Exposure to mercury can occur from breathing contaminated air\(^1\), eating foods containing mercury residues from processing, such as can occur with high-fructose corn syrup\(^2\), mercury vapor from amalgam dental restorations\(^3\), household products, paints or even cosmetics such as skin-lightening creams, which may contain high levels of mercury\(^4,5\). Historically, mercury compounds have been used in the preparation of beauty products for their purported skin-lightening effect. Mercury in such preparations can enter the human body through skin absorption\(^6\), which has been associated with renal, neurological and dermal toxicity\(^7\).

Despite the well-known hazards of mercury exposure and the ban against the sale of creams containing mercury in some countries like the United States, these products are still widely available in pharmacies, beauty aid stores and local cosmetic markets around the world, particularly in low-income communities\(^8−10\).

Palmer et al. (2000) proved in an vitro human model that mercury can be easily absorbed through the skin and that the rate of its absorption is related to the glycerol-containing formulation\(^11\).

A study of the association between the use of skin-lightening creams and urinary mercury in healthy Saudi women between the ages of 17 to 58 years\(^12\) revealed that 23% of studied women had mercury levels higher than the reference value proposed by the World Health Organization (WHO) for a non-exposed population.

On the other hand, the general population is exposed to Hg primarily through diet (mainly fish consumption) and dental amalgam fillings\(^13\). Dental amalgam, an alloy of ~50 percent elemental mercury, was first introduced in France in the early 19th century\(^14\). During the past two decades, this material has come under increasing scrutiny in respect to its safety, as it is known that amalgam restorations continuously

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**Field Study**

**Occupational and Environmental Exposure to Mercury among Iranian Hairdressers**

Hoda FAKOUR and Abbas ESMAILI-SARI

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Abstract: Occupational and Environmental Exposure to Mercury among Iranian Hairdressers: Hoda FAKOUR, et al. Department of Environment, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Iran—Objectives: The aim of this study was to describe the mercury concentrations in female hairdressers associated with occupational and environmental exposure through cosmetic products and amalgam fillings. Methods: Sixty-two hair and nail samples were collected randomly from Iranian hairdressers. Hg level determination was carried out using a LECO, AMA 254, Advanced Mercury Analyzer according to ASTM, standard No. D-6722. Results: The mean mercury levels were 1.15 ± 1.03 µg/g and 1.82 ± 1.12 µg/g in the hair and nail samples, respectively with a positive correlation among them (r=0.98). A significant relation was also observed between Hg levels and the number of amalgam fillings (p<0.001), use of cosmetics (p=0.001), and use of gloves (p=0.02). Conclusions: The Hg levels in about one-third of the studied samples were higher than the USEPA-recommended 1 µg/g, which represents a serious health risk. Hairdressers with continuous use of cosmetics and a high number of amalgam fillings had significantly elevated mercury concentrations in their hair and nails, suggesting the importance of mercury exposure assessment in hidden, less-explored sources of Hg in the workplace. (J Occup Health 2014; 56: 56–61)

Key words: Cosmetic, Hair, Iranian hairdressers, Mercury, Nail, Occupational

Mercury (Hg) is a chemical element that has long been used due to its many advantages from the physical and chemical points of view. The effect of mercury on different human groups (from occupational exposure or therapeutic applications) is a well-known topic these days.

Exposure to mercury can occur from breathing contaminated air\(^1\), eating foods containing mercury residues from processing, such as can occur with high-fructose corn syrup\(^2\), mercury vapor from amalgam dental restorations\(^3\), household products, paints or even cosmetics such as skin-lightening creams, which may contain high levels of mercury\(^4,5\). Historically, mercury compounds have been used in the preparation of beauty products for their purported skin-lightening effect. Mercury in such preparations can enter the human body through skin absorption\(^6\), which has been associated with renal, neurological and dermal toxicity\(^7\).

Despite the well-known hazards of mercury exposure and the ban against the sale of creams containing mercury in some countries like the United States, these products are still widely available in pharmacies, beauty aid stores and local cosmetic markets around the world, particularly in low-income communities\(^8−10\). Palmer et al. (2000) proved in an vitro human model that mercury can be easily absorbed through the skin and that the rate of its absorption is related to the glycerol-containing formulation\(^11\).

A study of the association between the use of skin-lightening creams and urinary mercury in healthy Saudi women between the ages of 17 to 58 years\(^12\) revealed that 23% of studied women had mercury levels higher than the reference value proposed by the World Health Organization (WHO) for a non-exposed population.

On the other hand, the general population is exposed to Hg primarily through diet (mainly fish consumption) and dental amalgam fillings\(^13\). Dental amalgam, an alloy of ~50 percent elemental mercury, was first introduced in France in the early 19th century\(^14\). During the past two decades, this material has come under increasing scrutiny in respect to its safety, as it is known that amalgam restorations continuously

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Sixty-two women who worked as hairdressers (with a mean age of 27.3 years) and had an occupational background of 8 to 10 years with the same fish consumption pattern (less than 3 times a month) were randomly selected to participate in this study. To select the sample, a multistage cluster sampling technique was used. In the first stage, the city was divided into 20 municipal districts, and then 10 districts were randomly chosen by a simple random sampling method. In each selected district, an alphabetical list of beauty salon names was provided. In the next step, 15 beauty salons were randomly selected to participate in this study from each list using a systematic sampling technique. From the 150 selected beauty salons, the study sample was determined by taking a systematic and random sample of 15 hairdressers. We studied hairdressers because among the different users of beauty products, hairdressers apply higher dosages of cosmetics whether for themselves or their customers (particularly in Middle East countries). Therefore, they are a good less-studied group of occupational mercury exposure. We also aimed to find out the relation between having dental amalgam fillings (as an important widespread inorganic source of mercury) and Hg levels with and without use of cosmetic products to estimate the individual and concurrent effects of occupational and environmental mercury exposure. In the present study, hair and nail samples were used as noninvasive biological materials for Hg analysis due to their numerous advantages for human biomonitoring such as easy collection, low cost and easy transfer and storage along with information about short- and long-term exposures.

Fingernails and hair have been also reported to be preferable markers for long-term exposure to mercury.

Materials and Methods

Study participants

Sixty-two women who worked as hairdressers (with a mean age of 27.3 years) and had an occupational background of 8 to 10 years with the same fish consumption pattern (less than 3 times a month) were randomly selected to participate in this study. To select the sample, a multistage cluster sampling technique was used. In the first stage, the city was divided into 20 municipal districts, and then 10 districts were randomly chosen by a simple random sampling method. In each selected district, an alphabetical list of beauty salon names was provided. In the next step, 15 beauty salons were randomly selected to participate in the study from each list using a systematic sampling technique. From the 150 selected beauty salons, the study sample was determined by taking a systematic and random sample of 15 hairdressers. We studied hairdressers because among the different users of beauty products, hairdressers apply higher dosages of cosmetics whether for themselves or their customers (particularly in Middle East countries). Therefore, they are a good less-studied group of occupational mercury exposure. We also aimed to find out the relation between having dental amalgam fillings (as an important widespread inorganic source of mercury) and Hg levels with and without use of cosmetic products to estimate the individual and concurrent effects of occupational and environmental mercury exposure. In the present study, hair and nail samples were used as noninvasive biological materials for Hg analysis due to their numerous advantages for human biomonitoring such as easy collection, low cost and easy transfer and storage along with information about short- and long-term exposures.

Fingernails and hair have been also reported to be preferable markers for long-term exposure to mercury.

Analytical procedure

A lock of scalp hair approximately 3 cm long from the root in the occipital region and about 0.5 g of fingernails was obtained from each participant. Hair and nail samples were coded and stored in plastic bags until analysis. For measurement of mercury concentrations, hair and nail samples were washed 3 times with a nonionic detergent (1% V/V Triton X-100) followed by rinsing 3 times with deionized water. The samples were then dried in an electric oven at 60°C. The determination of Hg level was carried out using a LECO AMA 254 Advanced Mercury Analyzer (USA) according to ASTM standard No. D-6722. This method requires no specific chemical pretreatment of the sample. A ten- to fifty-milligram sample was weighed in an analyzing shuttle and introduced into the instrument followed by determination of the Hg concentration in hair and nail samples by direct combustion atomic absorption spectrometry.

Quality control

The accuracy of total Hg analysis by advanced mercury analyzer was checked by running 3 samples of standard reference material (SRM). Recovery varied between 98.5 and 103%. There was a good agreement between the obtained mean and the certified value. In order to check the reproducibility of the analysis, 15% of the samples were randomly selected and analyzed 3 times. The coefficient of variation was between 0.05 and 2.5% (Table 1).

Statistical analyses

Statistical analyses were performed using the SPSS (version 16.0, SPSS Inc., Chicago, IL, USA) software. Among questionnaire variables, weight, age, number of amalgam fillings, use of beauty products and use of precautionary measures in the workplace were considered independent variables, and Hg concentrations in hair and nail samples were considered dependent variables. The data were tested for the assumption

...
of normality using the Kolmogorov-Smirnov test. In analyzing data, the independent samples t-test was used for comparing the means in two independent populations with a normal distribution, and the Mann-Whitney test was utilized for other variables with a non-normal distribution. Furthermore, the Wilcoxon and Kruskal-Wallis tests were employed for comparison of the mean of two and more than two dependent non-normal populations, respectively. Spearman’s correlation (r) tests and linear regression analysis were also applied for determination of the relationship between variables. Finally, a multiple linear regression analysis was also performed to assess the concurrent effects of different explanatory variables on Hg levels. p-values <0.05 were considered statistically significant.

Results

Sample characteristics

Sixty-two hair and nail samples were collected from Iranian women who worked as a hairdresser with average age of 27.3 years (ranged from 22 to 43 years) and weight of 59.9 kg. The descriptive statistics for the Hg concentrations in the hair and nails of this sample are summarized in Table 2. The numbers of hair and nail samples in different mercury concentration categories are also shown in Fig. 1.

Hg concentrations and independent variables

Using the Kolmogorov-Smirnov test, the Hg concentration in total samples (hair and nail) was not normally distributed (p<0.001). So, in order to assess the univariate relationship among the women’s ages, weights, and other independent parameters with the Hg concentration in hair and nail samples, Spearman’s correlation test was employed, and the results revealed significant relation between Hg levels and No. of amalgam fillings (r_h=0.51, r_n=0.42), use of cosmetics (r_h=0.48, r_n=0.69) and use of gloves (r_h=−0.39, r_n=−0.54). However, the correlation was stronger for No. of amalgam fillings and use of cosmetics (p-value <0.001) compared with use of gloves (p-value_h=0.02; p-value_n=0.006).

Effect of amalgam fillings

In the present work, participants were divided into

Table 1. Results of a quality assurance procedure for mercury (µg/g)

<table>
<thead>
<tr>
<th>Standard reference material</th>
<th>N</th>
<th>Certified value</th>
<th>Obtained mean</th>
<th>SD</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST-1633</td>
<td>3</td>
<td>0.141</td>
<td>0.139</td>
<td>0.015</td>
<td>98.5</td>
</tr>
<tr>
<td>NIST-2709</td>
<td>3</td>
<td>1.400</td>
<td>1.434</td>
<td>0.146</td>
<td>102</td>
</tr>
<tr>
<td>NIST-2711</td>
<td>3</td>
<td>6.250</td>
<td>6.437</td>
<td>0.419</td>
<td>103</td>
</tr>
</tbody>
</table>

a Standard deviation. b Recovery (%). c National Institute of Standards and Technology.

Table 2. Descriptive statistics for Hg concentrations in the hair and nails of this sample (µg/g)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Number</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>SD</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair</td>
<td>62</td>
<td>0.20</td>
<td>6.32</td>
<td>1.15</td>
<td>1.03</td>
<td>0.151</td>
</tr>
<tr>
<td>Nail</td>
<td>62</td>
<td>0.24</td>
<td>6.94</td>
<td>1.82</td>
<td>1.12</td>
<td>0.177</td>
</tr>
</tbody>
</table>

![Fig. 1. A histogram showing the distribution of samples in different mercury concentration categories.](image)
two groups in accordance with the number of amalgam fillings: the first group had less than 3 amalgam fillings, and second group had at least 5 amalgam fillings. Correlation testing showed that the Hg concentrations in hair and nail samples were significantly correlated with the number of amalgam fillings ($p<0.001$). Spearman’s correlation coefficients for hair and nail samples were 0.74 and 0.76 respectively. In a group of participants with at least 5 amalgam fillings, the Hg concentrations were significantly higher than the others ($p<0.001$) (Table 3).

**Effect of precautionary measures and cosmetic products**

Although there was no significant effect of using masks on Hg levels, the results indicated a significant difference in hair ($p=0.02$) and nails ($p=0.006$) between those who always use gloves and those who rarely use gloves (Table 3). Since amalgam fillings have been shown to be an important source of mercury, subjects who had high No. of amalgam fillings were excluded from calculation of the mean in subgroups who used precautionary measures.

Therefore, the computed mean in each subgroup for masks and gloves is lower than the overall mean (1.15).

Analysis of the data also revealed a significant effect of continuous use of cosmetics on Hg levels. It is noticeable that in many communities, high usage of cosmetics by hairdressers is considered as an indication of their professional skill and a way to attract more customers.

Furthermore, Spearman’s coefficient showed a significant correlation among Hg concentration in hair and nail samples ($r=0.98$, $p<0.001$) and significantly higher Hg concentrations in nails obtained by the Wilcoxon test ($p<0.001$).

**Multiple regression results**

In the last step, multiple regression of the Hg concentration for the whole sample was performed in order to assess the concurrent effects of different explanatory variables on Hg levels. Positive results were observed between the Hg concentration and two parameters: No. of amalgam fillings and use of cosmetic products for the whole sample. Table 4 presents the related results.

**Discussion**

Regarding the Hg level in the samples in this work, there was a significant difference between hair and nail samples of hairdressers who reported high usage of cosmetics, which could confirm that some of the beauty products contained mercury with the ability to be absorbed through the skin.$^{19}$

Furthermore, in terms of individual exposure through amalgam restorations, subjects who had at least 5 amalgam fillings, had elevated mercury concentrations in their hair and nail samples, which is well accordance with our previous study, which showed that amalgam restorations are one of the most important routes of Hg exposure$^{20}$.

According to the obtained results, age and weight had no significant influence on Hg levels, which is similar to what was reported by Agusa et al. (2007)$^{21}$ and Karouna-Renier et al. (2008)$^{22}$. Generally, Hg concentrations in nail samples were higher than in hair, which might be attributed to different chemical compositions of hair and nail samples, particularly

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Number</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>Mean ± SD</th>
<th>Range</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of amalgam fillings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3</td>
<td>35</td>
<td>0.38 ± 0.16</td>
<td>0.20–0.72</td>
<td>0.48 ± 0.23</td>
<td>0.24–1.00</td>
<td>&lt;0.001 &lt;0.001</td>
</tr>
<tr>
<td>≥5</td>
<td>27</td>
<td>2.33 ± 1.56</td>
<td>0.81–6.32</td>
<td>2.79 ± 1.67</td>
<td>0.99–6.94</td>
<td></td>
</tr>
<tr>
<td>Use of masks</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>29</td>
<td>0.37 ± 0.05</td>
<td>0.32–0.50</td>
<td>0.41 ± 0.05</td>
<td>0.32–0.52</td>
<td>0.80 0.57</td>
</tr>
<tr>
<td>Rarely</td>
<td>33</td>
<td>0.40 ± 0.06</td>
<td>0.32–0.51</td>
<td>0.42 ± 0.05</td>
<td>0.33–0.52</td>
<td></td>
</tr>
<tr>
<td>Use of gloves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>28</td>
<td>0.38 ± 0.06</td>
<td>0.29–0.50</td>
<td>0.39 ± 0.06</td>
<td>0.31–0.45</td>
<td>0.02 0.006</td>
</tr>
<tr>
<td>Rarely</td>
<td>34</td>
<td>0.47 ± 0.06</td>
<td>0.38–0.58</td>
<td>0.50 ± 0.05</td>
<td>0.39–0.58</td>
<td></td>
</tr>
<tr>
<td>Use of bleaching cream and nail polish</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always</td>
<td>36</td>
<td>1.25 ± 0.11</td>
<td>0.44–3.23</td>
<td>1.92 ± 0.23</td>
<td>0.68–3.89</td>
<td>&lt;0.001 &lt;0.001</td>
</tr>
<tr>
<td>Rarely</td>
<td>26</td>
<td>0.42 ± 0.08</td>
<td>0.20–0.53</td>
<td>0.48 ± 0.08</td>
<td>0.28–0.66</td>
<td></td>
</tr>
</tbody>
</table>
sulphur content, and blood flow during their formation. In the current work, about 30% of all mercury concentrations were higher than the USEPA-recommended 1 µg/g (Fig. 1). However, given that there is no special impact level for Hg toxicity, any concentration of mercury could be harmful to the human body.

Several studies on mercury toxicity in the human body are available in literature. Studies on animals and humans show that mercury is continuously released from dental amalgam and absorbed by several body tissues. It is widely accepted that the main source of mercury vapor is the dental amalgam and that contributes substantially to mercury load in human body tissues.

In a study by McRill et al. (2000), investigation of health effects associated with the use of a mercury-containing beauty cream demonstrated that the cosmetic cream was a significant source of mercury exposure. In a study of Mexican beauty cream users, Weldon et al. (2000) showed that 96% of the 330 cream users who contacted the health department were women and that most cream users had increased urine and blood mercury concentrations, which is in agreement with the high Hg concentrations in hair and nails of the cosmetic users in the present study.

The mercury content of cosmetic creams ranged from 660 to 57,000 ppm in the report of Sin and Tsang (2003), and the majority of cream users had increased urine and blood mercury concentrations, which is in agreement with the high Hg concentrations in hair and nails of the cosmetic users in the present study.

Although it has not yet been revealed how quickly skin-whitening creams will lead to health problems, some informal studies have claimed that impacts are observed just a few weeks after one begins applying them. The mercury compounds in such “beauty creams” is readily absorbed through the skin and may produce chronic Hg poisoning associated with clinical disorders.

Despite the insignificant effect of using gloves in the multiple regression analysis based on the defined significance level, this study showed that gloves may still have a considerable effect on Hg in the hair and nails. Continuous use of gloves resulted in a significant decrease in the Hg levels among the hairdressers and is considered an important protective measure that limits the absorption of mercury through the skin especially during application of bleaching creams on their customers.

It is noticeable that the concurrent effects of individual and occupational sources of exposure, herein amalgam fillings and beauty products, respectively, leads to increased concentrations of mercury in the human body, which confirms the importance of such complicated hidden sources of exposure in mercury assessment studies.

The results of this survey clearly showed that the screened hairdressers were exposed to Hg. The findings concerning dental amalgam fillings deserve further research to determine the magnitude of the effects of Hg exposure on health and to clarify their contribution to Hg body burden particularly once the Hg from amalgam fillings coalesces with that other source of exposure. Furthermore, environmental, cultural and occupational investigations are needed to identify the hidden, less-explored sources of Hg exposure in the workplace. Although the data in this study are not representative of the general community of hairdressers, they reveal an urgent need for a monitoring and regular testing program to check for mercury in cosmetic products followed by report of considerable cases to public health authorities.

### Conclusions

The overall results indicate that the mercury content in about one-third of all samples was higher than the USEPA-recommended 1 µg/g, which represents a serious health risk. This study revealed that increasing the number of amalgam fillings and use of cosmetic

### Table 4. Multiple linear regression results for assessing the concurrent effects of explanatory variables on the Hg concentration

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hair</th>
<th>Nail</th>
<th>Hair</th>
<th>Nail</th>
<th>Hair</th>
<th>Nail</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Est*</td>
<td>0.000</td>
<td>0.001</td>
<td>0.011</td>
<td>0.021</td>
<td>0.082</td>
<td>0.091</td>
<td></td>
</tr>
<tr>
<td>SE*</td>
<td>0.007</td>
<td>0.000</td>
<td>0.014</td>
<td>0.031</td>
<td>0.925</td>
<td>0.961</td>
<td></td>
</tr>
<tr>
<td>No. of amalgam fillings</td>
<td>0.343</td>
<td>0.423</td>
<td>0.026</td>
<td>0.021</td>
<td>0.002</td>
<td>0.004</td>
<td></td>
</tr>
<tr>
<td>Use of masks</td>
<td>−0.182</td>
<td>0.011</td>
<td>0.083</td>
<td>0.037</td>
<td>0.832</td>
<td>0.783</td>
<td></td>
</tr>
<tr>
<td>Use of gloves</td>
<td>0.210</td>
<td>0.226</td>
<td>0.031</td>
<td>0.011</td>
<td>0.076</td>
<td>0.088</td>
<td></td>
</tr>
<tr>
<td>Use of cosmetics</td>
<td>0.432</td>
<td>0.398</td>
<td>0.011</td>
<td>0.026</td>
<td>0.003</td>
<td>0.001</td>
<td></td>
</tr>
</tbody>
</table>

*Regression coefficient estimate. *Standard error of the estimate. *Regression p-value at the 95% significance level.
products leads to elevated Hg concentrations in the human body. It could be also concluded that since beauty products with no specific labels are obviously still available and commonly used in local marketplaces and their contents are poorly controlled, there is an urgent need for a mandatory regular testing program to check for mercury in cosmetic products and for the degree of usage in different groups of people to better understand the health impacts of such hidden, widely available mercury sources besides the more well-known individual sources of exposure.

References