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Hydrochemical and Quality Assessment of Groundwater in the Bayanzurkh District, Mongolia

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ABSTRACT
This study was carried out to find out the level of groundwater quality and composition in the ger area of Bayanzurkh district which is not connected to the water supply network. Fieldwork was carried out within the framework of the grant project on “Study of water quality in drinking water and economy of Ulaanbaatar city and development of recommendations to protect human health from water pollution” which was implemented in 2019 at our institute and the results of the study have been compiled and presented in this article. Samples were taken from 26 points in the 10th sub-district of the Bayanzurkh district and physicochemical parameters, microelements, and bacteriological analysis were performed to determine the chemical composition, quality, and pollution. According to the results of the water analysis, Ca-HCO_3, Ca[HCO_3-CI] and Ca-Mx were determined in the study area. As well total hardness (19.2%), Calcium (15.3%) and Magnesium (11.5%) are crosses the maximum permissible limits for human consumption as per the groundwater standards. According to the results of bacteriological analysis, 100 ml of Escherichia coli bacteria were detected in 100 ml of well water in the direction of Monel Altan Ulgii, Dari-Ekh, which is 15.4% of the total water point. 26.9% of the total water points have not met the requirements of drinking water standard MNS 0900:2018 and WHO recommendations in terms of total hardness, calcium, magnesium, and microbiological parameters. Water samples from private wells were found not meeting for human consumption and required treated and softened for drinking purpose.

Keywords: *Hydrochemical process, groundwater, water quality*

1. INTRODUCTION

Groundwater is the most important source of water in Mongolia. The activities of all socio-economic sectors are directly dependent on groundwater resources and their potential [1]. Where there is no surface water, herders use water from wells, and groundwater is widely used for agricultural irrigation, mining, and small and medium enterprises. Freshwater is one of the main factors influencing the development of any country. Increasing freshwater resources, protecting them from pollution and depletion, using them wisely, and not harming aquatic ecosystems is a vital global issue. Due to the unbalanced development of the population and settlements and the inconsistency of investment policies, the capital city has become overcrowded and the environment has become unbalanced [2].

Currently, 62 percent of Ulaanbaatar's households or 200,000 households live in the Ger district, and 38 percent live in an apartment with an engineering supply, by statistics information. Following the process of urbanization, there is a risk that the state of groundwater will change significantly due to human activities and technogenic processes. In particular, the natural properties of groundwater, especially its nutrition, exchange, location, movement, and regime, as well as its quality and composition, are beginning to change as an impact of human activities such as the construction process. On the other hand, the natural water that has changed as a result of these impacts, in turn, has a negative impact on our lives and economies.

Many studies have shown that due to the specifics of Ger districts in Ulaanbaatar, the quality and composition of water and soil change due to influence septic area (toilets, etc.) and does not meet sanitary requirements [3]. The study work was carried out within the framework of the grant project "Study of water quality in drinking water and economy of Ulaanbaatar city and development of recommendations to protect human health from water pollution", which was implemented in 2019 at our institute, and the results of the study have been compiled and presented in this article.

This study aimed to conduct on-site measurements to determine groundwater quality and composition that is not connected to the water supply network in the Ger district area of Bayanzurkh district, to determine the main ingredients and contamination by laboratory analysis, and to evaluate whether the water could be consumed by human drink based on the laboratory results.

2. STUDY AREA

Bayanzurkh district has 124.4 hectares of land, beautiful surrounded by hills, forests, and steppe. Around 10.6% of the total population of Mongolia and 23.8% of urban live in this district. According to the statistical information in 2018, 343619 people from 957114 of the family are living in this district. 43% of the population is in the Apartment area, other 53.7% of the population is living in the Ger area [4].

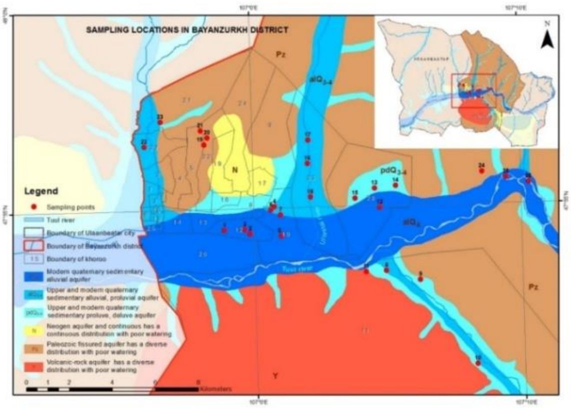

Figure 1. Sampling location of the study area

3. METHOD AND DATA

3.1. Physico-chemical methodology

Water samples for chemical, bacteriological and microelements analysis was taken from a location that is representatives of the water resource, 10th sub-districts in Ger district area. A total of 26 samples were collected from groundwater around the study area. Microbiological samples were analyzed immediately when they arrived at the laboratory within six to eight hours of collection. Groundwater samples were collected from 26.0 shallow wells with a depth range of 40–90 m across the basin during the March of 2019 (Figure 1).

Major ions were analyzed in a total of 26 samples were performed at the Laboratory for Water analyses of the Institute of Geography and Geoecology. The in situ measured parameters included the temperature, water temperature, pH, electrical conductivity (EC and turbidity, which were measured by using a multi-parameter on-site (HANNA HI 98195). Water quality parameters were determined by the following methods: the concentrations of microelements were measured using the ICP80T in the laboratory of "SGS IMME Mongolia" LLC; bacteriological analysis was measured in the Laboratory of Bio-Ecology of the Institute of Geography and Geoecology.

3.2. Processing the results

According to the classification of Russian scientist AM Ovchinnikov (mineralization) and hydro-chemist OA Alekin (hardness), we classify water as follows, taking into account the norms of drinking and animal water, applicable standards, and practical conditions in our country. And using this classification it was classified the salinity and hardness of the groundwater (Table 1).

Table 1. Classification of water mineralization and Hardness [5]

Mineralization level	Mineralization, g/l	Hardness level	Hardness, mg-eq/l
Very fresh	< 0.2	Very soft	<1.50
Fresh	0.2-0.5	Soft	1.51-3.00
Freshly	0.51-1.0	Softish	3.01-5.00
Salty	1.01-3.0	Hardish	5.01-7.00
Quasi-Salty	3.01-7.00	Hard	7.01-9.00
Very salty	>7.01	Very hard	>9.01

To assess the suitability of groundwater quality in the Bayanzurkh district for drinking purposes, hydrochemical parameters were compared with the guidelines recommended by the World Health Organization (WHO) and the National Drinking Water Standard (MNS 0900:2018). The results were processed using ArcGIS, Aquachem software, and SPSS version 26.0.

4. RESULTS

4.1. Statistical analysis

Descriptive statistics of analyzed parameters in the water samples are presented in Table 2, with the comparison of standard permissible limits. The parameter pH of groundwater is slightly acidic to alkaline ranging from 6.53 to7.37 with a mean value of 7.00. Groundwater exceeding the limit of 7 mg-eq/l is considered to be hard. Hard water is unsuitable for domestic use. In our study, total hardness (TH) is in the range of 1.80-12.70 mg-eq/l with a mean value of 5.05 mg-eq/l, which reveals that most of the samples are moderately hard category. The TH value in some parts of the study area was found to be 12.70 mg-eq/l which is beyond the permissible limit as per the National drinking water standard.

The electrical conductivity (EC) values of the collected water samples are observed to cover a wide range from 201-1384 µS/cm with an average value of 567.6 µS/cm. Lower values in of EC (331.2 µS/cm) are located in the alluvial aquifer along the Tuul River and Uliastai, while the highest values were observed in samples GW-5 1385 µS/cm), GW-19 (1263 µS/cm) and GW-22 (1370 µS/cm) located in the 10th sub-district of Amgalan, 22nd sub-district of Altan Ulgii, and 27th sub-district of Dari Ekh close to the ger district and dumping sites exceed the permissible limit of MNS (2018) standard. According to WHO (2011) recommendation, EC up to 1500 µS/cm is maximumly permissible. All of the samples of the study area fall within the permissible limit. TDS has an average value of 283.58 that ranges from 100.0 to 692 mg/L. The maximum allowable limit of TDS value in groundwater is 500 mg/l set by WHO (2011), and all the samples fall within the permissible limit except three samples (GW5, GW19, and GW22).

The mean value of calcium (Ca^{2+}) is 75.68 mg/l with ranges from 28.1 to 194.4 mg/l. The maximum allowable limit of Ca^{2+} in groundwater is 100 mg/l 75 mg/l (WHO, 2011) and Mongolian standard. All the samples fall within the permissible limit except GW1, GW5, GW7, GW19, and G22.

Magnesium (Mg^{2+}) concentration ranged from 4.9 to 45.0 mg/l, with an average value of 15.59 mg/l. The maximum allowable limit of Mg^{2+} in groundwater is 30 mg/l as per MNS (2018) and WHO (2011), and all the samples fall within the permissible limit except GW5, GW19, and GW21. The average value of bicarbonate (HCO3-) is 212.79 mg/l and ranged from 109.8 to 347.70 mg/l.

The mean value of chloride (Cl^-) is 39.48 mg/l with ranges from 3.60 mg/l to 170.40 mg/l. According to MNS (2018) and WHO (2011), all the samples fall within the permissible limit. Subsequently, sulfate (SO_4^{2-}) concentration ranged from 6.0 to 200.0 mg/l with an average value of 43.27 mg/l, all the samples fall within the permissible limit (Table 2).

Table 2. Statistical summary of the measured parameters of collected groundwater samples (maximum and minimum values, average values, standard deviations)

Parameters	Values form collected samples (n=26)					
	Min	Max	Mean	Std.Deviation	WHO2011	MNS0900:2018
pH	6.53	7.37	7.00	0.28	6.5-8.5	6.5-8.5
Total hardness (TH) (mg-eqv/l)	1.80	12.70	5.05	2.81	-	7.0
EC (µS/cm)	201.0	1384.0	567.57	331.16	1500	
TDS (mg/L)	100.0	692.0	283.58	165.62	500	
Ca^{2+} (mg/L)	28.10	194.40	75.68	41.45	75	100
Mg^{2+} (mg/L)	4.90	45.0	15.59	10.0	30	30
Na^{+} (mg/L)	3.20	29.30	15.76	6.99	200	200
HCO_3^- (mg/L)	109.80	347.70	212.79	52.43		
Cl^- (mg/L)	3.60	170.40	39.48	45.20	250	350
SO_4^{2-} (mg/L)	6.00	200.0	43.27	47.0	250	500

4.2. Correlation analysis

The chemical composition of groundwater is determined by major cations and anions such as Ca, Mg, Na, K, Cl, SO_4, and HCO_3. Both climate processes and anthropogenic factors are the main factors changing the groundwater geochemical composition [6].

Pearson's correlation matrix for the analyzed parameters of the groundwater samples is presented in Table 3. As can be seen with analysis results, the correlations between TDS and pH was weak, whereas TDS and Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^- and SO_4^{2-} are also strong positive correlation, which is explained by the dissolution of those minerals.

Table 3. Linear relationship between various chemical parameters of groundwater in the study area

Pearson correlations, N=26											
Chemical Parameters	**EC µS/cm**	**TDS ppm**	**Ca^{2+} mg/l**	**Mg^{2+} mg/l**	**Na^++K^+ mg/l**	**HCO_3^- mg/l**	**Cl^- mg/l**	**SO_4^{2-} mg/l**	**pH**	**Turb, NTU**	**TH, mg/l**
EC	1										
TDS	1.000**	1									
Ca^{2+}	**0.985****	**0.986****	1								
Mg^{2+}	**0.920****	**0.920****	**0.871***	1							
Na^++K^+	0.475*	0.475*	0.378	0.471*	1						
HCO_3^-	0.800**	0.799**	0.749**	0.847**	0.657**	1					
Cl^-	**0.962****	**0.962****	**0.947****	**0.931****	0.479*	0.763**	1				
SO_4^{2-}	**0.909****	**0.909****	**0.933****	0.745**	0.251	0.544**	0.821**	1			
NO_3^-	0.815**	0.815**	0.802**	0.728**	0.369	0.512**	0.812**	0.742**			
pH	-0.174	-0.175	-0.244	-0.025	-0.005	0.060	-0.255	-0.217	1		
Turb	0.220	0.220	0.159	0.355	0.270	0.316	0.236	0.097	0.059	1	
TH	**0.993****	**0.993****	**0.990****	**0.932****	0.416*	0.798**	**0.969****	**0.904****	-0.187	0.221	1

4.3. Hydrochemical facies

The concentrations of major ions determined in groundwater samples are presented in Piper (1944) trilinear diagram (Figure 2). The diagram revealed that most of the samples in this study belong to Ca-HCO_3 (92.3%) type followed by Ca [HCO_3-CI] (3.85%), and Ca-Mx (3.85%) respectively. It is also suggested that silicate weathering domination and rock–water interaction are the primary factors in increasing the major ion concentration in the groundwater [7].

The region is grouped by similar behavior of water chemical composition, namely, Dari-Ekh, Shar khad, Tsaiz, Monel, Altan-Ulgii, Ulaanhuaran, Amgalan, Uliastai, Khujirbulan, Bayanzurkh Tovchoo, and Gachuurt (Figure 2).

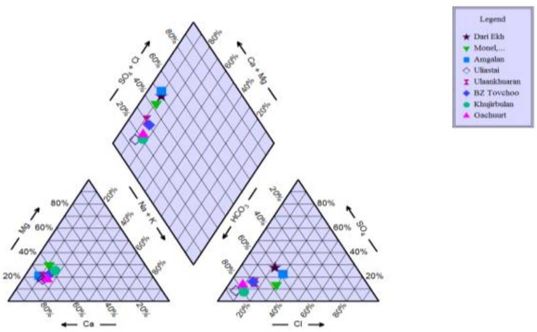

Figure 2. Piper diagram. Chemical composition of groundwater in Bayanzurkh district

Some wells located near ger district in the Dari-Ekh area (21st and 27th sub-district), water is included in the hydrocarbonate class, calcium group, the second and third category of Alekin's classification, fresh-relatively high level of mineralization (mineralization 368.9-846.3 mg/l), moderately hard-very hard (hardness 4.25-10.9 mg-eq/l). The ionic structure of the water samples in Dari-Ekh is dominated by calcium cation and the hydrocarbonate anion. The cation and anion ratios are $Ca^{2+}>Mg^{2+}>Na^++K^+$ and $HCO_3^->SO_4^{2-}>Cl^-$ (Figure 3, 4).

The results of the study show that Dari-Ekh, Amgalan, Uliastai, and Ulaanhuaran all had high mineralization and hardness, these samples are not suitable to use for drinking water. In this area, the total hardness of drinking water fluctuated between 2.1 and 6.4 mg-eq/l. But total hardness in the samples GW-18, GW-5, GW-19, GW-21, and GW-22 were 1.1-1.8 times more than standard (Figure 3). The result of the bacteriological study shows that the bacteria were revealed in the Dari-Ekh, Monel, and Altan-Ulgii sites at certain level. There is a need to soften, freshen, and clean.

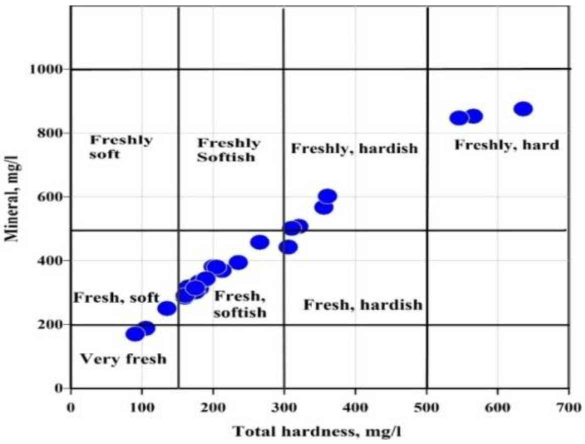

Figure 3. Groundwater quality in the Bayanzurkh district based on mineralization and total hardness

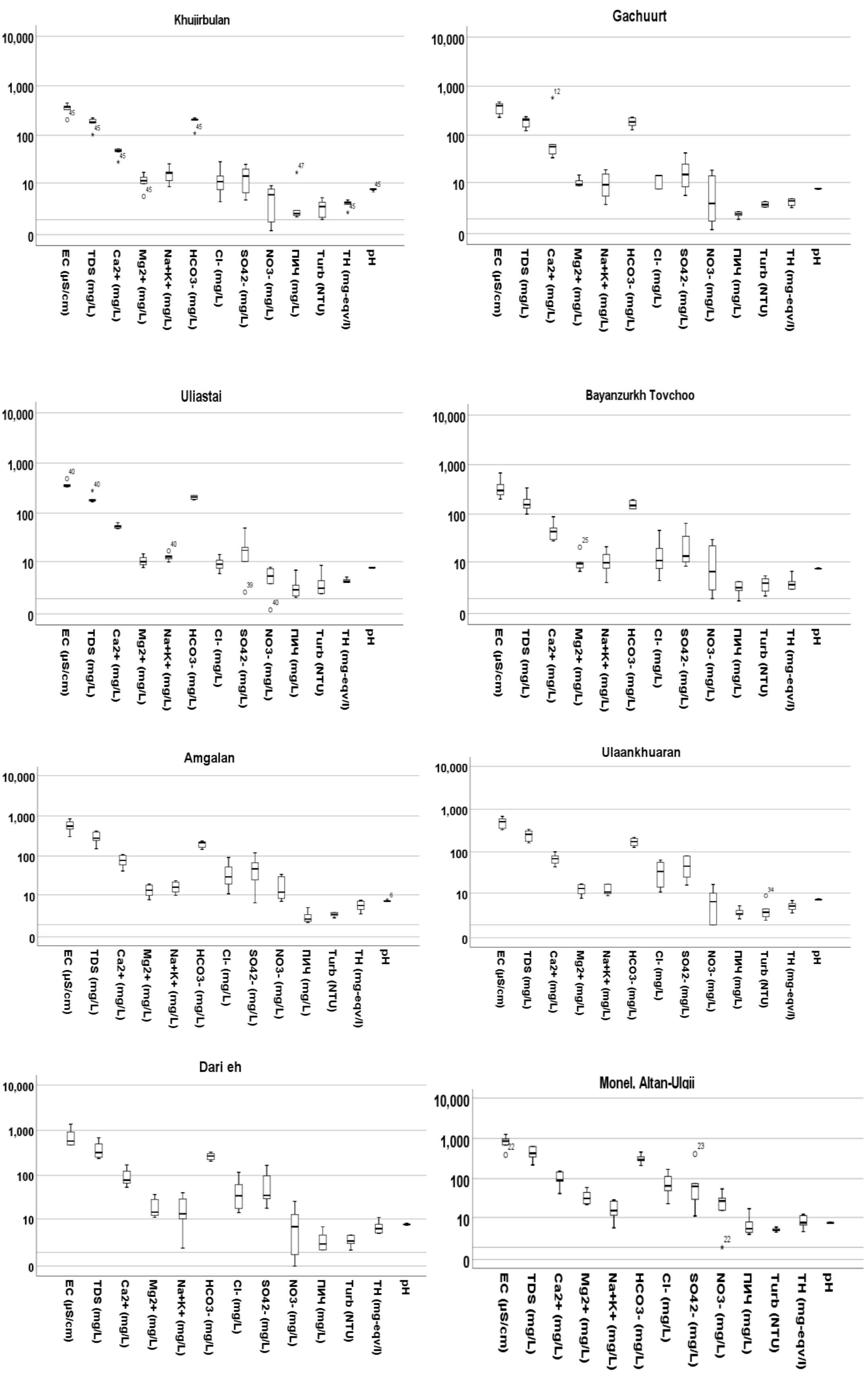

Figure 4. Box and Whisker plot showing the variation of major ion concentration of groundwater

4.4. Heavy metal analysis of groundwater

The drinking water quality in the Bayanzurkh district of Ulaanbaatar was assessed by analyzing heavy metals and compared with Mongolian drinking water standards. According to our results, the concentration of heavy metals in all 10 groundwater samples is within the standard values.

4.5. Bacteriological analysis of groundwater

Microbiological analysis of groundwater samples taken from GW-9, GW-19, GW-22 were free from *E.coli* and *thermotolerant bacteria* and are suitable for drinking purpose according to microbiological parameters on MNS 0900:2018. Additionally, other bacteria such as Thermo-tolerant, Salmonella, E. coli were not detected in this area.

5. CONCLUSIONS

The chemical composition and water quality of groundwater from wells around the Bayanzurkh district differ. Specifically, the water of some wells in the Altan-Ulgii and Monel contain relatively high mineralization with recorded values of 500.8 and 852.0 mg/l, respectively. The amount of hardness of groundwater in area Amgalan, Altan-Ulgii, Monel, and Dari-Ekh were higher than the drinking water standard (average hardness 7.1-12.7 mg-eq/l). Wells located in Ulaanhuaran, water is included slightly hard (6.1-6.4 mg-eq/l). Generally, the lowest values of hardness are found in the eastern part, it is included from soft to softish (hardness 2.1-4.7 mg-eq/l). Of the 26 samples analyzed for mineralization 7.7 percent of the water is very fresh, 65.4 percent is fresh, 26.2 percent is relatively high mineralization. In case of hardness, 11.6 percent of the water is soft, 53.9 percent is softish, 15.4 percent is moderately hard, 7.7 percent is hard and 11.5 percent is very hard. The concentration of calcium and magnesium were exceeded in 4 samples (15.3%) and in 3 samples (11.5%), respectively. As can be seen from the study results, approximately 15.4% of water samples were found to be contaminated coliform bacteria (per 100ml) in Dari-Ekh, Monel and Altan-Ulgii area. These samples were included in the research area not suitable to use for drinking purposes. Therefore, it is needed to be cleaned or treated before using for drinking water.

6. DISCUSSION

As can be seen with analysis results from previous studies showed that the most of groundwater samples in the Bayanzurkh district has relatively high mineralization and moderately hard category. The level of iron was high in some parts of the Bayanzurkh district. Narantuul, Tsaiz, and Ulaanhuaran all had high mineralization and hardness. This is showing that groundwater is polluted in these areas. It is related to the population density of Tsaiz and Narantuul trade center, and the concentration of the Ger districts. But Uliastai, Gachuurt, and Terelj areas have the lowest mineralization (116.7-412.2 mg/l) and hardness (0.85-4.30 mg-eq/l) of the Bayanzurkh area. The wells in the Narantuul, Ulaanhuaran, Amgalan, and Dari Ekh areas exhibited relatively high mineralization (530.7-718.1 mg/l). In terms of hardness, the amount of hardness of groundwater in areas Ulaanhuaran and Dari-Ekh were higher than the drinking water standard (hardness 7.6-7.84 mg-eq/l). Wells are located in Narantuul and Amgalan areas, water is included slightly hard (6.10-6.38 mg-eq/l). The other areas are located in, it is included from soft to softish (hardness 2.1-4.7 mg-eq/l). The remaining wells in the area, it is included from soft to softish 1.83-3.32 mg-eq/l. Narantuul, Ulaanhuaran, and Amgalan, the concentration of iron ion detected 0.6-1.1 mg/l and it is not satisfying the requirement of drinking water standard [8]. Our results are consistent with other research results of doctor Javzan et al [3].

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