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HYDROCHEMICAL STUDY OF WATER SUPPLY OF ULAANBAATAR CITY

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We conducted this study to determine the seasonal dynamics of chlorine organic compound and physico-chemical characteristics of two sources of drinking water in Ulaanbaatar city. There are seven sources of wells suppluying drinking water. The first is “Uildver” source

whuch is placed in the highly occupied industrial zone showing pH 6.11-6.94 and the conductivity (EC) 41.5-60.2 mS/m. The general hardness was 3.8-5.9 mg-eqv/l, general mineralization is classified as SO_4^{2-} - Ca^{2+} and Mg^{2+} which grades up to 274.96-470.8 mg/l.

The second industrial source called "Mah kombinat" shows pH 6.14-6.85 and the conductivity (EC) is 54.5-62.4 mS/m. The general hardness is 4.9-6.0 mg-eqv/l and the general mineralization is classified as SO_4^{2-}, Ca^{2+} and Mg^{2+} which grades up to 420.4-520.7 mg/l. In addition, in cations the main component is the Ca^{2+} ion in drinking water of these two sources and SO_4^{2-} and HCO_3^- ions are abundant anions. The obtained results meet the requirements of Drinking water standard MNS 0900:2016, any changes of composition depending on the season have not been revealed.

Moreover, the analysis of microelements by using ICP-MS facility in drinking water on the way to water supply to the user's pipeline showed presence of several elemental components and severe radioactive elements, but they don't exceed the national standards.

Keywords: Ulaanbaatar city; drinking water; hydrochemical composition.

Introduction

The capital Ulaanbaatar is located in Khangai Khentii mountainous region, located in the Valley of the Tuul River, surrounded by mountains of Bogd Mountain in the southwest of the Khentii Mountains [Chimedsuren, 2002]. Water supply for Ulaanbaatar residents is provided by underground fresh water in the depths of 35-40 m in the deep pit of the Tuul River. In 2012, a source of Gachuurt with 20 boreholes and 2014 Yarmag's water supply source and aviation sources were commissioned [Research on Mineral…, 2013]. Our country uses a world-class disinfection method for centralized water distribution to meet hygienic requirements. Our first drinking water was chlorinated in 1965 and the drinking water standard was approved in 1978 and it has been upgraded five times [Нарантуяа, 1998]. The chloro hydrochloride dose in the Ulaanbaatar water distribution system used in the 1960s and 1970s is still in use [Narantuya et al.,1996]. We have conducted a research to determine the physical and chemical composition of 7 sources of drinking water in Ulaanbaatar.

Materials and Methods

In this study seven water supply sources "Zavsar – A", "Gachuurt- B", "Tuv-C", "Uildver- D", "Makh-kombinat– E", " Buyant-Ukhaa-F", "Yarmag-G" were included (Figure 1). The "Deed" source is 55 deep wells and 55000 m^3 per day. The "Tuv" source is located at a distance of about 1 km and the end user is located at a distance of 15 km away, with the total number of wells being over 100 and 70% of the city's consumers. The source of the "Uildver" is 16 wells, and 36000 m^3 / day water is extracted and distributed. The "B" station of the "Mah kombinat" 11 deep wells and 18000 m^3/day of pure water extraction distributes to customers of Songinokhairkhan district. "Gachuurt" source is 21 deep wells, 15000 m^3 fresh water is extracted per day and distributed to Bayanzurkh district consumers. "Buyant-Ukhaa" source contains 30 deep wells and 3,000m^3 of fresh water per day. "Yarmag" source has 2 large deep wells. We extract 300-400m3 of water per day and distribute it to customers.

Totally 7 chemical sources of drinking water was analyzed in 2016 and 2017 in Ulaanbaatar. The measurements were made on the water samples of the sample pH (HM-30P), electrical conductivity or EC (CM-31P). The basic cations, such as Ca^{2+} and Mg^{2+}, are determined by the weight method by titrimetry of 0.1 granular B, the main ion anion CO_3^{2-}, HCO_3 of 0.1 gr HCL, CL of ion of 0.1 gr $AgNO_3$ and SO_4^2 of ion. Also defined as NH^{4+}, Fe, NO_3^- and NO_2^- S2100UV spectrophotometers [Drinking

water…, 2016]. Chemical analysis was carried out in the Ecological Chemistry Laboratory of the Institute of Chemistry and Chemical Technology.

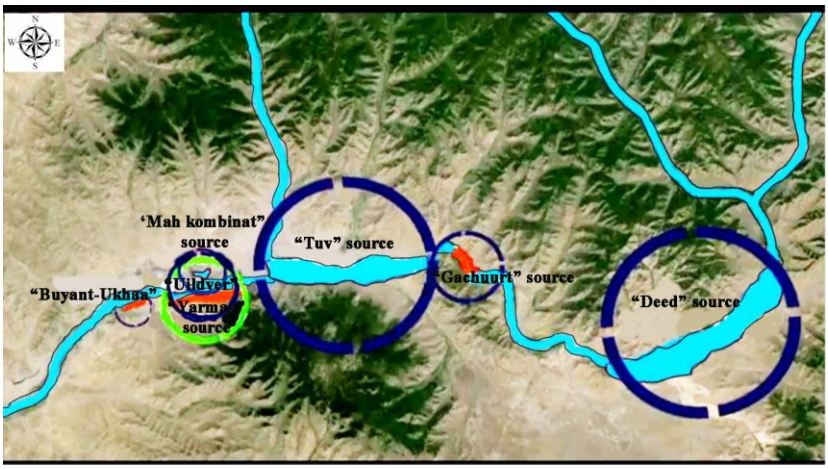

Figure 1. Location of drinking water sources

Results and discussion

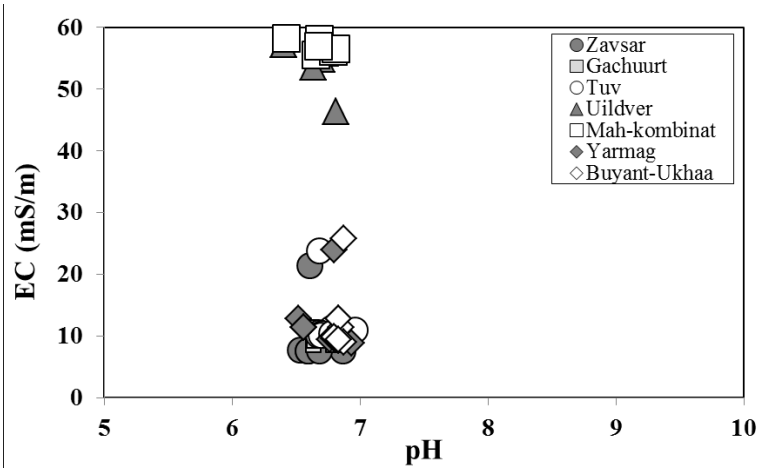

Figure 1. Electrical conductivity and pH dependence graphs

Physical-chemical characteristic: due to the electrical conductivity and pH dependence graphs 7 sources of drinking water pH 6.4-6.93 has a neutral environment with weak acidity. However, the conductivity of the B and C stations (EC) is 46.4-62.6 mS / m, while the conductivity (EC) of 7.45.8 mS / m is located in the Zasvar, Gachuurt, Tuv, Yarmag and Buyant-Ukhaa sources.

Uildver and Makh-kombinant sources have higher hydroelectricity than other stations, which are directly dependent on mineralization, and drinking water of Uildver and C Makh-kombinant have high mineralization from other plants.

Chemical characteristic: The results of the chemical analyses for each quarter of 2016 and 2017 for drinking water samples of seven stations are shown in Table 1.2 and

Figure: 2.3.4.5. According to the chemical analysis of 2016-2017, drinking water of Zavsar, Gachuurt, Tuv and Yarmmag sources is 0.6-1.0 mg-eqv/l, and the general mineralization is 50.5-128.1 mg/l. In addition, NO_2 of 7 stations of drinking water does not exceed 0.005mg/l. However, in the drinking water of Uildver station NO_3 is 15-28 mg / l (Table 1.2)whuch is in compliance with drinking water standard requirements [Drinking water…, 2016], but NO_3 (0.5-11.3 mg/l) is higher than the content.

Table 1

Chemical composition of each of the 7 sources of drinking water in 2016, mg / l

№	Season	Source	pH	EC, ms/m	general hardness, mg-eqv/l	Na^+	Ca^{2+}	Mg^{2+}	NH_4^+	CO_3^-	HCO_3^-	Cl^-	SO_4^-	NO_2^-	NO_3^-	general mineralization
1	I-Season	Zavar	6.6	7.4	0.6	5.44	9.2	1.5	0.064	-	32.9	4.9	5.8	0	1.3	61.1
2		Gachuurt	6.64	9.2	0.8	7.82	11.6	2.2	0.093	-	50.0	4.2	6.9	0.002	1.3	84.2
3		Tuv	6.68	9.9	0.8	5.78	12.1	2.6	0.046	-	44.2	4.7	8.7	0.001	2.1	80.3
4		Uildver	6.40	57.2	5.5	16.31	96.2	6.7	-	-	88.5	30.5	189.7	-	-	392.7
5		Mah-kombinat	6.43	58.1	5.0	29.3	80.2	12.8	0.091	-	134.2	38.3	135.4	0.001	18.1	448.3
6		Yarmag	6.76	9.4	0.7	8.15	10.4	1.7	0.066	-	43.3	4.2	8.8	0.001	0.4	77.0
7		Buyant-Ukhaa	6.81	9.5	0.8	5.48	11.4	2.3	0.076	-	38.4	4.9	9.0	0	2.8	74.4
1	II-Season	Zavar	6.60	7.4	0.6	4.65	8.8	1.9	0.005	-	34.2	3.8	5.2	0	1.4	59.9
2		Gachuurt	6.70	10.0	0.8	4.97	11.9	2.6	0.013	-	45.1	4.0	6.7	0	2.1	77.3
3		Tuv	6.70	9.9	0.8	8.21	12.1	2.4	0.006	-	43.3	8.6	7.9	0	2.6	85.1
4		Uildver	6.70	57.0	4.9	4.25	94.3	2.6	0.022	-	70.2	26.1	148.0	0	8.5	354.0
5		Mah-kombinat	6.80	55.9	4.9	29.8	80.2	11.6	0.026	-	137.3	36.7	130.8	0	15.0	441.3
6		Yarmag	6.80	9.6	0.6	8.88	10.2	1.4	0.009	-	45.8	3.8	6.9	0	0.6	77.6
7		Buyant-Ukhaa	6.80	9.8	0.8	3.63	11.4	2.7	0.006	-	34.8	5.2	8.1	0	4.0	69.8
1	III-Season	Zavar	6.87	7.4	0.6	16.36	8.02	2.4	-	-	48.8	13.3	8.2	-	-	98.6
2		Gachuurt	6.79	8.5	0.8	11.76	14.0	1.2	-	-	48.8	13.3	8.2	-	-	98.8
3		Tuv	6.97	10.8	1.0	16.86	16.0	2.4	-	-	61.0	20.0	9.9	-	0.3	128.1
4		Uildver	6.81	46.4	4.2	9.37	76.2	4.9	-	-	73.2	26.7	130.9	-	1.0	325.4
5		Mah-kombinat	6.82	56.3	5.0	18.43	80.2	12.2	-	-	122.0	26.7	148.1	-	3.7	415.0
6		Yarmag	6.93	8.8	0.9	12.04	12.0	3.6	-	-	48.8	13.3	14.0	-	-	105.5
7		Buyant-Ukhaa	6.87	9.0	1.0	7.84	12.0	3.6	-	-	48.8	13.3	4.9	-	0.4	92.6
1	IV-Season	Zavar	6.69	7.4	0.6	10.51	8.7	1.9	0.034	-	38.6	9.6	6.4	0.001	0.9	76.6
2		Gachuurt	6.71	9.2	0.8	8.41	12.5	2.0	0.053	-	48.0	7.2	7.3	0.002	1.1	86.5
3		Tuv	6.78	10.2	0.9	10.58	13.4	2.5	0.026	-	49.5	11.1	8.8	0.001	1.7	97.6
4		Uildver	6.63	53.5	4.8	12.81	88.8	4.7	0.022	-	77.3	27.7	156.2	0	4.7	372.3
5		Mah-kombinat	6.68	56.7	4.9	26.96	80.2	12.2	0.058	-	131.2	33.8	138.1	0.001	12.2	434.6
6		Yarmag	6.83	9.3	0.7	11.35	10.8	1.6	0.038	-	46.0	7.1	9.8	0	0.5	87.2
7		Buyant-Ukhaa	6.83	9.4	0.8	5.97	11.6	2.9	0.043	-	40.7	7.8	7.3	0	2.4	78.7

2016 and 2017 chemical analyses of each quarter (table 1, 2, graphs 2 and 3) are the dominant inhibitors of the anions in drinking water, inlets, at stations, Buyant-Ukhaa and Yarmag. The water content of the source is between 40°C and 41°C to 61°C / l / l, while the distance between the source and the water source is 29.3-48.8 mg / l. The main cation, ie, + ion, is 8.02-12.3 mg / l for drinking water at Zavsar stations, while the surfaces of Tuv station, Buyant-Ukhaa and Yarmag station are 10.8-17.9 mg / l for drinking water. Na^++ K^+ 2-16.8 mg / l, Mg^{2+} 1-3.6 mg / l contained in other drinking water sources, and CI 4.1-20 mg / l, SO_4^{2-} 3.0-14 mg / L meets the standard requirements of drinking water [Drinking water…, 2016]. As shown in graph 2.3, comparing the chemical composition of drinking water in these 5 stations in 2016 and 2017, the ions and seismic changes according to the season and year are identified.

Table 2

Chemical composition of each of the 7 sources of drinking water in 2017, mg / l

№	Season	Source	pH	EC, ms/m	general hardness, mg-eqv/l	Na^+	Ca^{2+}	Mg^{2+}	NH_4^+	CO_3^-	HCO_3^-	Cl^-	SO_4^-	NO_2^-	NO_3^-	general mineralization
1		Zavar	6.6	7.4	0.6	5.44	9.2	1.5	0.064	-	32.9	4.9	5.8	0	1.3	61.1
2		Gachuurt	6.64	9.2	0.8	7.82	11.6	2.2	0.093	-	50.0	4.2	6.9	0.002	1.3	84.2
3	I-Season	Tuv	6.68	9.9	0.8	5.78	12.1	2.6	0.046	-	44.2	4.7	8.7	0.001	2.1	80.3
4		Uildver	6.40	57.2	5.5	16.31	96.2	6.7	-	-	88.5	30.5	189.7	-	-	392.7
5		Mah-kombinat	6.43	58.1	5.0	29.3	80.2	12.8	0.091	-	134.2	38.3	135.4	0.001	18.1	448.3
6		Yarmag	6.76	9.4	0.7	8.15	10.4	1.7	0.066	-	43.3	4.2	8.8	0.001	0.4	77.0
7		Buyant-Ukhaa	6.81	9.5	0.8	5.48	11.4	2.3	0.076	-	38.4	4.9	9.0	0	2.8	74.4
1		Zavar	6.60	7.4	0.6	4.65	8.8	1.9	0.005	-	34.2	3.8	5.2	0	1.4	59.9
2		Gachuurt	6.70	10.0	0.8	4.97	11.9	2.6	0.013	-	45.1	4.0	6.7	0	2.1	77.3
3	II-Season	Tuv	6.70	9.9	0.8	8.21	12.1	2.4	0.006	-	43.3	8.6	7.9	0	2.6	85.1
4		Uildver	6.70	57.0	4.9	4.25	94.3	2.6	0.022	-	70.2	26.1	148.0	0	8.5	354.0
5		Mah-kombinat	6.80	55.9	4.9	29.8	80.2	11.6	0.026	-	137.3	36.7	130.8	0	15.0	441.3
6		Yarmag	6.80	9.6	0.6	8.88	10.2	1.4	0.009	-	45.8	3.8	6.9	0	0.6	77.6
7		Buyant-Ukhaa	6.80	9.8	0.8	3.63	11.4	2.7	0.006	-	34.8	5.2	8.1	0	4.0	69.8
1		Zavar	6.87	7.4	0.6	16.36	8.02	2.4	-	-	48.8	13.3	8.2	-	-	98.6
2		Gachuurt	6.79	8.5	0.8	11.76	14.0	1.2	-	-	48.8	13.3	8.2	-	-	98.8
3	III-Season	Tuv	6.97	10.8	1.0	16.86	16.0	2.4	-	-	61.0	20.0	9.9	-	0.3	128.1
4		Uildver	6.81	46.4	4.2	9.37	76.2	4.9	-	-	73.2	26.7	130.9	-	1.0	325.4
5		Mah-kombinat	6.82	56.3	5.0	18.43	80.2	12.2	-	-	122.0	26.7	148.1	-	3.7	415.0
6		Yarmag	6.93	8.8	0.9	12.04	12.0	3.6	-	-	48.8	13.3	14.0	-	-	105.5
7		Buyant-Ukhaa	6.87	9.0	1.0	7.84	12.0	3.6	-	-	48.8	13.3	4.9	-	0.4	92.6
1		Zavar	6.69	7.4	0.6	10.51	8.7	1.9	0.034	-	38.6	9.6	6.4	0.001	0.9	76.6
2		Gachuurt	6.71	9.2	0.8	8.41	12.5	2.0	0.053	-	48.0	7.2	7.3	0.002	1.1	86.5
3	IV-Season	Tuv	6.78	10.2	0.9	10.58	13.4	2.5	0.026	-	49.5	11.1	8.8	0.001	1.7	97.6
4		Uildver	6.63	53.5	4.8	12.81	88.8	4.7	0.022	-	77.3	27.7	156.2	0	4.7	372.3
5		Mah-kombinat	6.68	56.7	4.9	26.96	80.2	12.2	0.058	-	131.2	33.8	138.1	0.001	12.2	434.6
6		Yarmag	6.83	9.3	0.7	11.35	10.8	1.6	0.038	-	46.0	7.1	9.8	0	0.5	87.2
7		Buyant-Ukhaa	6.83	9.4	0.8	5.97	11.6	2.9	0.043	-	40.7	7.8	7.3	0	2.4	78.7

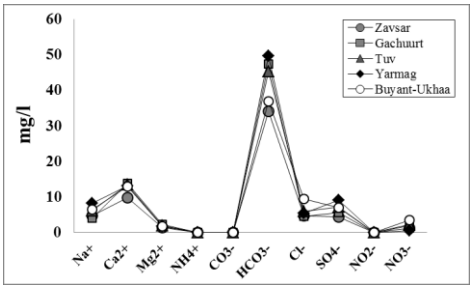

Figure 2. Chemical composition of water for drinking water in 2016

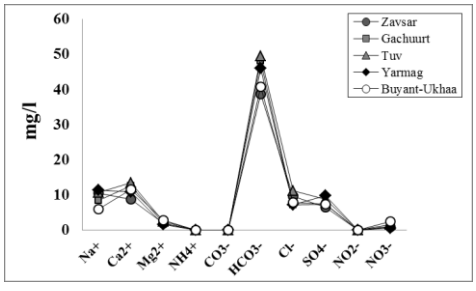

Figure 3. Chemical composition of water for drinking water in 2017

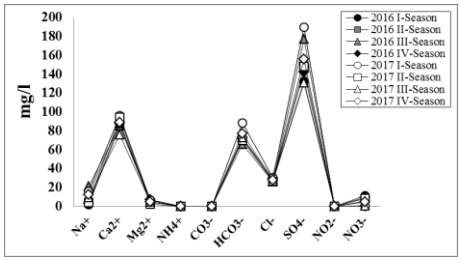

Figure 4. Chemical composition of annual and season of uidver

As shown in Figure 4, the Uidver station's water is dominant from cation ion to Ca^{+2} and SO_4^{2-} ion anion and general mineralization is up to 325.4-392.7 mg/l (Table 1.2). The main anion, Na^+ 65.8-96.2 mg / l, Mg^{2+} 2.6-7.5 mg / l, Na^++ K^+ 2.6-7.5 mg / l, is the main anion such as HCO_3^-65.9-88.5 mg / l, CI- 26.1-30.5 mg / l , SO_4^{2-} 130.9-189.7 mg / l, and meet drinking water requirements [Drinking water…, 2016] (Table 1.2). The values of the ions in the same quarter of 2016 and the 2017 years are slightly different, but the ions have no structural changes over the course of the year.

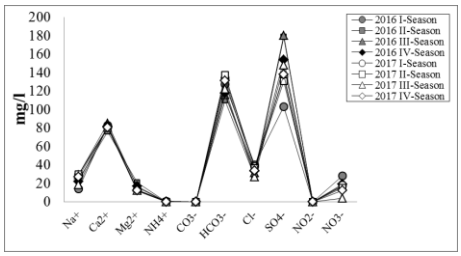

Figure 5. Chemical composition of annual and season of makh kombinat

As shown in the results of the study during the drinking water season and yearly drinking water source, the average hardness is 4.9-5.5 mg-eqv / l and the general mineralization is up to 407.2-474.7 mg / l (Table 1.2). In the potable water of the Makh- Kombinat station, the cations of ions predominate to 76.1-84.9 mg / l. In addition, anion ions are predominantly ion Ions of 2017 and I of 2017, with 126.9-137.3 mg / l content while SO_4^2 is less than 102.8-135.4 mg / l. In the second, third, and fourth quarter of 2016, SO_4^{2-} ion in 2017, III and IV in the fourth quarter was 138.1-180.2 mg / l, while HCO_3 was 109.8-131.2 mg / l (Table 1.2 and Figure 5). This is due to the fact that groundwater is mixed with lateral and soil water during the winter (when land is frozen). Other ion ions are contained in Na ++ K + 13.8-29.3 mg / l, Mg2 + 11.5-20.6 mg / l of anion ions CI-26.7-39.8 mg/l respectively (Table1.2). The drinking water of the Makh-kombinant station is generally higher than the standard water content of other 6 stations, as well as anion and cation content, but is in compliance with the drinking water standard requirements[Drinking water…, 2016].

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The groundwater that supplies drinking water for Ulaanbaatar residents is extremely fresh water for chemical composition. The drinking water of Zavsar, Gachuurt, Tuv station, Yarmag and Byuant Ukhaa, Uildver station sources is of the hydrocarbon-calcium type, and the drinking water of Makh-Kombinant station is sulfate-calcium type of water. In addition, the drinking water of the station B belongs to the category of water combining both sulfate-calcium and hydrocarbon-calcium.

Microelements. The elemental analysis of seven sources of drinking water in Ulaanbaatar for heavy metals and microelements was made. In total, 57 elements were determined and among them 22 elemental data shown in the table 3 that are compared with indicators of the national drinking water standards. As shown in table 3, several elements as Ba, Co, Sc, Ni and U are of higher concentrations in drinking water sources of Uildver and Makh kombinat than other 5 stations, but results met the national standard MNS0900: 2016 - requirements.

№	Elements	MNS 0900:2016	Zavsar	Gachuurt	Tuv	Uildver	Mah-Kombinat	Yarmag	Buyant-Ukhaa
1	Aluminum - Al	0.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	Barium-Ba	0.7	<0.01	<0.01	<0.01	0.029	0.036	<0.01	<0.01
3	Chromium-Cr	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4	Copper - Cu	1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
5	Iron-Fe	0.3	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
6	Zinc -Zn	5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
7	Beryllium -Be	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
8	Scandium -Sc		0.001	0.001	0.001	0.002	0.002	0.001	0.001
9	Cobalt- Co		<0.0006	<0.0006	<0.0006	0.00042	0.00044	<0.0006	<0.0006
10	Manganese -Mn	0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
11	Strontium- Sr	2	0.069	0.084	0.102	0.689	0.771	0.082	0.101
12	Nickel-Ni		<0.0003	<0.0003	<0.0003	0.0016	0.0021	<0.0003	<0.0003
13	Molybdenum - Mo	0.07	0.0004	0.0006	0.0008	0.03	0.0013	0.0012	0.001
14	Arsenic - As	0.01	0.00021	0.00023	0.00033	0.004	0.0003	<0.00003	0.00023
15	Rubidium-Rb		0.00014	0.00013	0.00015	0.00029	0.00018	0.00009	0.00016
16	Selenium -Se	0.04	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
17	Silver-Ag	0.1	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
18	Cadmium-Cd	0.003	0.00001	0.00001	0.00001	0.00003	<0.00001	0.00001	<0.00001
19	Tungsten-W		0.00062	0.00086	0.00144	0.007	0.0005	0.00062	0.00054
20	Mercury-Hg	0.006	<0.00005	0.00012	0.0009	0.0047	0.0008	0.0007	0.0007
21	lead-Pb	0.01	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
22	Uranium-U	0.03	5.7E-05	4.5E-05	6.4E-05	0.0012	0.004	2.9E-05	0.000046

Conclusion

- The results of the hydro-chemical analysis of the same period of 2016 and 2017 of drinking water sources Uildver station, Zavsar, Tuv, Gachhurt, Byuant –Ukhaa and Yarmag of the Ulaanbaatar city.
- A study of the drinking water regime of the Makh-Kombinat station dominates HCO_3^- ion in 2016 and 2017 during winter and SO_4^{2-} ions in the other seasons. This shows that changes in quantities between ions are dependent on the season.
- Chemical composition of 7 sources of drinking water in Ulaanbaatar meets the requirements of National Standard for the Drinking Water MNS 0900: 2016.

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ГИДРОХИМИЧЕСКОЕ ИССЛЕДОВАНИЕ ИСТОЧНИКОВ ПИТЬЕВОЙ ВОДЫ В УЛАН-БАТОРЕ

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Проведены исследования по определению физико-химического состава семи источников питьевой воды г. Улан-Батор. На основе этого предпринята попытка установить сезонную и годовую корреляцию. Результаты химического анализа семи источников, в том числе Тув, Завсар, Гачуурт, Буянт-Ухаа и Ярмаг, исследованных в 2016–2017 г. показывают pH 6.61– 6.85, проводимость (EC) 7.6–25.8 мСм/м, общая твердость 0,6–1,0 мг-экв/л. Состав гидрокарбонатно-кальциевой воды не изменился в течение сезона. Электропроводимость (EC) питьевой воды станций “Б” и “В” составляла 54.8–64.2 мсм/м, а общая плотность 4.99–5.5 мг-экв/л и pH 6.6–6.7. Однако питьевая вода станции “Б” относится к сульфатно-кальциевой и имеет смешанный состав. Химический состав всех семи источников соотвествует национальному стандарту MNS 0900:2016.

Ключевые слова: город Улан-Батор; питьевая вода; гидрохимический состав.