Lead and cadmium in human placentas and maternal and neonatal blood (in a heavily polluted area) measured by graphite furnace atomic absorption spectrometry

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Abstract

Objective—To measure the concentrations of the trace elements lead and cadmium in human placenta and in maternal and neonatal (cord) blood. To assess the influence of the strongly polluted environment on the content of metals in tissues and on the permeability of placenta to cadmium and lead. Various methods of mineralisation were tested before analysis.

Methods—Graphite furnace atomic absorption spectrometry was used for the determination of lead and cadmium. The samples for analysis were prepared by mineralisation under pressure in a Teflon bomb (HNO_3 , 110°C), by wet ashing under normal pressure ($\text{HNO}_3 + \text{H}_2\text{O}_2$ for 12 hours), and by microwave digestion in concentrated nitric acid.

Results—In analysed samples the following mean concentrations of cadmium and lead were found: in venous blood $\text{Pb} = 72.50 \text{ ng/ml}$, $\text{Cd} = 4.90 \text{ ng/ml}$; in placenta $\text{Pb} = 0.50 \mu\text{g/g}$, $\text{Cd} = 0.11 \mu\text{g/g}$; in cord blood $\text{Pb} = 38.31 \text{ ng/ml}$, $\text{Cd} = 1.13 \text{ ng/ml}$.

Conclusion—High concentrations of lead and cadmium were found in placentas and in maternal blood whereas in neonatal blood there was an increased concentration of lead and only traces of cadmium. It is concluded that the placenta is a better barrier for cadmium than for lead. Among the examined methods of mineralisation, microwave digestion was the best.

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Keywords: analysis; placenta; blood; heavy metals

Heavy metal pollution of an environment, particularly with lead and cadmium, results in the accumulation of these elements in human tissues. Analyses to measure the concentration of these elements in blood has become a routine procedure as a measure of pollution.

The influence of environmental pollution on pregnant women is of special interest and much attention has been paid to the investigation of heavy metals that are transferred from the mother's blood to the developing fetus, and to their influence on pregnancy outcome and fetal development. The biological material that seems to be the most useful in this

kind of analysis is the human placenta. During delivery, both blood and placenta are readily accessible tissues. Therefore, blood as well as placental analysis can help to answer the question as to what extent the placenta functions as a protective barrier between mother and fetus. The accumulation of heavy metals in pregnant women depends on the women's exposure to lead and cadmium from industrial and environment pollution, from water and food, smoking or the use of other chemical products. Environmental pollution is generally considered to be the main contributor to the body burden of heavy metals.¹⁻¹⁵

There are several publications devoted to the analysis of measurements of concentrations of heavy metals in human placentas. Most of the examined samples came from polluted regions.^{1-3,6-15} Only a few of the reported studies deal with analysis of samples originating from regions of low pollution.¹⁶⁻²⁰

The influence of lead and cadmium on the fetus is not completely established, especially in the situations of high exposure that can occur in very polluted areas. Also, there is no definitive answer to the question of the effectiveness of the placenta as a barrier for these metals. On the basis of the results obtained different authors draw different, sometimes contradictory conclusions. Some of them claim that both lead^{5,7,9,10,12-16,21,23} and cadmium^{5,7,15,19,20,23} cross the barrier, whereas others maintain that neither of them do.²⁴ There are also reports suggesting that lead crosses the placental barrier, but cadmium does not.¹⁶ On the other hand, there are reports indicating that it is lead, not cadmium that is blocked by the placenta.^{25,26} These contrary opinions also relate to the influence of a polluted environment on metal concentrations in the placenta. Some authors have reported that concentrations of heavy metals in the placenta depend on a woman's exposure to these elements during pregnancy^{1,3,6,12} whereas, others have found no such correlation.²⁷⁻³⁰

The analyses of the placenta and maternal and neonatal blood are discussed in this paper. Samples for the analyses were collected from women inhabiting the industrial district of Upper Silesia, one of the most polluted regions in Poland. Upper Silesia covers about 2.1% of the total area of Poland and it is inhabited by 10% of the total Polish population. In this area 98% of Polish coal and 100% of zinc and lead ores are mined, and 53% of steel, 35% of coke, and 29% of energy are produced. The industry is the source of

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Concentrations of trace elements in human placentas and maternal and neonatal cord blood

Variable	Placenta ($\mu\text{g/g}$)	Venous blood (ng/ml)	Cord blood (ng/ml)
Cadmium			
Number	24	24	15
Mean	0.11	4.90	1.13
Median	0.10	4.40	1.00
SD	0.07	2.43	0.23
Minimum	0.01	1.8	0.85
Maximum	0.30	12.20	1.60
Lower quartile	0.07	2.95	0.98
Upper quartile	0.16	5.85	1.30
Interquartile range	0.10	2.90	0.32
Lead			
Number	24	24	15
Mean	0.50	72.50	38.31
Median	0.57	75.35	38.80
SD	0.21	22.25	7.23
Minimum	0.05	30.50	22.30
Maximum	0.80	110.00	48.20
Lower quartile	0.39	55.65	33.00
Upper quartile	0.34	87.50	43.50
Interquartile range	0.25	31.85	10.50

enormous emissions of dust and gases into the atmosphere. Over 50% of industrial solid waste is generated in the region.

In the area, mean lead and cadmium fallout is 86 $\text{mg/m}^2/\text{year}$ and 4.79 $\text{mg/m}^2/\text{year}$ respectively (global fallout is 14.16 t/year and 0.79 t/year respectively). Mean (range) concentrations in air are $\text{Pb} = 0.45$ (0.11–0.69) $\mu\text{g/m}^3$ and $\text{Cd} = 11.3$ (2.1–25.4) ng/m^3 . A previous study³¹ on the analyses of placentas originating from women living in this region showed high concentrations of lead and cadmium in the tissue, and their relation to high industrial and transport pollution.

Materials and methods

COLLECTION OF SAMPLES

The placental samples (about 20–30 g) were always taken from the same location (cotyledons). Immediately before delivery, about 30

cm^3 of venous blood was taken from the mother, and after birth about 5 cm^3 of blood was taken from an umbilical cord of the baby. The samples were frozen immediately and stored at -20°C in acid washed and pre-rinsed polyethylene tubes until analysis.

PREPARATION OF SAMPLES

The placental samples were dried to a constant weight in quartz containers at a temperature of $105(2)^\circ\text{C}$. The blood samples were mineralised as whole blood. The mineralisation of all the samples was carried out with concentrated nitric acid (HNO_3) (Suprapure Grade E, Merck, Darmstadt, FRG) in a MLS 1200 MEGA microwave digestion system (Milestone—Italy). The mineralisation of placenta and blood was also performed under pressure in a Teflon bomb at 110°C with HNO_3 , and by wet ashing under normal pressure with $\text{HNO}_3 + \text{H}_2\text{O}_2$.

MEASUREMENT OF LEAD AND CADMIUM

Because of very low concentrations of metals, special attention had to be paid to the background values. Water was deionised and then doubly distilled in a quartz apparatus. All glassware, plastic tips, and autosampler cups were cleaned by soaking for 24 hours in 25% (v/v) HNO_3 . After cleaning, all the containers were thoroughly rinsed with water. Lead and cadmium were measured by graphite furnace atomic absorption spectroscopy (GF AAS). Electrothermal atomic absorption was carried out with a Carl Zeiss Jena Model 30 spectrometer with deuterium arc background correction. L'vov platforms were also used. Argon was applied as a neutral gas at a flow rate of 200 cm^3/min .

Wavelength and the temperature details for lead and cadmium measurements were as follows: $\lambda_{\text{Pb}} = 283.3\text{nm}$, $\lambda_{\text{Cd}} = 228.8\text{nm}$; dry 110°C , 120°C ; ash 350°C , 350°C ; atomise

Figure 1 Frequency histograms of lead and cadmium in placentas.

Figure 2 Frequency histograms of lead and cadmium in venous blood.

Figure 3 Frequency histograms of lead and cadmium in neonatal cord blood.

2000°C, 1200°C; cleaning 2900°C, 2900°C. Solutions of Pb and Cd (Tritisol grades from E Merck) were used as the standard solutions.

Results

The table and figures show the results of the analyses of maternal and neonatal cord blood and the placenta for lead and cadmium concentrations. Both mineralisation under pressure in a Teflon bomb (HNO_3 , 110°C) and wet ashing under normal pressure (HNO_3 + H_2O_2 , for 12 hours) were reliable. The microwave technique, however, seemed to be the fastest means of mineralisation and it also minimised contamination. The microwave digestion system gave a clear colourless solution, completely void of organic matrix solutions. Under the conditions chosen for analysis, no difficulties were encountered during the measurement of lead and cadmium. Usually, three calibration points were used and all the samples were measured in duplicate.

Discussion

The results obtained show that the lead and cadmium concentrations in maternal blood and placentas were higher than those determined by other authors.^{6 16 17 28} Undoubtedly, the results reflect the influence of the upper Silesian polluted environment, which the pregnant women inhabited. In the samples of placenta examined 0.50 µg/g of lead and 0.11 µg/g of cadmium were found. This contrasts with results of other investigators, who examined placentas from women not exposed to heavy metals and found lower concentrations ($\text{Pb} = 0.11 \mu\text{g/g}$, $\text{Cd} = 0.03 \mu\text{g/g}$ ¹⁶; $\text{Cd} = \text{ppb}$ ²⁸; $\text{Pb} = 0.37 \mu\text{g/g}$ ¹⁷).

There were similar differences in the cadmium and lead concentrations in blood samples from the mothers. Other authors have reported similarly high concentrations in placenta and blood samples from areas highly polluted by battery factories, smelters, and refineries.^{10-12 20} Lead and cadmium were also measured in neonatal cord blood, and although cadmium concentrations were very low our study agrees with earlier reports.^{13 16 21 22} It is assumed that the placenta is a better barrier against cadmium than it is for lead. Only traces of cadmium are transferred to the

neonatal blood despite relatively high concentrations in maternal blood and tissues.

In earlier studies where only placental samples were examined it was found that high concentrations of cadmium and lead were correlated with low values on the Apgar scale ($P < 0.01$; low values on the Apgar scale = poor condition of a newborn baby). My results suggest that passage of lead through the placenta may be the main cause of fetal intoxication. Other authors found a similar correlation between lead concentration in the placenta and blood samples, and fetal deaths or preterm births.¹¹

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