Mercury exposures and symptoms in smelting workers of artisanal mercury mines in Wuchuan, Guizhou, China

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Abstract

Mercury exposures to smelting workers of artisanal mercury mines in Wuchuan, Guizhou, China were evaluated by urine and hair mercury survey. The mean urinary mercury (U-Hg), hair total mercury (T-Hg), and hair methyl mercury (Me-Hg) for smelting workers was 1060 μg/g creatinine (μg/g Cr), 69.3 and 2.32 μg/g, respectively. The results were significantly higher than that of control group, which is 1.30 μg/g Cr, 0.78 and 0.65 μg/g, correspondingly. The average urinary β2-microglobulin (β2-MG) was 248 μg/g Cr for the exposed group contrasting to 73.5 μg/g Cr for the control group and the data showed a serious adverse effect on renal system for the smelting workers. The workers were exposed to mercury vapor through inhalation, and the exposure route of Me-Hg may be through intake of polluted diet. The results indicate that age, alcohol drinking, and smoking are not crucial factors controlling the urine and hair mercury levels for the exposed and the control group. Clinical symptoms including finger and eyelid tremor, gingivitis, and typical dark-line on gums were observed in six workers. This study indicated that the smelting workers in Wuchuan were seriously exposed to mercury vapor.

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Keywords: Mercury exposures; Smelting workers; Artisanal mercury mines; Urine; Hair

1. Introduction

Mercury (Hg) and its compounds are recognized as potentially hazardous materials and are rated in the top category of environmental pollutants. Mercury can cause significantly adverse effects on human health. The toxicity of mercury depends on its chemical form. Inhalation of mercury vapor and ingestion of Me-Hg via the diet are the most important routes of human exposure to mercury. Ingestion of Me-Hg via the diet is the most important route of human exposure.

Mercury vapor is the most important route of human exposure to mercury, while the dental amalgam filling is the predominant source of human exposure to elemental mercury in the general population (Clarkson, 2002).

About 80% of the inhaled mercury vapor is retained in the bloodstream and from there is distributed to the tissues. Urine and feces are the principal routes of mercury elimination and the urinary route dominates when exposure is high (WHO, 1990, 1991). The half-time for Hg in urine is about 2 months. U-Hg measurements are widely used for assessment of inorganic mercury (mainly mercury vapor) exposure in humans because U-Hg is thought to be indicating most closely the mercury levels present in the kidneys (Clarkson et al., 1988; Barregard, 1993).

Elemental mercury may cause a variety of adverse effects. Neurological effects, renal effects, cancer, respiratory effects, cardiovascular effects, gastrointestinal and...
hepatic effects, effects on the thyroid gland, effects on the immune system, effects on the skin, reproductive and developmental effects, and genotoxicity have been observed following exposure to mercury vapor (WHO, 1991; USEPA, 1997; ATSDR, 1999; UNEP, 2002). The specific symptoms are found in the central nervous system and the kidney.

China is rich in Hg and the reserve of Hg ranks the third in the world. The most important Hg production center in China is Guizhou Province. From the perspective of the global plate tectonics, Guizhou Province is situated in the circum-Pacific mercuriferous belt (Qiu et al., 2006), and so far 12 large or super-large Hg deposits have been discovered there. The reserve of cinnabar deposits in Guizhou, approximately 80,000 tons of metal Hg, represents approximately 70% of the total in China (Qu, 2004). Wuchuan mercury mine is one of the largest mercury mines in China with mercury reserve up to 23,320 metric tons. It has a long history of mercury production for approximately 400 years and more than 4000 tons of metal mercury has been produced. The large-scale mercury mining activities began in 1949 and ceased in 2003 mainly due to insufficient profits. However, the market for mercury demand has been increasing since China started to restrict importing mercury from Europe and other regions a few years ago. Consequently, mercury prices in the market went up sharply recently, which stimulated the revival of small-scale or artisanal mercury smelting activities in Guizhou. The illegal artisanal mining activities are extensively existed in mercury mining areas especially in Wuchuan area. The mercury ore (cinnabar) was crushed and then heated to 700–800 °C to produce mercury vapor that condensed in cooling wooden barrel, which contained water. Because the simple smelting processes are without any environmental protection measures, the mercury emission factors (the proportion of mercury in ore is released to the ambient air) ranged from 6.9% to 32.1% and the annual mercury emission from artisanal mercury smelting activities was up to 3.7–9.6 tons in Wuchuan area (Li et al., 2006). The artisanal mining activities have resulted in serious mercury pollution to the local environment (Qu, 2004; Qiu et al., 2006). Therefore, the health of the workers may be negatively affected through inhalation of mercury-polluted air.

Up to date, only a few studies regarding mercury contamination to the local environments have been carried out in Wuchuan mercury mining areas (Qu, 2004; Li et al., 2006; Qiu et al., 2006). To the best of our knowledge, human mercury exposure survey has not been reported in the study areas. The present study was designed to investigate mercury exposure to the smelting workers in Wuchuan areas by measuring their urine and hair mercury levels. Efforts were also made to identify clinical symptoms of mercury poisoning for the smelting workers. In a companion paper, the effects of mercury vapor exposure on the neuromotor function of the artisanal smelting workers were examined (Iwata et al., 2007).

2. Materials and methods

2.1. Study area and selected population

The Wuchuan county (E: 107°31′–108°31′, N: 28°11′–29°05′) is located at the northeast of Guizhou Province (Fig. 1) with an area of approximately 2778 km². The Wuchuan district is hilly, karstic and its average altitude is 1034m (with a range of 325–1743 m) above the sea level. Smelting workers in the artisanal mining mine in Wuchuan area were chosen to the mercury exposure survey. For comparison, residents in Changshun County were selected as the control group. Changshun County is located in the south of Guizhou Province (Fig. 1) and is about 90 km away from Guiyang City, the capital of the province. A large proportion of residents is ethnic minority groups both in Wuchuan and in Changshun County. The ethnic groups live on farming and have own traditional custom. Basically, the two selected groups have similar living habits so that it is favorable for comparison. The smelting workers in Wuchuan are mostly male, so that the control group also consists of all male residents. The present study obtained the ethics approval by the Institute of Geochemistry. All participants were required to sign a consent form.

2.2. Sample collection

In June 2005, 22 smelting workers in Wuchuan and 40 residents in Changshun joined in the investigation. Urine and scalp hair samples were collected for investigating mercury exposure levels. The urine samples were collected in pre-cleaned plastic centrifugal tubes, hermetically sealed and frozen at 4 °C until analysis. Hair samples were cut with a stainless steel scissors from the occipital region of the scalp, bundled together with scrip, placed and sealed in polyethylene bags, properly identified and taken to the laboratory for analysis.

Fig. 1. Locality of the study areas and the control site.
A questionnaire was utilized to collect information on residential history, occupational history, dietary habits, life style (smoking habit and alcohol drinking), and health history. Clinical examinations were carried out by specialists from National Institute for Minamata Disease, Japan.

2.3. Analytical method

Hair samples were washed with nonionic detergent, distilled water, and acetone, and dried in an oven at 60°C overnight. Urine and hair samples were digested in a water bath (95°C) with a fresh mixed acid of HNO$_3$:H$_2$SO$_4$ (4:1, v/v) for T-Hg analysis (Horvat et al., 1991). For Me-Hg analysis, prepared hair samples were digested using KOH–methanol/solvent extraction technique (Liang et al., 1994, 1996, 1996). T-Hg concentrations in hair and U-Hg were determined by cold vapor atomic fluorescence spectrometer (CVAFS) or cold vapor atomic absorption spectrometry (CVAAS). Me-Hg contents in hair samples were measured using gas chromatography–cold vapor atomic fluorescence spectrometer (GC–CVAFS) detection.

Urinary parameters (including urinary pH, protein, and hematuria) were assayed by test paper upon sample collection. Urinary creatinine (U-Cr) contents were analyzed with a HITACHI 7170A automatic determination. Urinary creatinine excretion was adjusted by creatinine excretion. The results of U-Hg as a biomarker for exposure to mercury vapor was adjusted by creatinine excretion. The results of U-Hg were given in μg/g creatinine (μg/g Cr). Normal creatinine values are between 0.5 and 3.0 g/L (ACGIH, 1997) so that the extreme creatinine concentrations were excluded from the evaluations. Urinary β2-MG concentrations were analyzed by radioimmunoassay method (Chen, 1985).

For the control group, we found some participants had kidney dysfunction from the urinary parameters tests. Since both mercury exposure and kidney dysfunction may cause the increase of β2-MG concentration in urine, we only selected those urine samples collected from participants who had no kidney dysfunction problem for β2-MG determination.

As part of a strict Quality Assurance/Quality Control program, method blanks, blank spikes, matrix spikes, certified reference material, and blind duplicates were analyzed along with field samples. The mean T-Hg in the certified reference material of hair samples (NIES-13) was 4.4±0.1 μg/g (n = 6) consistent with the certified value of 4.4±0.2 μg/g. The average Me-Hg was 3.5±0.1 μg/g (n = 5) in good agreement with the certified value of 3.8±0.4 μg/g. The recoveries from spiked samples ranged from 83% to 120% for Me-Hg in hair sample, and ranged from 98% to 103% for T-Hg in urine samples. The relative percent difference was lower than 5% for T-Hg in hair and urine duplicate samples.

2.4. Statistical analyses

Statistical analyses were performed using SPSS 11.5 for windows. Mean values were compared between the exposed and control groups using independent-samples t test to evaluate the differences between the two groups. The correlation coefficients among U-Hg, hair T-Hg, and Me-Hg in each group were studied by Pearson correlation analysis. The results of a statistical test were considered statistically significant if p<0.05.

3. Results and discussion

3.1. Urine, hair mercury levels

Urine, hair mercury levels, and other parameters were compared between the mercury exposed group and the control group, and the results are summarized in Table 1. The mean age was similar between the two selected groups. Furthermore, there was no significant difference in both U-Cr and U-pH in the two groups. However, there were significant differences in mean U-Hg (p<0.001), mean urinary β2-MG (p<0.05), mean hair T-Hg (p<0.001), mean hair Me-Hg (p<0.001) and mean percentage of T-Hg as Me-Hg (p<0.05) between the two groups, respectively.

The maximum urinary mercury concentration for occupational workers recommended by the WHO (1991) was 50 μg/g Cr. Urine mercury levels rarely exceed 5 μg/g Cr in people who are not occupationally exposed to mercury (UNIDO, 2003). The geometric mean U-Hg for smelting workers was 463 μg/g Cr which was considerably higher than 1.30 μg/g Cr for the control group. The highest U-Hg in smelting workers reached 6150 μg/g Cr which is about 120 times higher than the occupational exposure limit level (50 μg/g Cr) recommended by WHO (1991). Ninety-five percent (21/22) of U-Hg exceeded the limit value indicating that the smelting workers in the Wuchuan area were seriously exposed to mercury vapor.

β2-MG as a renal biomarker can be used to study human nephrotoxicity at an early stage (Lauwerys and Bernard, 1989; Mueller and Jay, 1989). It is useful to define the effects for assessing re-absorption function to indicate

### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>The exposed group (N = 22)</th>
<th>Range</th>
<th>The control group (N = 40)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>42±9</td>
<td>30–63</td>
<td>41±13</td>
<td>23–67</td>
</tr>
<tr>
<td>U-pH</td>
<td>5.5±0.7</td>
<td>5.0–7.5</td>
<td>5.5±0.6</td>
<td>5.0–7.0</td>
</tr>
<tr>
<td>U-Cr (g/L)</td>
<td>1.39±0.47</td>
<td>0.56–2.01</td>
<td>1.03±0.40</td>
<td>0.57–1.97</td>
</tr>
<tr>
<td>U-Hg (μg/L)</td>
<td>1080±1260***</td>
<td>41–4830</td>
<td>1.27±0.47</td>
<td>0.56–2.96</td>
</tr>
<tr>
<td>U-Hg (μg/g Cr)</td>
<td>1060±1510***</td>
<td>28–6150</td>
<td>1.30±0.39</td>
<td>0.68–2.32</td>
</tr>
<tr>
<td>Urinary β2-MG (μg/g Cr)</td>
<td>248±295*</td>
<td>26.3–1030</td>
<td>73.5±36.2</td>
<td>32.0–134</td>
</tr>
<tr>
<td>Hair T-Hg (μg/g)</td>
<td>69.3±44.4***</td>
<td>9.91–143</td>
<td>0.78±0.28</td>
<td>0.32–1.72</td>
</tr>
<tr>
<td>Hair Me-Hg (μg/g)</td>
<td>3.32±1.26r</td>
<td>0.83–5.89</td>
<td>0.65±0.23</td>
<td>0.26–1.38</td>
</tr>
<tr>
<td>%Me as Me-Hg (%)</td>
<td>7.18±8.65*</td>
<td>0.71–31.6</td>
<td>83.5±12.6</td>
<td>52.7–99.9</td>
</tr>
</tbody>
</table>

*Significant difference was observed between the exposed group and the control group at p<0.001.

***Significant difference was observed between the exposed group and the control group at p<0.05.
tubular injury. The average urinary \( \beta_2 \)-MG concentration for the exposed workers was 248 \( \mu \)g/g Cr, which was substantially higher than 73.5 \( \mu \)g/g Cr for the control group. In conclusion, the present study showed a serious adverse effect on renal system due to mercury vapor exposure for smelting workers. Significant correlation \((r = 0.85, p < 0.01)\) was found between U-Hg and urinary \( \beta_2 \)-MG concentrations of smelting workers in Wuchuan area (Fig. 2). This also confirmed that the elevation of urinary \( \beta_2 \)-MG concentrations of smelting workers is indeed resulted from the exposure to mercury vapor.

The smelting workers in Wuchuan showed very high U-Hg levels of which the mean value reached 1060 \( \mu \)g/g Cr (1080 \( \mu \)g/L). The data are comparable to the results obtained from smelting workers in Abbadia San Salvatore mine, Italy which was 1111.6 \( \mu \)g/L (Bellander et al., 1998). The comparison among mercury levels in human urine from different exposed populations is summarized in Table 2. Obviously, urinary mercury levels from smelting workers in the Wuchuan area were much significantly higher than those from other exposed populations around the world, indicating a high health risk to the smelting workers. The higher Me-Hg level in the hair of the exposed group also needed to be scrutinized though the percentage of Me-Hg as T-Hg was very low.

### 3.2. Correlation between hair Hg and U-Hg

The correlation coefficients between hair T-Hg, hair Me-Hg, and U-Hg for the two groups are listed in Table 3. For the control group, Me-Hg constitutes 83.5% of the T-Hg in the hair and shows significant correlation \((r = 0.90, p < 0.01)\) with hair T-Hg which is consistent with most previous studies. Me-Hg usually constitutes at least 80% of the T-Hg analyzed in hair among fish consumers (Mcdoowell et al., 2004). On the contrary, hair T-Hg concentrations had no significant correlation with hair Me-Hg concentrations, but had a significant correlation with U-Hg \((p < 0.05)\) for the exposed group. Moreover, hair Me-Hg in

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**Table 2**

<table>
<thead>
<tr>
<th>Location</th>
<th>( N )</th>
<th>Mean ± S.D. (( \mu )g/ g Cr)</th>
<th>Range (( \mu )g/g Cr)</th>
<th>Comments</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mwakitolyo and Katente, northern Tanzania</td>
<td>45</td>
<td>39.8 ± 0.9</td>
<td>7–172.0</td>
<td>Workers for small-scale gold mining with amalgam</td>
<td>Straaten (2000)</td>
</tr>
<tr>
<td>Suriname, Brazil</td>
<td>28</td>
<td>27.5 ± 21.1</td>
<td></td>
<td>Workers in the small-scale gold mining with amalgam</td>
<td>Kom et al. (1998)</td>
</tr>
<tr>
<td>Egypt</td>
<td>31</td>
<td>28.2 ± 21.4</td>
<td></td>
<td>Mercury exposed workers in a fluorescent lamp factory</td>
<td>El-Safty et al. (2003)</td>
</tr>
<tr>
<td>El Callao, Venezuela</td>
<td>33</td>
<td>101 ± 12</td>
<td>2.5–912</td>
<td>Workers for gold mining operation with amalgam</td>
<td>Drake et al. (2001)</td>
</tr>
<tr>
<td>Slovenia</td>
<td>54</td>
<td>69.3 ± 31.4</td>
<td>26–158</td>
<td>Mercury miners, average annual past exposure U-Hg levels</td>
<td>Kobal et al. (2004)</td>
</tr>
<tr>
<td>Mt. Diwata, Mindanao, Philippines</td>
<td>313</td>
<td>8.4 ± 0.1</td>
<td>0.1–196</td>
<td>Workers for small-scale gold mining with amalgam, local inhabitants and a control group</td>
<td>Drasch et al. (2001)</td>
</tr>
<tr>
<td>Algeria</td>
<td>64</td>
<td>139 ± 80.9</td>
<td>33–382</td>
<td>Workers from the mercury production plant</td>
<td>Abdennour et al. (2002)</td>
</tr>
<tr>
<td>Algeria</td>
<td>82</td>
<td>29.3 ± 23.2</td>
<td>0–132</td>
<td>Workers from the chlor-alkali unit</td>
<td>Abdennour et al. (2002)</td>
</tr>
<tr>
<td>Monte Amiata, Italy</td>
<td>606</td>
<td>AM 160 ( \mu )g/L, GM 83 ( \mu )g/L</td>
<td>1.3–10565 ( \mu )g/L</td>
<td>Workers in Abbadia San Salvatore mine, in the period 1968–1983 Workers, job with cinnabar</td>
<td>Bellander et al. (1998)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 AM 1111.6 ( \mu )g/L, GM 182.6 ( \mu )g/L</td>
<td>17–10565 ( \mu )g/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wuchuan, Guízhou, China</td>
<td>22</td>
<td>1060 ± 1510 GM 463 (GM)</td>
<td>28–6150</td>
<td>Mercury smelting workers</td>
<td>This study</td>
</tr>
</tbody>
</table>

AM, arithmetic mean and GM, geometric mean.
the exposed group just accounted for 7.2% of T-Hg, which is very low compared with the control group. Research showed that hair T-Hg analysis is difficult in differentiating between exogenous metal contamination and the metal deposited endogenously (Hat and Krechniak, 1993). Therefore, we measured both hair T-Hg and Me-Hg to distinguish the Me-Hg intake and external exposure to mercury vapor. Low percents Hg as Me-Hg and no correlation between hair T-Hg and hair Me-Hg explained the different exposure route of inorganic mercury and Me-Hg. The workers were exposed to mercury vapor through inhalation, and the exposure route of Me-Hg may be through intake of polluted diet. Previous studies demonstrated that rice cultivated in mercury mining areas generally contained high level of Me-Hg (Horvat et al., 2003; Qiu et al., 2006). The local residents in the study area seldom eat fish and rice is the staple food. Thus, the intake of mercury contaminated rice as a route of Me-Hg exposure to the local inhabitants in mercury mining areas in Guizhou Province should be taken into account.

### 3.3. The impacts of smoking and alcohol drinking on U-Hg and hair mercury

The correlation coefficients between age and hair T-Hg, Me-Hg, and U-Hg for the exposed group and the control group were analyzed and listed in Table 4. The comparison of hair Hg and U-Hg levels between smokers and nonsmokers for the exposed group is given in Table 5. As tobacco leaves contain mercury, smoking may also contribute to inhalation exposure. However, no significant difference in U-Hg was observed between smokers and nonsmokers both for the exposed group and for the control group. It is obvious that smoking may have very less contribution to mercury exposure for smelting workers compared with inhalation of highly Hg contaminated air.

The comparison of hair Hg and U-Hg levels between alcohol drinkers and nondrinkers for the exposed group and the control group is listed in Table 6. For the control group, alcohol drinkers have significant lower mean hair T-Hg concentrations ($p = 0.003$) and hair Me-Hg concentrations ($p = 0.002$) than the nondrinkers. A number of interactions have been identified for chemicals that affect the pharmacokinetics and/or toxicity of mercury compounds. Generally, ethanol inhibits the enzyme catalase, which is the main enzyme responsible for the oxidation of mercury vapor into ionic mercury in blood. Ethanol consumption can decrease mercury vapor absorption (USEPA, 1997; UNEP, 2002). However, for the control group, the source of hair T-Hg and Me-Hg is through diet intake, but not from inhalation of mercury vapor. Generally, the alcohol drinkers eat less rice, which may be responsible for the lower hair T-Hg and Me-Hg concentrations. For the exposed groups, on the other hand, drinking alcohol is not the decisive factor of hair Hg and U-Hg levels.

The results indicate that alcohol drinking and smoking are not crucial factors controlling the urine and hair mercury levels for the exposed and the control group.

### 3.4. Mercury in the air and its relationship with U-Hg

Total gaseous mercury (TGM) concentrations in the ambient air in Wuchuan mining areas were highly elevated. The mean TGM concentration near the smelting furnace was up to 40 µg/m$^3$ ($n = 10$), greatly exceeding 20 µg/m$^3$ according to the Chinese occupational criterion (GB 16227-1996). In 1980, the World Health Organization (WHO) recommended an 8-h time-weighted average (TWA) mercury exposure standard of 25 µg/m$^3$ (WHO, 1980). The serious mercury contamination in ambient air was certainly attributed to the artisanal mercury smelting activities. The mercury emission factors (the proportion of mercury in ore is released to the ambient air) during the smelting processes ranged from 6.9% to 32.1% (Li et al., 2006); as a result, a large amount of mercury vapor was released to the ambient air.

Many studies have showed a strong correlation between the level of mercury in urine and the level of elemental mercury in air in occupational settings. Values for air concentration (in µg/m$^3$) are approximately the same as those for urine mercury concentration (expressed in µg/g Cr) (WHO, 1991). A significant correlation ($r^2 = 0.599$; $p < 0.001$) was found between mercury in air versus urine from various studies, including at lower air concentrations ranging from approximately 10 to 50 µg/m$^3$ (Tsuji et al.,
The regression equation fitting to all studies is
\[ \text{urine} = 3.24 \times \text{air}^{0.833}. \]  

Using Eq. (1), however, the corresponding urine mercury should just be about 70 mg/L, if the average mercury concentration in air is 40 mg/m³. According to the WHO (1991), air mercury concentration of 40 mg/m³ is approximately corresponding to 40 mg/g Cr urinary mercury. However, the geometric mean of urinary mercury for the smelting workers in YQG in Wuchuan mining areas was 602 mg/L (463 mg/g Cr) corresponding to the air mercury concentration of 40 mg/m³. During our investigation, TGM concentrations in ambient air around the smelters were only measured at one site 2–3 m away from one of the smelter. The sampling time of TGM measurement only lasted for 5 min. It is obviously that the average TGM concentrations of 40 mg/m³ is not representative of the average personal exposure since air mercury levels are highly variable (i.e. Symanski et al., 2000). In order to better evaluate Hg vapor exposure for the smelting workers, systematical air Hg measurements are needed (Roels et al., 1987).

### 3.5. Clinical symptoms

Most studies focused on the effects on the central nervous system following occupational exposure to mercury vapor, and the occupational exposure has resulted in erethism, irritability, excitability, excessive shyness, and insomnia as the principal features of a broad-ranging functional disturbance. With continuing exposure, a fine tremor develops, initially involving the hands and later spreading to the eyelids, lips, and tongue, causing violent muscular spasms in the most severe cases (WHO, 1990). Gingivitis and typical dark line on gums have been reported after high inhalation exposures (Bluhm et al., 1992; Barregard et al., 1996). Clinical symptoms were also found in the smelting workers by health examination. Clinical symptoms and correlative parameters of mercury poisoning workers in Wuchuan areas are listed in Table 7.

<table>
<thead>
<tr>
<th>Clinical symptom</th>
<th>Urinary T-Hg (mg/g Cr)</th>
<th>Urinary parameters</th>
<th>Urinary β2-MG (mg/g Cr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worker 1 Lightly tremor (finger and eyelid)</td>
<td>3680</td>
<td>Hematuria (+ +)</td>
<td>–</td>
</tr>
<tr>
<td>Worker 2 Lightly tremor (eyelid)</td>
<td>202</td>
<td>Hematuria (±)</td>
<td>72.7</td>
</tr>
<tr>
<td>Worker 3 Lightly tremor (eyelid)</td>
<td>567</td>
<td>Normal</td>
<td>105</td>
</tr>
<tr>
<td>Worker 4 Gingivitis and typical dark-line on gums</td>
<td>1370</td>
<td>Normal</td>
<td>52.7</td>
</tr>
<tr>
<td>Worker 5 Gingivitis and typical dark-line on gums</td>
<td>586</td>
<td>Normal</td>
<td>326</td>
</tr>
<tr>
<td>Worker 6 Lightly tremor (finger and eyelid), gingivitis</td>
<td>229</td>
<td>Proteinuria (±)</td>
<td>204</td>
</tr>
</tbody>
</table>

**Significant difference was observed between drinkers and nondrinkers at \( p < 0.01 \).**
Symptoms include finger and eyelid tremor, gingivitis and typical dark-line on gums were observed in six workers. These indicated that physical impairments were occurred and the workers were heavily exposed to mercury vapor during the process of cinnabar roasting.

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