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Original Research

Research on Mercury Levels in Scalp Hair

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Abstract

The aim of the present work was to evaluate the mercury content in hair of inhabitants of Wrocław, in southwestern Poland. On the basis of a questionnaire and analysis of hair by atomic absorption spectroscopy, it was possible to indicate the sources of mercury exposure. The mean mercury level in hair of the whole population (n=321) was 0.203±0.181 mg·kg^{-1}. The content of mercury in hair of subjects who consumed fish exceeded the upper limit of reference value, which was 0.397 mg·kg^{-1}. Subjects who declared consumption of fish, honey, and mouldy cheese, contained statistically more mercury: 60.5%, 35.4%, and 37.8%, respectively, than those who did not eat these types of food. It was noticed that there was no effect from the place of residence, the presence of pollution emitters, gender, age, weight, height, presence of amalgam fillings, hair dyeing, and smoking cigarettes on mercury content in hair.

Keywords: mercury, content in hair, exposure, environment

Introduction

Mercury (Hg) is a toxic element present in the environment and which can accumulate in the food chain. It is mentioned as a carcinogen on the list of the International Agency for Research on Cancer (IARC). Poland is regarded as a country with one of the highest anthropogenic mercury emissions in Europe, which is caused mainly by burning of fossil fuels and industrial processes [1]. Two groups of anthropogenic sources of mercury can be distinguished. Primary sources include: mining (both for mercury and for other minerals), and extraction and burning of fossil fuels, which contain mercury as a trace contaminant. Secondary anthropogenic sources are those where emissions occur from the intentional use of mercury, including mercury use in industrial processes or in a variety of products. Besides industry, many factors such as fish diet, the presence of amalgam tooth fillings, and smoking influence the content of mercury in human tissues. For people with dental amalgam fillings, this can constitute a major source of inorganic mercury exposure, because an amalgam filling contains about 50% mercury and the possible health risks have been debated for a long time [2]. Fakour et al. demonstrated that subjects (n=195 Iranian women from the southern port town of Mahshahr) with more than 6 amalgam fillings had significantly higher Hg levels in hair (2.29±0.65 mg·kg^{-1}) than women with less than 3 amalgam fillings (0.86±0.43 mg·kg^{-1}) [3]. However, they admit that the main determinant of Hg exposure is the intake of Hg through fish consumption [4]. Similar findings were reported by Al-Saleh and Al-Sedairi [5]. The authors found that children (n=182 Saudi children) with amalgam fillings had significantly higher hair mercury content (0.614 μg·g^{-1}) than children without (0.242 μg·g^{-1}). Al-Saleh and Al-Sedairi showed that cigarettes increased mercury concentrations in blood. The higher level of mercury in blood samples of passive smoking (n=1578 Saudi women) was 3.43 μg·L^{-1} while for non-smokers 2.86 μg·L^{-1}. Higher levels of mercury in blood caused higher levels of mercury in hair, since blood delivers elements to hair papilla and the excess is permanently

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incorporated in keratinous structure of hair [5]. The literature indicates that mercury also is present in foods and meals consumed by people. For example, the potential intake of Hg in different types of lunch and dinner in the faculty cafeteria (University of Perugia, Italy) was: pasta – 0.8 μg/person, bread – 0.2 μg/person, and meat, cheese, and fruit – 0.1 μg/person each [6]. Emissions to the environment from both primary and secondary sources can occur via direct discharge of exhaust gases and effluents, and through the generation of mercury-containing wastes, and cause the contamination of many aquatic and terrestrial environments [7]. Contaminated food, air, water, and random contacts with mercury or its compounds play a major role in exposure to this element [8]. Pollution of the environment with compounds of mercury results in the accumulation in various tissues, including hair. Mercury level in hair is frequently used as a marker of mercury exposure in humans. If hair is long and analyzed in segments, it can show a history of exposure [9].

The aim of the present work was to identify the possible sources of human exposure to mercury based on the analysis of hair mercury content of individuals.

Experimental Procedures

Sampling and Preparation

The work described in the article has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. This research received approval from the ethics committee at the Medical University of Wrocław in Poland (available upon request). The hair samples were provided by volunteers, from whom consent for participation in experiments was received and who had previously filled out a questionnaire (Fig. 1) concerning the individual properties (i.e., age, gender, weight, height), lifestyle, diet, health condition, etc. Questionnaires for children were filled in by their parents.

The present research was carried out on hair sampled from 321 subjects (115 males and 206 females), average age 25±10 years. The population consisted of individuals who have lived in Wrocław and in surrounding area for at least 3 years. This means that the volunteers underwent similar environmental and occupational exposure. The participants cut hair (5 cm long) from the nape of the neck directly after four consecutive washings of their hair with Johnson's Baby shampoo (Johnson & Johnson) and drying. For cutting hair, new, surgical scissors made from stainless steel were used (Hilbro International). The selection of the shampoo was determined by its composition – among the metal cations, only Na was present. This information was based on the shampoo composition as given by the manufacturer. This shampoo does not contain other elements, like Se and Zn, which are ingredients of biologically active compounds in anti-dandruff shampoos, which can lead to their exogenous deposition on hair. The hair was stored in a paper envelope and was analyzed directly without additional washing steps. The goal was to elaborate easier analyti-

Questionnaire

Individual characteristics

1. Gender ☐ Male ☐ Female
2. Age, years ☐
3. Weight, kg ☐
4. Height, cm ☐

Environmental exposure

5. Place of residence (city, village) ☐
6. Presence of emitters (in a surrounding area) ☐ Yes ☐ No
7. Kind of emitter ☐

Diet

8. Consumption of fish ☐ Yes ☐ No
9. Frequency of fish consumption (times/week) ☐
10. Consumption of honey ☐ Yes ☐ No
11. Consumption of mouldy cheese ☐ Yes ☐ No
12. Consumption of mushrooms ☐ Yes ☐ No
13. Source of fruits and vegetables ☐ Supermarket ☐ District shop ☐ Stall ☐ Own cultivation

Other

14. Amalgam fillings ☐ Yes ☐ No
15. Hair dying ☐ Yes ☐ No
16. Dandruff ☐ Yes ☐ No
17. Smoking cigarettes ☐ Yes ☐ No
18. Passive smoking ☐ Yes ☐ No

Fig. 1. The questionnaire administered to the subjects.

cal procedures without steps of washing hair with acids, organic solvents, etc., which on one hand are presented in the literature as a method that removes exogenous contamination, but on the other is source of contamination.

Mercury Analysis

Mercury was determined by atomic absorption spectroscopy AMA-254 (Czech Republic). The parameters were as follows: sample mass 0.05 g, drying time 40 s, decomposition time 150 s, waiting time 40 s. The presented data are the arithmetic average from three measurements. The detection limit for mercury analysis was 0.03 ng (0.0006 $mg \cdot kg^{-1}$). The analytical process was controlled by NCS reference material – Human Hair NCS ZC81002 from China National Analysis Center. Recovery was 97.5%. The analyses were carried out in a laboratory certified by ILAC-MRA and the Polish Centre of Accreditation (No AB 696) according to ISO/IEC 17025.

Statistical Methods

The results were elaborated upon statistically by Statistica ver. 9.0. Descriptive statistics (means, standard deviations, percentiles) were reported. Normality of distribution of experimental results was assessed by Shapiro-Wilk test. On this basis, a statistical test was selected, which was used to investigate the significance of differences between the groups. The differences between the groups were investigated with one-way analysis of variance (ANOVA) using the Tukey test. Results were considered significantly different when $p < 0.05$.

Results and Discussion

The presence of mercury in the environment is associated with the activity of different industries; pollution of water reservoirs, atmosphere, and food; and agricultural application of preparations containing this element. The examined subjects filled out a questionnaire that enabled us to identify the sources of exposure to mercury.

In the present paper, the reference value (RV) for mercury content in hair for this population was determined (as values between the 10^{th} and 90^{th} percentiles). It was assumed that the extreme low and high 10% of the population reflected deficiency and excess (respectively) of a given element. For the whole population, the range between the 10^{th} and 90^{th} percentiles was 0.0614-0.397 $mg \cdot kg^{-1}$ (reference value should be below 0.397 $mg \cdot kg^{-1}$). The RV and mean reported in the literature vary. This value was lower than the RV proposed for Korean preschool children: 0-1.0 $mg \cdot kg^{-1}$ [10], Korean children: 0.5-0.7 $mg \cdot kg^{-1}$ [11], and the value suggested by a commercial laboratory (Doctor's Data Inc), which should be below 2.0 (http://doctorsdata.com). On the other hand, RV values determined in the present study were higher (upper limit) than the RV suggested by other commercial laboratories: Trace Elements Inc. 0.09-0.18 $mg \cdot kg^{-1}$ [12] and HairAnalysisKit mean: 0.18 $mg \cdot kg^{-1}$ (hairanalysiskit.com) [13]. The difference could result from the methodology, manner of sample preparation (i.e., washing), analytical methods (i.e., AAS – atomic absorption spectroscopy, ICP-OES), or environmental exposure.

In this paper the mean mercury level in hair of the whole examined population from Wrocław (n=321) was 0.203±0.181 $mg \cdot kg^{-1}$. This value was lower than the content of mercury in hair of citizens of Wrocław in 2005, which was 0.500±0.390 $mg \cdot kg^{-1}$ [14]. The differences could be explained by the differences between those two groups of subjects that were undergoing experiments. In the case of the work of Chojnacka et al., the material studied was sampled in the years 1996-2003 from 83 subjects of different ages [14]. The sub-population included persons either working or studying at the university or children studying in schools located near the university campus. The criterion was to choose subjects that spend their working day in the same place. In this paper hair samples were collected in 2010, from the same region but the age range was narrower. Similar levels of mercury in hair according to our current results was found in hair of students of the Faculty of Chemistry at the Technical University of Łódź (central Poland), which was 0.294 $mg \cdot kg^{-1}$ [15] in 2007. The change in mercury hair level over the last decade could be associated with significant improvements of environmental pollution loads in Poland. In 2004 Poland entered into the European Union and, consequently, previous environmental regulations had to change, which may have be the reason for lower levels of mercury in hair observed after 2004. Additionally, in that time mercury thermometers were withdrawn from the market.

Influence of Individual Characteristics on Mercury Content in Hair

Taking into account individual characteristics of the examined subjects, it was found that there was no effect of gender on the content of mercury in the samples of scalp hair. Hair of females (n=206) contained 0.193±0.140 $mg \cdot kg^{-1}$, whereas males (n=115) contained 0.191±0.149 $mg \cdot kg^{-1}$. In the literature several papers cover the dependence of mercury content in hair between the genders. Also, Olivero et al. showed that gender was unlikely to play a role in determination of mercury accumulation in hair. There was no statistical difference between hair Hg content in males from Colombia (n=56): 4.31±0.42 $mg \cdot kg^{-1}$ and females (n=38): 5.78±1.21 $mg \cdot kg^{-1}$ [16]. Different results were presented by Babi et al., who found that the mean value of mercury content in hair of females from Albania (n=47) was higher (0.75±0.495 $mg \cdot kg^{-1}$) than of males (n=14): 0.52±0.39 $mg \cdot kg^{-1}$. They also pointed out that there were some doubts about the validity of their findings, since the number of males was lower than the number of females [17]. Agusa et al., who examined the possible effect of mercury content in hair of females from Phnom Penh city in Cambodia on serum hormone levels for Cambodians, also found that mean Hg content in hair of female (n=15): 4.0 $mg \cdot kg^{-1}$ was higher than that of male (n=5): 2.1 $mg \cdot kg^{-1}$, but the difference was not statistically

significant, which might be due to the small sample size in the study (n=20) [18].

Contradictory findings have been presented by Díez et al., who reported that hair of females from southern Italy (n=115) contained 0.563±0.274 mg·kg^{-1}, whereas hair of males (n=122) 0.709±0.449 mg·kg^{-1} [19]. Szynkowska and Pawlaczyk examined the content of mercury in hair of Technical University of Łódź students. Fish consumption and total number of dental amalgamate fillings were considered as factors that may considerably influence the mercury content in the hair. It was noticed that hair of males contained 2.5 times more mercury than hair of females. But authors did not mention the correlation between fish consumption and dental amalgamate according to the gender. It is possible that the 2.5 times greater level in male hair was caused by these two factors [15].

It is worth pointing out that on the basis of the literature data, the content of mercury in hair also differed according to the place of residence (city, country) and type of diet. For example: both Olivero et al. [16] and Babi et al. [17] determined the mercury content in hair by cold vapor atomic absorption spectroscopy. The average content of mercury in hair of males in Olivero's study was 8 times higher than in Babi's study. This difference could be attributed to eating habits – hair in the first study was collected from fish-eating people. From the comparison of the mercury content in hair of males and females, it could be noticed that Poles are not so highly exposed to mercury as compared with the subjects examined by other authors. Reported levels of mercury in hair of subjects (n=219, Bangladesh) that declared moderated fish consumption averaging 2.1 kg/month is also higher (0.44±0.19 μgHg·g^{-1} (range 0.02-0.95)) than those reported in this study [20]. Endo and Haraguchi reported that the average level of total mercury in the hair from residents (n=50, Taiji, Japanese) who ate whale meat more than once a month was 24.6 μg·g^{-1}, whereas the average from the residents who did not consume any whale meat was 4.3 μg·g^{-1}, which is still lower than those reported in this study [21].

Also, age did not influence significantly the content of mercury in hair. For age range 0-10 years (n=9) mercury content was 0.113±0.055 mg·kg^{-1}; for 10-20 (n=13) 0.206±0.168 mg·kg^{-1}; for 20-30 (n=263) 0.181±0.139 mg·kg^{-1}; for 30–40 (n=12) 0.279±0.162 mg·kg^{-1}; for 40-50 (n=9) 0.282±0.107 mg·kg^{-1}; for 50-60 (n=8) 0.242±0.149 mg·kg^{-1}; for >60 (n=6) 0.326±0.179 mg·kg^{-1}. Hać et al. investigated the mercury level in hair of Poles from Gdańsk (northern Poland) for the following age groups: 17-40 (n=11), 41-60 (n=29) and 61-90 (n=6). The content of mercury in hair was as follows: 0.370±0.311 mg·kg^{-1}; 0.410±0.345 mg·kg^{-1}, and 0.244±0.085 mg·kg^{-1} [22]. Applying the same age ranges for the group examined in this paper gave the following results: for 17-40 age range (n=285) mercury content was 0.187±0.142 mg·kg^{-1}, for 41-60 (n=17) it was 0.273±0.122 mg·kg^{-1} and for 61-90 (n=6) it was 0.326±0.179 mg·kg^{-1}. In our research, the content of mercury in hair increased with age. Although, due to sample size, it appears that none of the differences related to age are significant, so that it cannot really be stated that hair mercury content increased with age. Additionally, Fig. 2 shows that generally the content of mercury in hair increased with age. However, the level of mercury in the oldest participants was much higher for fish consumers (Fig. 2a) than for subjects who did not eat fish (Fig. 2b).

Reports in the available literature also present the tendency to increase the amount of accumulated mercury in hair along with age. Szynkowska and Pawlaczyk noticed the lowest amount of Hg for the youngest investigated group – children. This could be connected with malfunction of defense mechanisms in elderly people or as a result of mercury accumulation in the body through the whole lifetime [15]. Also, Karabedian et al. found that hair of older individuals contained higher levels of mercury, particularly in subjects older than 60 years [23].

In the examined group of subjects there was no statistically significant difference between the content of mercury in hair and weight, but an increase was observed with the increase of body weight: 0-19 kg: 0.0937±0.0238 mg·kg^{-1} (n=7 – small population), 20-39 kg: 0.212±0.164 mg·kg^{-1} (n=6 – small population), 40-59 kg: 0.186±0.145 mg·kg^{-1} (n=124), 60-79 kg: 0.193±0.141 mg·kg^{-1} (n=131), 80-100 kg: 0.211±0.144 mg·kg^{-1} (n=52). Karabedian et al. showed

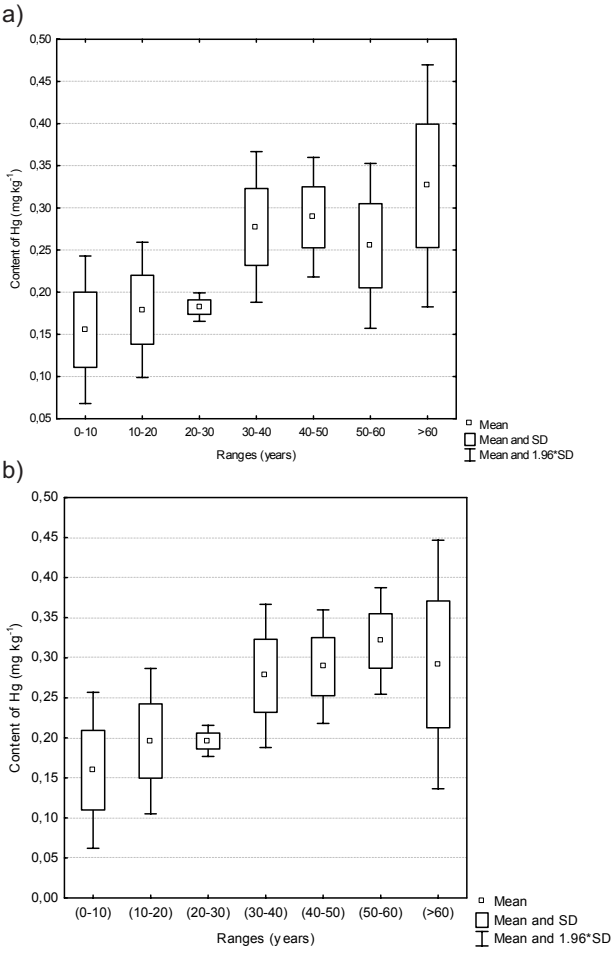

Fig. 2. The effect of age on Hg content in scalp hair (mg·kg^{-1}) (a) for fish consumers (0-10 years: n=10; 10-20: n= 13; 20-30: n=263; 30-40: n=12; 40-50: n=9; 50-60: n=8; >60: n=6) and (b) subjects not consuming fish (0-10 years: n=9; 10-20: n=11; 20-30: n=205; 30-40: n=12; 40-50: n=9; 50-60: n=6; >60: n=5).

that in hair of the citizens of Iraq there was a significant difference in the mercury content as body weight increased. The authors supposed that this higher content could also be related to the use of drugs, dental amalgams, and food additives [23]. In the case of height, the differences were also not statistically significant. The content of mercury in hair was as follows: 150-159 cm: 0.206±0.143 mg·kg^{-1} (n=23), 160-169 cm: 0.184±0.142 mg·kg^{-1} (n=108), 170-179 cm: 0.204±0.136 mg·kg^{-1} (n=110), 180-189 cm: 0.187±0.165 mg·kg^{-1} (n=57), and 190-199 cm: 0.165±0.089 mg·kg^{-1} (n=12). The positive relationship between total mercury content in hair and weight and height was observed by Díez et al. [19].

For the examined group of subjects, body mass index (BMI) also was calculated, as the ratio of weight in kilograms to the square of height in meters. BMI is commonly used to classify weight as "healthy" or "unhealthy." BMIs under 18.5 are considered "underweight," between 18.5 and 24.9 are considered "normal" or "healthy" weight, between 25 and 29.9 are considered "overweight," and 30 and above are considered "obese." BMIs above 25 are unhealthy and have been shown to increase the risk of certain chronic diseases [23]. In our study, generally, the content of mercury in hair increased with the increase of BMI (Fig. 3). A statistically significant difference (p=0.00767) was observed between underweight (content of mercury in hair 0.144±0.099 mg·kg^{-1}) and overweight subjects (0.247±0.156 mg·kg^{-1}).

Environmental Exposure to Mercury

It was found that subjects living in Wrocław had the same level of mercury in hair (n=239): 0.194±0.144 mg·kg^{-1}, than subjects living outside the city (n=81): 0.190±0.142 mg·kg^{-1}. On the basis of the obtained results, it could be supposed that in Wrocław region (a typical urban area without a mercury industry) there was no influence of the presence of emitters on pollution (especially thermal – electric power station) on the content of mercury in hair. It could be supposed that mercury did not seep to the organism from contaminated air or tap water. Probably, the main sources of the variability of mercury content in human hair are dietary habits, as it is suggested in the available literature [4, 19, 20].

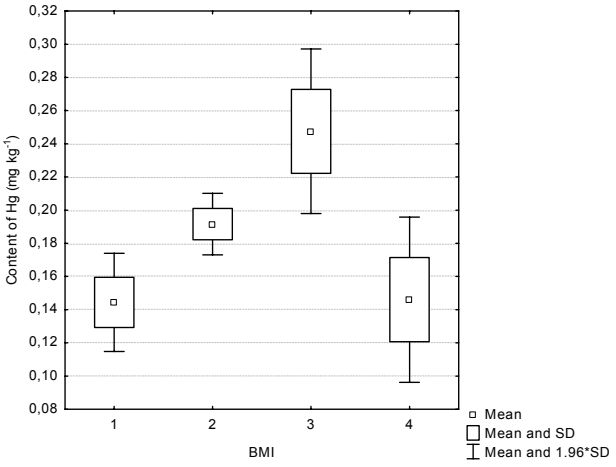

Fig. 3. The effect of BMI on Hg content in scalp hair (mg·kg^{-1}) (1) underweight: n=43; (2) normal weight: n=236; (3) overweight: n=38; (4) obese: n=3.

Exposure to Mercury from the Diet

In the literature it is indicated that there are two main sources of mercury exposure in a population that is not occupationally exposed: methylmercury mainly through the consumption of fish and inorganic mercury mainly through the release of mercury vapour from amalgam fillings (this problem will be discussed later in this paper) [19]. In our research it was found that the consumption of fish influenced significantly the content of mercury in hair (Fig. 4a). Subjects who declared in the questionnaire eating fish (n=257) contained 0.207±0.144 mg·kg^{-1} of mercury, in comparison with subjects who did not have fish in their diet (n=63) – their hair contained 0.129±0.117 mg·kg^{-1} of mercury. This difference was statistically significant (p=0.00183). It was also found that the content of mercury in hair increased with the frequency of fish consumption (Fig. 4b). Subjects who consumed fish once per week (n=185) contained in hair 0.192±0.127 mg·kg^{-1} of mercury, twice per week (n=39) 0.237±0.168 mg·kg^{-1}, three times (n=11) 0.274±0.157 mg·kg^{-1}, and four and more times (n=4)

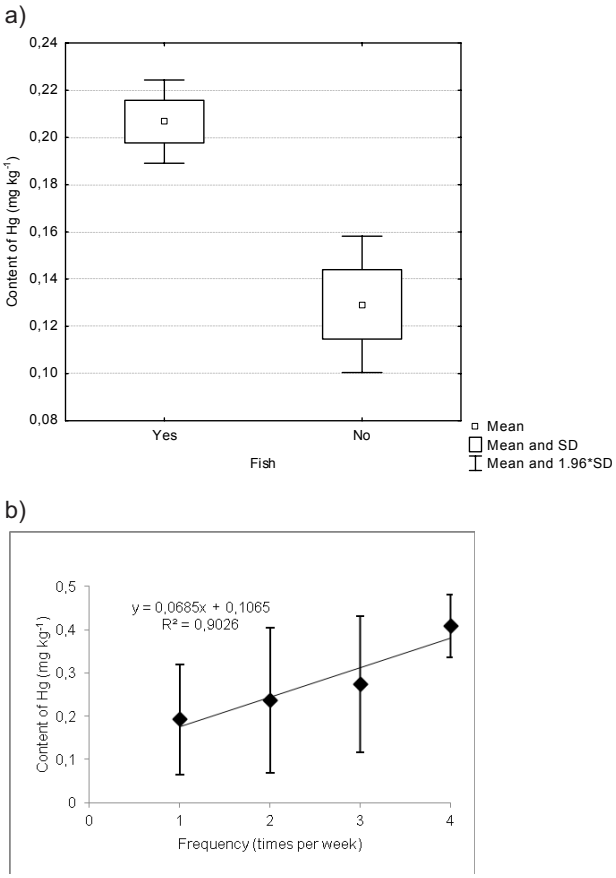

Fig. 4. The effect of (a) fish consumption (Yes: n=257; No: n=63) and (b) frequency of consumption (1) once per week: n=185; (2) twice: n=39; (3) three times: n=11; (4) four and more times: n=4, on Hg content in scalp hair (mg·kg^{-1}).

0.408±0.0723 mg·kg^{-1}. It was found that there was a linear relationship between the content of Hg in hair and frequency of fish consumption:

$$\textit{Content of Hg in hair} = 0.0685 \times \textit{Frequency} + 0.1065; \quad R = 0.950$$

In the last group, the upper limit of RV (0.397 mg·kg^{-1}) was exceeded, which suggests that fish should not be consumed more often than four times per week.

Oskarsson et al. confirmed that a fish diet is considered the primary pathway of human exposure to methylmercury, resulting in statistically significant differences between high and low fish consumption groups [25]. Johnsson et al. found that the median mercury level in subjects who consumed freshwater fish more than twice a week was about eight times higher than the group who rarely or never ate freshwater fish [26]. Fang et al. noticed that total hair mercury concentration was positively associated with the average mass of fish consumed weekly, indicating that fish consumption is the main contributor to hair mercury [27].

In the case of consumption of other foods, statistically significant differences also concerned: honey, mouldy cheese, mushrooms, fruits and vegetables. A statistically significant difference (p=0.00341) in mercury content in hair was found between subjects who used honey (0.222±0.158 mg·kg^{-1}) in comparison with subjects who did not use (0.164±0.121 mg·kg^{-1}) (Fig. 5). Another product that could be the source of mercury in hair was mouldy cheese. The effect of its consumption on mercury levels in hair is presented in Fig. 6. Subjects consuming mouldy cheese contained significantly higher (p=0.000188) levels of mercury in hair than individuals who did not consume this kind of cheese. The consumption of mushrooms was reflected by the content of mercury in scalp hair. Although the difference between subjects eating (0.206±0.144 mg·kg^{-1}; n=174) or not (0.174±0.139 mg·kg^{-1}; n=146) was not statistically significant (p=0.0596). Subjects who declared mushroom consumption had 18% higher content of mercury in hair. Mushroom collection is very popular among Poles, even though mushrooms are known as bioaccumulators of toxic metals. This property is also used in biomonitoring of environmental pollution. The flesh of edible mushrooms containing mercury can result in significant dietary human exposure, for example: very popular in Poland, Bay Bolete (*Xerocomus badius*) from Augustow Forest contained in the cap: 0.11±0.05 mg·kg^{-1} of mercury and in stalk: 0.065±0.022 mg·kg^{-1} [28]. Wildly grown mushrooms are attractive and popular constituents of many meals traditional to European and Polish culinary culture.

A visible difference (but not statistically significant) was observed in the content of mercury in hair of subjects who bought fruits and vegetables in different places (Fig. 7). The highest level of mercury was determined in hair of subjects who bought fruits and vegetables in stalls (0.217±0.148 mg·kg^{-1}), then in the supermarket (0.190±0.146 mg·kg^{-1}), in the district shop (0.189±0.138 mg·kg^{-1}), and finally in hair of subjects who had their own cultivation (0.0996±0.0333 mg·kg^{-1}); however, this last group was the smallest.

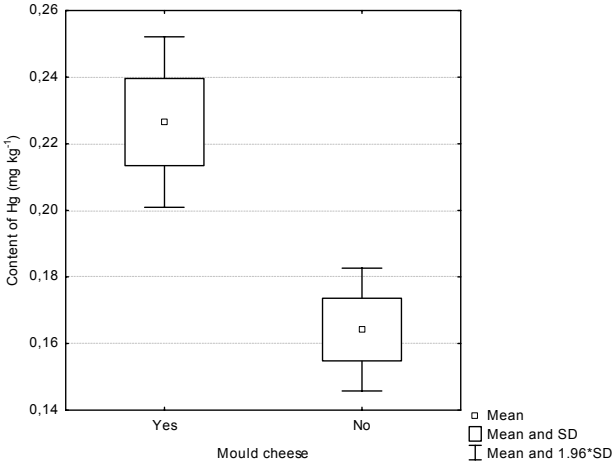

Fig. 6. The effect of consuming mouldy cheese on Hg content in scalp hair (mg·kg^{-1}) (Yes: n=140; No: n=180).

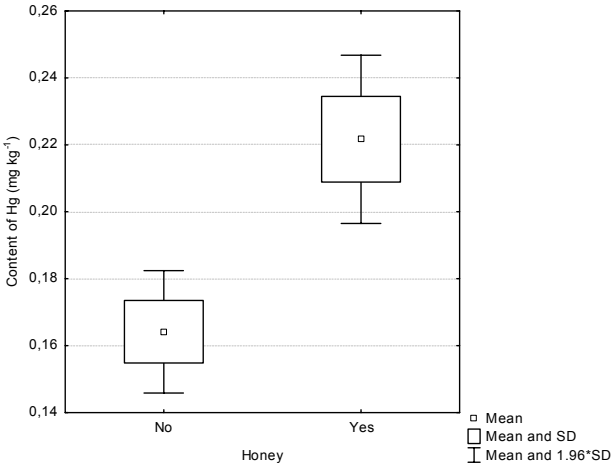

Fig. 5. The effect of honey on Hg content in scalp hair (mg·kg^{-1}) (Yes: n=152; No: n=168).

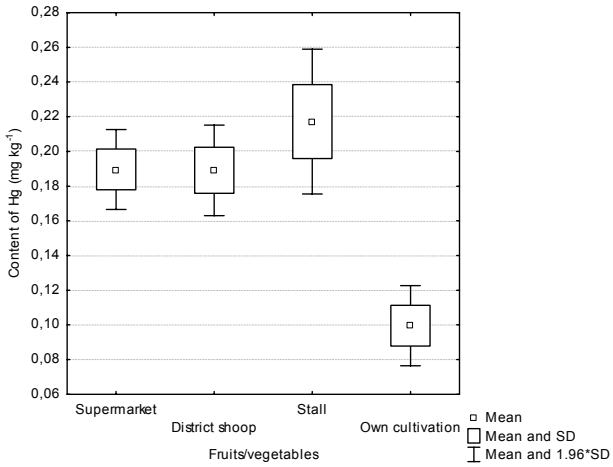

Fig. 7. The effect of sources of fruits and vegetables on Hg content in scalp hair (mg·kg^{-1}) (supermarket: n= 155; district shop: n=108; stall: n=48; own cultivation: n=8).

Exposure to Mercury from Other Sources

Surprisingly, it was found that subjects who had amalgam fillings at present (n=85) had similar levels of mercury in hair (0.201±0.147 mg·kg^{-1}) as subjects without these kinds of fillings (n=174: 0.191±0.146 mg·kg^{-1}). Similar results were found by Díez et al., who did not observe significant differences in the content of mercury in hair between the group with amalgam fillings (n=175) and without (n=62): 0.621 mg·kg^{-1} vs. 0.688 mg·kg^{-1} [19]. Fakour et al. indicated that dental amalgam fillings may be an important source for releasing mercury to saliva and such mercury can be absorbed systematically upon swallowing and to be concentrated in different body tissues, such as hair. They found a strong positive correlation between the mercury content in hair and saliva of the Iranian women. The content of Hg in hair of females without amalgam fillings (n=20) was 0.209±0.040 mg·kg^{-1}, for 1-4 fillings (n=30) was 0.456±0.138 mg·kg^{-1}, and for ≥ 5 (n=32) was 2.72±1.20 mg·kg^{-1} [3].

Hair dyeing did not influence significantly the content of mercury in hair. Subjects who declared in the questionnaire dyeing their hair (n=80) had slightly higher levels of mercury (3%): 0.196±0.143 mg·kg^{-1} in comparison with subjects with natural hair color (n=240): 0.190±0.143 mg·kg^{-1}. Also, Kowalski and Wierciński did not observe influence of hair dyeing on mercury content [8].

It was found that subjects who suffered presently from dandruff (n=57) had statistically significant (p=0.00795) higher levels of mercury in hair (0.258±0.195 mg·kg^{-1}) than subjects without this hair problem (n=162): 0.180±0.120 mg·kg^{-1}. The reason for higher levels of mercury in hair might be dermal problems caused by presence of mercury. Risher and Amler reported that exposure to excessive doses of mercury can result in dermatological disorders [29].

The last aspect, which is discussed in this paper, is the effect of smoking cigarettes on the content of mercury in hair. The literature includes contradictory data. In some papers authors found that hair of smokers contained significantly higher mercury levels than that of non-smoking respondents [8, 23], and others revealed that no significant differences between smokers and non-smokers were found [30]. In our examined group, the second tendency was confirmed. Subjects who declared smoking cigarettes (n=66) contained in hair 0.168±0.117 mg·kg^{-1} of mercury, whereas non-smokers (n=253): 0.196±0.147 mg·kg^{-1} (this difference was not statistically significant).

Summary

Significant differences in mercury content in hair were particularly visible in the case of food consumption, showing the role of dietary exposure. Subjects who declared eating fish contained 60% more mercury in hair in comparison with subjects who did not have fish in their diet. Moreover, the content of mercury in hair increased with the frequency of fish consumption. Subjects who consumed fish more than four times per week slightly exceeded the content of mercury in hair, taking into account the upper limit of RV (0.397 mg·kg^{-1}), which suggests that fish should not be consumed more often than four times per week.

The obtained results showed that mercury content in hair samples reflect the differences in lifestyle and food consumption. It was found that there was no effect of gender on mineral composition of scalp hair. There was no effect of weight and height. However, the content of mercury in hair increased with the increase of BMI – a statistically significant difference was observed between subjects with under – and overweight.

The consumption of some products that commonly occur in the diet caused increased levels of mercury – subjects who declared consumption of honey, mouldy cheese, and mushrooms contained 35%, 38%, and 18%, respectively, more mercury in hair versus subjects who did not eat these products. However, the mercury content did not exceed the value of the 90th percentile, which was determined as 0.397 mg·kg^{-1}. A visible difference (but not statistically significant) also was observed in the content of mercury in hair of subjects who bought fruits and vegetables in different places: supermarket, district shop, stall, or own cultivation. Surprisingly, it was found that subjects who had amalgam fillings at present had similar levels of mercury in hair than those without. There was no effect of hair dyeing, smoking cigarettes, place of residence, and the presence of emitters on the mercury content in hair of citizens of southwestern Poland.

Conclusions

Based on a combination of questionnaire survey and analytical determinations, it was found that hair mercury level is a useful biomarker of human exposure to this element. This enabled us to identify the sources of mercury exposure to humans: fish (more frequently than 4 times a week), honey, mouldy cheese, and mushroom consumption. The comparison of average mercury levels in the population with previous reports showed that the extent of the exposure in the past years has decreased in Poland.

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