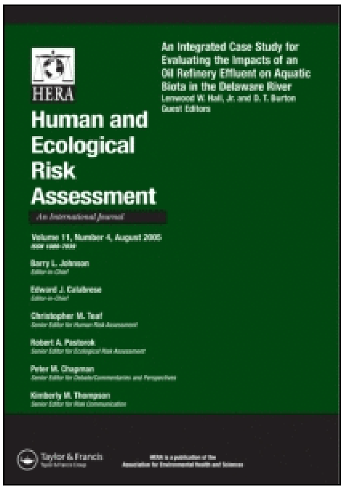

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A Dietary Risk Assessment for Indigenous Consumption of Natural Salt Deposits in the Darhad Valley, Northern Mongolia

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ABSTRACT

The nomadic herding population of the Darhad Valley, in northern Mongolia, collects and utilizes a salt precipitate, called *hujir,* which develops at the saline system, Tohi. This culturally important indigenous dietary supplement is consumed daily as an ingredient in a salty milk-tea and because of its essential micro- and macronutrients it is a beneficial and necessary part of their daily diet. Despite its benefits, there are increasing health concerns among the Darhad people as a result of consuming *hujir.* Therefore, we conducted a dietary risk assessment. Consumption rates were obtained from interviews with nomadic herders of the valley and a chronic exposure assessment was completed using chemical analyses on *hujir* samples. A combination of chronic toxicity threshold values, dietary reference intake recommendations, and drinking water guidelines were used to estimate dietary risks related to *hujir* consumption. Exposures to arsenic, fluoride, and nitrate were as high as 33, 1.2, and 1.3 times the chronic oral reference dose, respectively. Exposures to antimony, arsenic, and lead were 1.7, 19, and 14 times the drinking water guidelines, respectively. Given these results, additional studies are needed to better understand possible health effects associated with *hujir* consumption in the Darhad population, especially for arsenic.

Key Words: arsenic exposure, indigenous salt source, nomadic population, Mongolia, dietary risk assessment.

INTRODUCTION

As with many cultures past and present, it is common tradition for Mongolian nomadic herders to collect mineral precipitate that forms on the surface of saline

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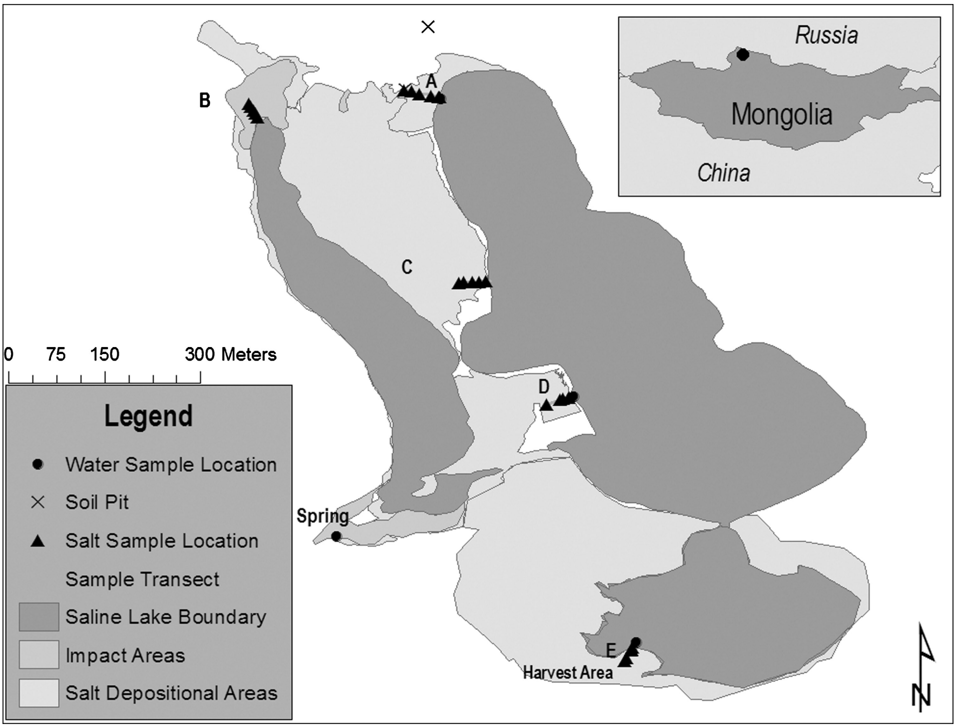

Figure 1. Study location in Mongolia and the GPS–created map of Tohi saline lake. The Darhad Valley's location is symbolized by a dot on the map of Mongolia.

systems and utilize it as an indigenous salt source. The people of the Darhad Valley, in northern Mongolia, obtain precipitate from a saline system called Tohi. The mineral precipitate, *hujir*, is an ingredient in the popular salty tea, *suuti tsai*, and is consumed throughout a typical Mongolian herder's day.

The Darhad Valley is located in Mongolia's northern-most Khovsgol Aimag (defined as a government province) approximately between 50°35′ 56.4″ to 51°24′ 8.4″N, and 99°1′ 20.1″ to 100°3′ 13.3″E (Figure 1). It covers approximately 150 square kilometers and is part of the Baikal Rift System (Goulden *et al.* 2006).

The human population of the entire valley is 9,989 and residents live primarily as nomadic herders who move four or more times each year, following optimal livestock forage each season (Batchimeg 2007). They raise goats, sheep, horses, cattle, and yaks subsisting on what they can produce from these animals, with few imported goods. The most prevalent cause of death in the Khovsgol Aimag is circulatory failure, including organ failures at 31.8% of all deaths in 2006 (Batchimeg 2007).

Tohi is located at approximately 51°23′ 29″N and 99°27′ 43″E and consists of three lakes fed by a groundwater spring on the southwest bank. Tohi is the common collection area for hujir in the valley. The composition of hujir used for consumption has not been previously determined.

The precipitate is formed on the surface of the saline lakes' banks through evaporation and is collected by Darhad residents using a "dragging and gathering" method similar to the method used 8,000 years ago at Lake Yuncheng, China (Kurlansky 2002). The hujir is then transferred to 25–50 kg storage bags. According to our interviews with Darhad residents, they collect an average of 18.1 kg/year (SD $\pm$ 17.6 kg/year, 95% CI 6.2) for family use and 191.8 kg/year (SD $\pm$ 201.6, 95% CI 71.5) for livestock.

The precipitate that forms at Tohi is considered a resource for the people of the Darhad Valley in their everyday lives. Not only is hujir consumed, it is also utilized as soap to wash hair and skin, for cleaning grease from hands and clothing, in baking, and to stop the fermentation process in milk. It is also used in livestock management for ridding horses of parasites, improving livestock strength, increasing the quality of goat's cashmere, increasing the quality of cattle's milk, keeping the livestock warm during the winter months, and for weight gain. It is described traditionally as a cure for any health problem and is used as an ingredient in several Darhad traditional medicines (Bashbish, personal communication).

Despite the cultural and nutritional significance of hujir, the Darhad people have communicated their concerns about potential adverse health effects of consuming hujir. These concerns have arisen because of an increased awareness of health issues and curiosity about whether there are potentially toxic amounts of substances that make up hujir. Therefore, the objective of this study was to estimate dietary risks of hujir consumption. The assessment was based on the chemical composition of hujir and focused on exposure levels estimated for four groups based on gender and age.

MATERIALS AND METHODS

Data for the exposure assessment were received from interviews conducted in the summer of 2007 and from chemical analyses to estimate human exposure levels.[1] Mongolian body weight data were obtained from the World Health Organization (WHO 2007). Dietary threshold values were acquired from several sources including different intake recommendations or standards due to limited availability of toxic endpoints for several ions present in the hujir samples. Toxic endpoint values and drinking water guidelines were obtained from the WHO. The U.S. Environmental Protection Agency's (USEPA's) chronic oral toxic threshold values were applied when WHO values were not available. The U.S. National Academy of Science's (USNAS's) dietary reference intake (DRI) levels specific to ions present were used for comparison.

Problem Formulation and Conceptual Model

We created a conceptual model for toxicological assessment to represent the flow or pathway between the stressor source and the impacts it may cause on a target, organism, or population (Morgan 2005). This conceptual model symbolizes the

[1]The study was exempted by the Montana State University's Institutional Review Board (IRB) from the requirement of IRB review in accordance with the Code of Federal Regulations, Part 46, section 101.

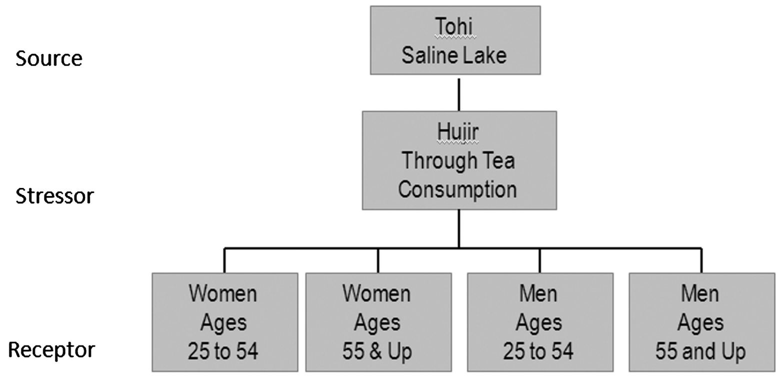

Figure 2. Conceptual model for the dietary risk assessment of Hujir.

dietary risk for hujir and signifies the connection between the harvesting area, Tohi, to the dietary source, the salty milk-tea, *suuti tsai*, and then to the four categories of receptors (Figure 2). The environmental stressor was hujir, and the receptor was the Darhad resident. The route of exposure was chronic dietary consumption defined as an average daily exposure over a lifetime (WHO 2006).

When hujir is added to milk or water-tea, soluble minerals dissolve resulting in increased concentrations of aluminum, antimony, arsenic, barium, boron, calcium, copper, fluoride, iron, lead, magnesium, manganese, nitrate, phosphate, potassium, sodium, sulfate, and zinc. Upon consumption, these elements or compounds can become bioavailable in the human body. Hujir intake provides a source of dietary minerals to the Darhad people and their livestock. However, too much hujir intake may lead to chronic adverse health effects. For the purpose of this dietary risk assessment, the focus was only on human consumption of hujir.

Interviews

To estimate daily exposure of specific constituents found in hujir, it was important to determine the Darhad people's hujir consumption rates (Xu *et al.* 2006). This was completed through culturally respectful interviews including 32 Darhad residents, representing 122 people (family members) throughout the valley. The subjects' locations were dispersed throughout the valley and were chosen based on random stops on travel routes. A more conventional stratified random sample was not feasible because of the nomadic lifestyle of the Darhad population and lack of governmental census tracts or postal codes. Therefore, there is uncertainty as to whether the non-stratified random sampling of individuals accurately represents the hujir consumption habits of the Darhad population. We believe that the sampling most likely represents hujir consumption more broadly because there was little variation in consumption rates among age groups (see later). Only individuals older than age 25 were interviewed because younger residents tend not to add hujir to their tea. All those interviewed agreed to questioning; therefore, we had 100% participation.

A consistent set of interview questions was used to evaluate hujir usage, health issues, and environmental concerns surrounding Tohi. Questions for hujir usage included whether individuals harvest hujir, harvest location(s), amount collected, retention time of amount collected, hujir applications, amount used for each purpose, usage per day, usage per year, and reasons for consumption. Questions related to health included specific health issues in the family such as prevalence of high blood pressure, kidney or liver issues, and the importance of hujir to their family (length of use).

Many interviewees answered the consumption question by stating the amount of hujir added to a batch of tea. A further question was then asked to determine the amount of tea that was made in a day and the specific quantity consumed by that individual and others in the household.

Sample Collection

Samples of hujir were collected in June 2007 both at the Tohi saline area and directly from family supplies. Environmental samples were collected at the hujir harvesting location to gain variety in hujir consumed by the people throughout the valley. Hujir samples of about 20–200 g each (depending on amount available) were taken from this area at Tohi. Six samples were also collected from personal supplies of those interviewed and one sample was bought from a local Darhad store. All samples were labeled and bagged for storage.

The samples were transported for chemical analysis from Mongolia to Montana State University's Soil Laboratory (Bozeman, Montana). A U.S. Soil Permit was acquired for this purpose, and the proper Mongolia governmental documentation for exporting soil samples was completed.

Sample Preparation and Chemical Analysis

To gain a representative sample of the hujir being consumed, both samples collected from the interviewees as well as the environmental samples taken from the human harvest area at Tohi were analyzed. These samples were prepared for analysis by creating a precipitate to water dilution of 1 g hujir to 10 ml deionized water, 1 to 100, and 1 to 1000. Eleven total samples were used for analysis and dilutions applicable depended on the amount of ion present related to the analysis detection limit.

To determine the soluble ionic content, the dilutions were analyzed via ion chromatography (IC) and inductively coupled plasma atomic emission spectrometry (ICP-AES). For the ICP-AES analysis, 5% nitric acid was added to the hujir:water dilutions. IC data included chloride, fluoride, sulfate, nitrate, phosphate, and arsenate (V) concentrations. ICP-AES data included aluminum, antimony, arsenic, barium, boron, calcium, copper, iron, lead, magnesium, manganese, phosphate, potassium, silica, sodium, sulfur, and zinc concentrations. The ICP-AES arsenic concentrations were used rather than the results for the IC arsenate (V) due to a lower detection limit and the ability of measuring total arsenic in the samples.

Data obtained from IC and ICP-AES were compared to the specific ion detection limit for the machine in which it was received. Detection limits for both the ICP-AES and IC are standard to the specific instrument (Table 1). Values below the ion

Table 1. Detection limits for ion chromatography (IC) and inductively coupled plasma atomic emission spectrometry (ICP-AES) analyses.

Method	Soluble ion	Detection limit (mg/l)
Inductively Coupled Plasma Atomic Emission Spectrometry	Al	0.05
	As	0.05
	B	0.05
	Ba	0.05
	Ca	0.1
	Cu	0.1
	Fe	0.01
	K	0.1
	Mg	0.1
	Mn	0.01
	Na	1
	P	0.05
	Pb	0.05
	S	1
	Sb	0.05
	Si	1
	Zn	0.01
Ion Chromatography	Cl	1
	CO_3	1
	F	1
	NO_3	0.01
	PO_4	0.3
	SO_4	1

detection limit were disregarded in the exposure assessment calculations because they were few in number and were considered unreliable for estimating exposures.

Exposure Assessment

Interviewees' answers to the amount of hujir added to a batch of tea were indicated by the size of spoon they utilized. Therefore, the hujir bought in the Darhad was placed into both measuring units, a teaspoon and a tablespoon, and weighed. This measurement was completed 10 times for each spoonful by placing a new amount of hujir in the spoon each time. The weights obtained for each spoon size and replicates were used to obtain the mean and standard deviations. The mean result was then utilized in calculating consumption rates.

Body weights were obtained from the WHO 2006 Mongolian STEPS *Survey on the Prevalence of Non-communicable Disease Risk Factors* (2007). The data were divided into age groups according to gender. A mean value of 68.5 and 63.6 kg for men and women, respectively, was calculated for the 25–54 age classifications. Values of 70.3 and 63 kg were given for men and women ages 55–64, respectively, and were extrapolated for the 55 and over age classifications for this assessment.

The daily consumption rate of hujir was determined by multiplying the amount of hujir added to a batch of tea in g/l by the liters consumed per individual per day to obtain g/day. The consumption data were analyzed for significant differences between age and gender using a mixed model procedure in SAS 9.1.3 (SAS Institute, Cary, NC, USA). A p-value $\leq .05$ was considered significant. The exposure assessment included dividing both genders into two age groups to incorporate Mongolian body weights. These four groups were women ages 25–54, women ages 55 and over, men ages 25–54, and men ages 55 and over.

Each ionic concentration was converted to mg ion/g hujir by first multiplying the data received from the analyses in mg/1000 ml by the volume in ml used for the specific hujir:water dilution. The mean and standard deviation were obtained for each ion in the samples analyzed.

The mean consumption rate (g hujir/day) specific to each age group was multiplied by the mean concentration of each ion (mg ion/g hujir) to obtain the consumption rate in mg ion/day for each age group. The values for each ion were then divided by the average body weight specific to each gender and age group resulting in mg ion/kg body weight/day (Tables 2–3).

To compare exposures to recommended dietary intake levels (DRI), exposures were calculated in mg ion/day (Table 4) through multiplying the ion content (mg ion/g hujir) by consumption rate (g hujir/day) for each age group. Differences in gender are not applicable for this exposure calculation.

To compare exposures to drinking water guidelines, overall exposure was needed in mg ion/l (Table 5). Mean consumption rates (g hujir/l) were multiplied by the mean ion concentration (mg ion/g hujir) to obtain exposure in mg ion/l. These were also separated specific to age group.

Toxicity

Chronic oral toxic threshold values established by the WHO and the USEPA were used in this risk assessment (Tables 2–3). The toxic endpoints available from the WHO were applied first, if available. These included tolerable daily intakes (TDIs), determined by the equation:

$$\text{TDI} = (\text{NOAEL} \quad \text{or} \quad \text{LOAEL}) \div \text{UF}, \tag{1}$$

where UF is the uncertainty factor, ranging from 1–1000 (WHO 2006). Whether the lowest observed adverse effect level (LOAEL) or NOAEL is applied depends on the more sensitive endpoint available from the most relevant study for that specific substance (WHO 2006). The available TDIs included antimony, boron, and manganese.

Chronic oral RfD, NOAEL, and LOAEL values for arsenic, barium, copper, fluorine (the soluble form of fluoride), nitrate, sulfate, and zinc were obtained from the USEPA (USEPA 1987, 1988, 1991, 1998, 2003, 2005a,b). The chronic oral RfD for a specific substance is determined using the equation:

$$\text{RfD} = \text{NOAEL} \div (\text{UF} \times \text{MF}), \tag{2}$$

where the UF is the uncertainty factor, ranging from 1–1000, and MF is the modifying factor, determined by professional judgment (USEPA 1993). The benchmark dose (BMD_{50}) and the lower benchmark dose ($BMDL_{50}$) for barium were used because

Table 2. Dietary risk assessment for women, ages 25–54, based on chronic mean exposures. Women's exposure is 1.08 times greater than men's due to lighter body weight.

Soluble ion	Exposure[a,b]	Chronic RfD[a,c]	UF[d] for RfD[a]	RQ[e] Chronic RfD	LOAEL[a,f]	RQ[e] LOAEL	NOAEL[a,g]	RQ[e] NOAEL	Endpoint source
Boron	0.004 (0.012)	0.16	60	0.02	N/A[i]	N/A[i]	9.6	0.0004	WHO (2006)
Copper	0.001 (0.006)	0.005	1000	0.26	15	0.0001	5	0.0003	USEPA (1988)
Manganese	0.001 (0.002)	0.06	3	0.17	N/A[i]	N/A[i]	N/A[i]	N/A[i]	WHO (2006)
Zinc	0.002 (0.007)	0.2	N/A[i]	0.009	2.14	0.001	N/A[i]	N/A[i]	USEPA (2005b)
Arsenic	0.008 (0.028)	0.0004	3	21	0.01	0.6	0.0008	10.5	USEPA (1998)
Barium	0.002 (0.005)	0.2	300	0.008	64[h]	0.00002	84[h]	0.00002	USEPA (2005a)
Antimony	0.002 (0.005)	0.006	1000	0.25	N/A[i]	N/A[i]	6	0.0003	WHO (2006)
Fluoride	0.05 (0.14)	0.06	1	0.8	0.12	0.4	0.06	0.8	USEPA (1987)
Nitrate	1.36 (7.56)	1.6	1	0.85	11	0.12	10	0.14	USEPA (1991)
Sulfate	8.59 (38.56)	N/A[i]	N/A[i]	N/A[i]	630	0.01	N/A[i]	N/A[i]	USEPA (2003)

[a]mg/kg body weight/day; [b]95th percentile exposure; [c]Oral reference dose; [d]Uncertainty factor; [e]Risk quotient; [f]Lowest observed adverse effect level; [g]No observed adverse effect level; [h]Value = benchmark dose, low ($BMDL_{50}$) and benchmark dose (BMD_{50}), respectively; [i]Not available through WHO and/or USEPA.

Table 3. Dietary risk assessment for women, ages 55 and over, based on chronic mean exposures. Women's exposure is 1.16 times greater than men's due to lighter body weight.

Soluble ion	Exposure[a,b]	Chronic RfD[a,c]	RQ[d] Chronic RfD	LOAEL[a,e]	RQ[d] LOAEL	NOAEL[a,f]	RQ[d] NOAEL	Endpoint source
Boron	0.006 (0.015)	0.16	0.04	N/A[h]	N/A[h]	9.6	0.001	WHO (2006)
Copper	0.002 (0.007)	0.005	0.4	15	0.0001	5	0.0004	USEPA (1988)
Manganese	0.001 (0.002)	0.06	0.17	N/A[h]	N/A[h]	N/A[h]	N/A[h]	WHO (2006)
Zinc	0.003 (0.008)	0.2	0.02	2.14	0.001	N/A[h]	N/A[h]	USEPA (2005b)
Arsenic	0.01 (0.034)	0.0004	32.5	0.01	0.93	0.0008	16.25	USEPA (1998)
Barium	0.002 (0.006)	0.2	0.01	64[g]	0.00003	84[g]	0.00002	USEPA (2005a)
Antimony	0.002 (0.006)	0.006	0.33	N/A[h]	N/A[h]	6	0.0003	WHO (2006)
Fluoride	0.07 (0.17)	0.06	1.23	0.12	0.62	0.06	1.23	USEPA (1987)
Nitrate	2.14 (9.37)	1.6	1.34	11	0.19	10	0.21	USEPA (1991)
Sulfate	13.47 (47.81)	N/A[h]	N/A[h]	630	0.02	N/A[h]	N/A[h]	USEPA (2003)

[a]mg/kg body weight/day; [b]95th percentile exposure; [c]Oral reference dose; [d]Risk quotient; [e]Lowest observed adverse effect level; [f]No observed adverse effect level; [g]Value = benchmark dose, low ($BMDL_{50}$) and benchmark dose (BMD_{50}), respectively; [h]Not available through WHO and/or USEPA.

Table 4. Dietary risk assessment for men and women, ages 25–54 and 55 and over, based on chronic mean exposures and dietary reference intakes.

Soluble ion	Exposure[a,b] (25–54)	Exposure[a,b] (55 and over)	DRI[c] (25–54)	DRI[c] (55 and over)	RQ[d] DRI (25–54)	RQ[d] DRI (55 and over)	UL[e]	RQ[d] UL (25–54)	RQ[d] UL (55 and over)
Calcium	4.99 (17.62)	7.74 (21.64)	1000	1200	0.005	0.006	2500	0.002	0.003
Magnesium	3.67 (17.01)	5.69 (20.89)	410	420	0.009	0.014	350	0.01	0.016
Sodium	974.85 (3575.4)	1512.91 (4391.4)	1500	1300	0.65	1.164	2300	0.424	0.658
Potassium	5.59 (22.9)	8.68 (28.13)	4700	4700	0.001	0.002	N/A[f]	N/A[f]	N/A[f]
Copper	0.09 (0.37)	0.13 (0.46)	0.9	0.9	0.095	0.147	10	0.009	0.013
Iron	1.33 (9.16)	2.06 (11.26)	8	8	0.166	0.258	45	0.029	0.046
Manganese	0.04 (0.12)	0.07 (0.13)	2.3	2.3	0.019	0.03	11	0.004	0.006
Zinc	0.11 (0.43)	0.16 (0.53)	11	11	0.01	0.015	40	0.003	0.004
Phosphate	3.78 (13.54)	5.87 (16.63)	700	700	0.005	0.008	4000	0.001	0.001
Fluoride	3.02 (8.63)	4.69 (10.60)	4	4	0.756	1.173	10	0.302	0.469
Chloride	153.99 (516.5)	238.97 (634.4)	2300	2000	0.067	0.119	3600	0.043	0.066

Data obtained from the U.S. National Academy of Science (USNAS 2004a,b); [a]mg/day; [b]95th percentile exposure; [c]Dietary reference intakes; [d]Risk quotient; [e]Tolerable upper level intake; [f]Not available.

Table 5. Dietary risk assessment of hujir using drinking water guidelines and chronic mean exposures.

Soluble ion	Exposure[a,b] (25–54)	Exposure[a,b] (55 and over)	WHO DW Guideline[a]	RQ[c] (25–54)	RQ[c] (55 and over)
Aluminum	0.16 (0.52)	0.17 (0.57)	0.2	0.79	0.84
Antimony	0.03 (0.09)	0.04 (0.09)	0.02	1.62	1.74
Arsenic	0.18 (4.57)	0.19 (4.97)	0.01	17.89	19.16
Barium	0.03 (0.08)	0.04 (0.09)	0.7	0.05	0.05
Boron	0.08 (0.2)	0.08 (0.21)	0.5	0.15	0.16
Copper	0.45 (2.37)	0.48 (2.57)	2	0.22	0.24
Fluoride	0.03 (0.1)	0.03 (0.11)	1.5	0.02	0.02
Iron	1.02 (2.23)	1.09 (2.42)	2	0.51	0.55
Lead	0.13 (0.79)	0.14 (0.86)	0.01	13.11	14.04
Manganese	0.02 (0.03)	0.02 (0.03)	0.4	0.04	0.04
Nitrate	29.18 (124.22)	31.26 (135.08)	50	0.58	0.63

Data obtained from the WHO's drinking-water guidelines (WHO 2006); [a]mg/l; [b]Numbers in parenthesis are 95th percentile exposures (mg/l); [c]Risk quotient.

the NOAEL and LOAEL were not available. The BMD_{50} is defined as a dose in the range of 1–10% of a health effect (USEPA 2008). The $BMDL_{50}$ is the lower limit of a one-sided 95th confidence interval of the BMD_{50} (USEPA 2008).

Arsenic is the only ion among those analyzed that is a known carcinogen via the oral exposure route. The USEPA's cancer risk estimate is an oral slope factor of 1.5 mg/kg BW/day (USEPA 1988), and was compared to exposures of arsenic among the different groups. The following equation was used:

$$\text{Population Cancer Risk Rate} = \text{Oral Slope Factor} \times \text{Exposure}. \tag{3}$$

Published DRIs and tolerable upper level intakes (ULs) for calcium, chloride, copper, fluoride, iron, magnesium, manganese, phosphate, potassium, sodium, and zinc were obtained from the USNAS (2004a, 2004b) (Table 4).

For several ions, oral toxicity or dietary references were not available; therefore the WHO's drinking water guidelines were compared to estimated exposures (Table 5). The WHO gives these values in mg/l and the guideline value (GV) is determined by the equation:

$$GV = (TDI \times BW \times P) \div C, \tag{4}$$

where BW is body weight (60 kg for adults), P is the fraction of the TDI allocated to drinking water (a factor of 2–4), and C is the daily drinking water consumption (2 liters for adults) (WHO 2006). The available GVs included aluminum, antimony, arsenic, barium, boron, copper, fluoride, iron, lead, manganese, and nitrate. The recommended quantity obtained for aluminum was given as 0.1–0.2 mg/l as a guideline for water treatment, however, these values are suggested considering the potential neurotoxicity health effects related to aluminum (WHO 2006).

Risk Characterization

A RQ was calculated to compare mean exposure to thresholds for each ion and according to each gender represented age group. The equation was:

$$RQ = \text{Exposure} \div \text{Endpoint} \tag{5}$$

A result greater than 1.0 indicates an exposure value higher than the given endpoint value.

RESULTS

Data were not collected for individuals below age 25 for reasons stated earlier. Results indicated that there was a significant difference in consumption rate for the two age groups (df $= 48$, $F = 5.86$, $p < .019$). Data from the interviews revealed a 5.12 g hujir/day greater consumption among Darhad residents 55 years and over compared to the 25–54 age group. There was no significant difference between genders for consumption rates (df $= 48$, $F = 0.32$, $p > .574$). Therefore, consumption rate data were separated into two age groups, 25–54 years of age and 55 and older, as described in the methods.

Exposures Compared to Chronic Oral RfDs

The mean exposure values of some ions present in hujir resulted in RQs greater than 1.0 (Tables 2–3). According to the calculated RQs, dietary exposures for arsenic, fluoride, and nitrate were greater than their associated RfDs. This finding was associated with all groups, especially 55 and over.

Results using the mean arsenic daily intake level were 19 to 33 times the chronic oral RfD, depending on age group and gender. When these intake values were compared to the LOAEL and NOAEL for arsenic, oral intake was 10 to 16 times the NOAEL and 0.5 to 0.9 times the LOAEL value. The population cancer risk estimated from chronic exposure to arsenic was 12 in 1,000 for those 25–54 and 15 in 1,000 for those 55 and older. A more refined calculation using a lifetime adjusted daily dose (LADD) of hujir until age 60 (exposure is essentially zero from ages 0–24) results in an estimated cancer risk of 7 in 1,000.

When comparing the mean exposure of nitrate to the oral RfD, both genders 55 and over exceeded an RQ of 1.0. Exposures for nitrate were 0.8 to 1.3 times the RfD, and 0.1 to 0.2 times the NOAEL and LOAEL, respectively. Estimated fluoride exposures were 0.7 to 1.2 times the RfD. The RQs were 0.4 to 0.6 times the LOAEL.

Exposures Compared to DRIs

The mean sodium and fluoride exposures for residents ages 55 and over exceeded their respective DRI levels; however, exposures did not exceed ULs (Table 4). The estimated mean exposures for sodium were 0.7 and 1.2 times the DRI value for both age groups, respectively. Exposure to fluoride was 0.8 to 1.2 times the DRI.

Exposures Compared to Drinking Water GVs

RQs for antimony, arsenic, and lead for each age group were greater than 1.0 compared to the WHO's drinking water GVs (Table 5). Soluble antimony daily exposures were 1.6 to 1.7 times greater than the GVs for the age groups 25–54 and 55 and over, respectively. The exposure levels for arsenic were 18 and 19 times the guidelines for the age group 25–54 and 55 and over, respectively. The consumption rates of lead were 13 to 14 times the guidelines for ages 25–54 and 55 and over, respectively.

DISCUSSION

Arsenic toxicity is a major health concern throughout the world due to both natural and human-made sources. Based on our assessment, chronic oral exposure to arsenic through consumption may be of concern to the Darhad population. Exposure to arsenic was as high as 33 times the USEPA's RfD, 19 times the WHO's drinking water GVs, and approached the LOAEL. Oral exposure to arsenic by those 25–54, and 55 and older indicates worst case of 12 and 15 in 1,000 occurrence of cancer above background levels due to lifetime arsenic consumption, respectively. A more refined calculation using life adjusted daily dose (LADD) and incorporating exposure over a lifetime until age 60 (exposure is essentially zero from 0–24) results in a cancer risk of 7 in 1,000.

Chronic oral exposure to arsenic (at or above the LOAEL) can lead to human health effects related to hyperpigmentation, keratosis, and possible vascular complications (USEPA 1998). Arsenic ingestion from drinking water has been linked to lung, bladder, and skin cancers as indicated by the NRC (1999), Karagas *et al.* (2002), and Chen *et al.* (2004). Chen *et al.* (2004) examined Taiwanese cancer risk associated with a lifetime exposure to drinking water from wells with different concentrations of arsenic. Their results indicated a relative risk (population exposed compared to a control population) of 2.28, 95% CI of 1.22–4.27, for those exposed over a lifetime of drinking water with arsenic concentrations between 100–299 μg/l (exposure to arsenic from hujir consumption ranges from 180–190 μg/l). Symptoms indicated in an epidemiological study of 4,216 people from West Bengal exposed to arsenic levels of 50 μg/l or greater included: 8.8% with symptoms of hyperpigmentation, 3.6% keratosis, 10.2% hepatmegaly, 5% weakness, 27.8% abdomen pain, 0.7% nausea, 11.7% lung disease, and 4.7% with symptoms of neuropathy (Mazumder 2003). However, Vahter *et al.* (1995) showed remarkably high metabolism of inorganic arsenic among 30 women from four Andean villages, located in northwestern Argentina, exposed to a range of 2.5 to 200 μg/l arsenic in their drinking water. This suggests a difference in arsenic metabolism rates and possible genetic variance among certain populations. Because health effects from arsenic do not appear to be readily apparent within the Darhad population a higher human arsenic metabolism rate might exist.

Antimony decreases body weight and reduces food and water intake in rats above the NOAEL of 6.0 mg/kg body weight/day (WHO 2006). The WHO's drinking water GV for antimony is 10% of the TDI, which was calculated with a 1000 UF related to the NOAEL (WHO 2006). According to this risk assessment, the Darhad people's exposure to antimony was 1.6 to 1.7 times the drinking water guideline. Cancer has been correlated to inhalation of antimony, but not linked to oral intake (WHO 2006).

According to an epidemiologic study among children, fluoride toxicity has been shown to result in dental fluorosis, a cosmetic effect, at or above the LOAEL (USEPA 1987). The results of this dietary risk assessment revealed an exposure of 1.2 times the NOAEL for those 55 and over; however, the mean exposure did not exceed the WHO's drinking water GV.

High salt (sodium) consumption accelerates the effects of chronic kidney disease (Jones-Burton *et al.* 2006). High dietary sodium intake has also been shown to increase blood pressure, which can stimulate atherosclerosis, eventually leading to heart disease, stroke, and heart failure (MacGregor and He 2005). In addition, a decrease in dietary salt intake has shown to be beneficial to skeletal health in those who consume equal to or less than the U.S. daily salt intake of 3,400 mg/day (Carbone *et al.* 2005). High salt diets can also lead to increased occurrence of stomach cancer as indicated in a study on Japanese diets (Hirohata and Kono 1997). Our results indicated a mean daily exposure to sodium 1.2 times the DRI for those 55 and over. This exposure did not exceed the UL recommendations and is within the 3,400 mg/day intake evaluated by Carbone *et al.* (2005). The results from this study are important to consider for the Darhad population because of the increasing abundance of kidney disease and blood pressure rates among local residents (Batchimeg 2007).

The Darhad people's exposure to lead may be of concern because our results indicated exposures as much as 14 times the WHO's drinking water GV. Adverse effects due to lead toxicity are more prominent in infants, children, and pregnant women. Evidence suggests lead exposure, even at low concentrations, can cause neurotoxicity in humans (WHO 2006). Therefore, the most at-risk groups in this risk assessment are pregnant women and those 55 and over. The WHO's guideline is based on cancer prevention and is 50% of the given WHO's provisional tolerable weekly intake (PTWI) of 25 μg/kg body weight/day (2006).

Estimated health risks increase when the 95th percentile exposures are incorporated into the RQ instead of the mean exposures. Antimony, arsenic, copper, fluoride, and nitrate exposures exceed their chronic oral RfDs or TDIs. Arsenic and fluoride were the only two that exceed both their respective LOAELs and NOAELs. The 95th percentile exposure to arsenic was 2.5 times the LOAEL and fluoride's was 1.4 times. The 95th percentile exposures to sodium, iron, and fluoride exceeded their associated DRIs; however, only exposures to sodium and fluoride exceeded their ULs by 1.9 and 1.1 times, respectively. Comparing exposure to the WHO's drinking water GVs, aluminum, antimony, arsenic, copper, iron, lead, and nitrate exceed their guideline quantities.

Uncertainty in this dietary risk assessment is potentially associated with the number of interviewees related to the total population of the valley. We collected data for 122 people out of a total population of 9,989 (1.2%), which may not have been sufficient. Even though the sample may not represent the entire population of the valley, it does indicate that at least a subset of the population's exposure may be exceeding levels of concern. Another uncertainty in the interview process was associated with translations due to the language barrier of the local Mongolian dialect. The detection limits of the ICP-AES and IC analyses also indicate uncertainties of the ionic concentrations that were below these levels, even though these were minimal.

Future research should include obtaining additional data on dietary consumption rates among the Darhad population, including a variety of age groups. An assessment of total daily exposure (*i.e.*, aggregate exposure) should also be completed, specifically by examining other food-related items based on the daily diet of individual Darhad residents. Because all of the interviewees also feed hujir to their livestock, they may be receiving additional ionic concentrations through meat and dairy consumption. Also, inductively coupled plasma mass spectrometry (ICP-MS) would give a more refined analysis because of its lower detection limits.

A detailed epidemiological and biomonitoring study would also be beneficial in relating health effects to toxicity from hujir consumption. These data would lead to a more refined risk assessment for the Darhad community. A small proportion of community members consume very high quantities of hujir on a chronic basis. Additional data need to be generated especially for this group to determine if they are experiencing deleterious health effects.

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REFERENCES

Batchimeg B. 2007. Health Indicators of Khovsgol Aimag. Health Department of Mongolia, Ulan Bator, Mongolia

Carbone LD, Barrow KD, Bush AJ, *et al.* 2005. Effects of a low sodium diet on bone metabolism. J of Bone Miner Metab 23:506–13

Chen CL, Hsu LI, Chiou HY, *et al.* 2004. Ingested arsenic, cigarette smoking, and lung cancer risk follow-up study in arseniasis-endemic areas in Taiwan. JAMA 292:2984–90

Goulden CE, Sitnikova T, Gelhaus J, *et al.* 2006. The Geology, Biodiversity and Ecology of Lake Hovsgol (Mongolia), p 5. Backhuys Publishers, The Netherlands

Hirohata T and Kono S. 1997. Diet/nutrition and stomach cancer in Japan. Int J Can 10(suppl):34–6

Jones-Burton C, Mishra SI, Fink JC, *et al.* 2006. An in-depth review of the evidence linking dietary salt intake and progression of chronic kidney disease. Am J Nephr 26:268–75

Karagas MR, Stukel TA, and Tosteson TD. 2002. Assessment of cancer risk and environmental levels of arsenic in New Hampshire. Int J Hyg Environ Health 205:85–94

Kurlansky M. 2002. Salt: A World History. Penguin Books, New York, NY, USA

MacGregor GA and He FJ. 2005. Importance of controlling blood pressure. Climacteric 8(suppl 3):13–8

Mazumder DNG. 2003. Chronic arsenic toxicity: Clinical features, epidemiology, and treatment: Experience in West Bengal. J Environ Sc Health Part A—Toxic/Hazardous Substances & Environmental Engineering. A38:141–63

Morgan A. 2005. Basic Guidance for Cross-Cutting Tools: Conceptual Models. WWF Standards of Conservation Project and Programme Management, Resources for Implementing the WWF Standards. Available at https://intranet.panda.org/documents/folder.cfm?uFolderID=60979

NRC (National Research Council). 1983. Risk Assessment in the Federal Government: Managing the Process. National Academy Press, Washington, DC, USA

NRC. 1999. Arsenic in Drinking Water. National Research Council, National Academy Press Washington, DC, USA

USEPA (US Environmental Protection Agency). 1987. Fluoride. CASRN 7782-41-4. Washington, DC, USA

USEPA. 1988. Copper. CASRN 7440-50-8. Washington, DC, USA

USEPA. 1991. Nitrate. CASRN 14797-55-8. Washington, DC, USA

USEPA. 1993. Reference Dose (RfD): Description and Use in Health Risk Assessments, Background Document 1A. Washington, DC, USA

USEPA. 1998. Arsenic. CASRN 7440-38-2. Washington, DC, USA

USEPA. 2003. Drinking Water Contaminants. 816-F-03-016. Available at http://www.epa.gov/safewater/contaminants/index.html

USEPA. 2005a. Barium. CASRN 7440-39-3. Washington, DC, USA

USEPA. 2005b. Zinc. CASRN 7440-66-6. Washington, DC, USA

USEPA. 2008. Benchmark Dose (BMD) Methodology. Available at http://www.epa.gov/ncea/bmds/bmds_training/methodology/intro.htm

USNAS (US National Academy of Science). 2004a. Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals, Elements. Food and Nutrition Board, Institute of Medicine, National Academies, Washington, DC, USA

USNAS. 2004b. Dietary Reference Intakes (DRIs): Tolerable Upper Intake Levels (UL*a*), Elements. Food and Nutrition Board, Institute of Medicine, National Academies, Washington, DC, USA

WHO (World Health Organization). 2006. Guidelines for Drinking-Water Quality: Incorporated First Addendum, Vol.1 Recommendations, 3rd Edition. World Health Organization, Geneva, Switzerland

WHO. 2007. Mongolian STEPS Survey on the Prevalence of Non-communicable Disease Risk Factors, 2006. Available at www.who.int/entity/chp/steps/27%20December%202006%20Mongolia%20STEPS%20Survey.pdf

Vahter M, Concha G, Nermell B, *et al.* 1995. A unique metabolism of inorganic arsenic in native Andean women. Eur J Pharmacol Environ Toxicol Pharmacol 293:455–62

Xu P, Lagos G, Huang SB, *et al.* 2006. Summer exposure assessment of Cu and Zn in drinking water in Shanghai, China. J Environ Sc Health Part A 41:2465–81