Journal of Geological Issues 446 (14); (2016) 171-177

GIMAR 2016
Geological Issues of Mongolia and Adjacent Regions

Major ion chemistry of shallow groundwater in Khaliviin gol, Umnugovi province

D. Altantungalag*

Department of Geology and Geophysics, SAS, National University of Mongolia

ABSTRACT

A hydrogeochemical study was conducted in the Khaliviin gol, Umnugovi province, to assess chemical composition of shallow groundwater and 27 groundwater samples were collected from different herder wells to monitor the water chemistry of various ions. Samples were collected in plastic polyethylene bottles for physicochemical analysis as well as all of the samples were analyzed in the laboratory of the Khanlab. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-}, and NO_3^{-} are carried out. This paper investigated the major ion chemistry of shallow groundwater in the area with two different methods such as statistical analysis, tri-linear diagrams. The water quality for drinking purposes was also assessed comparing with standards of National and World Health Organization.

The concentrations of major ions were relatively lower in the upstream than downstream of shallow groundwater in the area, indicating from good to moderate water quality. The hydrochemical facies of the shallow groundwater in the study area are dominantly Na-HCO3-Cl, Na-Ca-HCO3, Ca-HCO3-SO4 and Na-Ca-HCO3 types. The chemical composition of the aquifer in the study area is related to rock-forming minerals and hydrochemical processes. It is confirmed by the result of correlation matrix. The main hydrochemical process in this aquifer is dissolution of the halite, gypsum, calcite and dolomite. Moreover, increasing and decreasing number of some ions can be explained local recharge from precipitation.

Key words: Khaliviin gol, groundwater, hydrogeochemical process

*Corresponding author. Tel.: +976-99801616
E-mail address: altantungalag@num.edu.mn

1.Introduction

Umnugovi province of Mongolia has an arid to semi-arid climate. This semi-arid area is mostly distributed in south Mongolia where groundwater is major source of water. The quantity and quality of groundwater resources have been affected by the rapid development of mine industries over past decades. Since 2004, groundwater quantity and quality of Gunii khooloi have been monitored by groundwater monitoring program in accordance with operation of Oyu tolgoi Cu-Au deposit (Tuvdendorj, 2011). This is especially important in mining areas, since water is an essential component of the mining process (Agartan & Yazicigil, 2012). Thus, water resource protection requires an understanding of water quality in natural conditions and control major ion chemistry before adverse effects occur.

2.Study area

Study area is located in southeastern part of Umnugovi province, Mongolia Fig.1. The climate of the study area is considered to be semi-arid, the annual average precipitation being approximately 95.4 mm. 90% out of total precipitation occurs from October to May, the least precipitation is usually measured in January (Mijiddorj, 1992). The mean monthly temperatures varies between 3.2-3.7^{0}C to 21.58^{0}C, the mean annual value being 3.2-3.7^{0}C. The annual potential evaporation is about 3000 mm (Oyun, 2010) (Tuvdendorj, 2011). Monthly evaporation average is higher than 10 mm in dry season of spring and summer whereas in July monthly evaporation average reaches the highest, 15.25mm. There are no large rivers in the study area and the few surface water bodies are a small springs in the ravines.

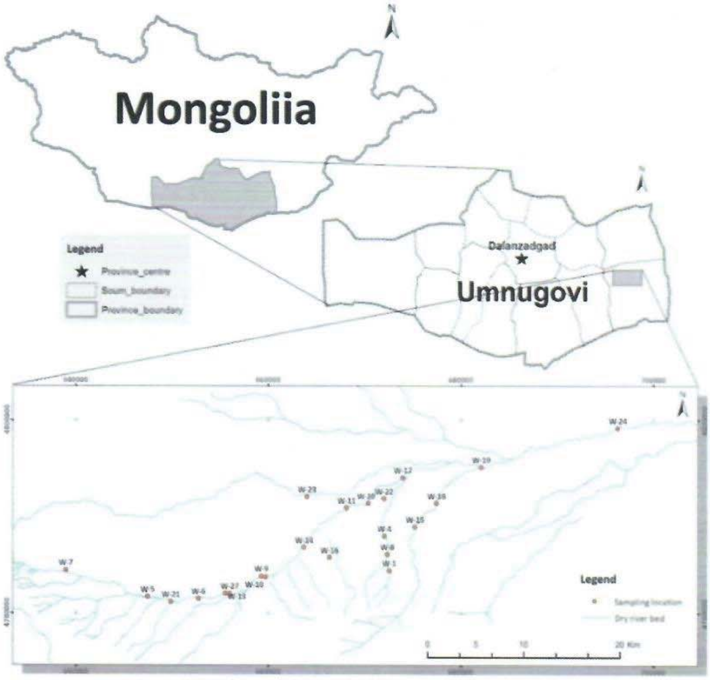

Fig.1. Location of the study area and sampling point

3.Hydrogeology

A Cretaceous formation composed of sedimentary sandstones and conglomerates can be widely observed in the study area. Quaternary sediments composed of alluvial and eolian sediments are distributed along the ravines which commonly occur in gobi desert.

The thickness of the quaternary aquifer is 3-20m. It can be subdivided into a quaternary alluvial and a diluvium aquifer. The alluvial aquifer is mainly distributed at the bottom of the dry channels and its tributaries. Its lithology includes Holocene alluvial sand, cobble, pebble, gravelstone, and occasionally sandstone. The depth to water level in this aquifer is usually within 1–3 m and its water is preferable for domestic use.

The Cretaceous aquifer is the most widespread and important water supply aquifer in the area, with a thickness exceeding 300 m. Sedimentary units of Bayanshiree formation within Gunii Khooloi depression is subdivided into two sequences. Upper section, 2-8m in thickness, consists of dark red, reddish brown, light brown sandy clay with silt, sandstone, gravelstone and conglomerate. It ranges from 44m to 118m in thickness (Munkhbaatar, 2006).

Lower section is made up of light grey, grey sandstone of various sizes, gravelstone, conglomerate, green grey and light grey clay beds. The rocks are loose and medium cemented (Buyankhishig, 2008).

Shallow groundwater levels were contoured to show the general flow pattern in the area (Fig.2). Groundwater levels were measured during June 2015 from 27 dug wells screened at the phreatic aquifer. These shallow aquifers are recharged mainly by precipitation.

4.Samples and Methods

A total of 27 shallow groundwater samples were collected during June and July 2015. The sampling locations are shown in Fig.1. Samples were collected in plastic polyethylene bottles for physicochemical analysis. Before to sample, all the water sampling bottles were rinsed thoroughly with the groundwater to be taken for analysis **Error! Reference source not found.**. The groundwater samples were analyzed in the laboratory of the Khanlab. For each sample, indices including major cations and anions, total dissolved solids (TDS), pH, electrical conductivity (EC) and total hardness (TH) were analyzed.

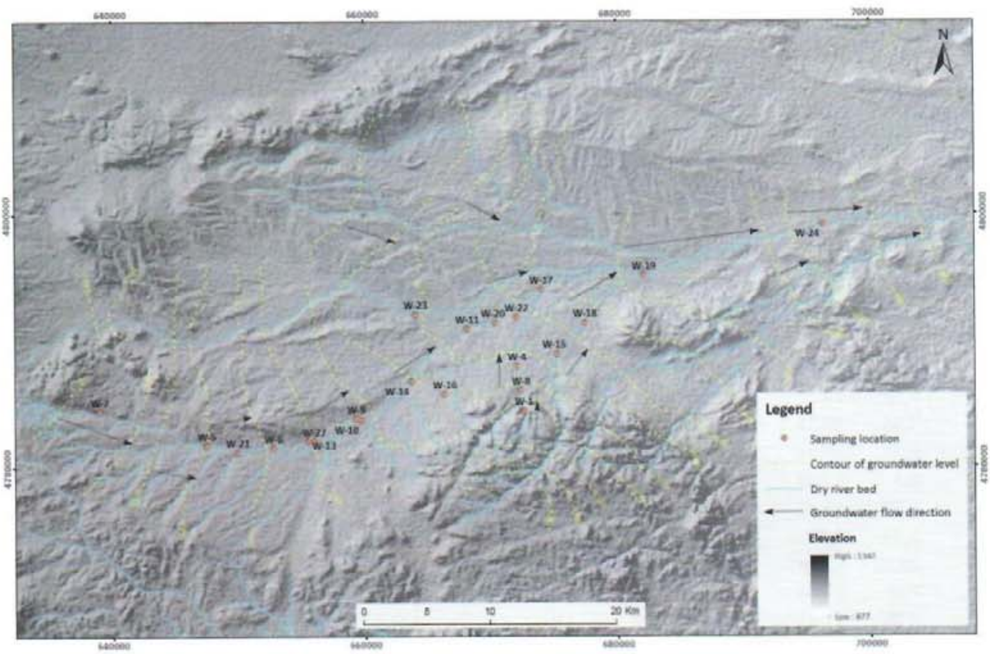

Fig.2. Contours of Shallow Groundwater level

Fig.3. Sampling bottle

5.Result and discussion

5.1.Hydrogeochemical characteristics

The result of the water sample analysis is shown

Table 1. The concentration of TDS varied from 318-2586 mg/l, with in average 826.6mg/l, indicating from fresh water to brackish water. TH is varied from 0.31-8.91 mg-eq/l, illustrating soft to hard water that suitable for drinking. But hardness values of 2 samples are higher than National Standard. In this study, Na^+ and Ca^{2+} were dominant cations whereas HCO_3^-, Cl^- were dominant anions followed by SO_4^{2-}.

HCO_3^- ion concentration decreased from the west to the east part of the study area. The high concentrations were found upper zone in contrast, the low concentrations the middle of the area. The concentration of HCO_3^- are highest in groundwater indicates that more calcite and dolomite has dissolved in the water (Cherry, 1979).

The distribution Na^+ and Cl^- ion concentration was similar, increasing from the upstream to the downstream of the area. Therefore, dissolution of the halite is a significantly source of Na^+ ion, but there can be other factors increasing concentration of Na^+ (Peiyue, 2013).

Ca_2^+ concentrations decreased from the south and east to the middle, and the highest concentration was observed in Elgen dug well, while the lowest concentration was seen Zaarakht well located in the middle of the area.

It can be observed that about all of the major ions had a high concentration area joining river bed, which may have been caused by similar hydrogeochemical processes. The topography around central part of the area is much flatter than other places, as well as groundwater flow velocity is slower, which may produce more dissolution mineral. Additionally, evaporation in the area is intense (Mijiddorj, 1992).

Table 1.
General Information of the sample analysis

Well ID	Cations				Anions			pH	TDS	EC	TH
	Mg^{2+}	Ca^{2+}	K^{+}	Na^{+}	SO_4^{2-}	Cl^{-}	HCO_3^{-}				
W-1	8,06	60,18	38,61	18,36	77,36	57,9	146,4	6,93	356	0,61	3,67
W-2	6,67	33,18	1,75	189,4	149,8	61,25	349	7,87	666	1,039	2,2
W-3	4,25	38,51	4,06	241,3	155,6	151,4	305,1	7,88	774	1,345	2,27
W-4	5,72	35,32	1,84	83,05	84,79	40,84	184,3	7,9	366	0,6	2,23
W-5	7,87	48,56	2,23	47,14	64,02	37,43	193,7	7,78	320	0,5	3,07
W-6	26,03	135,7	7,31	659,1	684,2	779,3	274,6	7,66	2586	3,48	8,91
W-7	3,28	164	21,19	637,7	685,6	667,6	366,1	7,58	2520	3,43	8,45
W-8	6,38	24,53	0,4	126,2	93,02	64,66	176,9	7,85	422	0,683	1,75
W-9	7,68	40,26	5,02	141,6	43,62	119,1	274,6	7,7	502	0,695	2,64
W-10	6,74	19,78	3,18	295,3	197,5	170,2	341,7	7,9	912	1,283	1,54
W-11	6,3	22,34	1,27	263,1	168,7	125,9	335,6	7,97	792	1,105	1,63
W-12	3,79	17,82	0,53	165,7	116,1	64,66	244	8,03	498	0,8	1,2
W-13	2,93	8,57	0,4	123,9	39,6	44,2	231,9	8,2	352	0,493	0,67
W-14	25,12	63,66	8,56	583,2	470,8	574,3	305,1	7,7	1964	2,87	5,24
W-15	7,29	49,16	4,15	63,38	51,86	37,43	248,6	7,83	352	0,6	3,05
W-16	6,76	31,05	2,28	72,07	33	30,63	237,9	7,89	318	0,6	2,11
W-17	9,77	26,52	0,58	449,1	409	265,5	433,2	8,04	1458	2,01	2,13
W-18	8,98	35,24	0,2	68,49	47,73	27,2	238	7,89	330	0,437	2,5
W-19	12,05	37,85	0,32	376,4	314,4	299,5	250,2	6,9	1264	1,718	2,88
W-20	5,1	17,97	9,78	270,8	158,8	187,2	286,8	7,98	830	1,186	1,32
W-21	8,79	45,13	1,8	223,3	176,1	187,2	256,3	7,85	792	1,103	2,97
W-22	2,34	12,55	0,89	174,7	77,36	68,1	286,8	8,1	518	0,688	0,82
W-23	5,44	22,68	1,43	131,6	41,15	102,1	213,6	7,9	444	0,575	1,58
W-24	13,13	51,4	2,7	361,5	388,5	353,9	122	6,68	1324	1,863	3,64
W-25	4,04	16,67	2,95	175,1	118,5	68,06	292,9	9,08	552	0,925	1,16
W-26	4,41	16,18	1,04	188,4	117,7	59,55	317,3	8,18	600	0,9	1,17
W-27	1,58	3,59	0,26	193,7	52,67	40,8	360	8,38	496	0,719	0,31
National Standard	30	100	-	200	500	350	-	6.5-8.5	1000	-	7
WHO	150	200	200	200	600	600	600	6.5–9.2	1500	1500	-

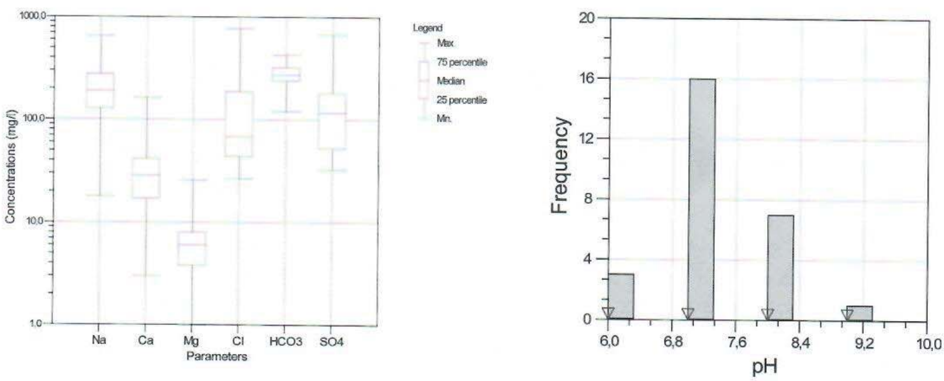

Fig.4. a).Multi parameters Box and Whisker Plot b). Histogram of pH

The Fig.4.b shows that pH frequency of water samples. As of the result, As indicated in the pH histogram, 18% of total samples are characterized by pH ranges of 6-6.8; 56% pH ranging between 6.8-7.6; 22% pH ranging between 7.7-8.4 and 4% of total samples have pH ranges of 8.4-9.2%. Consequently, water can be referred moderately to strong alkaline type.

Tri-linear diagrams such as the Piper diagram (Piper 1953) are perhaps the most commonly used techniques for finding hydrochemical patterns in major ion data. A Piper diagram drawn with AquaChem 4.0 (Waterloo Hydrogeologic Inc. 2003) is shown in Fig.5.

According to the diagram, four principal hydrochemical water types have been delineated. These are Na-HCO_3-Cl or Na-Cl, water type I. This type is the dominant water type, which may apparently evolve from a combination of processes that include halite dissolution from the soil zone and evaporative concentration (Peiyue, 2013). These water types constitute about 48% of the groundwater samples from the study area. The second water type Na-Ca-HCO_3 designated as II is the mixed water type where no particular cation dominates and HCO_3 is the main anion. This occupies about 22% of the samples in the area. The third water type III is Na-Cl-HCO_3-SO_4 and Na-SO_4-Cl this water type constitutes about 18% of the groundwater in the area. These types of water occur in the intermediate zone of groundwater recharge and discharge area (Cherry, 1979).

Finally, the fourth water type is Ca-HCO_3-SO_4. This water type constitutes 2% of the study area.

5.2.Major Ion Variation along Flow Path

As groundwater moves along its flow paths in the saturated zone, increases of total dissolved solids and most of major ions normally occur. As would be expected from this generalization, it has been observed in groundwater investigation in many parts of the world that shallow groundwater in recharge areas is lower in dissolved solids than in discharge areas (Fitts, Charles R., 2002). Generally, it is confirmed that the regional evolutionary trend of the dominant anions along the groundwater flow path is: $HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$ (Chebotarev, 1955). Chebotarev sequence can be described in terms of three main zones including upper, intermediate and lower zone. With the groundwater flowing from the upper to lower reaches of a region, Ca^{2+} and HCO_3^- tend to decrease while $Na^+ + K^+$, SO_4^- and Cl^- ions tend to increase.

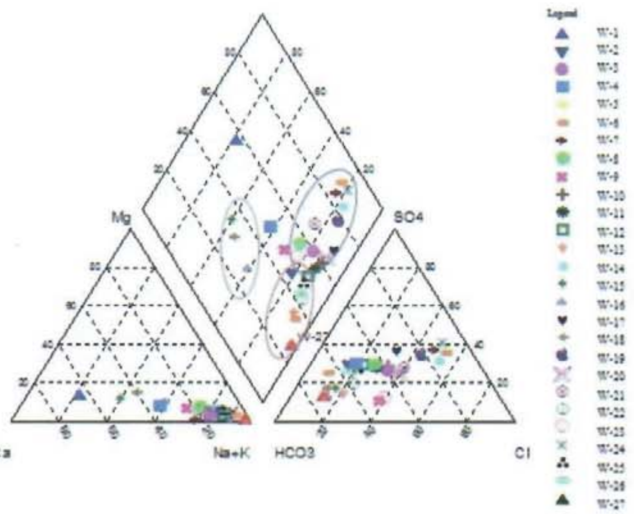

Fig.5. Piper diagram of Water samples

There is general type of groundwater evolution patterns in the study area. Firstly, Fig.6 illustrates the most general hydrochemical evolution along flow path between the well W-13 and W-19. Concentrations of Na^+ and HCO_3^- decrease but Cl^- and SO_4^{2-} increase in downstream, resulting in the transition of hydrochemical type from Na-HCO_3-Cl to Na-Cl-SO_4-HCO_3 type.

It is indicate that the groundwater quality in the study area is influenced by local recharge and discharge.

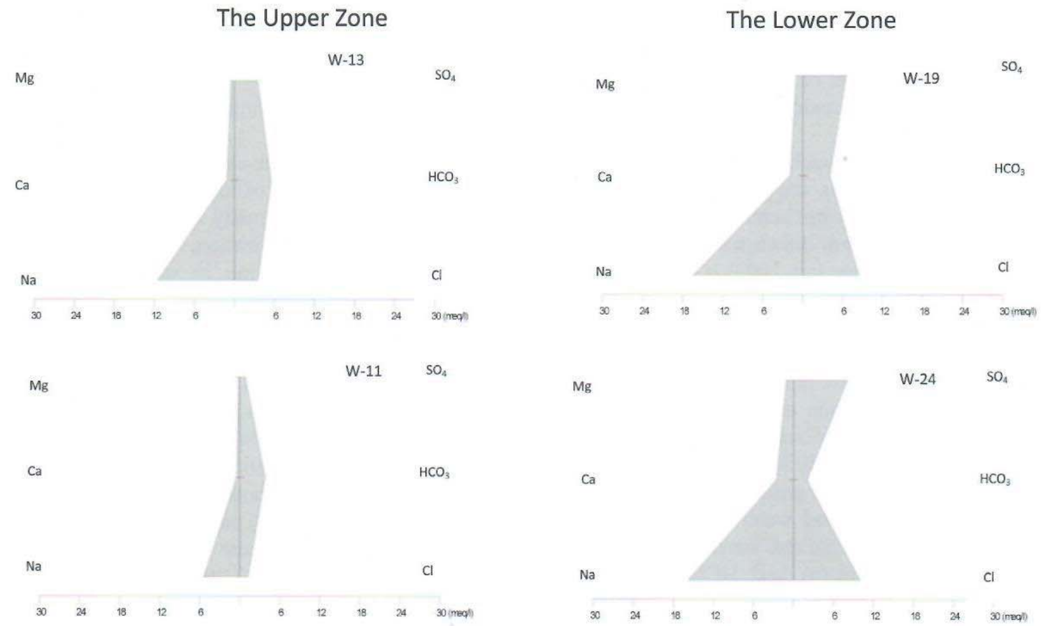

Fig.6. Stiff diagram for Major ion variation along flow path

Table 2.
Correlation matrix of major parameters

	pH	Cond	TDS	TH	Na	K	Ca	Mg	HCO3	Cl	SO4
pH	1,0	0,332	-0,203	-0,436	-0,109	-0,406	-0,387	-0,406	0,505	-0,283	-0,219
Cond		1,0	0,946	0,896	0,927	0,753	0,879	0,45	0,308	0,895	0,933
TDS			1,0	0,841	0,979	0,202	0,796	0,66	0,293	0,981	0,99
TH				1,0	0,72	0,432	0,978	0,674	-4,9E-2	0,886	0,842
Na					1,0	8,3E-2	0,666	0,623	0,397	0,944	0,961
K						1,0	0,474	5,5E-2	-0,201	0,22	0,224
Ca							1,0	0,506	-1,6E-2	0,829	0,801
Mg								1,0	-0,136	0,73	0,645
HCO3									1,0	0,142	0,248
Cl										1,0	0,964
SO4											1,0

5.3.Statistical Analysis

Study of correlation reduces the range of uncertainty associated with decision making. The correlation coefficient "r" was calculated using the equation:

$$r = \frac{\sum XY}{\sqrt{\sum X^2 + \sum Y^2}}$$

The correlation matrix for the water quality

Table 2.

Correlation matrix is important to understand major ion interrelations. pH is positively moderate correlated with HCO_3^-. Electrical conductivity is significantly but positively correlated with TDS, TH, Na^+, Ca^{2+}, Cl and SO_4. TDS is correlated with TH, concentration of Na^+, Ca^{2+}, Cl^- and SO_4^{2-}.

The major anions and cations, except for Ca^{2+}, Cl^-, SO_4^{2-} and Na^+, are significantly correlated with TDS, which suggests that the continuous addition of these cations and anions into groundwater has promoted increased TDS. The concentration of Cl^- is correlated with Ca^{2+}, Na^+ and $Mg2^+$, with correlation coefficients of 0.829, 0.944 and 0.730, respectively. Cation exchange could possibly explain the correlation between Cl^-, Na^+, Ca^{2+} and Mg^{2+}. The concentration of Ca^{2+} is correlated with Cond, TDS and Na^+. In addition, Ca^{2+} exhibits a positive strong correlation with TH with a correlation coefficient of 0.978, because hardness is an approximate measure of Ca^{2+} and Mg^{2+}. Additionally, source of Ca^{2+} ion can be gypsum and other carbonate silicates from the solution of ratio of calcium ions and sulfate ions by Aquachem software.

6.Conclusion

A total of 27 groundwater samples were collected in July 2015 from the shallow aquifer along the Khaliviin Gol, Umnugovi Province. Groundwater is an important sources for drinking water in this area where is non surface water. This paper investigated the major ion chemistry of shallow groundwater in the area with two different methods such as statistical analysis, tri-linear diagrams. The water quality for drinking purposes was also assessed comparing with standards of National and World Health Organization.

The conclusions are as follows:

1.The concentrations of major ions were relatively lower in the upstream than downstream of shallow groundwater in the area, indicating from good to moderate water quality. The hydrochemical facies of the shallow groundwater in the study area are parameters of groundwater was given dominantly Na-HCO3-Cl, Na-Ca-HCO3, Ca-HCO_3-SO_4 and Na-Ca-HCO_3 types.

2.From the study it is concluded some water sample were exceed the National and WHO standard limit in respect of Na, Cl, SO_4, TDS for drinking purpose. In particular, the concentrations of Na^+ is higher than WHO standard in 6 point and Cl^- is higher in 2 point, TDS is in 3 samples, SO_4 is in 2 samples higher than National and WHO standards.

3.The chemical composition of the aquifer in the study area is related to rock-forming minerals and hydrochemical processes. It is confirmed by the result of correlation matrix. The main hydrochemical process in this aquifer is dissolution of the halite, gypsum, calcite and dolomite. Moreover, increasing and decreasing number of some ions can be explained local recharge from precipitation.

Reference

Agartan, E., Yazicigil, H. (2012). Assessment of water supply impacts for a mine site in western Turkey. *Mine Water Environ, 31*, 112–128.

Buyankhishig. N, Jadambaa.N, Oyun.D. (2008). Impact of Water compumption of Gunii khooloi groundwater deposits. *Geology journal, 18*, хуудсд. 28-140.

Cherry, J. A., Freeze, R. A. (1979). *Groundwater*. Prentice-Hall.

Fitts, Charles R. (2002). *Groundwater Science*. Boston: Academic Press.

Mijiddorj, P. (1992). *Climate characteristics of Gobi desert of Mongolia* . Ulaanbaatar.

Munkhbaatar, N., Sanjdorj, S., Ulziibayar, G., Chuluunbaatar, S. (2006). *Report on hydrogeological survey for water supply for Oyutolgoy deposit production conducted in Gunii holloi and Galbin gobi 2003-2004*. Khanbogd: Oyu tolgoi LLC.

Oyun, R. (2010). *Report on environmental impact assessment of water consumption of Gunii khooloi groundwater deposits for Oyu tolgoi project*. Ulaanbaatar: JEMR LLC.

Peiyue, L., Qian, H., Wu, J., Zhang, Y., Zhang, H. (2013). Major Ion Chemistry of Shallow Groundwater in the Dongsheng Coalfield, Ordos Basin, China. *Mine Water Environ, 32*, 195-206.

Singh, S., Singh, P., Kumar, R., Saharan, S. (2012). Groundwater Quality Analysis of Safidon and Julana Blocks of District Jind, Haryana, India. *Journal of Water Resource and Protection, 4*, 39-47.

Tuvdendorj, A., Ulziibayar, G., Uuganbayar, P., Ochbayar, G. (2011). *Water monitoring report For Oyu Tolgoi project*. Khanbogd: Oyu Tolgoi LLC.

Waterloo. (2003). AquaChem v.4.0. Canada: Schlumberger Water Service.