

Mercury Levels of Environmentally and Occupationally Exposed Residents in Bornuur and Jargalant Districts of Mongolia

Davaadorj Rendoo¹, Baatartsol Dayanjav¹, Uyanga Ganbold¹, Stephan Bose-O'Reilly²,
Altanchimeg Onom¹, Unursaikhan Surenjav¹, Suvd Duvjir^{1,*}

¹Toxicology Sector, National Center for Public Health, Ministry of Health, Mongolia

²Institute and Outpatient Clinic for Occupational, Social and Environmental Medicine, WHO Collaborating Centre for Occupational Health, University Hospital Munich, Germany

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Abstract Introduction: Bornuur and Jargalant districts are sites with relatively long history of artisanal gold mining. The findings of this study are presented in the context of previous mercury exposure assessment conducted in 2008 by the WHO. This article summarizes the assessment of environmental and occupational exposure to mercury in the region following recent implementation of National Mercury Risk Management policies. Methods: A total of 79 blood and urine samples were analyzed for mercury content and grouped as: (1) as occupational exposure for high and medium values and (2) as an environmental exposure for low values. Mongolian background values for mercury content in blood and urine were used as a control. Internal mercury content distributions of the subgroups were compared using statistical tests. Results: The study revealed substantial reduction of mercury urine levels for both occupational (from 5.7µl/L in 2008 to 2.5µl/L in 2012) and environmental (4.78µl/L in 2008 to 1.09µl/L in 2012) exposure, opposite to the increase its level in blood (from 0.55µl/L in 2008 to 0.7µl/L in 2012 for occupational and from 0.33µl/L in 2008 to 0.48µl/L in 2012 for environmental exposure). Conclusion: Lowered urine levels of mercury indicate tendency for gradual decrease of exposure to it in study area, despite recent to the time of study exposure. Mining is remaining to be main exposure source for mercury in Mongolia; therefore the issue of mercury pollution could be regulated and prevented by proper policy measurements from the government towards artisanal mining.

Keywords ASM, Mercury, Bornuur, Jargalant, Health Risk Assessment

1. Introduction

The mining industry is now being considered a key area of growth and development in Mongolia. It is significantly

contributing to the economic and social development, and it is expected to be the main source of long-term growth. The International Monetary Fund (IMF) foresees a double-digit annual growth rate of the mining industry for years to come; the country's growth domestic product is expected to rise by as much as 10 percent per year, from the current \$5 billion to \$30 billion by 2020, as a result of outputs from mining alone [1]. Gold mining industries in particular have had expanded rapidly in the last fourteen years and now generates 70% of the country's total foreign currency [2]. There is a large extent of artisanal or informal mining activity in Mongolia. According to a World Bank (2008b) study, some 67,000 people were employed in artisanal and small scale mining (ASM) [3]. Worldwide, small-scale miners use mercury to extract gold from milled ore. The improper use of mercury can lead to environmental pollution and can cause serious health problems in miners and communities. Mercury has high neurotoxic, nephrotoxic and teratogenic effects and can cause acute and chronic intoxication. The main affected organs are the brain (cerebellum) and the kidney [4]. An elemental mercury fume, which is the main intoxication pathway for occupational exposure of informal miners in Mongolia are particularly toxic to human nervous system [5, 6, 7]. Mercury exposure in children is of particular importance because of its neurodevelopmental toxicity, which occurs even at low concentrations of exposure [8, 9].

1.1. Mercury Exposure in the Study Region

Bornuur and Jargalant are districts located in Töv district, 100 km north of Ulaanbaatar. Since the turn of the century, these two districts have been known for as gold mining sites. Bornuur has population of 4,516 distributed in 1088 households. According to National environmental analysis of 2005 by the Asia Development Bank, as well as based on several studies, seventy-six percent of the households in Bornuur and adjacent districts in the Boroo river basin were

hard-rock informal gold miners using mercury for gold recovery [10, 11]. Participating households are known to involve all family members in some capacity. The miners of Bornuur consume approximately kilograms of mercury each year, or 2.4 tons over the past 5 years (2000-2005). Of this, 56.0% goes to the atmosphere and 44.0% to the soil. Of the mercury waste, 83.3% of miners dump it in the open air in their fenced yards. The JICA study showed that peak mercury content in household yard soil was as high as 230 times the National standard, 2 mg Hg per kg soil (MNS 5850:2008) [12]; A survey performed by Geological Survey of Denmark and Greenland (GEUS) in 2005 revealed that the number of small-scale miners had increased and the release of mercury likewise since the JICA survey took place [13]. According to this report, the ore was delivered in small rock bits no larger than a few centimeters. During the grinding process, approximately 5 kg of mercury was added per 3-4 tons of rock. The overflow, which contains an estimated 30% of the added mercury, was discarded without any precautions [13]. From 2007 to 2010 the Mongolian government implemented sequence actions to enforce and regulate mercury use. Actions were taken to reduce illegal importation and mining related use of mercury by terminating gold-mining licenses (using unknown methods) and confiscating small-scale mills, including those operating in Bornuur and Jargalant. From 2008 to 2012, the number of legal license holders for gold mining reduced from 18 to 3 in Bornuur district and 10 to 1 in Jargalant district [12]. In Bornuur district, a service-based mercury-free gold extraction technology was introduced with the support of Government and International projects for processing ASM's ore in 2009 [14]. The measures taken resulted in a decrease in scale gold mining activities in the study districts, including artisanal activities.

Additional measures to eliminate the burden of Hg exposure included the excavation contaminated soils followed by neutralization of the affected areas [12].

1.2. History of Study Population Mercury Health Risk Assessment

To address the health risk posed by mercury exposure in women of reproductive age and their children, the World Health Organization, Mongolian Ministry of Health and Austrian University of Health Sciences, Medical Informatics and Technologies carried out an environmental epidemiological study in Bornuur and Jargalant districts in 2008, when artisanal gold mining practice using mercury was at its peak in these areas [7]. The Hg biomonitoring studies included a behavioral survey to assess all possible exposure routes, including fish consumption. A nationwide background level study showed very low levels for fish consumption; however the study region population showed especially low fish consumption, i.e. 99.8% reported a fish-exclusive diet year round [15, 16]. Instead, women in the study had been mostly exposed to mercury vapors during smelting, while mostly men had greater elemental

mercury exposure while performing activities of mercury-gold amalgamation and purification. In the study, urine-mercury concentrations were assessed as a biomarker for exposure to elemental mercury. The average mean mercury concentration in urine of the highly exposed study population of Bornuur district 4.27 μ g/l and the average mean mercury concentration in urine of the exposed study population of Jargalant was 6.07 μ g/l [17]. Contributing to the high mean values, the study reported that 11 out of 51 blood-mercury samples in Bornuur district exceeded the Category 1 of German Human Bio Monitoring Value (greater than 7 μ g/l), 2 samples exceeded Category 2 (greater than 25 μ g/l); and in Jargalant district 9 out of 45 samples exceeded Category 1, while 1 sample exceeded Category 2 [7, 18].

1.3. Study Objective

The objective of this study was to assess the environmental and occupational exposure to mercury of the residents of districts with a history of prevalent artisanal small scale mining communities. Bornuur and Jargalant districts have been identified as populations at risk to mercury exposure based on the results of a health survey conducted in 2008 [17]. The current study seeks to gain knowledge on any changes in levels of mercury exposure in populations living in Bornuur and Jargalant districts.

The data is analyzed in the context of the Mongolian national background level and the German derived Human Biomonitoring index [19, 20, 15]. This study focuses on the health burden that is unique to a population exposed to Hg contamination solely ASM activities in Mongolia. The results are discussed in the context of possible needs for developing a lower threshold levels specific to the Mongolian population, whose exposure is limited to environmental Hg and very little to none from fish consumption.

2. Materials and Methods

2.1. Study Region and Study Population

Gold mineralization occurs along disseminated sulphides and also in quartz-sulphide veins in which gold is commonly coarse-grained. Gold extraction by small scale artisanal methods most likely occurs in near-surface quartz-sulphide veins. In 1910, gold deposits in the region were discovered, including one of the largest known deposits in nearby Boroo district, less than 30 km to the north of the study region [11, 13]. Industrial mining began at Boroo shortly thereafter and continued intermittently until present day Small-scale artisanal mining exploiting nearby gold deposits likely began around the same time.

2.2. Laboratory Methods

A total of 158 biological samples were collected:

consisting of 79 blood samples and 79 urine samples. Samples of approximately 10 ml of blood (EDTA vials) were collected in sterile vacuum tubes and approximately 10 ml of urine in sterile tubes. Mercury concentrations in urine samples were measured in the Mercury Laboratory of the Toxicological Center of Public Health Institute (PHI). Mercury concentrations in blood samples were measured in Mercury laboratory of National Institute for Minamata Disease Japan.

Laboratory analyses of Hg in urine: A mobile atomic absorption spectrometer with Zeeman background correction (LUMEX RA-915+ with liquid attachment RP-91; Russia) was used to quantify the amount of inorganic mercury in urine. To analyze for inorganic Hg, 1.0 ml of urine was added into the reaction vessel already filled with 1 ml of a hydrochloric acid containing 5% tin (II) chloride-solution for reduction of mercury in samples. The detection limit for inorganic Hg in urine was 0.1 µg/l using standard methods CA3 01:2010, CA3 02:2010, and CA3 03:2010 approved by order No. 4 of the Science Committee meeting of PHI on 14th May, 2010. Samples with values below method detection limit were retained for 3rd party analysis not included in this study.

Laboratory analyses of Hg in blood: Laboratory analysis of Hg in blood was performed in mercury laboratory in National Institute for Minamata Disease of Japan. Mercury concentrations were determined by cold vapor atomic absorption spectrophotometry (CVAAS) according to the method of Akagi (Akagi *et al.*, 2000), which involves sample digestion with nitric acid (HNO₃), perchloric acid (HClO₄) and sulfuric acid (H₂SO₄) followed by reduction to Hg⁰ by stannous chloride (SnCl₂). This method detection limit, calculated as 3 times the standard deviation (SD) obtained from 7 repeated measurements of a blank solution, was 0.001ng/g. For mercury analysis in blood, samples were precisely weighted to approximately 0.5g. Reference blood material level 1, MR4026 (Nycomed.Co., Oslo, Norway) was measured to check for accuracy of the results. The measured average (n=3) and SD of Hg concentration was 2.1 ng/g±0.2, recommended 2.0-2.4µg/L. All analyses had done by 2-3 times. Final result of every sample was calculated by the average of frequencies.

2.3. Controlling for Confounders

Volunteers that participated in the study were notified of the research objectives, methods and privacy statement according to guidelines discussed and approved by the PHI Scientists Board and the Ministry of Health Medical Ethics Committee. Several potential confounders for mercury concentration in the human body were considered, which were reflected in questionnaire as amalgam fillings, alcohol and tobacco use and fish consumption. Furthermore, the survey design followed previous models that account for these potential confounders [7].

2.4. Data Processing

Statistical analysis with data for questionnaire and

laboratory results of biological samples was performed with SPSS 19.0. Independent samples t-test method was used for laboratory metric data to evaluate difference between Mongolian background blood and urine mercury levels data and the data of this study. The significance was tested on α= 0.05. The possible differences in human specimen mercury levels was tested using Kruskal-Wallis one-way analysis method between variously exposed groups from Bornuur district where introduction of mercury free technology is occurred and Jargalant district, where traditional gold extraction is practiced.

3. Results

The laboratory data is compared with the data of the study “Reference value of mercury in blood and urine of Mongolian people”, conducted at our laboratory, with sponsorship of WHO [16], Table 1. From the t-test value we can assume that exposure in target areas is significantly elevated from background level of mercury in Mongolians. Difference in blood mercury level between communities of Bornuur and Jargalant districts were observed, which could be attributed to the recent to the time of the study secret gold extraction in Bornuur district at their homes, and not much difference in urine mercury level Table 2. The mercury levels in urine was similar for both districts, although it was lowered compare to that of 2008 assessment, which obviously displays that despite to banning measurements for illegal use of mercury low dose exposure still continued in these two regions. From the exposure comparison by the gender we can see that women had higher urine mercury level both for occupational and environmental cases of chronic and acute exposures, which might relate to their duties in ASM activities which were also noted in 2008 study [7], Tables 3 and 4.

Table 1. Laboratory data, 2012

Urine		
Hg content in µg/l	Mongolian Reference ^c (n=1485)	Target area (Bornuur & Jargalant) (n=79)
Mean	0.14	2.1
Median	0.034	0.18
Maximum	32.43	52.85
95 th percentile	0.31	14.80
t-test (p-value)	**p-value 0.007	
Blood		
Hg content in µg/l	Mongolian Reference (n=1422)	Target area (Bornuur & Jargalant) (n=79)
Mean	0.63	0.66
Median	0.31	0.31
Maximum	9.69	9.41
95 th percentile	2.3	3.36
t-test (p-value)	**p-value 0.000	

^cToxicology Sector of National Center of Public Health, Ministry of Health Mongolia, 2012. Study report
n.s. = no significant differences, * = p < 0.05, ** = p < 0.01

Table 2. Blood and urine Hg content comparison by districts (Bornuur vs Jargalant), 2012

Blood content (µg/l)			
	Median	Maximal	Mean
Bornuur, (n=37)	0.59	9.41	1.13
Jargalant, (n=42)	0.31	1.23	0.29
Kruskal-Wallis test	* <i>p</i> -value 0.007		
Urine content (µg/l)			
Bornuur, (n=37)	0.19	52.85	3.28
Jargalant, (n=42)	0.16	16.65	1.11
Kruskal-Wallis test	<i>n.s.</i> , <i>p</i> -value 0.393		

n.s. = no significant differences, * = *p* < 0.05, ** = *p* < 0.01

Table 3. Urea Hg content comparison by gender in both districts, 2012 study

Urine Hg content in µg/l	Environmental (n=23)		Occupational (56)	
	Male, n=7	Female, n=16	Male, n=29	Female, n=27
Mean	0.55	1.32	2.4	2.7
Median	0.04	0.052	0.24	0.41
Maximum	3.57	12.75	52.85	19.4
Minimum	0.01	0.01	0.01	0.02
<i>Kruskal Wallis test</i>	<i>n.s.</i> , <i>p</i> value 0.404		<i>n.s.</i> , <i>p</i> value 0.44	
<i>Kruskal Wallis test</i>	* <i>p</i> value 0.018			

n.s. = no significant differences, * = *p* < 0.05, ** = *p* < 0.01

Table 4. Blood Hg content comparison by gender in both districts, 2012 study

Blood Hg content in µg/l	Environmental (n=23)		Occupational (56)	
	Male, n=7	Female, n=16	Male, n=29	Female, n=27
Mean	0.28	0.55	0.35	1.15
Median	0.15	0.31	0.15	0.47
Maximum	0.92	3.36	1.88	9.41
<i>Kruskal Wallis test</i>	<i>n.s.</i> , <i>p</i> value 0.4		<i>n.s.</i> , <i>p</i> value 0.307	
<i>Kruskal Wallis test</i>	<i>n.s.</i> , <i>p</i> value 0.88			

n.s. = no significant differences, * = *p* < 0.05, ** = *p* < 0.01

Table 5. Mean Hg in urine samples from residents of Bornuur, Jargalant villages- a permanent small artisanal mining area by years along with various related reference levels

Data sources	Urine Hg content µg/l				
	Environment				
	Nr	Minimum	Median	Maximum	Mean
^a 2008	92	0.25	2.88	78.45	4.78
2012	23	0.1	0.05	12.75	1.08
Occupational					
^a 2008	63	0.25	4.37	51.46	5.70
2012	56	0.1	0.25	52.85	2.55
^a Khushaat	42	< 0.10	.10	1.24	.15
^b Mongolian background level	1485	0.1	0.034	32.43	0.14
^a German background level	4741	<0.2	0.43	143.8	0.89
HBM Levels µg/l (health based)					
^d HBMI	7		^d HBMII	25	

^aBaeuml, J., 2011 ^dBoese R-O'Reilly, 2008
^bSteckling, N., 2011 ^cToxicology sector, NCPH, Mongolia, 2012

Table 6. Mean Hg in blood samples from residents of Bornuur, Jargalant villages- a permanent small artisanal mining area by years along with various related reference levels

Data sources	Blood Hg content µg/l				
	Environment				
	Nr	Minimum	Median	Maximum	Mean
^a 2008	92	<0.2	0.2	7.6	0.33
2012	23	0.2	0.31	3.36	0.47
Occupational					
^a 2008	63	<0.2	0.2	9.6	0.55
2012	56	0.2	0.31	9.41	0.74
^a Khushaat	42	<0.2	<0.2	3.6	0.24
^b Mongolian background level	1327	0.2	0.46	9.6	0.7
^a German background level	4645	<0.2	0.58	12.3	0.86
HBM Levels µg/l (health based)					
^d HBMI	5		^d HBMII	15	

^aBaeuml, J., 2011 ^dBoese R-O'Reilly, 2008
^bSteckling, N., 2011 ^cToxicology sector, NCPH, Mongolia, 2012

Table 7. Number of participants in %-age by HBMI & HBMI levels for urine Hg analysis, a2008 & 2012 studies

Years	HBMI (%)		HBMI (%)		Total participants Nr_Env	Total participants Nr_Occup	Total participants Nr
	Env	Occup	Env	Occup			
^a 2008	8.7	17.5	2.2	1.6	92	63	155
2012	2.5	9.3	0.0	2.3	23	56	79

^aBaeuml, J. 2011

4. Discussion

There was a positive response to the study in both Bornuur and Jargalant districts, especially from citizens, which participated in the first health assessment for mercury exposure conducted in 2008, when artisanal gold mining practice using mercury was at its peak in these areas [6, 12]. The community members welcomed the opportunity to learn of their health status and test the levels of Hg in their blood and urine samples as they had long-term involvement in artisanal gold mining. Laboratory data of the current study is presented in Table 1. Results of this study are shown in reference to the results of the study conducted in 2008 [6, 12] and to the German Human Biomonitoring (HBMI and HBMI), the threshold levels Hg in blood and urine of ASGM that characterize health risk for human and to the reference values of German [13] and Mongolian [14] population background levels for urine in table 5, and for blood in table 6, respectively.

Tables 5 and 6 show substantial reduction in urine mercury levels both for occupational and environmental exposure, compare to that of 2008 study. While slight increase its level in blood first of all indicates recent to the time of study exposure and the fact that chronic low dose mercury exposure still occurring in these mining areas. However, from these 2 tables (table 5 & 6) and Table 1 we can notice that mercury background level in Mongolian population is significantly lower than that of German population, which might be related with low almost no consumption of fish and seafood. Therefore even the low level exposure to Hg still might cause body burden in artisanal miners.

Mongolian government implemented policy towards restriction of illegal mercury import, its use in artisanal mining and undertook actions such as cleaning polluted with mercury sites, stopping and withdrawal in-operation mills. In respond to this policy service for processing ASM's ore based on mercury-free gold extraction technology was introduced in 2008 in Bornuur district with the support of Government and international projects, which was operating till 2012, while in Jargalant district artisanal miners continued traditional method of gold extracting with the use of mercury. The number of operating mining sites is reduced from 18 to 2 in Bornuur and from 10 to 1 in Jargalant districts. Despite to our expectation community in Bornuur district displayed higher urine and blood mercury level compare to that of Jargalant district, table 2. Our repeated subsequent visit to the sampling site revealed that due to non-operation of mercury free gold extraction facilities and government prohibition of artisanal mining, miners in Bornuur district switched to the home gold extraction which is resulted in more exposure of miners to Hg vapor and higher urine and blood level respectively, versus to miners from Jargalant district, which did extraction using mercury at the remote from their homes mining sites on open air. The number of participants in %-age by HBMI & HBMI levels for urine Hg analysis

in 2012 lowered compare to that in 2008 as shown in Table 6. This might be related to the overall reduction of artisanal mining activities over gold resource depletion in that area.

5. Conclusions

The main result of this study is that mining is the main exposure source for mercury in Mongolia; therefore issue of mercury pollution could be regulated and prevented by proper policy and measurements towards artisanal mining from the government. The study verified the results of former [7, 17, 18] studies conducted in 2008 in Bornuur and Jargalant districts and came to the conclusion that rising awareness about negative health impact of mercury among population is a powerful key in reducing exposure to mercury in susceptible communities.

Simple restriction of artisanal mining might worsen the situation (as in Bornuur district case), therefore an integrated approaches providing alternative sources for income, together with improving health services and health education is essential.

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