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ARTICLE

Water quality and environmental wellness of mineral springs in the Uvs province based on diatom studies

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Abstract: Fifty-eight diatom species belonging to 34 genera, 20 families, 11 orders, and one class are identified in the diatom survey of mineral springs near Uvs and Khyargas lakes in northwest Mongolia. The water quality of the mineral springs of Uvs Lake is fresh, and the mineral spring belonging to Khyargas Lake is fresh to brackish based on the diatom community. The environmental well-being of those springs is 78.5-83.5. Conservation management has to be based on aquatic diversity studies to restore these springs to nature. Conservation management of springs based on algae communities is an issue that is being raised for the first time in Mongolia.

Keywords: *diatoms, spring, water quality, Uvs, Khyargas;*

INTRODUCTION

Spring ecosystems are unique due to their diverse characteristics and ecological significance [1, 2, 3]. However, these invaluable ecosystems are under severe threat globally, with rampant ecological impairment reported in developed regions and declining trends in ecosystem conditions. Pollution and climate change significantly endanger the quality and quantity of spring water flow, highlighting the urgent need for sustainable management to protect the ecosystem services they provide. Additionally, springs offer cultural services, attract tourists, and provide health benefits, emphasizing their unique and multifaceted importance [4].

Natural water that has a medical effect on the human body or any organ is called a spring [5]. Internationally, mineral water is defined as drinking water containing one or more unique components, such as dissolved substances, minerals, or gases, at concentrations of 1000 mg/dm3 or more that have a sanative effect on the human body [6].

In Mongolia, the distribution of hot and cold springs, their temperature, gas composition, geochemical characteristics, classification, and spring regions have been determined, and indications for spa treatment in spring were issued [7].

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In Uvs province, the water chemistry of seven springs, such as Green Tsegee, Khavtal, Boom, Burgastain, Chandman Ulaan, Khar Termes, Urt Bulag, and Ikh Gol has been analyzed. However, no investigation into the diatom community has been conducted. However, with the development of mining, industry, and agriculture, the consequences of human activities, such as lowering water levels, drying, and pollution due to excessive groundwater use, continue [8]. Protective concrete fences are sometimes built, increasing water temperature and catchment. Wrong protection management is involved in this case, requiring re-establishing environmental sanitation zones [9]. They may show activity levels comparable to standard mineral springs, from slight bubbling to intermittent bursts to steady, violent boiling. So, local people call it a boiling spring. In other words, it is similar to boiling water. However, the water temperature during summer is between 16°C and 20°C.

Diatoms are excellent water quality indicators in mineral springs due to their diverse nature and sensitivity to environmental changes [10]. Research indicates that epilithic and bryophytic substrates can effectively be used for diatom-based water-quality biomonitoring in mesotrophic and eutrophic environments [11]. Studies on karst springs highlight the importance of analyzing epilithic diatom assemblages to assess environmental quality, with various indices indicating good biotic integrity and water quality despite some organic contamination [12]. Predictive models based on diatom communities have shown promising results in assessing water quality, with diatoms being particularly sensitive to changes in water chemistry, making them valuable for evaluating environmental conditions in lowland streams [13].

In our country, diatom research has intensified since the 2000s and is widely used in water quality assessment. A diatom community was used to assess the water quality of lakes in western Mongolia [14]. There is no research material on water quality using aquatic organisms. The study aimed to evaluate the water quality and environmental wellness of two springs near the Uvs and Khyargas lakes based on the diversity and diatom community. This study will improve our knowledge of the diversity of diatoms in mineral springs and the protection management of springs in Mongolia.

MATERIALS AND METHODS

In June and July 2022, 11 algae samples were collected from mineral springs and springs near Uvs and Khyargas lakes. Table 1 summarises the study points.

Table 1. Study points and samples

Point	Coordinate	Samples	Province
Mineral springs of Uvs Lake	N50° 10' 35", E92° 3' 7"; 820м	6	Uvs, Turgen soum
Mineral springs of Khyargas Lake	N49° 16' 21", E93° 23' 4"; 1040м	5	Uvs, Khyargas soum

Our study points are located in two different water basins: the Uvs Lake and Tes River basins and the Khyargas Lake and Zavhan River basins. Both are in the western hydrogeological system, where the underground water table and pressure water are distributed together. Pressure water is mainly distributed between intermountain and intramountain basins by classifying Mongolian hydrogeological district

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principles and taxonomic units. However, the groundwater accumulation zone depends on the groundwater accumulation-foot range of Quaternary and Neogene sediments [15]. Uvs Lake is 759 m above sea level and is the lowest point in the depression of the Great Lakes of Central Asia. The spring is located 5 km from Uvs Lake, to the west of the lake. According to the category of water basins in Mongolia, Uvs Lake belongs to the Uvs Lake-Tes River basin. Khyargas Lake is located in a tectonic depression 1028 meters above sea level in the Great Lakes depression, in the southern part of the Khan Khokhi mountain range. It is the end of all the rivers flowing into the Great Lake Depression from the Altai Khangai mountains. The spring near Khyargas Lake is 500 m on the northern shore. The spring that was researched belongs to the Khyargas Lake - Zavkhan River basin. Survey points are shown in the following figure.

Figure 1. Study points

The samples were collected from the bottom of the spring, from aquatic vascular plants, mud, and sand, and then stored in a container labeled with the collection label [16]. A standard preparation for identifying diatoms at the species level was prepared accordingly [17]. To completely clean the organic component from the collected sample, we cut a small part, put it in a glass beaker, added nitric acid to 30 ml of 70%, and gently heated it for about an hour on a hotplate in a laboratory chemical fume hood. After that, the preparation was cooled to room temperature and deacidified by passing it through distilled water 6 times for 6 hours. 11 permanent slides were prepared by instilling the valve from the cleaned sample into the coverslip and evaporating, sticking it to the tray glass using Naprax balsam, and affixing the collection label with the same address as the number of raw sample in the right corner. All preparation was identified at the level of species under a light microscope with 1000x magnification immersion oil, using essential books [18-21] and websites https://www.algaebase.org/; https://diatoms.org/. The richness and relative abundance of each species were calculated using total abundance and individual species' abundance [22-23]. The similarity of the species composition was calculated by the jaccard index. The diversity of diatom, evenness [24] and water quality index [25] were calculated, which were used for assessing the environmental wellness biodiversity level [26]. The Shannon-Wiener diversity index (H) was employed in calculating environmental wellness and restoration level [26] and determining the evenness (E) of respective ecosystems.

This approach, where (H) represents the Shannon-Wiener diversity Index and Pi denotes the relative proportion (n/N) of the individual of one particular species found, is crucial in our understanding of ecosystem health and balance.

To begin with, the Shannon diversity index and evenness are determined, following which the individual species number logarithmic index (ISNLI) is determined. The next step is to determine the mean individual species number logarithmic index (mISNLI) as well as the integrated index of an ecosystem (IIE).

The following equation is used: H and E

$$H = -\Sigma PiLNPi \text{ and } E = H/Hmax .$$

$$mISNLI=(ISNLI1+ ISNLI2+ ISNLI3+ ISNLI4+ ISNLIn)/N$$

$$IIE=(H+E+mISNLI)/3$$

The last calculation determines the environmental wellness and biodiversity levels (EWBLP) under non-comparative scenarios and estimates the restoration effort levels (REL) needed in a particular environment.

$$EWBLP=(IIE/\text{maximum reference value our ecosystem})x100\%$$

$$REL= (100\%- EWBLP)$$

In figure 2, we have shown a photo of their spring.

The spring nearby of Uvs lake	The spring nearby of Khyargas lake
	

Figure 2. Spring image

RESULTS AND DISCUSSION

58 species belonging to 11 orders, 20 families, and 34 genera were identified from the studied springs. 46 species belonging to 10 orders, 16 families, and 25 genera were found in Uvs Lake springs. Seven orders, 14 families, 20 genera, and 36 species were found in Khyargas Lake springs and the diatoms were recorded

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respectively. Table 2 shows the species list for each taxon. Naviculales (16), Cymbellales (12), and Fragilariales (10) were the orders with the highest number of species richness, while only one species was recorded for Licmophorales, Mastogloiales, and Surirellales. However, the wealthiest families included Cymbellaceae (8), Bacillariaceae (7), Naviculaceae (7), Fragilariaceae (6), Gomphonemataceae (4), Pinnulariaceae (4), Staurosiraceae (4). 5), Nitzschia (4), Gomphonema (4), Fragilaria (4), and Pinnularia (4). Cymbellaceae (8), Fragilariaceae (5), and Gomphonemataceae (4) families had more species in the spring near Uvs Lake than in other springs. In contrast, species of Eunotiaceae (2), Staurosiraceae (4), Tabellariaceae (2), and Ulnariaceae (1) species were found in the spring of Khyargas lake.

Table 2. Taxon list of diatoms

Order	Family	Genera	Species	Occurrence
Achnanthales	Cocconeidaceae	*Cocconeis*	*Cocconeis pediculus f. abruptus* O.S.Korotkevich	1, 2
	Achnanthidiaceae	*Planothidium*	*Planothidium hauckianum* (Grunow) Bukhtiyarova 1999	1, 2
			Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot 1999	2
		Rossithidium	*Rossithidium nodosum* (Cleve) Aboal 2003	2
Bacillariales	Bacillariaceae	*Denticula*	*Denticula elegans* Kützing 1844	1, 2
			Denticula subtilis Grunow 1862	1, 2
		Hantzschia	*Hantzschia amphioxys* (Ehrenberg) Grunow 1880	1, 2
		Nitzschia	*Nitzschia palea* (Kützing) W.Smith 1856	1, 2
			Nitzschia liebethruthii Rabenhorst 1864	1, 2
			Nitzschia amphibia Grunow 1862	1, 2
			Nitzschia incognita Legler & Krasske 1940	1, 2
Cymbellales	Cymbellaceae	*Cymbella*	*Cymbella cespitosa* (Kützing) Brun 1880	1, 2
			Cymbella cistula (Ehrenberg) O.Kirchner, 1878	1
			Cymbella elginensis Krammer 1980	1
			Cymbella helvetica Kützing 1844	1, 2
			Cymbella subturgidula Krammer 2002	1
			Cymbella tumida (Brébisson) Van Heurck 1880	1

		Cymbopleura	*Cymbopleura naviculiformis*(Auerswald ex Heiberg) Krammer 2003	1
		Encyonopsis	*Encyonopsis descripta* (Hustedt) Krammer 1997	1, 2
	Gomphonemataceae	*Gomphonema*	*Gomphonema subclavatum* (Grunow) Grunow 1884	1, 2
			Gomphonema acuminatum Ehrenberg 1832	1
			Gomphonema constrictum Ehrenberg 1844	1
			Gomphonema parvulum (Kützing) Kützing 1849	1, 2
Eunotiales	Eunotiaceae	*Eunotia*	*Eunotia glacialifalsa* Lange-Bertalot 2000	1
			Eunotia paludosa Grunow 1862	1
Fragilariales	Fragilariaceae	*Fragilaria*	*Fragilaria capucina* Desmazières 1830	1, 2
			Fragilaria vaucheriae (Kützing) J.B.Petersen 1938	1, 2
			Fragilaria mesolepta Rabenhorst 1861	2
			Fragilaria famelica (Kützing) Lange-Bertalot 1980	1, 2
		Fragilariforma	*Fragilariforma marylandica* M.B.Edlund, B.Laub, P.A.Siver, P.B.Hamilton, & E.A.Morales 2011	1
	Staurosiraceae	*Nanofrustulum*	*Nanofrustulum trainorii (E.Morales) E.Morales 2019*	1
		Pseudostaurosira	*Pseudostaurosira elliptica* (Schumann) Edlund, Morales & Spaulding 2006	1
		Staurosira	*Staurosira construens* Ehrenberg 1843	1
		Staurosirella	*Staurosirella pinnata* (Ehrenberg) D.M.Williams & Round 1988	1
	Fragilariaceae	*Synedra*	*Synedra mazamaensis* Sovereign 1960	1
Licmophorales	Ulnariaceae	*Ulnaria*	*Ulnaria ulna* (Nitzsch) Compère 2001	1
Mastogloiales	Mastogloiaceae	*Aneumastus*	*Aneumastus rostratus* (Hustedt) Lange-Bertalot 2001	1
Naviculales	Cosmioneidaceae	*Cosmioneis*	*Cosmioneis citriformis* R.L.Lowe & A.R.Sherwood 2010	1
	Naviculaceae	*Navicula*	*Navicula cari* Ehrenberg 1836	1, 2

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			Navicula capitatoradiata H.Germain ex Gasse 1986	2
			Navicula trivialis Lange-Bertalot 1980	2
			Navicula tenelloides Hustedt 1937	1, 2
			Navicula gregaria Donkin 1861	2
		Caloneis	*Caloneis ventricosa* F.Meister 1912	2
		Hippodonta	*Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski 1996	2
	Pinnulariaceae	*Pinnularia*	*Pinnularia lata* (Brébisson) W.Smith 1853	1, 2
			Pinnularia major (Kützing) Rabenhorst 1853	1
			Pinnularia brebissonii (Kützing) Rabenhorst 1864	1
			Pinnularia undula (Schumann) Krammer 2000	1, 2
	Pleurosigmataceae	*Pleurosigma*	*Pleurosigma angulatum* (J.T.Quekett) W.Smith 1852	2
	Sellaphoraceae	*Fallacia*	*Fallacia pygmaea* (Kützing) Stickle & D.G.Mann 1990	2
	Stauroneidaceae	*Craticula*	*Craticula ambigua* (Ehrenberg) D.G.Mann 1990	1, 2
		Stauroneis	*Stauroneis smithii* Grunow 1860	2
Rhabdonematales	Tabellariaceae	*Tabellaria*	*Tabellaria flocculosa* (Roth) Kützing 1844	1
		Tetracyclus	*Tetracyclus rupestris* (Kützing) Grunow 1881	1
Surirellales	Surirellaceae	*Surirella*	*Surirella linearis* W.Smith 1853	2
Thalassiophysales	Catenulaceae	*Halamphora*	*Halamphora veneta* (Kützing) Levkov 2009	1, 2
		Amphora	*Amphora ovalis* (Kützing) Kützing 1844	1
11	20	34	58	46/35

Note: 1 – mineral spring of Uvs Lake, 2 – mineral spring of Khyargas Lake

Cymbella cuspidata (Kützing) Brun occurred in all samples of 2 study sites. In contrast, *Cymbella helvetica* Kützing, *Gomphonema constrictum* Ehrenberg, *Nitzschia palea* (Kützing) W.Smith, *Halamphora veneta* (Kützing) Levkov, *Navicula cari* (Ehrenberg), *Navicula tenelloides* Hustedt, *Denticula subtilis* Grunow occurred in 85.7% of all samples. *Fragilaria capucina* Desmazières, *Nitzschia liebethruthii* Rabenhorst, *Nitzschia incognita* Legler & Krasske, *Cocconeis pediculus f. abruptus* Korotkevich occurred in 71.4%, *Fragilaria vaucheriae* (Kützing) Petersen and *Stauroneis smithii* Grunow in 57.1%

respectively. However, *Cosmioneis pusilla* (Smith) D.G.Mann & A.J.Stickle, and *Pleurosigma angulatum* (J.T.Quekett) W.Smith occurred in a single community. The similarity of the species composition is 39% when calculated using the Djakarta index. The evenness ranges from 0.68 to 0.81.

Table 3. Species richness, diversity, and evenness

	mineral spring of Uvs Lake	mineral spring of Khyargas Lake	F	P (F<=f)
Species richness (S)	24.6 (4.2)	19.75 (1.25)	8.69	0.056*
Shannon index	2.3 (0.07)	2.2 (0.15)	0.19	0.16
Evenness index	0.74 (0.036)	0.74 (0.036)	0.75	0.15

The Shannon-Weiner diversity index in the spring of Khyargas Lake is 1.77-2.43, and the spring of Uvs Lake is 2.22-2.49. Based on the relative abundance of each diatom species, water environment, salinity, nutrient uptake, oxygenation, and saprobes and trophic indices were evaluated for each boiling spring. The results are shown in Table 4.

Table 4. Water quality assessment using Van Dam Mertens, 1994

classification of ecological indicator value	The spring of Uvs Lake	The spring of Khyargas Lake
pH	7	7
Salinity	Fresh	Fresh brackish
Nitrogen uptake metabolism	Nitrogen autotrophic taxa, tolerating minimal concentration	Nitrogen autotrophic taxa, tolerating elevated concentration
Oxygen requirements	100%	75%
Saprobity	oligosaprobous	oligosaprobous
Trophic state	oligotraphentic	oligo-mesotraphentic
Moisture	Mainly occurring in wet and moist or temporarily dry places	Nearly exclusively occurring outside water bodies

In the following table, we first assessed the integrated index of an ecosystem using the Shannon-Weiner diversity index, evenness index, and mean individual species number logarithmic index. The environmental wellness and biodiversity level established an integrated index of ecosystem value and maximum logarithmic abundance index. The EWBL in Uvs Lake and Khyargas Lake's mineral springs are 83.51 and 78.52 respectively. Based on the above results, if we calculate the required percentage of restoration, it is possible to restore 21.47 percent of the mineral spring near Khyargas Lake to their natural conditions.

Table 5. Environmental wellness biodiversity level and required restoration percent

	mineral spring of Uvs Lake	mineral spring of Khyargas Lake
Environmental wellness biodiversity level (EWBL)	83.52	78.53
Restoration effort levels needed in a particular environment	16.48	21.47

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No dominant species exist in the mineral springs near Khyargas and Uvs lakes. Freshwater indicator genera species in the mineral springs near Uvs Lake are more widespread, while only in the spring near Khyargas Lake species belonging to the families Naviculaceae and Surirellaceae, which survive riparian soil erosion and nutrient pollution, were recorded. The diversity of species is more significant in the mineral spring of Khyargas Lake than in the mineral spring of Uvs Lake. When evaluating the water quality, the Uvs Lake mineral spring shows that the oxygen content is 100% oligo saprobe, oligotrophic or unpolluted, and very fresh. However, the mineral spring of Khyargas Lake is salty, the oxygen content is 75%, oligo-mesotrophic or secondary water, and the environment outside the reservoir is dry, indicating that the spring is affected by external influences. While collecting samples, we find large amounts of garbage left behind by people traveling and resting at the tourist camp sites near the mineral spring of Khyargas Lake. All garbage in this area is destroyed. It was felt that the water was taken from the spring by running a water suction pump which may have contributed to the pollution of the spring. On the other hand, during springtime, herdsmen of Zavkhan Soum pasture their domestic animals along the lake's northern shore or near the mineral spring. In summer, herders of Khyargas Sum pasture their livestock animals surrounding the lake, which causes soil erosion and damage due to the impact of livestock grazing. Local and climatic factors influence species distribution in thermal springs [27]. The pasture has the greatest effect on spring diatom diversity [28].

Livestock grazing and mining activities are intensively implemented along the spring shores, increasing sediment accumulation [29]. Diatoms have a silica valve and respond quickly to changes in the habitat, manifesting as changes in the structure of the community and the number of individuals. As riparian soil erosion increases, the relative abundance of mobile diatoms increases [30]. This is also indicated by species that are less resistant to external nutrients and organic pollution in the algal community of the spring. The locals protected the source of the spring by pouring cement around it without the guidance of a professional organization, which may have contributed to the nature of the spring by blocking the outflow of water.

The key to the sustainable use of mineral water is to establish proper protection zones, reduce pollution sources, conduct water quality monitoring studies, and determine the quality of water treatment [31]. Mongolia has the world's most minuscule renewable water resources [32-33]. Therefore, we must conduct thorough research, analysis, laws, and regulations in underground water protection and disseminate knowledge to the public. Local authorities should issue policy documents and decisions on the protection of springs, empower environmental policy experts and conservationists in the field of algal studies, conduct regular water surveys in the area, and educate local people on water conservation and rehabilitation. It is necessary to take adequate measures to prevent animals from entering the lake, to provide local animal wash basins, to develop responsible tourism, and to improve waste management along the shores of the lake. The EWBL of the mineral spring of Uvs Lake is higher than Khyargas, and the mineral spring of Khyargas Lake should be restored by 21.47 percent.

CONCLUSIONS

The orders Naviculales, Cymbellales, and Fragilariales had the most species richness in our study. The mineral spring of Uvs Lake is richer in diatom species than the mineral spring of Khyargas Lake. Diversity of diatom and evenness are not significant between springs. However, It can be concluded that the water quality of the mineral spring of Khyargas Lake is fresh to brackish. Protecting springs, such as groundwater source, will be necessary in the future, but our results reveal the importance of aquatic biology investigations. The percentage of required restoration of their springs is 16.48-21.47 based on diatom community.

It is likewise extremely important to establish the sanitary zone of the spring environment and introduce relevant protection management.

REFERENCES

1. M. Cantonati, K. Lichtenwöhrer, G. Leonhardt, L. Seifert, A. Mustoni, R. Hotzy, R. Gerecke. 2022. Using springs as sentinels of climate change in nature parks north and south of the alps: A critical evaluation of methodological aspects and recommendations for long-term monitoring. Water, 14(18), 2843. https://doi.org/10.3390/w14182843
2. L. Stevens, A. Aly, S. Arpin, I. Apostolova, G. Ashley, P. Barba, O. Voldoire. 2021. The ecological integrity of spring ecosystems: A global review. Earth Systems and Environmental Sciences, Reference Module, Elsevier.
3. S. Bhat, S. Dar, I. Sabha. 2022. Assessment of threats to freshwater spring ecosystems. https://doi.org/10.1016/B978-0-12-821139-7.00068-4.
4. J. Bikse, M. Gavinolla. (2022). Tourism and Restoration of Spring Ecosystem Services: Case Study of Latvia. In Management of Tourism Ecosystem Services in a Post Pandemic Context (pp. 339-361). Routledge. https://doi.org/10.4324/b23145-26.
5. Z. Tserendorj, S. Erdenetsogt. 2015. Brief guidance of springs in Mongolia. 114 p. ISBN 99973-7148-8. (in Mongolian).
6. G. Odontuya. 2012. Study of a regime of chemical composition in Uvur Janchivlan spring with carbon dioxide gas. Master thesis. National University of Mongolia.p. 65. (in Mongolian).
7. D. Oyuntsetseg, G. Odontuya, A. Tsiiregzen, O. Khureldavaa, B. Amarsanaa. 2017. Mongolian's hot mineral waters distribution and hydrochemical composition Ikh Shargaljuut's mineral water. Mongolian University Science and Technology // Proceeding of MUST. Vol. 7. No. 212. pp. 118-825. (in Mongolian).
8. S. Adelana. (Ed.S.). 2015. Groundwater: Hydrogeochemistry, environmental impacts, and management practices. Nova Publishers. p. 274.
9. Ch. Javzan. 2011. Hydrochemistry of Orkohn River Basin. Ulaanbaatar. P. 248.
10. F. Millan, C. Izere, V. Breton, O. Voldoire, D. Biron, C. Wetzel, A. Beauger. (2020). The effect of natural radioactivity on diatom communities in mineral springs. Botany letters, 167(1), 95-113. https://doi.org/10.1080/23818107.2019.1691051.
11. A. Wojtal, Ł. Sobczyk. 2012. The influence of substrates and physicochemical factors on the composition of diatom assemblages in karst springs and their applicability in water-quality assessment. Hydrobiologia, 695, 97-108. https://doi.org/10.1007/s10750-012-1203-0.

12. G. Lai, B. Padedda, C. Wetzel, A. Lugliè, N. Sechi, L. Ector. (2016). Epilithic diatom assemblages and environmental quality of the Su Gologone karst spring (central eastern Sardinia, Italy). Acta Botanica Croatica, 75(1), pp. 129-143. https://doi.org/10.1515/botcro-2016-0008.
13. M. Feio, S. Almeida, S. Craveiro, A. Calado. (2007). Diatoms and macroinvertebrates provide consistent and complementary information on environmental quality. https://doi.org/10.1127/18639135/2007/0169-0247.
14. A. Shinneman, M. Edlund, J. Almendinger, & N. Soninkhishig. 2009. Diatoms as indicators of water quality in Western Mongolian lakes: A 54-site calibration set // Journal of Paleolimnology. Vol. 42. No. 3. pp. 373-389. https://doi.org/10.1007/s10933-008-9282-7.
15. N. Jadambaa. 2009. Geology and Mineral Resources of Mongolia: Hydrogeology. Vol. 8. p. 249. Ulaanbaatar, Soyombo Printing. (in Mongolian).
16. M. Hohn, J. Hellerman. 1963. The taxonomy and structure of the diatom populations from three Eastern North American Rivers using three sampling methods // Transactions of the American Microscopical Society. Vol. 82. pp. 250-329. https://doi.org/10.2307/3223932.
17. E. Stoermer, M. Edlund, C. Pilskaln, C. Schelske. 1995. Siliceous microfossil distribution in the surficial sediments of Lake Baikal / Journal of Paleolimnology. Vol. 14. No. 1. pp. 69-82. https://doi.org/10.1007/BF00682594.
18. K. Krammer, H. Lange-Bertalot. 1991a. Bacillariophyceae.Teil: Centrales, Fragilariaceae, Eunotiaceae. p. 576.
19. K. Krammer, H. Lange-Bertalot. 1991b. Bacillariophyceae.Teil: Achnanthaceae, Kritische Erganzungen zu Navicula und Gomphonema. p. 437[
20. K. Krammer, H. Lange-Bertalot. 1997a. Bacillariophyceae. Teil: Naviculaceae. p. 876.
21. K. Krammer, H. Lange-Bertalot. 1997b. Bacillariophyceae. Teil: Bacillariaceae, Epithemiaceae, Surirelaceae. p. 596.
22. J. Taylor, W. Harding, C. Archibald. 2007. A methods manual for the collection, preparation and analysis of diatom samples. 60 p. Water Research Commission (WRC).
23. H. Birks. 2010. Numerical methods for the analysis of diatom assemblage data // In The Diatoms: Applications for the Environmental and Earth Sciences. pp. 23-54. Cambridge University Press. https://doi.org/10.1017/CBO9780511763175.004.
24. C. Shannon, W. Wiener. 1949. The mathematical theory of communication. P. 131. Urbana, Illinois.
25. A. Herman van Dam. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands // Netherlands Journal of Aquatic Ecology. Vol. 28. No. 1. pp. 117-133. https://doi.org/10.1007/BF02334251.
26. D. Omayio, E. Mzungu. 2019. Modification of Shannon-Wiener Diversity Index towards Quantitative Estimation of Environmental Wellness and Biodiversity Levels under a Non-comparative Scenario // Journal of Environment and Earth Science. Vol. 9. No. 9. https://doi.org/10.7176/JEES/9-9-06.
27. G. Lai, A. Beauger, C. Wetzel, B. Padedda, O. Voldoire, A. Lugliè, L. Ector. 2019. Diversity, ecology and

distribution of benthic diatoms in thermo-mineral springs in Auvergne (France) and Sardinia (Italy). PeerJ, 7, e7238. https://doi.org/10.7717/peerj.7238.

28. M. Mogna, M. Cantonati, F. Andreucci, N. Angeli, G. Berta, L. Miserere. 2015. Diatom communities and vegetation of springs in the south-western Alps. Acta Botanica Croatica, 74(2), pp. 265-285. https://doi.org/10.1515/botcro-2015-0024.
29. P. Theuring, M. Rode, S. Behrens, G. Kirchner, A. Jha. 2013. Identification of fluvial sediment sources in the Kharaa River catchment, Northern Mongolia: Identification of fluvial sediment sources // Hydrological Processes. Vol. 27. No. 6. https://doi.org/10.1002/hyp.9684.
30. E. Stoermer, J. Smol. (Eds.). (2001). The diatoms: Applications for the environmental and earth sciences (1. paperback ed). Cambridge University Press.
31. N. Goldscheider. 2010. Delineation of spring protection zones // Ed. Neven Kresic, Zoran Stevanovicn. Groundwater Hydrology of Springs. pp. 305-338.Elsevier. https://doi.org/10.1016/B978-1-85617-502-9.00008-6.
32. G. Davaa. 2015. Surface water regime and resources of Mongolia. Ulaanbaatar. Admon Printing. p. 408. (in Mongolian).
33. N. Jadambaa, N. Buyankhishig. 2007. An overview of the hydrogeological study of underground water resources and regimes in Mongolia // Problems of Mongolian Geology: Mongolian Academy of Sciences.