



## Original article

### HYDROGEOCHEMICAL IMPLICATIONS FROM IDER RIVER IN NORTHERN MONGOLIA

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#### ABSTRACT

This study presents the hydrogeochemical implications resulted from Ider River, one of headwaters of Selenge River in northern Mongolia which is a main headwater of Lake Baikal in southeastern Russia, being included in a drainage basin of the North Arctic Ocean. Surface water and groundwater were collected and estimated with hydrogeochemical analyses of major ionic compositions in order to determine water quality in the catchment of Ider River in northern Mongolia. Result shows that the downstream of Ider River is more polluted than upstream of Ider River and Khunjlil River, an inflow of the Ider River. Surface water of Ider River and groundwater in the catchment of the Ider River are comparable with their anions and cations. Ider River is highly enriched with an anion of  $\text{Cl}^-$  in 2-3 times, cations of  $\text{Na}^+ + \text{K}^+$  in 2-3 times and  $\text{NH}_4^+$  in 0.5-1.0 times than those in groundwater in the catchment of Ider River. The hydrogeochemical results show that the surface water of Ider River is mainly polluted by solid wastes along its valley. More investigations with detail geochemical analyses are needed from the large rivers comprising surface water resource in Mongolia to review the hydrological evolution in Mongolia and Central Asia in the late Holocene.

**Keywords:** hydrology, water quality, runoff, groundwater, Northern Mongolia

#### INTRODUCTION

Surface water and groundwater are important components of the terrestrial hydrology and major water resources in semi-arid regions such as Mongolia in Central Asia. Water sources are particularly crucial for natural and managed ecosystems in areas where summer aridity would otherwise be a major limiting factor. This is a major concern in a region that depends so

heavily on glacier melting to sustain water supplies for agriculture and other ecosystem services in summer months (Orkhonselenge and Harbor, 2018). Groundwater is a very significant water source used for irrigation and drinking purposes in the karst region, and therefore understanding the hydrogeochemistry of karst water is extremely important (Wu et al., 2009). Water resources in Mongolia play a vital role in

regional ecological, social and economic development in Central Asia. The water bodies in Central Asia have been largely changed by water shortage and pollutants (Karthe, 2018). As regards the water resources, their geochemical characteristics are modulated by climate change, having a large impact on regional developments, through alteration of water temperature. However, in regions with relatively limited water resources anthropogenic impacts of water pollution are particularly severe and generate a serious problem. There has been a lack of work linking surface water and groundwater geochemical fluctuations and their effects by human activities. The purpose of this paper is to determine water pollution of Ider River caused by human activity and to provide a hydrogeochemical implication based on such a connection for the catchment of Ider River in northern Mongolia.

Hydrogeochemical implication from Ider River and assessment of its pollution level are essential to estimate hydrological evolution of watersheds in northern Mongolia. Determining changes in geochemical components of runoff and groundwater in response to climate change is thus an important component of understanding the context for sustainable water

health in Mongolia and Central Asia. In recent years, large rivers in Mongolia are impacted by climate change and polluted by human activities such as mining, tourism and solid wastes. Among the main factors solid wastes provided by human activity are widely spread in urban areas.

Ider River is one of three headwaters of Selenge River feeding Lake Baikal, the deepest freshwater lake in the world (Fig. 1). Ider River plays an important role to feed these large fluvial systems in the basin of the North Arctic Ocean and transports sediments and pollutants through its drainage basin. Ider River is a good example of these rivers in which valleys solid wastes are overloaded by settlements and tourists and pollute the environmental components including soil, vegetation and air in their basins. Hydrogeochemical estimation has not been analytically conducted yet in the catchment of the Ider River although hydrogeological survey in the catchment of the Ider River is completed. This study aims to provide the complex geochemical implication in the catchment of Ider River.

In 1950-1960s, hydrologist Kuznetsov conducted hydrological survey in Mongolia including morphometry and water regime of



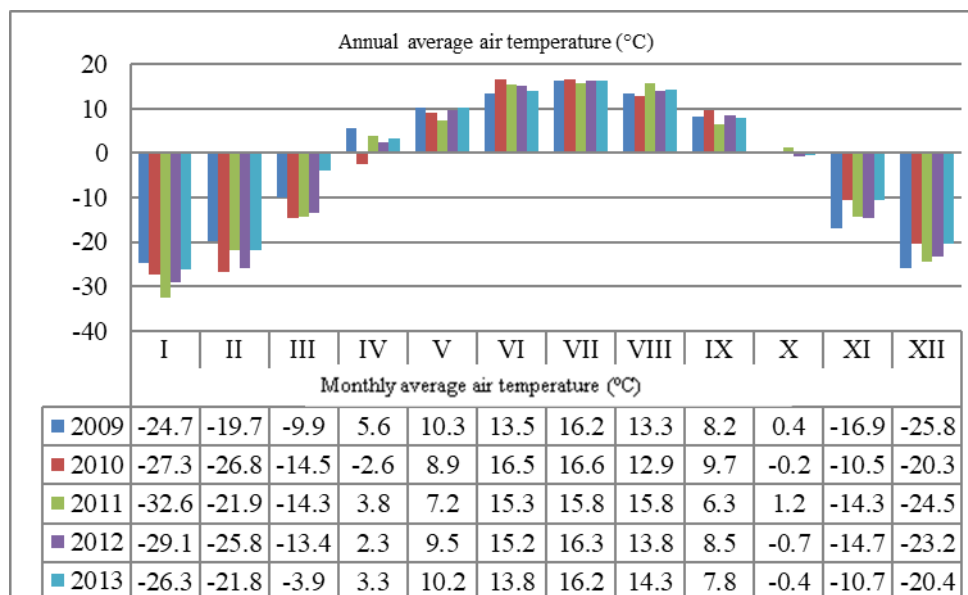
**Figure 1.** Geographical location of Ider River.

rivers, and origins, morphometry and water regime of lakes (Sanjmyatav, 2007). Murzaev gave physico-geographical feedback of Ider River including water regime, water level, and development of its valley (Tsegmid, 1969). Natsag studied rivers, including Ider River, in a basin of Selenge River. Davaa (2015) synthesized surface water of Mongolia with their water regime and resource. Recently, Mongolian Water Forum has initiated water management in the catchment of Ider River. Since 1990s investigation of solid waste began in Mongolia. In 2004, the JICA International Association studied accurately solid wastes in settlement areas of Mongolia in a frame of plan for a master program of solid waste in Ulaanbaatar (Bolorchimeg, 2013). In 2004, the Ministry of Nature and Environment promoted a model to classify the solid wastes (Ministry of Nature and Environment, 2004). Amgalan-Erdene (2014) developed the first model on how to manage solid wastes in rural areas in case of Jargalant soum, Khuvsgul aimag. Here, we consider the hydrological relationship between surface water and groundwater based on hydrogeochemical estimation in the catchment of Ider River in northern Mongolia (Fig. 1). This study contributes to provide the complex hydrogeochemical implication in valley of the Ider River. This study on

hydrogeochemical estimation in Ider River highlights significant point to provide ecological evaluations along the valley of the Ider River in northern Mongolia, and the basins of Selenge River and Lake Baikal in Central Asia.

**GEOGRAPHIC SETTING**

Ider River consisting of Shiree and Gyalgar Rivers (Davaa, 2015) is included in a basin of the North Arctic Ocean (Fig.1). Ider River drains through a valley between the Bulnai (2619 m) and Tarvagatai (3227 m) Mountain Ranges, heading from the northern slope of Mt. Otgontenger (4021 m) of the Khangai Mountain Range, and joins the Delger and Bugsei Rivers. Ider River extends 452 km in length and occupies an area of 24,555 km<sup>2</sup> (Tsegmid, 1969). According to Davaa (2015), it extents 466 km in length and comprises an area of 44,420 km<sup>2</sup>. A valley of Ider River is morphometrically developed well. Ider River is fed by more than 30 rivers such as Chuluut, Khojuul, Zart, Tsetsuukh and Khunjil Rivers draining from the Tarvagatai Mountain Range. A flow rate of Ider River is 7.2–10.8 km/h and reaches 2.0-2.5 km/h in its downstream (Davaa, 2015). Its prevailing rate is 1.5-2.0 m/s (Dashdeleg, 1970); and 5.3 m<sup>3</sup>/s in Ider soum, 17.3 m<sup>3</sup>/s in Tosontsengel soum, and 33.9 m<sup>3</sup>/s in Galt soum (Davaa, 2015). Channel of Ider



**Figure 2.** Monthly average air temperature at Jargalant meteorological station

River meanly lies at 1588 m a.s.l. and is 10-15 m wide and 0.7-2.0 m deep, and 80-100 m wide and 3.0-3.5 m deep at the upstream and downstream, respectively. Water pH of Ider River is 6.2-7.0 and contains ions of hydrocarbonate and calcium (Tsegmid, 1969). Geologically, Ider metamorphic formation consists of shale and gneiss in the early Proterozoic paleostructure of Baidrag containing dark-grey metamorphic rocks and

light limes (Mitrophanov et al, 1981). It includes layers of gneiss, granite-gneiss, amphibolite, shale, magmatite, lime and quarsite. Climatic conision is characterized with a harsh continental climatic system with longer cold winter and shorter moisture summer. Daily average air temperature is more than 10°C (National Atlas of Mongolia, 2009). Annual minimum and maximum air temperatures are -45°C in December and January and 30°C in July,

**Table 1.** Precipitation at Jargalant meteorological station

Year	Monthly average precipitation (mm)											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
2009	1.2	2	7.8	2.1	25.3	14	92.5	58	3.2	8.4	11.1	7.9
2010	8.5	3.4	3.5	2.4	27.6	48.5	86.1	87.4	5.8	10.9	4.3	1.6
2011	0.9	3.2	1.7	4.6	3.2	65.9	30.7	17.5	12.9	5.7	8.1	2.3
2012	1	0	2.3	13	5.8	29.9	40.3	46	2.2	2.9	3.6	1.4
2013	2	1.8	0.9	10.5	9.5	62.5	37.2	64.7	14.2	6.7	4.6	1

respectively (Fig. 2). 60-70% of total precipitation occurs in June to August (Table 1). In winter snow thickness is 5-30 cm. Annual rainfall is approximately 300 mm (Jargalant Meteorological Station, 2009-2013).

**METHODS**

Water samplings of Ider River were taken from 2100-2700 m a.s.l (N48° 35' 00.23" E99° 20' 59.96". Totally, six water samplings of Ider River and groundwater in its valley were obtained during a field work conducted in

September, 2013 (Figs. 3, 4) and were hydrogeochemically analyzed for hardness, electric conductivity, oxidation and ions at Laboratory of Hydrology, Institute of Geocology, Mongolian Academy of Sciences (MAS).

**RESULTS**

Hydrogeochemical composition is an intricate system depending on geographical position, bedrock, soil, vegetation and human impact. Most settlements and industrialisation take a



**Figure 3.** Upstream (right) and downstream (left) of Ider River. Photo by A.Orkhonselenge. 09.20.2013





Figure 4. Groundwater sampling in school (right) and center of Jargalant soum (left)

place in valleys of large rivers where they impact on. Upstream of Ider River is characterized as hydrocarbonate type with total anions and cations of 173.1 mg/dm<sup>3</sup>, hardness of 1.7 mg-

eqv/dm<sup>3</sup>, pH of 7.97, oxidation of 2.1 mg/dm<sup>3</sup> and electric conductivity of 187 μS/sm, and is polluted with ammonium. Khunjil River is characterized as hydrocarbonate type with total anions and cations of 153.2 mg/dm<sup>3</sup>, hardness of

Table 2. Ions in Ider and Khunjil Rivers

Upstream of Ider River (N 48°36'04.1", E 99°21'01.1", 1541 m)							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	32.0	0.90	36.93	Na <sup>+</sup> +K <sup>+</sup>	16.4	0.71	29.33
SO <sub>4</sub> <sup>-2</sup>	1.0	0.02	0.85	Ca <sup>+2</sup>	26.1	1.30	53.35
NO <sub>2</sub> <sup>-</sup>	0.00	0.00	0.00	Mg <sup>+2</sup>	4.9	0.40	16.41
NO <sub>3</sub> <sup>-</sup>	1.0	0.02	0.66	NH <sub>4</sub> <sup>+</sup>	0.4	0.02	0.91
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	91.5	1.50	61.55	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	125.5	2.44	100.00	Total	47.8	2.44	100.00
Khunjil River (N 48°35'20.2" ,E 99°21'23.1" ,154 6m )							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	14.9	0.42	20.55	Na <sup>+</sup> +K <sup>+</sup>	14.3	0.62	30.40
SO <sub>4</sub> <sup>-2</sup>	0.5	0.01	0.51	Ca <sup>+2</sup>	20.0	1.00	48.94
NO <sub>2</sub> <sup>-</sup>	0.00	0.00	0.00	Mg <sup>+2</sup>	4.9	0.40	19.58
NO <sub>3</sub> <sup>-</sup>	0.8	0.01	0.63	NH <sub>4</sub> <sup>+</sup>	0.4	0.02	1.09
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	97.6	1.60	78.30	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	113.8	2.04	100.00	Total	39.6	2.04	100.00
Downstream of Ider River (N 48°35'27.1", E 99°19'28.3", 1544 m )							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	14.2	0.40	17.22	Na <sup>+</sup> +K <sup>+</sup>	7.8	0.34	14.61
SO <sub>4</sub> <sup>-2</sup>	0.3	0.01	0.27	Ca <sup>+2</sup>	28.1	1.40	60.28
NO <sub>2</sub> <sup>-</sup>	0.01	0.00	0.01	Mg <sup>+2</sup>	6.1	0.50	21.53
NO <sub>3</sub> <sup>-</sup>	1.0	0.02	0.69	NH <sub>4</sub> <sup>+</sup>	1.5	0.08	3.59
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	115.9	1.90	81.80	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	131.4	2.32	100.00	Total	43.4	2.32	100.00

1.4 mg-eqv/dm<sup>3</sup>, pH of 7.97, oxidation of 3.36 mg/dm<sup>3</sup> and electric conductivity of 136 μS/sm, and is polluted with azane. Downstream of Ider River is characterized as hydrocarbonate with total anions and cations of 175.3 mg/dm<sup>3</sup>, hardness of 1.9 mg-eqv/dm<sup>3</sup>, pH of 7.9, oxidation of 2.2 mg/dm<sup>3</sup> and electric conductivity of 136 μS/sm, and is highly polluted with ammonium.

Table 2 shows that only HCO<sub>3</sub><sup>-2</sup> in upstream of Ider River is lower than that of Khunjlil River although all anions in upstream of Ider River is higher than those in Khunjlil River. NO<sub>3</sub><sup>-</sup> and HCO<sub>3</sub><sup>-2</sup> in downstream of Ider River are higher than those in upstream of Ider River and Khunjlil River. All cations in upstream of Ider River is higher than those in Khunjlil River (Table 2). Meanwhile Ca<sup>+2</sup>, Mg<sup>+2</sup> and NH<sub>4</sub><sup>+</sup> in downstream

of Ider River are higher than those in upstream of Ider River and Khunjlil River. Hardness in upstream of Ider River is higher than those in downstream of Ider River and Khunjlil River. Oxidation of Khunjlil River is greater than that of Ider River. The upstream and downstream of Ider River are polluted with NH<sub>4</sub><sup>+</sup>, while Khunjlil River is polluted with NH<sub>3</sub><sup>+</sup>. Our results from ion concentration in runoff of Ider River are hydrogeochemically coincided with that by Tsegmid (1969) noted that Ider River is a hydrocarbonate and calcium type with ranging in pH from 6.2 to 7.0 although it is smoothly alkalisied.

Groundwater is temporarily protected from runoff and transportation of materials and pollutants. However in addition to that human activity such as mining (e.g., oil drilling, ore

**Table 3.** Ions in groundwaters in valley of the Ider River

Groundwater in school (N 48°35'1.13", E 99°20'59.15", 1560 m)							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	3.6	0.10	3.09	Na <sup>+</sup> +K <sup>+</sup>	4.8	0.21	6.51
SO <sub>4</sub> <sup>-2</sup>	20.0	0.42	12.89	Ca <sup>+2</sup>	42.1	2.10	64.96
NO <sub>2</sub> <sup>-</sup>	0.00	0.00	0.00	Mg <sup>+2</sup>	10.9	0.90	27.84
NO <sub>3</sub> <sup>-</sup>	1.0	0.02	0.50	NH <sub>4</sub> <sup>+</sup>	0.4	0.02	0.69
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	164.7	2.70	83.52	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	189.3	3.23	100.00	Total	58.3	3.23	100.00
Groundwater in center of Jargalant soum (N 48°34'54.82", E 99°21'8.28", 1561 m)							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	21.3	0.60	13.13	Na <sup>+</sup> +K <sup>+</sup>	14.9	0.65	14.16
SO <sub>4</sub> <sup>-2</sup>	1.0	0.02	0.46	Ca <sup>+2</sup>	50.1	2.50	54.71
NO <sub>2</sub> <sup>-</sup>	0.01	0.00	0.00	Mg <sup>+2</sup>	17.0	1.40	30.64
NO <sub>3</sub> <sup>-</sup>	3.0	0.05	1.06	NH <sub>4</sub> <sup>+</sup>	0.4	0.02	0.49
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	237.9	3.90	85.35	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	263.2	4.57	100.00	Total	82.4	4.57	100.00
Groundwater in floodplain of Ider River (N 48°35'7.23" ,E 99°20'29.12" ,15 59m)							
Anions	In 1 dm <sup>3</sup>			Cations	In 1 dm <sup>3</sup>		
	mg	mg-eqv	mg-eqv (%)		mg	mg-eqv	mg-eqv (%)
Cl <sup>-</sup>	21.3	0.60	10.58	Na <sup>+</sup> +K <sup>+</sup>	15.7	0.68	12.00
SO <sub>4</sub> <sup>-2</sup>	25.0	0.52	9.19	Ca <sup>+2</sup>	57.1	2.85	50.27
NO <sub>2</sub> <sup>-</sup>	0.01	0.00	0.00	Mg <sup>+2</sup>	25.5	2.10	37.04
NO <sub>3</sub> <sup>-</sup>	3.0	0.05	0.85	NH <sub>4</sub> <sup>+</sup>	0.7	0.04	0.69
CO <sub>3</sub> <sup>-2</sup>	0.0	0.00	0.00	Fe <sup>+2</sup>	0.0	0.00	0.00
HCO <sub>3</sub> <sup>-</sup>	274.5	4.50	79.37	Fe <sup>+3</sup>	0.0	0.00	0.00
Total	323.8	5.67	100.00	Total	99.0	5.67	100.00

operation, etc.), agriculture and solid wastes strongly impact on groundwater level, infiltration of chemicals by runoff and capillary action through soil profiles influences in the groundwater composition. Because flow rate of groundwater running through bedrocks is lower than that of runoff, pollution of groundwater depends on infiltration through soils and bedrocks (Dorj et al., 2005).

Table 3 shows hydrogeochemical results from groundwater in valley of the Ider River along Jargalant soum, Khuvsgul aimag. Groundwater in school is characterised as hydrocarbonate with total anions and cations of 247.5 mg/dm<sup>3</sup>, hardness of 3.0 mg-eqv/dm<sup>3</sup>, pH of 7.56, oxidation of 4.8 mg/dm<sup>3</sup> and electric conductivity of 346 µS/sm, and is polluted with ammonium. It is coincided with national standard level of drinking water (MNS 900:2010). Groundwater in center of Jargalant soum is characterised as hydrocarbonate with total anions and cations of 345.6 mg/dm<sup>3</sup>, hardness of 3.9 mg-eqv/dm<sup>3</sup>, pH of 7.56, oxidation of 1.28 mg/dm<sup>3</sup> and electric conductivity of 310 µS/sm, and is polluted with ammonium. It is also coincided with national standard level of drinking water (MNS 900:2010). Groundwater of well locating at 600 m away from channel of Ider River is characterized as hydrocarbonate with total

anions and cations of 422.8 mg/dm<sup>3</sup>, hardness of 4.95 mg-eqv/dm<sup>3</sup>, pH of 7.59, oxidation of 0.8 mg/dm<sup>3</sup> and electric conductivity of 461 µS/sm, and is polluted with ammonium. It is coincided with national standard level of drinking water (MNS 900:2010).

Anions of groundwater in school is more enriched with SO<sub>4</sub><sup>-2</sup> than those in center of Jargalant soum and floodplain of Ider River (Table 3). Groundwater in center of Jargalant soum is highly enriched with Cl<sup>-</sup> and NO<sub>3</sub><sup>-</sup> than those in school and floodplain of Ider River. Groundwater in floodplain is higher with HCO<sub>3</sub><sup>-</sup>. Cations in groundwater in center of Jargalant soum is enriched with Na<sup>+</sup>+K<sup>+</sup>, while groundwater in floodplain is higher with Ca<sup>+2</sup>, Mg<sup>+2</sup> and NH<sub>4</sub><sup>+</sup> than those in groundwater in school and center of Jargalant soum.

Generally, Ider River and groundwater in valley of the Ider River are comparable with their anions and cations. Ider River is highly polluted with an anion of Cl<sup>-</sup> in 2-3 times, cations of Na<sup>+</sup>+K<sup>+</sup> in 2-3 times and NH<sub>4</sub><sup>+</sup> in 0.5-1.0 times than its groundwater although hardness and electric conductivity are higher in groundwater than those in Ider River. Table 4 shows our hydrogeochemical results from Ider River coincides with previous study by Davaa (2015) except for the anions of SO<sub>4</sub><sup>-2</sup> and Cl<sup>-</sup>.

**Table 4.** Ion components in Ider River

Ions (mg/l)	Ca <sup>+2</sup>	Mg <sup>+2</sup>	Na <sup>+</sup> +K <sup>+</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	Cl <sup>-</sup>
Ider River (Davaa, 2015)	22.94	6.46	13.95	101	16.56	5.57
Ider River (This study)	26.1	4.9	16.4	91.5	1.0	32.0

## DISCUSSION

Hydrogeochemical data reveal that the water of Ider River is more influenced by anthropogenic activities including over exploitation by local people and tourists. This fits with that the Integrated Water Management Plan (IWMP) by the Ministry of Environment and Green Development (2013) showing that the most important key factors for determining the water demands are population, municipal services, industries, mines and energy productions, agriculture, tourism and environment.

Groundwater in the cathment of Ider River is characterized by ions. The main contributor of Ca<sup>2+</sup>, Mg<sup>2+</sup> and HCO<sub>3</sub> ions to the groundwater on Rameswaram Island was carbonate weathering process (Kumar et al., 2012).

## CONCLUSIONS

This study shows that hydrogeochemical characteristics of Ider River and groundwater in its valley are spatially clarified in northern Mongolia. It indicates

that runoff and groundwater are hydrogeochemically estimated with hydrocarbonate type. The upstream of Ider River and Khunjil River draining into the Ider River have more freshwater in comparison with downstream of Ider River enriched with  $\text{NH}_4^+$ . Runoff is highlighted by  $\text{N}^+\text{K}^+$ ,  $\text{NH}_4^+$  and  $\text{Cl}^-$  than those in groundwater. The changing trends in the hydrogeochemical components in the downstream of Ider River show the more influence by solid wastes along the settlement areas such as Ider, Tosontsengel, Ikh Uul and Jargalant soums than natural processes influencing water regime of Ider River linked with local geomorphic feature and climatic conditions in the Ider River basin. Hydrogeochemical controls on runoff and groundwater of large rivers are necessary for a more complete understanding of the hydrological evolution in drainage basins in Mongolia.

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