Mercury in human hair as an indicator of the fish consumption

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Abstract

OBJECTIVES: Mercury and most of its compounds are extremely toxic and should be handled with care. It can be inhaled and absorbed through the skin and mucous membranes. The most toxic forms of mercury are its organic compounds such as dimethylmercury and methylmercury. Fish have a natural tendency to accumulate mercury. Methylmercury is produced by microbial methylation of inorganic mercury in water sediment then it infiltrates the food chain and it consequently accumulates in fish. Fish are the main source of methylmercury in human food. Mercury is transferred into a hair; and this can be than used to monitor the long-term exposure to mercury. The content of mercury in hair depends on the frequency of fish consumption. The aim of our study was to compare mercury content in the hair of children that had various amounts of fish consumption (increased or reduced).

DESIGN: Total mercury content in hair was determined by direct method of cold vapors using an AMA 245 analyzer. A total of 174 hair samples from the children (9–17 years old) were analyzed. In this study, the following localities were compared: Neratovice (n=42), Jeseníky (n=44), Prague (n=59) in Czech Republic and Olsztyn in Poland (n=29). Every sample was accompanied with questionnaire about age, gender, regions, amalgam fillings and fish consumption.

RESULTS: We did not find a correlation between the content of mercury in hair with age, gender or amalgam fillings. We did find a correlation between fish consumption and the amount of mercury found in the hair samples.

CONCLUSION: The amount of mercury in hair increases with more frequent consumption of freshwater and marine fish.

ORIGINAL ARTICLE

Abbreviations

Hg - mercury
AMA 254 - Advance mercury analyzer 254
LOD - limit of detection
CRM - certified reference material

INTRODUCTION

The toxic effects of mercury on humans have been known for a long time. The developing brain and its neurons is a primary target of Hg in the body. Chronic low levels of the organic form of mercury (methylmercury) have been associated with subtle learning difficulties in children (National Research Council, 2000; Wojcik, 2006). Neurological and behavioral disorders may be observed after inhalation, ingestion or dermal application of different mercury compounds. Symptoms include tremors, insomnia, memory loss, neuromuscular effects, headaches and cognitive and motor dysfunction. Methylmercury bio-accumulated in fish and consumed by pregnant women may lead to neurodevelopmental problems in developing fetuses. Transplacental exposure is the most dangerous, as the fetal brain is very sensitive (WHO, 2007). Moreover, the increased amount of mercury has been found in breast cancer in comparison with breast tissue control group (Ionescu *et al*. 2006)

Animal and human studies show that inorganic and organic mercury may act upon the endocrine system to alert hormonal levels, although the mechanisms of this process are unproven (Keith, 1997). Humans become exposed to mercury mainly through the consumption of contaminated water and food (especially by fish). Children are especially vulnerable as they can be exposed directly by eating contaminated fish. Hair is the most useful first line medium for the measurement of mercury exposure because the collection and storage of hair is very easy and the cutting of hair is not stressful (Sarmani & Alakili, 2004).

The aim of the present study is

- to assess the mercury content in schoolchildren's hair from elementary schools and special elementary schools
- to compare three selected sites in the Czech Republic and one site in Poland
- to evaluate the correlation between mercury content and the consumption of freshwater and marine fish on the basis of our results
- to establish the effect of age, gender and amalgam filling

MATERIALS AND METHODS

Sample collection

A total of 174 hair samples was collected from schoolchildren 9 to 17 years old (90 boys and 84 girls) from four different localities. The mean age of the children was 12.5 years (the median was 13). In this study, samples of children's hair were compared and analyzed from the following sites: Neratovice, (n=42) a town near the chemical factory Spolana Neratovice (producing of chlorine by amalgam electrode); Jeseníky, (n=44) a region located in the mountains in the eastern part of the Czech Republic and a characteristically non-polluted area; Prague, (n=59) the industrialized capital of the Czech Republic; and Olsztyn, in Poland (n=29). Olsztyn is situated in northern Poland in the Masuria area. We chose children from Poland because of their larger consumption of fish compared with Czech children. From these sites, excluding Olsztyn, we compared two groups – children from a special elementary school and from a normal elementary school. The children who attend the special school have learning and behavior disabilities.

Each sample was accompanied with a questionnaire inquiring data on age, gender, amalgam filling and region. The important criterion was the consumption of fish (fresh water fish and marine fish) because fish are the primary source of mercury intake.

The consumption of fish was written down by following numerical codes.

Consumption of freshwater fish:	*Consumption of marine fish:*
0 – none	0 – none
1 – sometimes	1 – rarely
2 – often	2 – once a month
	3 – several times a month

Mercury determination

Hair samples were collected from the children in an area of the cranium 3 cm above the nape of the neck. These samples were cut into small slivers (2–5 mm) and then washed according to the standard method (wash in acetone, three times in water and once more in acetone; then the samples were dried overnight) (Kratzer *et al*. 1994; Cejchanova *et al*. 2008). About 5–10 mg of the prepared sample was eventually used for the mercury analysis. Every sample was measured twice, but the sample was measured three times when the standard deviation between the two measurements was higher than 10%. Total mercury content in hair was determined by the direct method of cold vapors using the AMA 245 (Altec Ltd., Czech Republic) analyzer (LOD 1 $\mu g.kg^{-1}$). For the determination of moisture, the following procedure was used: approximately 250 mg of hair was obtained by mixing, ten individual samples were dried at 80 °C for 6 h, and the ratios of wet weight/dried weight were calculated. The ratios varied from 1.08 to 1.18.

The accuracy of the results of Hg content was validated using the standard reference material CRM No.13 HUMAN HAIR (National Institute for Environmental Studies).

Data analysis

Statistical analysis of the data was performed using the program STATISTICA 8.0 for Windows (StatSoft CR). The data were assessed by a non-parametric Kruskal-Wallis test because the data normality was not proven. Whenever the Kruskal-Wallis test showed statistically significant differences between profiles ($p<0.05$), multiple comparisons of all profiles were subsequently performed.

RESULTS

All results of the total mercury concentrations are given in $\mu g.g^{-1}$ dry weight. The mercury contents in children's hair in analyzed localities are showed in the Table 1. The highest median (0.156 $\mu g.g^{-1}$) was found at the elementary school in Prague; the lowest content of mercury was found at the special elementary school from Neratovice (0.084 $\mu g.g^{-1}$).

Significant differences between the elementary and special elementary schools were not proven; therefore we combined the samples from the elementary and special elementary schools from the selected site into one group (Jeseníky, Prague, Neratovice and Olsztyn). Figure 1 shows the statistical differences among the chosen localities. The statistical analysis shows a higher content of mercury in children's hair from Prague and Olsztyn in comparison with the Neratovice site ($p<0.05$).

When the data was combined into one group, a positive data correlation between mercury content in hair and the consumption of fish was found. The amount of mercury in hair rose with increased consumption of fish, indicating the influence of fish consumption on mercury intake. Figure 2 and Figure 3 show this verity and the comparison of mercury levels in relation to the consumption of freshwater and marine fish ($p<0.05$). We did not find any correlation between the amounts of mercury in hair in relation to age, gender and amalgam feelings.

DISCUSSION

In the Czech Republic the fish consumption is traditionally very low averaging 5 kg per year for common consumer. The amount of mercury was so low that the neurotoxic effect in our (environmental) situation could not be asserted. In our study, the highest average mercury level in hair was (0.238 ± 0.311 $\mu g.g^{-1}$; median 0.156 $\mu g.g^{-1}$) found in children from elementary school in Prague. A similar study in the Czech Republic was performed by Cejchanova *et al.* (2008). They analyzed hair samples from children (13–14 years) living in three localities (Kašperské Hory, Starý Plzenec and Benešov). The highest median value was 0.46 $\mu g.g^{-1}$ and occurred in children from Benešov. This value was significantly higher ($p<0.01$) than at Kašperské Hory and Starý Plzenec. In a study performed in Germany in 1996 (Pesch *et al.* 2002) the mean mercury content in children's hair was 0.23±0.20 $\mu g.g^{-1}$ (median was 0.18 $\mu g.g^{-1}$), and is very similar to the values that we found. Higher values (0.45±0.67 $\mu g.g^{-1}$) were found by Gundacker *et al.* (2007) in students from Austria. These values are very low compared with what we found in the literature from other studies (mainly in populations living in seaside states). Most likely it is because of a much lower consumption of fish in comparison with countries with traditionally high consumption of fish.

The concentration of total mercury in hair includes possible exogenous contamination because of strong bonding capacity of hair to mercury. Mercury incorporated in hair is very resistant to various washing procedures (Morton *et al.* 2002). In the Czech Republic mercury content in air does not appear a problem and from this reason isn't normally monitored (NIPH, 2007). This fact is confirmed by our results from this study (low mercury contamination in hair's samples from Neratovice).

Table 1. Content of mercury in hair from individual school

			Average	SD	Median	Min	Max
School		**n**	**($\mu g.g^{-1}$ dry weight)**				
Jeseníky	Elementary school	23	0.154	0.081	0.136	0.039	0.345
	Special elementary school	21	0.099	0.051	0.084	0.032	0.21
Prague	Elementary school	36	0.238	0.311	0.156	0.028	1.618
	Special elementary school	23	0.159	0.143	0.132	0.040	0.684
Neratovice	Elementary school	26	0.121	0.106	0.089	0.034	0.437
	Special elementary school	16	0.083	0.042	0.084	0.024	0.173
Olsztyn (Poland)	Elementary school	29	0.199	0.155	0.148	0.013	0.736

(n= number of analyzed samples; SD= standard deviation)

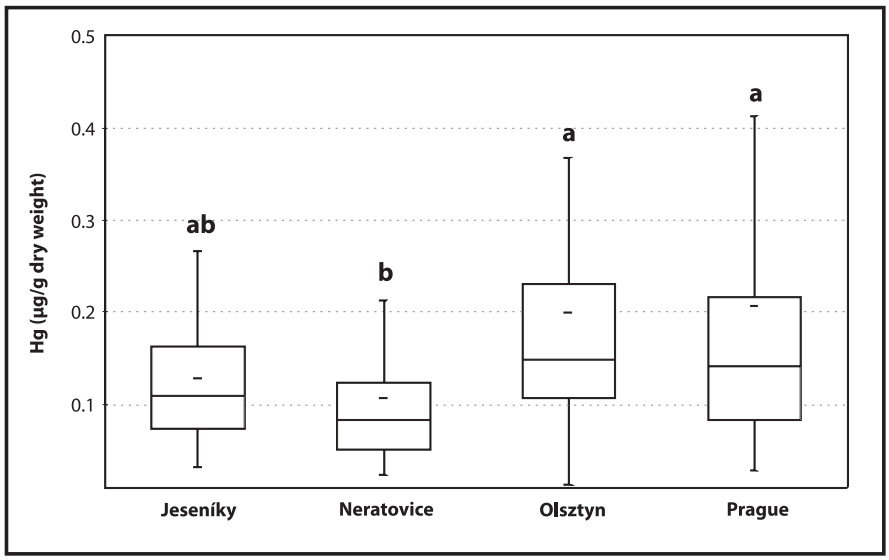

Figure 1. Comparison of Hg concentration in selected localities
a, b different alphabetic letters differ significantly ($p<0.05$)
Median=Middle line of the box; Lower (upper) Quartile=Bottom (Top) line of the box; Lower (Upper) Whisker=Lower (Upper) adjacent value

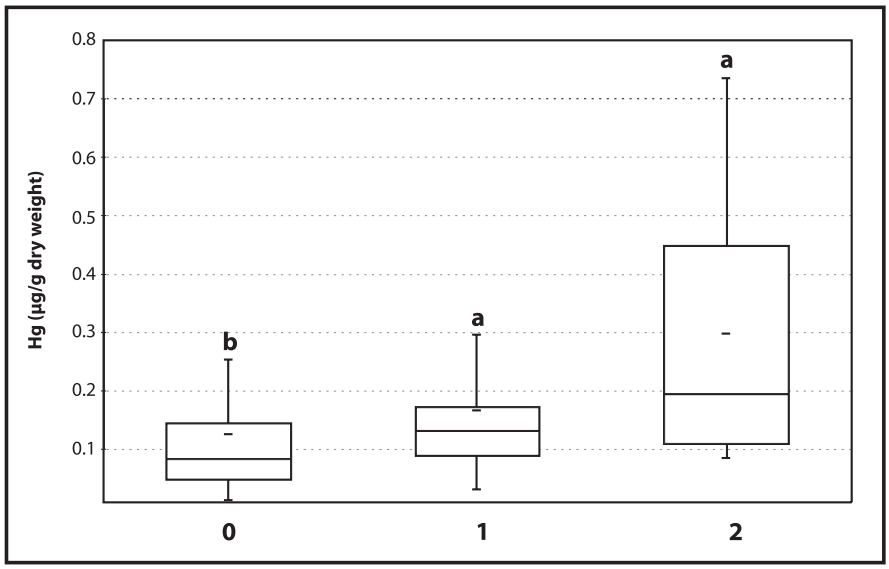

Figure 2. Content of mercury in hair in relation to the consumption of freshwater fish
Consumption of freshwater fish:
0 – none; 1 – sometimes; 2 – often
a, b different alphabetic letters differ significantly ($p<0.05$)
Median=Middle line of the box; Lower (upper) Quartile=Bottom (Top) line of the box; Lower (Upper) Whisker=Lower (Upper) adjacent value

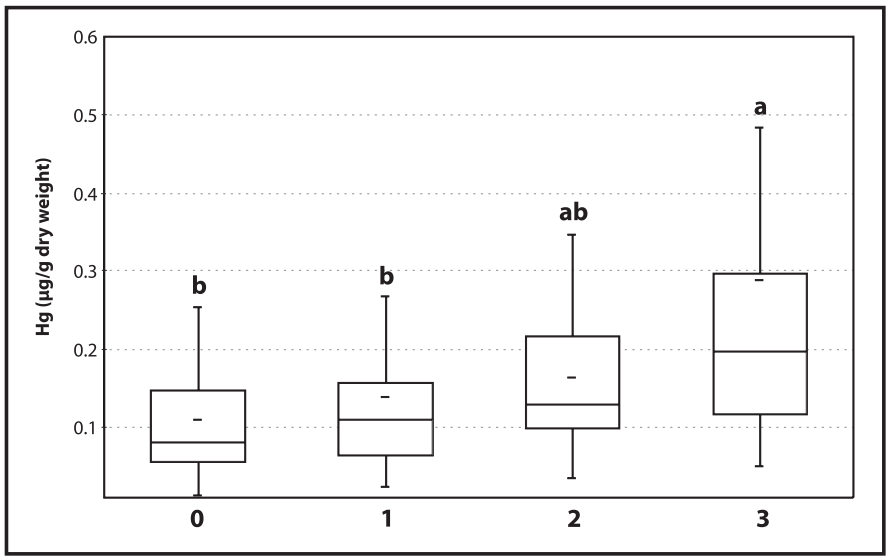

Figure 3. Content of mercury in hair in relation to the consumption of marine fish
Consumption of marine fish:
0 – none; 1 – rarely; 2 – once a month; 3 – several times a month
a, b different alphabetic letters differ significantly ($p<0.05$)
Median=Middle line of the box; Lower (upper) Quartile=Bottom (Top) line of the box; Lower (Upper) Whisker=Lower (Upper) adjacent value

We were not able to confirm our initial hypothesis that the mercury content in children's hair from the special elementary school was higher in comparison than with children from the normal elementary school. Moderate amounts of mercury in hair from children (preliminary school) were found in the study from Nambija (Ecuador) 6.0 $\mu g.g^{-1}$ (Counter *et al*. 2005). These children were assisting their parents in several aspects of gold prospecting, including excavation, manual transport of gold ore and amalgamation. Another study reports that the children who live along the Tocantins river (Amazon area) have a higher concentration of mercury in hair (about 3 $\mu g.g^{-1}$) (Pinheiro *et al*. 2006). This is a much higher level than we found in our study. Sarmani & Alakili (2004) showed data from an adult population in Malaysia, and the mean of the Hg content was 4.01 $\mu g.g^{-1}$. Adimado & Baah (2002) reported data of mercury content in hair in 217 subjects (12–18 years) from Ghana, and the highest mean value was 4.27 $\mu g.g^{-1}$.

We did not find any correlation between the amounts of mercury in hair in relation to age, the same results ascertained by Adimado & Baah (2002). Moreover, our data shows that the amount of Hg does not correlate with either gender or amalgam filling.

The eating of fish in the Czech Republic is very low in comparison with European and others countries. In our study, the consumption of fish in Czech children was lower than in Polish children. This is the main reason why Czech children have statistically lower concentrations of mercury in their hair in comparison with children from Poland. The consumption of fish in Poland is 12 kg per year for the average consumer.

CONCLUSION

Consumption of fish is low in the Czech Republic in comparison with Poland and the other European states. Our results show that the content of mercury in hair depends on the degree of fish consumption, because there is a positive dependency between these parameters. Only two samples (from 174) exceeded the value 1 $\mu g.Hg.g^{-1}$ hair. This data indicates a low exposure to the Czech children (and children from Poland) population from mercury.

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