

*Letter to Editor*

# Lead, Cadmium, Copper and Zinc Concentrations in Blood and Hair of Mothers of Children with Locomotor System Malformations

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## Abstract

Cadmium, copper and zinc concentrations in the blood and hair of 51 women after delivery of children with locomotor system malformations (Group I) and, as a control, 46 women who gave birth to healthy children (Group II) were different but none of the values were statistically significant. However, lead concentrations in the blood and the hair of women from the Group I (median: 109.63 µg/L and 1.31 µg/g) were notably higher than in Group II (median: 66.45 µg/L and 0.58 µg/g, respectively). Maternal lead concentrations in the blood of 17 women from Group I decreased to 60.73 µg/L, and in their hair to 1.20 µg/g after 12 months.

We observed a significant correlation between lead concentrations and copper levels in the hair of the mothers.

**Keywords:** metals, children, locomotor system malformations

## Introduction

The first reports of the toxicity of lead on newborns appeared at the beginning of the 19<sup>th</sup> century in England. The population of women exposed to lead either at work or in their home environment showed a correlation between high lead content in the blood and the low birth weight of their children [1].

It was also shown that lead toxicity may cause mental and psychomotor retardation of children without encephalopathy [2, 3, 4]. According to B. Dudek, blood lead

levels between 100 and 150 µg/L are in the lower range of a concentration which may cause infantile development disorders [5]. Cadmium toxicity may cause premature birth, low birth weight and even disturb production of chorionic gonadotrophin by the placenta and impair development of the newborn vascular system [6]. Fang et al. demonstrates that cadmium affects the genes involved with growth regulation of initiated cells [7]. Maternal zinc deficiency in rats and humans is teratogenic [8, 9]. Krachler et al. [10] indicated a mobilization of copper in the mother's body during pregnancy. Copper deficiency may cause bone disorders (11). The correlation between metal toxicity, trace elements, and newborn congenital

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malformations is still controversial. In our research we assessed the content of lead, cadmium, zinc and copper in the blood and hair of women after the delivery of children with locomotor system malformations.

## Experimental Procedures

### Subjects

During the 3-year period 1997-1999, there were 4,519 live births at the teaching hospital. The newborns were clinically examined with ultrasound screening for hip dysplasia, performed by orthopaedic surgeons usually 7-14 days after birth. During these examinations we found 51 newborns with locomotor system malformations. According to the International Classification of Diseases (ICD-10), the locomotor system malformations in the newborns were: limb reduction defects - 4, clubfoot - 21, hip dislocation - 14, syndactylia - 4, polydactylia - 5, arthrogryposis - 3 cases. Their mothers (Group I), aged 17-37 years (mean age 26.2 years) gave consent to allow the measurement of lead, cadmium, copper and zinc concentrations in their blood and hair. 46 mothers (Group II), aged 17-42 years (mean age 28.1 years) who gave birth to healthy children during the same 3-year period, and who voluntarily gave consent to allow the same measurement of lead, cadmium, copper and zinc concentrations in their blood and hair, served as our control group. Samples of blood and hair from 97 women were collected during the second week after delivery. Samples from 17 women from Group I were collected for a second time 12 months from delivery, after the termination of lactation. We obtained the consent of the local Committee of Ethics to perform the examinations.

### Dietary Data

Food-frequency questionnaires were implemented to collect the dietary data. Women were asked to complete a questionnaire concerning the consumption frequency of 25 food products: milk, white bread, wholemeal bread, noodles and macaroni, fresh meat (pork or beef), luncheon meat, organ meat (giblets, tripe, etc.), poultry, fish, cottage cheese, cheese, eggs, butter, pork lard and bacon, vegetable oil, margarine, legumes, vegetables, potatoes, fruit, honey, sweets and pastry, coffee, tea, alcohol. The consumption frequency of foods was estimated according to the following criteria: frequent consumption was defined as intake of a certain food twelve to thirty days monthly, except fish, which were eaten four to twelve days a month. Food products eaten less frequently were classified into the "sporadic consumption" group.

### Sample Storage and Determination

Blood samples were collected in a vacuum test tube Vacutainer from Becton Dickinson (France). The whole blood, before measuring the content of lead and cadmium,

was deproteinized with 1 mol/L nitric acid and diluted in 1% Triton X-100 (Sigma). After stirring and centrifugation the blood was diluted with 0.1 mol/L nitric acid to the necessary volume. The deproteinization of serum for zinc and copper content determination was performed by the same method as used for the whole blood. Certified reference materials – Seronorm Trace Elements 404108 (Nycomed, Norway) for whole blood, – Seronorm Trace Elements 704121 (SeroAS, Norway) for serum and GBW 09101 for human hair (from the Chinese Academy of Science) – were used to test the accuracy of this method. Calibration solutions of proper concentration were prepared from standard solutions from the Fluka company (concentration 1g/L).

For metal content determination in hair, samples 3-4 cm in length from the scalp were collected, and a washing procedure recommended by the International Atomic Energy Agency (IAEA), was used in order to remove exogenous contamination. Afterwards, samples were washed three times in acetone, deionized water, acetone and finally in absolute alcohol.

Digestion by concentrated nitric acid (for atomic spectroscopy, Spectrosol, England) was done in a microwave mineralizer (BM-1z UniClever – Plazmatronika, Poland).

The metal content was analyzed using atomic absorption spectrometry on a Z-5000 instrument Hitachi (Japan) with Zeeman background correction. Copper and zinc content were analyzed by flame atomic absorption spectrometry-FAAS (air-acetylene flame). Lead and cadmium content were analyzed by electrothermal atomization (ETAAS) in a graphite tube coated by pyrolysis from CPI (USA). Lead content measurement was performed with the use of 0.5% ammonium dihydrophosphate (Sigma, Germany) and cadmium content with 0.1 % palladium nitrate (Merck, Germany), as a matrix modifier. The Department of Bromatology participates in a quality control program with the National Institute of Hygiene. The results of the quality control analyses were in good agreement with reference values.

### Statistical Analysis

For statistical analysis a STATISTICA for Windows, v.5.97, StatSoft Inc. Pack was used. Statistical analysis was performed with a non-parametric test. When not otherwise stated, values of  $p < 0.05$  were considered significantly different.

## Results

The measured lead, cadmium, copper and zinc contents in blood and hair of women after delivery of children with locomotor system malformations (Group I) and women who gave birth to healthy children (Group II) are shown in Table 1. In both groups mean metals content in blood and hair were within a reference range. The concentrations of cadmium, copper and zinc in blood and hair were not significantly altered in all mothers.

In Group I, mean blood lead content was 132.71  $\mu\text{g/L}$  (median 109.63  $\mu\text{g/L}$ ) and was statistically higher than in Group II – 62.97  $\mu\text{g/L}$  (median 66.45  $\mu\text{g/L}$ );  $p=0.0000001$ . Blood lead concentrations higher than 100.00  $\mu\text{g/L}$  were found in 29 women from Group I. Mean hair lead content in Groups I and II were 1.93  $\mu\text{g/g}$  (median 1.31  $\mu\text{g/g}$ ) and 0.77  $\mu\text{g/g}$  (median 0.58  $\mu\text{g/g}$  ( $p<0.001$ ), respectively. There was the correlation coefficient ( $r=0.24$ ;  $p=0.05$ ) between lead and copper in hair of all mothers and was highest in mothers of malformed children ( $r=0.34$ ;  $p<0.03$ ).

Lead levels in blood and hair samples collected for the second time from 17 women from Group I, 12 months after delivery, are shown in Table 2. 12 months after the initial test their blood and hair lead content were 60.73  $\mu\text{g/L}$  and 1.20  $\mu\text{g/g}$ , respectively.

The mean gestational ages in Groups I and II were 38.03 and 39.81 weeks, respectively. Those differences were statistically significant ( $p<0.03$ ).

Environmental factors, the drinking of alcohol and coffee, cigarette smoking, as well as the nutritional habits of pregnant woman were not statistically associated with the concentrations of lead, cadmium, zinc and copper in blood and hair (except Cu). Only frequent consumption of organ meats (giblets, etc.) was associated with statistically increased hair copper (median 15.5  $\mu\text{g/g}$ ;  $p<0.03$ ) in 7 mothers of malformed children with clubfoot – 4, limb reduction defect – 2 and polydactylyia – 1.

## Discussion

In our study lead, cadmium, zinc and copper concentrations in the blood and hair of women from both groups were within the reference range [11-16] (Table 1). No differences were found between blood and hair concentrations of cadmium, copper and zinc in mothers of malformed children and in the mothers of the control group. Stoll et al. [17] have also shown that maternal plas-

Table 1. The content of lead, cadmium, copper and zinc in blood and hair of the examined groups of mothers and reference range for the general population.

| Metal | Biological material            | Mothers of children with locomotor system malformations (n=51) |        | Mothers of healthy children (n=46)   |        | Reference range      |
|-------|--------------------------------|--|--------|--------------------------------------|--------|----------------------|
|       |                                | x $\pm$ SD<br>min. – max.                                      | Median | x $\pm$ SD<br>min. – max.            | Median |                      |
| Pb    | whole blood<br>$\mu\text{g/L}$ | 132.71 $\pm$ 77.64<br>12.55 – 300.80                           | 109.63 | 62.97 $\pm$ 35.15<br>6.75 – 151.63   | 66.45  | 0.0-350.0 [12]       |
|       | hair<br>$\mu\text{g/g}$        | 1.93 $\pm$ 2.17<br>0.00 – 10.69                                | 1.31   | 0.77 $\pm$ 0.71<br>0.00 – 2.35       | 0.58   | 4.06 $\pm$ 4.87 [13] |
| Cd    | whole blood<br>$\mu\text{g/L}$ | 2.04 $\pm$ 1.78<br>0.33 – 8.23                                 | 1.53   | 2.81 $\pm$ 2.46<br>0.00 – 12.10      | 2.59   | 0.52-2.63 [14]       |
|       | hair<br>$\mu\text{g/g}$        | 0.84 $\pm$ 1.56<br>0.04 – 10.01                                | 0.47   | 0.71 $\pm$ 1.21<br>0.03 – 4.06       | 0.22   | 0.41 $\pm$ 0.38 [13] |
| Cu    | serum<br>$\text{mg/L}$         | 1.11 $\pm$ 0.32<br>0.65 – 2.47                                 | 1.04   | 1.18 $\pm$ 0.23<br>0.76 – 1.77       | 1.16   | 0.75-1.50 [15]       |
|       | hair<br>$\mu\text{g/g}$        | 11.69 $\pm$ 5.00<br>1.20 – 26.92                               | 10.63  | 12.28 $\pm$ 4.24<br>5.14 – 21.32     | 11.26  | 5.0-55.0 [16]        |
| Zn    | serum<br>$\text{mg/L}$         | 0.73 $\pm$ 0.20<br>0.36 – 1.18                                 | 0.74   | 0.66 $\pm$ 0.21<br>0.20 – 1.19       | 0.64   | 0.70-1.20 [15]       |
|       | hair<br>$\mu\text{g/g}$        | 217.87 $\pm$ 54.21<br>85.48 – 437.92                           | 212.23 | 224.21 $\pm$ 68.40<br>82.24 – 443.81 | 210.80 | 105-309 [16]         |

x - mean; SD – standard deviation; n – numbers of mothers

Table 2. Lead concentration in blood and hair of mothers of children with locomotor system malformation in second week and 12th month after delivery.

| Metal | Biological materials           | Second week after delivery n=51    |        | 12 <sup>th</sup> month after delivery n=17 |        | Significance  |
|-------|--------------------------------|------------------------------------|--------|--|--------|---------------|
|       |                                | x $\pm$ SD<br>min. – max.          | Median | x $\pm$ SD<br>min. – max.                  | Median |               |
| Pb    | Whole blood<br>$\mu\text{g/L}$ | 132.71 $\pm$ 77.64<br>12.55-300.80 | 109.63 | 60.73 $\pm$ 23.08<br>34.50-105.20          | 53.78  | * $p=0.00037$ |
|       | Hair<br>$\mu\text{g/g}$        | 1.93 $\pm$ 2.17<br>0.001-10.69     | 1.31   | 1.20 $\pm$ 0.97<br>0.144-3.545             | 0.85   | $p=0.182$     |

x - mean; SD – standard deviation; n – numbers of mothers

ma concentrations of zinc and copper in 12 malformed children with limb reduction defects did not differ from the control. Serum Cu increases during pregnancy up to at least twice the normal concentration of healthy adults [10] and decreases to a normal level within two weeks post partum [18]. Our results demonstrate that the mean concentration of cadmium in blood was near the reference range [13] but was 4-5 fold decreased (0.56 µg/L) than in 83 pregnant women from Szczecin [19]. The transplacental gradient for cadmium was 37.5% [19]. Only a weak positive correlation ( $r=0.34$ ) exists between concentrations of lead and copper in the hair of mothers of children with locomotor system malformations, but no correlation between maternal lead levels and cadmium and zinc in the blood and hair, could be found. However, we found that mothers of children with locomotor malformations had higher blood and hair lead content (mean: 132.71 µg/L and 1.93 µg/g respectively) in comparison to mothers from the control group (mean: 62.97 µg/L and 0.77 µg/g respectively). Measurement of lead concentration was repeated 12 months after delivery in samples of blood and hair from 17 women from Group II, who consented to this procedure. Lead concentrations in the blood of those women during the first test averaged 132.71 µg/L. After 12 months we could observe a decrease to 60.73 µg/L. In the same group of 17 women, hair lead content decreased from 1.93 to 1.20 µg/g (Table 2).

A precise interview, related to social environment and diet, was conducted prior to the testing phase, in order to make research conditions comparable. The primary aim of this study was to find that coffee drinking, alcohol and cigarette smoking as well as the nutritional habits of pregnant woman did not influence lead, cadmium and zinc concentrations in blood and hair [20]. At present, only frequent consumption of organ meat was statistically associated with hair copper levels in mothers of children with locomotor system malformations.

The higher content of lead in the blood and hair of women from Group I could be explained by its mobilization from the bones during pregnancy. Earlier research has showed that pregnancy and lactation may change the metabolism of calcium, and along with decalcification, increase lead mobilization from bones where it was accumulated during earlier exposure [21]. M. E. Markowitz and Xia-Ming Shen in their research [22] in a population of Afro-American and Spanish-American women from poor neighborhoods in the Bronx, New York, showed changes in blood lead concentrations during pregnancy. They observed in the second and third term of pregnancy and in the second month after delivery, decreasing lead concentrations in the tibia with a simultaneously growing concentration in the blood. In the second term of pregnancy lead blood content was 120 µg/L, in the third term – 190 µg/L, and two months after delivery – 380 µg/L. Work and home environment was the source of lead contamination and long-term exposure to leaded paint is mentioned as the most probable source. Mobilization of

lead from bones during pregnancy may cause a significant risk for fetal development. Lead easily penetrates the umbilical cord and its increased concentration in fetal circulation may be detected [22, 23, 24]. Blood lead values in newborns higher than 100 µg/L are considered to be high and currently define childhood lead poisoning [22].

The results of our study demonstrated that when the concentration of lead in the blood and hair of mothers of children with locomotor system malformations increased, concentrations of cadmium, copper and zinc did not differ from controls. The results of the present study indicated too, that copper levels in the hair may depend on the frequency of organ meat consumption.

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## The Chernobyl Accident: A Comprehensive Risk Assessment

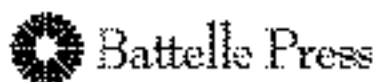
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The authors, all of whom are Ukrainian and Russian scientists involved with the Chernobyl nuclear power plant since the April 1986 accident, present a comprehensive review of the accident. In addition, they present a risk assessment of the remains of the destroyed reactor and its surrounding shelter, Chernobyl radioactive waste storage and disposal sites, and environmental contamination in the region. The authors explore such questions as the risks posed by a collapse of the shelter, radionuclide migration from storage and disposal facilities in the exclusion zone, and transfer from soil to vegetation and its potential regional impact.

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