A study of the quality and hygienic conditions of spring water in Mongolia

Altanzagas Badrakh, Tsolmon Chultemdorji, Robert Hagan, Salik Govind, Tsevegdorj Tserendorj, Delgermaa Vanya, Chimeddulam Dalaijamts and Enhtsetseg Shinee

ABSTRACT

An assessment on quality and hygienic conditions of spring water was undertaken in Mongolia in 2004 with financial and technical support from the World Health Organization through AGFUND.

Methodology: A total of 127 springs, 99 from rural areas and 28 from Ulaanbaatar city were included in the study. The study included hygienic conditions, physical, microbiological and chemical parameters of springs. Based on the results of laboratory analysis, the quality of springs were classified into five degrees of contamination.

Results: The majority of springs studied and especially in UB city and the Central region had poor hygienic conditions such as low flow rate, turbidity or pollution sources in the vicinity of springs. 78% of the total studied springs did not have any protection or upgrade and 22% have only wooden, iron and stone fences. The water quality parameters such as hardness, total dissolved solids, oxygen demand, nitrogenous compounds, total microbial count, Escherichia coli were also significantly higher in springs located in UB city, the Central region and the East region. 47.6% of all studied aimag's (countryside) spring water were significantly polluted by more than three parameters especially *E. coli*, ammonia, oxygen demand, which indicated a recent contamination by human and animal excreta in water.

Conclusion: The current study revealed that the majority of springs in peri urban areas close to UB city and the Central region had poor hygienic conditions. Different levels of contamination using both microbiological and chemical tests were found in studied springs. It is recommended that regular assessment of spring water quality be undertaken to create awareness among communities and local authorities for further protection and upgrading of spring water sources.

Key words | chemical parameters, cleanliness of surface water, hygienic condition, microbiological parameters, rural and countryside (aimag), Ulaanbaatar (UB city)

Altanzagas Badrakh (corresponding author)
Tsolmon Chultemdorji
Tsevegdorj Tserendorj
Delgermaa Vanya
Chimeddulam Dalaijamts
School of Public Health,
Health Sciences University of Mongolia,
Choidog street 3,
P.O. 48, Box 111,
Ulaanbaatar,
Mongolia
Tel.: 976-99154959
E-mail: *baltanzagas@yahoo.com*

Robert Hagan
Salik Govind
WHO Respresentative Office, Ministry of Health,
Government Building No. 8, Ulaanbaatar,
Mongolia

Enhtsetseg Shinee
Ministry of Health,
Government Building No. 8, Ulaanbaatar,
Mongolia

INTRODUCTION

Natural springs are a common source of household water supply to periurban and rural Mongolian population. It is estimated that 9.1 percent of Mongolians are using spring water for their drinking and domestic needs.

About ten thousand springs have been identified nation wide. Many of these springs (1484) have recently dried up due to natural and anthropogenic activities such as mining and deforestation (Natural Characteristics of Mongolia 2001; Bathold *et al*. 2004).

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Recent assessment of the water quality of the springs by the Professional Inspectorate Agency found that about 50% of the springs are contaminated in Ulaanbaatar city (Annual Report 2003).

The economic transition and the recent winter disasters in Mongolia have resulted in a real increase in urban migration by the rural poor. This has put a burden on piped water supply to periurban areas and more and more people are using spring water as their main water source.

The water related health issues remain a major public health problem. Diarrhoeal diseases are one of the major causes of mortality among under age five children. The incidence of Hepatitis A is about 92% of the total incidence of all types of reported cases of hepatitis (Health Indicators 2002). The lack of a sufficient quality and quantity of safe drinking water is a risk factor for infectious diseases.

This study on the Quality and Hygienic conditions of Spring Water was undertaken to assess the quality and hygienic conditions of spring water in periurban and urban areas with the aim of improving the quality standards, hygienic conditions and increasing awareness among the community on safe water use.

MATERIALS AND METHODS

A total of 127 springs, 99 from rural areas including 21 administrative aimags (rural and countryside) and 5 regions and 28 from Ulaanbaatar City were selected as the study sample using simple random sampling method. Four or five springs were studied from each aimag and district of UB city. The data sources included a review of previous data on surface water by the Ministry of Nature and Environment in 2002, data from the water quality survey of Professional Inspectorate Agency of the City and perception of the local community regarding their spring water quality.

The study method was an epidemiological descriptive crossectional design. Statistical analysis was done by using descriptive methods on SPSS 10.0 programme. The parameters including mean, standard error mean, percentage, standard devation, chi-square value, partial correlations and two sided significance value were calculated.

The level of flow rate, colour, turbidity of spring water, hygienic conditions (pollutants related with anthropogenic activities) of springs; distance between the spring and the source of pollution including pit latrine, sewage system, animal fence, location of house; and protection level of spring were studied at the study area.

A total of 252 water samples were collected from selected springs and analysed using standard methods at the Laboratory of Professional Inspector Agency in UB city and aimags. The laboratory analysis of the samples included total microbial count, escherichia coli, total dissolved solids, hardness, oxygen demand and nitrogenous compounds. The method of analysis was MNS (Mongolian National Standard) 6222-98, the membrane filtration method MNS and ISO 6059-2001, the balance of weight method MNS 3899-86, the titer method MNS and ISO 6059-2001, the titer Cubel's method and the spectrophotometer MNS 4428-97, 4431-97, 4429-97.

Based on the results of laboratory analysis, the quality of springs were classified into five degrees of contamination. The classification of surface water was based on technical guidelines of the Ministry of Nature and Environment and Ministry of Health (1997*a*, *b*) of Mongolia. Water which is assessed as a 1st degree is very clean and could be used directly for drinking and domestic purpose, 2nd degree is clean water and could be used after water treatment, 3rd degree is low polluted water and could be used after advanced measures of treatment and protection, 4th degree and 5th degree is polluted and very polluted water and should not be used for drinking and domestic consumption.

BENEFIT OF THE STUDY

Lecturers and students from the School of Public Health of Health Sciences University of Mongolia and the School of Civil Engineering of Mongolian University of Science and Technology participated and benefited from the study. Knowledge, skills and practice of lecturers (20) and students (185) have been improved on methodology of this study.

As a result of the findings of the study, twenty nine springs with a daily use rate exceeding 100 persons through out the country were selected for protection and upgrading. About 30,000 people now have safe drinking water.

FINDINGS

The physical parameters and hygienic conditions

Table 1 shows the physical parameters and hygienic conditions of all the springs studied by region and UB city:

Table 1 | The physical parameters and hygienic conditions of all the springs studied by region and UB city

	Region	**Center**		**West**		**North**		**East**		**Gobi**		**UB city**		**Total**	
Parameters	**Assessment**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Flow rate ($\chi^2 = 15.532$; $df = 15$; $p = 0.561$)	Good	8	26	7	30	6	46	2	13	8	47	7	25	38	30
	Relatively good	11	36	7	30	4	31	7	47	7	41	12	43	48	37.8
	Middle	8	26	8	35	2	15	5	33			6	21	29	22.8
	Low	4	13	1	4.3	1	8	1	6.7	2	12	3	11	12	9.4
View ($\chi^2 = 41.65$; $df = 15$; $p = 0.0001^*$)	Clear	20	65	12	52	13	100	12	80	14	82	15	54	86	67.7
	Turbidity	7	23	4	17					2	12	13	46	29	22.8
	With particulates	4	13	7	30			3	20	1	5.9			12	9.5
Protection ($\chi^2 = 15.91$; $df = 20$; $p = 0.722$)	No protection	24	77	18	78	11	85	11	73	13	77	22	79	99	78
	Wooden	2	6.5					1	6.7	1	5.9			4	3.1
	Iron	4	13	2	8.7	2	15	2	13	2	12	2	7.1	14	11
	Stone	1	3.2	3	13			1	6.7	1	5.9	4	14	10	7.9
Existed pollutant sources in SPZ ($\chi^2 = 25.21$; $df = 15$; $p = 0.047^*$)	0–100 m	7	22.7	2	8.7	1	7.7	4	26.6			13	46.4	25	21.2
	>100 m	24	77	21	91	12	92	11	73.3	17	100	15	53.6	100	78.8
	Total	31	100	23	100	13	100	15	100	17	100	28	100	127	100

**Note.* Statistical significant ($p < 0.05$)

- 67.8 percent of the studied springs flow rate were assessed as good and relatively good. Relatively more springs in Gobi Region (47%) and North Region (46%) were determined as good springs by flow rate ($\chi^2 = 13.53$; $p < 0.01$).
- 67.7% of the springs had clear water and 22.8% of the springs had turbid water. There was significant difference between springs in UB city (46%) and rest of the regions in terms of turbidity which may be due to high population density in UB city ($\chi^2 = 41.65$; $p < 0.01$).
- 78% of the total studied springs did not have any protection or upgrade and 22% have only wooden, iron and stone fences ($\chi^2 = 15.91$; $p > 0.01$) (Figures 1 and 2).
- 21.2% of the total studied springs had sources of pollution (litters, pit latrine, sewage and animal excreta) within 100 m area in terms of inside of their Sanitation Protection Zone (SPZ is built around 50–100 m zone around the spring) (Ministry of Nature and Environment and Ministry of Health 1997*a*, *b*). Springs in UB city (47%) were more contaminated by litters and excreta inside of their SPZ ($\chi^2 = 25.21$; $p < 0.05$).

Figure 1 | Spring with protection and upgrade, 'Gants modnii' spring, Arkhangai aimag, 2004.08.05.

Figure 2 | Spring without protection and upgrade, 'Shine' spring, Tuv aimag, 2004.07.02.

Spring water quality

Table 2 shows the water quality indicators by regions and UB city:

- 93.6% springs were classified as very clean (total microbial count $<10^5$ per liter water) and 6.4% of them were classified as 3rd and 4th degree of cleanliness by total microbial count ($\chi^2 = 15.76$; $p > 0.01$).
- 45.4% of all springs had *E. Coli* contamination (from 3rd to 5th degree of cleanliness of spring water) and UB city springs had with highest *E. Coli* contamination (67.9%) as significant ($\chi^2 = 70.96$; $p < 0.01$).
- One third (35.2%) of all studied springs were contaminated (from 3rd to 5th degree of cleanliness of spring water) by ammonia and East region springs had highest ammonia contamination (from 4th to 5th degree of cleanliness of spring water, 86.7%), which indicated recent organic pollution ($\chi^2 = 71.16$; $p < 0.01$).
- 80% of springs were assessed as very clean and clean by oxygen demand. 33.4% of springs in East region were polluted by this parameter ($\chi^2 = 26.30$; $p > 0.01$), in terms of this region's spring water more polluted by oxygen demand to compare other regions.
- Most (85.8%) of all studied springs overall were classified as clean and very clean level by concentration of total dissolved solids (TDS). Relatively more springs in UB city (39.3%) and Gobi region (35.3%) were identified as 3rd to 5th degree by concentration of TDS ($\chi^2 = 41.83$; $p < 0.01$).
- 88.2% of the total tested springs water were evaluated into 1st and 2nd degree of cleanliness by concentration of hardness, which indicated as very clean and clean level. By this parameter spring water (47.1%) in Gobi region was more contaminated than other regions ($\chi^2 = 62.93$; $p < 0.01$).

  Figure 3 shows percentage of contaminated springs by selected microbiological and chemical parameters by aimags.
- 47.6% of all studied aimag's (Bayanhongor, Bulgan, Dornogobi, Dornod, Dundgobi, Gobisumber, Orhon, Uvurhangai, Tuv, Hentii aimag) spring water were significantly polluted ($p < 0.01$) by more than three parameters especially *E. coli*, ammonia and oxygen demand, which indicated a recent contamination of human and animal excreta in water.

Nondirect parameters to indicate pathogenic contamination of water

The distance between pollutant source and spring was chosen as a control variable (excluded from analysis) for analysing the relationship between nondirect parameters (ammonia, nitrites, nitrates, oxygen demand and total microbial count) and *E. coli*.

As shown in Table 3 the level of oxygen demand of spring water associated significantly with total microbial count and nitrogenous compounds. The concentration of nitrate correlated significantly with *E. coli* contamination and nitrite, as well as significant correlation between

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Table 2 | Spring water quality by selected parameters by regions and UB city

	Region	**Center**		**West**		**North**		**East**		**Gobi**		**UB city**		**Total**	
Parameters	**Degree†**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Total microbial count ($\chi^2 = 15.76$; $df = 10$; $p = 0.126$)	I	26	83.9	21	100	13	100	15	100	14	82.4	28	100	117	93.6
	III	3	9.7							1	5.9			4	3.2
	IV	2	6.5							2	11.8			4	3.2
E. Coli ($\chi^2 = \ = 70.96$; $df = 20$; $p = 0.0000^*$)	I	12	38.7	7	46.7	10	76.9	6	40	9	52.9	6	21.4	50	42
	II	2	6.5	7	46.7	1	7.7	1	6.7	1	5.9	3	10.7	15	12.6
	III	8	25.8					3	20	1	5.9	5	17.9	17	14.3
	IV	1	3.2	1	6.7	2	15.4			6	35.3	13	46.4	23	19.3
	V	8	25.8					5	33.3			1	3.6	14	11.8
Ammonia ($\chi^2 = 71.16$; $df = 20$; $p = 0.000^*$)	I	13	44.8	20	87.9	6	46.2			12	70.6	17	60.7	68	54.4
	II	3	10.3	3	13	3	23.1	2	13.3	1	5.9	1	3.6	13	10.4
	III	10	34.5			1	7.7			2	11.8	3	10.7	16	12.8
	IV	2	6.8			1	7.7	6	40			3	10.7	12	9.6
	V	1	3.4			2	15.4	7	46.7	2	11.8	4	14.3	16	12.8
Total dissolved solids ($\chi^2 = 41.83$; $df = 20$; $p = 0.000^*$)	I	28	90.3	21	95.5	13	100	15	100	10	58.8	15	53.6	102	81.0
	II	2	6.5	1	4.5					1	5.9	2	7.1	6	4.8
	III									4	23.5	7	25	7	25
	IV	1	3.2							1	5.9	4	14.3	4	14.3
	V									1	5.9			1	0.8
Oxygen demand ($\chi^2 = 26.30$; $df = 20$; $p = 0.156$)	I	21	67.7	14	60.9	9	69.2	9	60	10	58.8	18	64.3	81	63.8
	II	4	12.9	2	8.7	3	23.1	1	6.7	4	23.5	4	14.3	18	14.2
	III	3	9.7	7	30.4	1	7.7	1	6.7	2	11.8	6	21.4	20	15.7
	IV	1	3.2					1	6.7	1	5.9			3	2.4
	V	2	6.5					3	20					5	3.9

Table 2 | (*continued*)

	Region	Center		West		North		East		Gobi		UB city		Total	
Parameters	**Degree**†	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Hardness ($\chi^2 = 62.93$; $df = 20; p = 0.0025^*$)	I	31	100	22	95.7	15	100	15	100	9	52.9	22	78.6	112	88.2
	II			1								4	14	5	3.9
	III											1	3.6	1	0.8
	IV									2	11.8			2	1.6
	V									6	35.3	1	3.6	7	5.5

**Note.* *statistical significance ($p < 0.01$)
†I—very clean—safe for drinking without treatment or with only disinfection; II—clean—safe for drinking with treatment; III—low polluted—safe for drinking with treatment under strict conditions; IV—polluted, V—very polluted—not safe for drinking

ammonia and nitrites. This result confirmed that ammonia, nitrites, nitrates, oxygen demand and total microbial count are nondirect parameters to indicate *E. coli* contamination as well as other organic contamination of water.

DISCUSSION

There was limited data especially on the countryside to compare our study to other studies. This is the first such study to assess spring water quality nationwide. Most springs in the countryside are not controlled by Inspectorate Agency for analysing water quality, however they are used for drinking and domestic use by nomadics.

Our study found that most of the springs were unprotected and easily liable to contamination by human and animal excreta and other pollutants. Many springs were recently polluted in terms of *E. Coli*, ammonia and oxygen demand. These contaminated springs were mostly

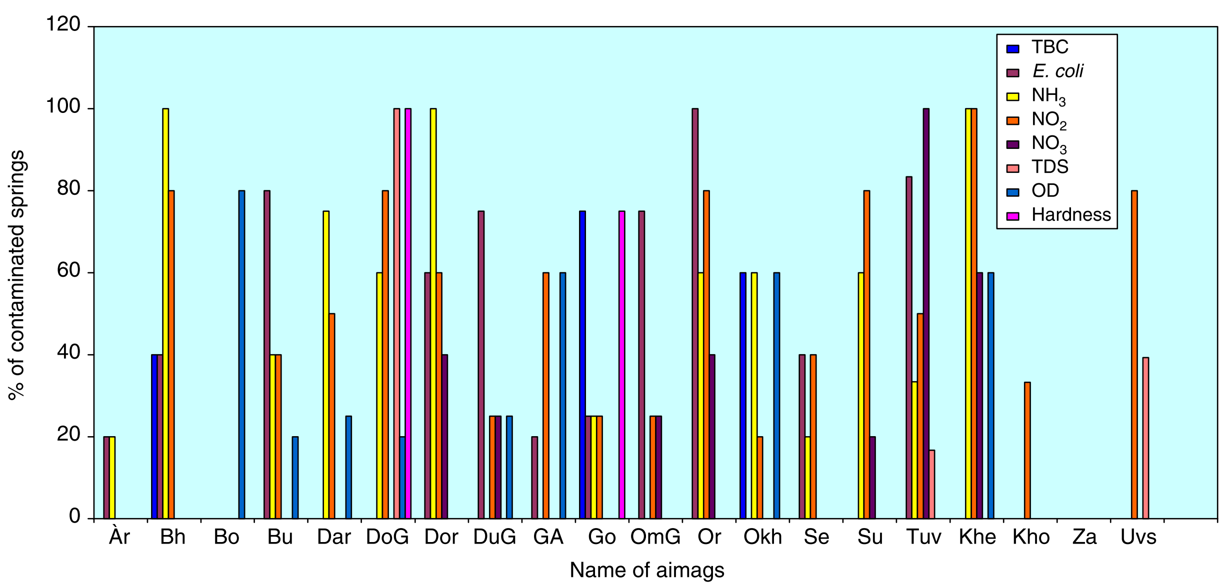

Figure 3 | Percentage of contaminated springs by selected parameters by aimags.

Table 3 | Correlations between nondirect parameters and *E. coli* of spring water

Parameters	Total microbial count	*E. coli*	Ammonia	Nitrites	Nitrates	Oxygen demand
Total microbial count	$1.000\ p = 0.000$	$-0.1097\ p = 0.245$	$0.0569\ p = 0.548$	$0.0391\ p = 0.680$	$-0.0982\ p = 0.299$	$0.2063\ p = 0.028^{*}$
E.coli	$-0.1097\ p = 0.245$	$1.000\ p = 0.000$	$0.0569\ p = 0.548$	$0.0798\ p = 0.399$	$0.2418\ p = 0.010^{*}$	$0.1663\ p = 0.077$
Ammonia	$0.0569\ p = 0.548$	$-0.0323\ p = 0.733$	$1.000\ p = 0.000$	$0.4642\ p = 0.00^{*}$	$0.1620\ p = 0.085$	$0.2375\ p = 0.011^{*}$
Nitrite	$0.0391\ p = 0.680$	$0.0798\ p = 0.399$	$0.4642\ p = 0.00^{*}$	$1.000\ p = 0.000$	$0.2127\ p = 0.02^{*}$	$0.3248\ p = 0.011^{*}$
Nitrate	$-0.0982\ p = 0.299$	$0.2418\ p = 0.010^{*}$	$0.1620\ p = 0.085$	$0.2127\ p = 0.02^{*}$	$1.000\ p = 0.000$	$0.1993\ p = 0.034^{*}$
Oxygen demand	$0.2063\ p = 0.028^{*}$	$-0.1663\ p = 0.077$	$0.3248\ p = 0.00^{*}$	$0.2375\ p = 0.011^{*}$	$0.1993\ p = 0.034^{*}$	$1.000\ p = 0.000$

**Note*. Statistical significance ($p < 0.05$)

located in periurban areas close to UB city and East and Central region's aimags compared to springs in remote aimags.

In comparing our study with the study conducted during the last six years in UB city the nitrogenous compound contamination in spring water increasd twofold (Environmental Risk Assessment 2004).

Our findings suggest that spring water quality should be tested regularly and springs must be protected and updgraded for providing people with safe and hygienic drinking water sources. The study also revealed that it is not necesary to utilize sophisticated microbiological laboratory tests to identify pathogenic contamination of spring water, simple non-direct parameters such as level of nitrogenous compounds, oxygen demand and total microbial count are sufficient to classify contaminated springs.

CONCLUSIONS

The current study revealed that the majority of springs in peri urban areas close to UB city and Central regions had poor hygienic conditions. The majority of springs studied needed protection and upgrading for safe drinking and domestic water sources. Different levels of contamination using both the microbiological and chemical test were found in studied springs. It is recommended that regular assessment of spring water quality be undertaken to create awareness among communities and local authorities for further protection and upgrading of spring water sources.

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