Internal lead and cadmium exposure in 6-year-old children from western and eastern Germany

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Abstract Lead and cadmium levels in blood and deciduous teeth (shed incisors only) of 6-year-old German children were determined in 1991 in a large epidemiological study carried out in rural and urban areas of western Germany (Duisburg, Essen, Gelsenkirchen, Dortmund, Bochum) and eastern Germany (Leipzig, Halle, Magdeburg, Osterburg, Gardelegen, Salzwedel). In total, blood lead and cadmium levels of 2311 German children and tooth lead and cadmium levels of 790 German children were analyzed. Blood lead levels were generally low in all study areas with geometric means between 39.3 μg/l and 50.8 μg/l in the western German and between 42.3 μg/l and 68.1 μg/l in the eastern German study areas. The mean blood lead level of Turkish children (n = 213) living in the western German study areas was 50.1 μg/l and thus 5.6 μg/l higher than the overall geometric mean of the western German children. The higher exposure may be explained by a higher oral uptake from food and different living conditions. These children were excluded from multiple regression analysis because they were all living in the western study areas. The mean tooth lead levels ranged between 1.50 and 1.74 μg/g in the western and between 1.51 μg/g and 2.72 μg/g in the eastern study areas. Thus, they show a distribution pattern similar to blood. Blood and tooth lead levels were higher in urban than in rural areas and higher in the eastern German than in the western German study areas. With regard to the blood and tooth cadmium concentrations, no significant differences between the study areas could be found. The mean cadmium levels in blood ranged between 0.12 μg/l and 0.14 μg/l and the mean tooth cadmium concentrations between 20.8 ng/g and 27.8 ng/g. Blood and tooth lead and cadmium levels of the eastern and western German children were thus mainly at a relatively low level in all rural and urban study areas. The study demonstrates and confirms that blood and tooth lead levels are influenced by several demographic, social, and environmental variables. The results indicate that there has been a further significant decrease of lead and cadmium exposure in western German children since our last epidemiological study carried out in the same study areas in 1985/1986.

Key words Lead · Cadmium · Blood · Teeth · Children

Introduction

Human environmental exposure to lead and cadmium has received much attention in the past decade. Regarding lead exposure there is general agreement in the meantime that children are particularly at risk. The increased risk for children compared to adults results from children's higher sensitivity, higher absorption rates in the gastrointestinal tract, and their specific behavior (outdoor activity, hand-to-mouth activity). The effects of low-level lead exposure on children's cognitive development have been verified in several studies [1, 6, 11, 13, 16, 17, 23]. The results regarding the effects on the central nervous system obtained in the context of the present study have been published elsewhere [15].

Blood lead and cadmium analyses reflect the current levels of exposure to these metals, but are unreliable indicators of chronic or past exposure. Since lead is preferably incorporated and stored in calcified tissue such as bone and teeth, tooth lead levels, especially of shed deciduous teeth, can be used to assess the cumulative exposure of children from the time of tooth formation to the shedding of the teeth.

In contrast to lead, cadmium accumulates mainly in the liver and the kidneys. The results of some studies [10, 12] indicate that cadmium is also accumulated to a small extent in teeth.

In the past two decades several extensive surveys were conducted to obtain data on the internal lead and cadmium
exposure of western German children. Comparable results from eastern Germany were not available. The objective of this study was to obtain data on the internal lead and cadmium exposure of children from different parts of Germany. The study should furthermore indicate, whether there are striking differences in lead and cadmium exposure between eastern and western Germany.

Internal exposure to lead and cadmium was assessed by analysis of concentrations in blood and teeth. Since the lead concentrations were found to be different between the upper and lower jaws and between tooth types [10] the sampling was restricted to deciduous teeth from the upper jaw.

Because tooth lead levels also depend on the compartment of the tooth [14] only whole teeth with no dental work (amalgam or composite fillings, etc.) were taken.

### Subjects and methods

#### Subjects and study areas

The study was conducted in Duisburg, Essen, Gelsenkirchen, and Dortmund, industrialized cities in North Rhine-Westphalia (western Germany), Leipzig, Halle and Magdeburg, industrialized cities in Saxony and Saxony-Anhalt (eastern Germany). Borken (North Rhine-Westphalia), Gardelegen, Osterburg and Salzwedel (Saxony-Anhalt), small towns without industrial lead and cadmium sources, served as reference areas.

Blood samples were obtained from 6-year-old German (n = 231) and Turkish children (n = 231) on the occasion of their school entrance medical examination. Participation in the study was voluntary. The participation rate was 55% in the western German and 76% in the eastern German study areas.

Shed milk teeth (incisors of the upper jaw only) were collected from German children of the same study group (n = 790) living in Duisburg, Leipzig, Halle, Magdeburg, Borken, Gardelegen, Osterburg, and Salzwedel. Children who had lived less than 2 years in the study areas were excluded from statistical analysis. Turkish children were also excluded because they had substantially higher lead and cadmium levels in blood and, without exception, lived in the western German study areas. The higher exposure of the Turkish children may be explained by an increased oral uptake due to different living conditions (dietary habits, outdoor activity etc.). In the western German study areas, lead and cadmium levels in dust precipitates were measured continuously by the Landesanstalt für Immissionsschutz Nordrhein-Westfalen (LIS). In the eastern German study areas lead and cadmium levels in dust precipitates were measured periodically by the Landesanstalt für Umweltvermessung und Forschung (LUF) and known influencing factors as dependent variables (x1, …, xN). The regression coefficients of this analysis were given as adjusted quotients of the geometric means.

#### Sample collection and analytical procedures

For metal analyses at ultratrace levels all chemicals were of highest purity and all materials were carefully cleaned. All work was performed on a clean bench. Before use all syringes, needles, glassware, chemicals etc. that came into contact with the samples were randomly checked for contamination.

Venous blood samples were taken with monovettes containing K2-EDTA as anticoagulant. The samples were deep-frozen in liquid nitrogen within the monovettes and stored at −20°C until analysis.

The lead and cadmium concentrations in blood were determined by electrothermal atomic absorption spectrometry with a Perkin-Elmer model 4100 ZL with Zeeman background correction. Standards were prepared and calibration done according to a method described by Ewers et al. [10]. For calibration as well as for internal and external quality control purposes pulverized animal teeth were used. The detection limits were 0.05 µg/ml lead and 2.2 ng/ml cadmium. Day-to-day precision was 5.4% for lead (GM = 4.73 µg/l; n = 50) and 8.7% for cadmium (GM = 94.8 ng/g; n = 50). The within-day precision was 5.4% for lead (GM = 3.22 µg/l; n = 10) and 10.5% for cadmium (GM = 23.6 ng/g; n = 10).

#### Statistical analysis

Lead and cadmium levels in blood and teeth were log-normally distributed. Therefore, the GM and appropriate standard deviations were used to describe the values. Differences between study areas and associations to lead in dustfall were judged after taking confounding variables into account. This analysis was done by multiple linear regression models with the logarithm of lead or cadmium as dependent variable (y) and known influencing factors as dependent variables (x1, …, xN). The regression coefficients of this analysis were given as adjusted quotients of the geometric means.

For internal quality control commercially available control blood (Behringwerke, Marburg, Germany) was used. External quality control was achieved on several occasions by participation in international comparison programs.

#### Results

#### Lead exposure

The results of the lead analyses in blood and teeth are shown in Table 1, giving the GM, geometric standard deviations, 95th percentiles, and ranges for all study areas. Blood lead levels were generally low in all study areas with a GM between 39.3 µg/l and 50.8 µg/l in the western German and between 42.3 µg/l and 68.1 µg/l in the eastern German study areas. The mean blood lead level of the Turkish children living in the western German study areas was 50.1 µg/l and thus 5.6 µg/l higher than the overall GM of the western German children. Fourteen German children and one Turkish child had blood lead levels above 150 µg/l, the present standard value of the German Bundesgesundheitsamt (Federal Health Office). In 103 German and 11 Turkish children blood lead levels exceeded 100 µg/l, which is presently under consideration as future standard value. Tooth lead levels were on average between 1.50 and 1.74 µg/g in the western and be-