3.57	279	5.55	2.35	403	6.73	3.25	291	4.46	1.71

laboratory. The Heavy Metal Toxicology Laboratory of the Foundation for Children from The Copper Basin regularly evaluates laboratory procedures for quality control [21].

Descriptive statistics (means, standard deviations) were calculated by year, region, and gender. Age and age squared were covariates in the analysis of covariance (ANCOVA) comparing blood lead levels between years (1995 and 2007), regions (Głogów and Legnica), and genders. Age controls for potential age-associated linear effects on blood lead levels and age^2 controls for potential non-linear effects associated with age were implemented. Since the distribution of blood lead levels were skewed (sk=2.17), blood lead was log transformed for analysis. Statistical analyses were performed using SPSS version 14 with Bonferroni adjustments for multiple comparisons. A significance level of $p<0.05$ was accepted.

Frequencies of children with blood lead levels >6 µg/dl were calculated by year, region, and gender, and compared with the chi square statistic (χ^2). Blood lead levels >6 µg/dl are generally considered high [22].

Table 2. Results of the analysis of covariance of differences in non-transformed and log transformed blood lead levels by year, region, gender, and age group with age and age squared as covariates.

	Non-transformed		Log transformed	
	F	p	F	p
Year	193.53	<0.001	294.35	<0.001
Region	18	<0.001	53.14	<0.001
Gender	67.34	<0.001	110.45	<0.001
Interactions:				
Year × Region	0.89	ns*	1.21	ns
Year × Gender	8.87	<0.01	4.72	<0.05
Region × Gender	0.09	ns	2.87	ns
Year × Region × Gender	0.99	ns	3.09	ns

*ns – not significant

Results

Sample sizes and descriptive statistics by gender, years, community, and region are summarized in Table 1. Results of the ANCOVA are summarized in Table 2. Blood lead levels differed significantly between years, regions, and genders. The age-adjusted mean for blood lead in the total samples in each year was significantly higher ($p<0.001$) in 1995 (7.52±0.12 µg/dL, CI 7.29-7.74) compared to 2007 (4.80±0.16 µg/dL, CI 4.49-5.11); blood lead level was lower by 2.72±0.19 µg/dL (CI 2.33-3.10) over the 12-year interval. The difference in blood lead levels of children in Głogów (6.58±0.09 µg/dL, CI 6.40-6.75) and Legnica (5.74±0.17 µg/dL, CI 5.40-6.08), though small (0.84±0.19 µg/dL, CI 0.45-1.22), was significant ($p<0.001$). In both years and regions, blood lead levels were also significantly ($p<0.001$) higher in boys (6.96±0.14 µg/dL, CI 6.68-7.23) than in girls (5.36±0.14 µg/dL, CI 5.09-5.63).

The interaction between year and gender was significant ($p<0.05$); other interactions were not significant (Table 2). The year X gender interaction indicated that both boys and girls have significantly lower levels of blood lead in 2007 compared to 1995 (Table 3). Age-adjusted means and standard errors for blood lead levels in boys in 1995 and 2007 were, respectively, 8.61±0.16 µg/dL (CI 8.28-8.93) and 5.31±0.23 µg/dL (CI 4.87-575). Corresponding statistics for girls in 1995 and 2007 were, respectively, 6.43±0.17 µg/dL (CI 6.10-6.75) and 4.29±0.22 µg/dL (CI 3.86-4.72). The lack of overlap in confidence intervals indicates that the differences between genders in each year were also significant.

Table 3. Age-adjusted[1] means (M), standard errors (SE) and 95% confidence intervals (95% CI) for blood lead levels by gender, region, and year.

Region	Year	Boys			Girls		
		M	SE	95% CI	M	SE	95% CI
Głogów	1995	8.99	0.16	8.67-9.31	7.06	0.17	6.73-7.39
	2007	5.7	0.19	5.32-6.08	4.55	0.19	4.17-4.92
Legnica	1995	8.22	0.29	7.66-8.78	5.79	0.29	5.23-6.35
	2007	4.92	0.41	4.12-5.71	4.03	0.39	3.27-4.80
Total	1995	8.61	0.16	8.28-8.93	6.43	0.17	6.10-6.75
	2007	5.31	0.23	4.87-5.75	4.29	0.22	3.86-4.72

[1]Data are adjusted for age and age squared using ANCOVA.

Table 4. Percentages of children with blood lead levels >6.0 µg/dL by gender, year and region, and results of chi square tests.

Gender/Region	Year	Blood Lead >6.0 µg/dL	Comparison between Years		Comparison between Regions		Comparison between Genders	
		%	χ^2	p	χ^2	p	χ^2	p
Males								
Głogów	1995	82.9						
	2007	34.8	138.66	<0.001				
Legnica	1995	60.6			22.65	<0.001		
	2007	23.1	19.53	<0.001	2.65	ns		
All Males	1995	77.5						
	2007	32.6	142.43	<0.001				
Females								
Głogów	1995	60.7					38.44	<0.001
	2007	17.4	101.32	<0.001			18.09	<0.001
Legnica	1995	26.7			36.1	<0.001	24.44	<0.001
	2007	12.5	4.31	<0.05	0.8	ns	2.08	ns
All Females	1995	51.9					60.58	<0.001
	2007	16.5	90.64	<0.001			20.08	<0.001

Percentages of children with high blood lead levels (>6 µg/dL) declined between 1995 and 2007 (Table 4). Overall, 65.1% of children (sexes combined) in 1995 had blood lead levels >6 µg/dL compared to 24.4% in 2007 (χ^2=225.33, p<0.001). Percentages of high lead levels were also significantly higher in boys than girls in both years (1995: 77.5% and 51.9%, respectively, χ^2=60.58, p<0.001; 2007: 32.6% and 16.5%, respectively, χ^2=20.08, p<0.001), and declined significantly between 1995 and 2007 in both sexes (boys: 77.5% to 32.6%, χ^2=142.49, p<0.001; girls: 51.9% to 16.5%, χ^2=90.64, p<0.001).

Comparisons of percentages of children with high blood lead levels between regions indicated a significantly higher prevalence in Głogów compared to Legnica in both sexes in 1995 (boys: 82.9% vs 60.6%, χ^2=22.65, p<0.001; girls: 60.7% vs 26.7%, χ^2=36.10, p<0.001), but no significant difference between regions in 2007 (boys: 34.8% vs 23.1, χ^2=12.65, ns; girls: 17.4% vs 12.5%, χ^2=0.80, ns). Nevertheless, percentages of children with high blood lead levels declined significantly in each region between 1995 and 2007 (Table 4).

Discussion

Blood lead levels of school children 7-15 years resident in the Legnica-Głogów Copper Mining District declined, on average, by 2.72±0.19 µg/dL between 1995 and 2007.

Blood lead levels were higher in boys than in girls in both years, but the difference between age-adjusted means for boys and girls was smaller in 2007 (2.14 μg/dL) compared to 1995 (3.30 μg/dL). Lead levels of children 7-15 years in the Legnica-Głogów Copper Mining District in 1995 were, on average, higher than those of children 7-11 years in the Bytom region in 1996-97 [4] and children 12-13 years in the Grodno region in the late 1990s [23], while corresponding levels in 2007 were similar to those of children in Bytom and Mosty in the second half of the 1990s.

The gender difference in blood lead lead levels is consistent with observations for children in Mosty, Grodno region [23] and in Dallas, Texas [24]. Males had higher blood lead levels than females. The difference in Dallas children was attributed to differences in personal hygiene [24]. Boys also tend to spend more time outdoors and are, on average, more engaged in physical activity than girls. Gender differences in physical activity during childhood and adolescence are well documented and physically active children tend to spend more time outdoors [25]. Increased inhalation of air pollutants, including lead, is likely during outdoor physical activities. With lead smelters as the point source of heavy metal pollution, the direct route of exposure to lead is inhalation of emissions (Pb dust in the air). Hence, time outdoors, a more physically active lifestyle, and less concern for hygienic conditions perhaps interact to influence elevated blood lead levels in boys compared to girls. Unfortunately, physical activity levels of children resident in the Głogów and Legnica region are not available.

A related factor in the elevated blood lead levels of boys compared to girls may be the greater sensitivity of boys to environmental stresses, including pollutants such as lead. Evidence from the Kraków Prospective Cohort Study suggests greater susceptibility of boys to prenatal exposure to low levels of lead as manifest in lower scores on the Bayley Mental Development Index at 3 years of age compared to girls [26].

Environmental regulation has changed in the post-Soviet era, and reducing pollution has become an important issue in Eastern Europe [27]. The present investigation provides empirical evidence that changes in environmental policy over the 12 years between 1995 and 2007 have had a positive effect with significant implications for children's health. Numbers of children with high blood lead levels (>6 μg/dL) declined significantly between 1995 and 2007 (Table 4). The United States Centers for Disease Control and Prevention [28] consider blood lead levels ≥10 μg/dL as needing active intervention. The numbers of school children resident in the Legnica-Głogów Copper Mining District who had blood lead levels ≥10 μg/dL were reduced from 181 (22%) in 1995 to 21 (4%) in 2007. Thus, health status of school children and presumably the communities has been significantly improved in the Copper Basin over the study period.

Results of the present study thus demonstrate that decreased lead emissions were associated with lower child blood lead levels in 2007 compared to 1995 among school children in the Legnica-Głogów Copper Mining District. Our previous investigations in this region indicated that growth status [9] and physical fitness [10] are significantly reduced with increased blood lead levels. Analyses of correlates of the reduced lead levels in the growth status and physical fitness of the school children and in the age at menarche are currently in process.

Lead is a global public health hazard, especially for children. Apparently, effects of lead on growth and neurodevelopment occur at any lead level because it is relatively well-established that effects are not a threshold phenomenon [29, 30]. The single most important intervention is to remove lead from the environment by abating emissions, or closing the point source of the pollution (i.e. smelters). With lead smelters as the point source of heavy metal pollution, the direct route of exposure is inhalation of emissions (Pb dust in the air). Secondary sources are Pb dust that has settled on eating and other household surfaces. Lead from these sources enter the body through eating, drinking, and from unwashed hands that have touched the lead dust. Effective non-medical interventions to reduce blood lead levels in children include improvement in personal hygiene and nutritional supplements (iron, calcium, magnesium). If the source of lead is water polluted by lead plumbing, then use of distilled water would be added.

In summary, environmental lead is associated with the increased blood lead levels in children. Blood lead levels decreased over the interval of 12 years (1995 to 2007) in school children resident in the Legnica-Głogów Copper Mining District. The trend provides empirical evidence that changes in environmental policy over this interval have had a significant, positive effect on blood lead levels in children which has significant implications for child health. It is anticipated that lead abatement will be associated with improved child health and growth status justifying further efforts to remove lead from the environment.

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