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Physicochemical variations and water quality conditions of the Delgermurun River basin, Khuvsgul province

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ABSTRACT

River water quality is crucial as rivers support multiple uses in human needs as well as in sustaining the aquatic ecosystems. In this study, we assessed the physicochemical characteristics and water quality of the Delgermurun River Basin (DRB). We collected water samples from 16 sites along the Delgermurun River and its tributaries in June 2024. Eleven physicochemical parameters were measured onsite, and a permanganate index (CODMn) was analyzed in the laboratory. Seven heavy metals (Mn, Zn, Co, Ni, Mo, As, and Cd) were analyzed at SGS IMME Mongolia LLC, a certified laboratory. Principal component analysis (PCA) was used to explore variations in physicochemical characteristics, while water quality index (WQI) and heavy metal pollution index (HPI) were calculated to assess overall water quality of the DRB. According to the PCA, pH, turbidity, water temperature (Temp.), total dissolved solids (TDS), and elevation contributed the most to variation across the DRB. The highest values of pH, turbidity, and Temp. were found at lower sites (DELBugsei, DELG03, and DELW01), while the highest TDS was recorded at DELR02. In terms of the water quality, WQI and HPI values ranged from 0.04 to 0.1 and 5.98 to 29.20, respectively, remaining within the category of "very clean" by WQI and level of lower pollution by HPI (MNS 4586:1998). Our findings indicate that physicochemical parameters and water quality varied across the DRB, but it remains suitable for potable use. Our results can inform future water resource management, for example, identifying and protecting critical habitats, such as those for the endangered taimen (Hucho taimen), and contributing to the conservation of the DRB ecosystem.

KEYWORDS

Delgermurun River basin, Water quality conditions, Water quality index, Heavy metal pollution index

1. INTRODUCTION

Studies considering physicochemical characteristics provide essential insights into the river basin's conditions and its interaction with the surrounding environment. Changes in physicochemical conditions can lead to various ecological effects on aquatic ecosystems. For example, it can reduce the water quality, and poor water quality often reflect broader environmental changes and biodiversity patterns across the river basin [1].

In recent years, numerous studies have been conducted on determining the physicochemical characteristics of rivers, with a primary focus on both climatic and anthropogenic-induced changes in physicochemical parameters and heavy metals. Most of the studies have focused on determining pollution sources and water quality assessments in larger rivers and lakes, including the Selenge River Basin [2,3], Kharaa River Basin [4], the Tuul River [5], Lake Khuvsgul [6], and Lake Ugii, across various regions.

The Delgermurun River Basin (DRB), a major tributary of the Selenge River. It serves as a critical habitat for *Hucho taimen*, a freshwater indicator species that is widely distributed across northern Eurasia. The RDB is a major water supply for local communities and plays an important role in the local economy by supporting fisheries, livestock watering, and ecotourism activities. Despite its ecological and economic significance, the DRB's role in supporting diverse aquatic life and maintaining ecosystem health has not been well studied, and no comprehensive studies addressing environmental variability (e.g., physicochemical parameters) within the DRB have been reported.

In this study, we aim to fill that gap by examining environmental variability through selected eleven physicochemical parameters and evaluating water quality using two integrated approaches: the Water Quality Index (WQI) and the Heavy Metal Pollution Index (HPI).

2. RESEARCH METHODS

2.1. Study area

The Delgermurun River Basin (DRB) is located in Khuvsgul Province, the northern part of Mongolia. The upper DRB covers Ulaan-Uul Soum and Bayanzurkh Soum, whereas the lower DRB flows through Tumurbulag Soum. It originates from the foothills of the Ulaan-Taiga Range and flows for 445 km before merging with the Ider River to become the origin of the Selenge River. Many large and small tributaries, such as Taris (75 km), Beltes (92 km), and Bugsei (110 km) feed the Delgermurun River.

Water sampling was conducted from upstream to downstream, covering the main course of the Delgermurun River and its major tributaries (Figure 1).

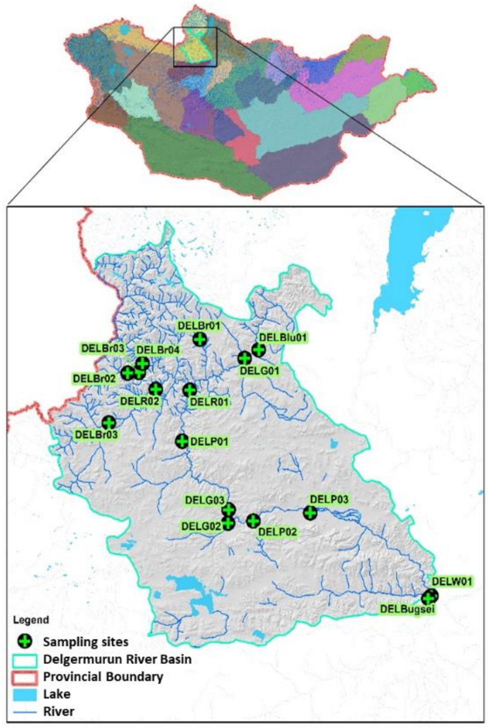

Figure 1. Location of sampling sites in DRB

A total of 16 sampling sites (Table 1) were selected along the DRB based on variations in hydrogeomorphic conditions, including channel width, sinuosity, and elevation, criteria previously defined by the Macroecological Riverine Synthesis project.

Table 1. Sampling sites along the DRB

Rivers	Site code	Latitude	Longitude
Agar	DELR02	50.11004°N	98.62103°E
Altarga	DELBr01	50.34759°N	98.91065°E
Bayan	DELG02	49.54838°N	99.21260°E
Buriad	DELR03	50.17785°N	98.49001°E
Buriad	DELBr02	50.16976°N	98.40815°E
Bugsei	DELBugsei	49.27799°N	100.67390°E
Beltes	DELG01	50.27996°N	99.24554°E
Beltes	DELBlu01	50.32228°N	99.34300°E
Zos	DELBr03	49.94333°N	98.30435°E
Delgermurun	DELR01	50.11938°N	98.86721°E

Delgermurun	DELR04	50.21915 °N	98.51082 °E
Delgermurun	DELP01	49.89222 °N	98.84143 °E
Delgermurun	DELP02	49.56681 °N	99.39297 °E
Delgermurun	DELP03	49.62186 °N	99.79616 °E
Delgermurun	DELG03	49.60712 °N	99.21042 °E
Delgermurun	DELW01	49.29133 °N	100.69460 °E

2.2. Water sampling

Water sampling took place in June 2024, during the low-flow period of the DRB. The following physicochemical parameters were measured on-site using portable instruments: elevation, pH, water temperature (Temp.) in celsius degree, electrical conductivity (EC), and total dissolved solids (TDS) with a multiparameter meter (HI98195); velocity (veloc.) by streamflow meter; turbidity (Turb) with a Hanna portable turbidimeter (HI93703); dissolved oxygen (DO) with an OXI 96 meter; and chemical test kits for measuring the concentrations of ammonium (NH_4^+), nitrate (NO_3^-), and phosphate (PO_4^{3-}) were determined with a Multiparameter Photometer HI83399 (HANNA).

Chemical oxygen demand (COD_{Mn}) was analyzed at the Water Analysis Laboratory of the Institute of Geography and Geoecology, Mongolian Academy of Sciences. Heavy metal concentrations, including Mn, Zn, Co, Ni, Mo, As, and Cd, were determined at SGS IMME Mongolia LLC, a certified laboratory.

2.3. Data analyses

We calculated mean, maximum (Max) and minimum (Min) values and standard deviation (SD) of 10 physicochemical parameters (elevation, velocity, pH, Temp., EC, TDS, turbidity, DO, NH_4^+, and NO_3^-) measured at 16 sampling sites within the DRB.

In order to determine physicochemical variations within the DRB, we conducted principal component analysis (PCA) using the 10 physicochemical parameters. The PCA is a statistical technique used to simplify complex datasets by reducing the number of variables while preserving as much of the original data's variation as possible. The PCA was conducted using package *FactoMineR* in RStudio.

The Water Quality Index (WQI) was employed to assess pollution levels at 16 sites along the DRB. The WQI was calculated based on seven key parameters (DO, NH_4^+, NO_3^-, COD_{Mn}, PO_4^{3-}, As, and Ni) using Formula (1). The resulting WQI values at each site were then compared against the national standard 'Water Quality – General Requirements' (MNS 4586:1998) to determine whether pollutant concentrations exceeded the permissible limits [7].

$$WQI=\frac{\sum\left(\frac{C_i}{PL_i}\right)}{n} \quad (1)$$

where:

WQI – water quality index
C_i - concentration of the i^{th} pollutant
PLi - maximum permissible level of the i^{th} pollutant in accordance with the MNS 4586:1998.
n - total number of pollutants.

Table 2. Water quality classification

WQI	Category	Classification
≤0.30	I	Very clean
0.31-0.89	II	Clean
0.90-2.49	III	Moderately polluted
2.50-3.99	IV	Polluted
4.00-5.99	V	Highly pollutd
≥6.00	VI	Extremely polluted

The Heavy Metal Pollution Index (HPI) is a rating method that reflects the combined impact of individual heavy metals on overall water quality [8]. A total of 53 heavy metals were measured, and those heavy metals (e.g., Mn, Zn, Co, Ni, Mo, As, Cd, Hg, and Pb) detected at the sampling sites were considered in the result. Based on the detected heavy metals, we calculated the HPI using the following equation (2) [9].

$$HPI=\sum_{i=1}^{n} W_i Q_i / \sum_{i=1}^{n} W_i \quad (2)$$

where:

W_i and Q_i - sub-index and unit weightage of i^{th} parameter respectively
n – total number of parameters to be considered as shown in Formula (2).
The sub-index Qi is calculated by the equation (3),

$$Q_i = \sum_{i=1}^{n} \frac{Mi-Ii}{Si-Ii} * 100 \quad (3)$$

where:

Mi and Ii – monitored and ideal values of the i^{th} parameter, Si-standard value of the i^{th} parameter in parts per million (ppm) as shown in equation (3).

A critical threshold value of 100 is commonly used; HPI values exceeding this limit indicate a higher potential risk to human health according to the MNS 4586:1998.

3. RESULT

3.1. Physicochemical conditions of the DRB

Among the physicochemical parameters, EC, TDS, Temp. and NO_3^- exhibited relatively wide ranges of values. The mean EC and TDS were 299 µS/cm and 162 ppm, with respective ranges of 174-433 µS/cm and 93-260 ppm. NO_3- ranged from 0.2 to 9.6 mg/L, with a mean of 2.4 mg/L, while Temp. varied between 8.5°C to 23.2 °C, with a mean of 13.4°C (Table 3). In contrast, the remaining physicochemical parameters exhibited relatively narrow ranges, with lower mean and SD.

Table 3. Mean, Max, and Min values and SD of the physicochemical parameters measured in DRB

Physicochemical parameters	Mean	Max	Min	SD
pH	8.36	8.64	8.1	0.15
EC µS/cm	299	433	174	66.6
TDS ppm	162	260	93	38.1
Temp. °C	13.4	23.2	8.5	4.17
Turbidity NTU	2.10	4.12	0.36	1.05
DO mg/L	8.03	9.82	6.76	0.74
COD_{Mn} mg/L	3.84	4.16	2.24	0.61
NH_4^+ mg/L	0.03	0.09	0	0.03
NO_3^- mg/L	2.45	9.6	0.2	2.52
PO_4^{3-} mg/L	0.28	0.38	0.16	0.05

3.2. Spatial variations of physicochemical parameters within DRB

We used PCA analysis to indicate whether the sampling sites vary with the physicochemical paramteres. According to the PCA, the first two principal components (Dim 1 and Dim 2) explained 61.1% of the total variance. Along Dim 1, pH, turbidity and Temp. were positively correlated, while elevation showed a negative correlation. Dim 2 was positively associated with TDS, NO_3^-, and EC (Figure 2, upper graph).

In terms of site-specific relationships (Figure 2, lower graph), the sites DELBugsei, DELG03, and DELW01 were associated with higher values of pH, turb., and Temp.. Upstream sites such as DELBlu01, DELG01, and DELBr02 were more closely linked to higher elev. The DELR02 site exhibited the highest values, for example, for TDS (260 ppm) and EC (433 µS/cm).

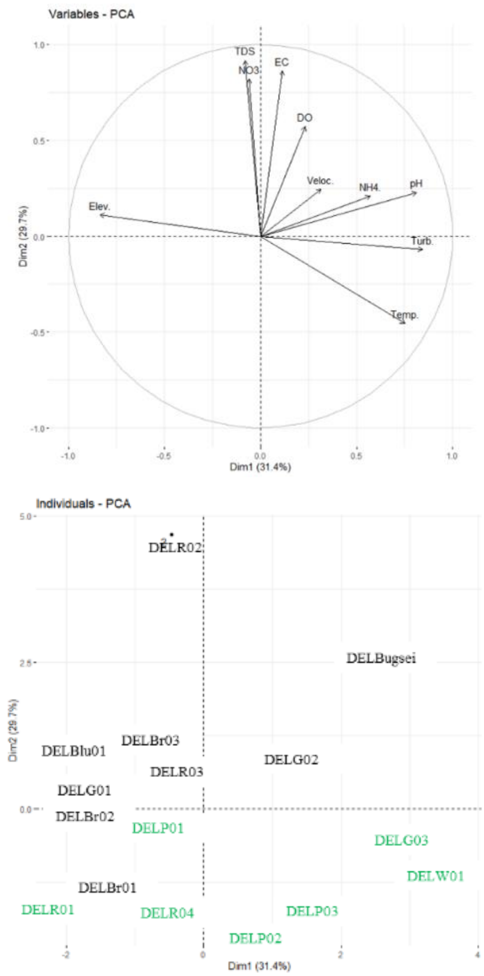

Figure 2. PCA: Physicochemical parameters (upper) and corresponding sampling sites (lower) in DRB. Sites highlighted in green refer to the main stem of the Delgermurun

3.3. Classification of water quality in the DRB

WQI. The WQI values for the 16 sampling sites ranged from 0.04 to 0.10, which falls under the "very clean" category, according to the WQI classification.

Table 4. Categories of water qualyat sampling sites

Site code	WQI	
	Value	Classification
DELR01	0.06	Very clean
DELR02	0.08	Very clean
DELR03	0.07	Very clean
DELR04	0.1	Very clean
DELBr01	0.06	Very clean
DELBr02	0.06	Very clean
DELBr03	0.08	Very clean

DELP01	0.06	Very clean
DELP02	0.08	Very clean
DELP03	0.04	Very clean
DELG01	0.07	Very clean
DELG02	0.07	Very clean
DELG03	0.1	Very clean
DELBlu01	0.1	Very clean
DELW01	0.09	Very clean
DELBugsei	0.09	Very clean

HPI. The observed HPI values were all below the critical threshold of 100, with an average value of 14.4. As the concentrations of all analyzed heavy metals were within the permissible limits specified in the MNS 4586:1998 standard, it indicated that all study sites were unpolluted.

4. DISCUSSION

Our findings revealed that physicochemical parameters varied across sites along the DRB, and both the Water Quality Index (WQI) and Heavy Metal Pollution Index (HPI) indicated that the basin is in a relatively pristine condition when assessed using the selected pollutants and heavy metals.

4.1. Spatial Variation of physicochemical parameters

The highest values of electrical conductivity (EC) and total dissolved solids (TDS), recorded at the DELR02 site, suggest an elevated concentration of dissolved ions. This may be attributed to natural geological sources, such as the weathering of rocks and soils rich in soluble minerals [10]. Although the river's chemical characteristics are influenced by factors such as soil type, topography, and climate, the overall concentration of dissolved minerals at the remaining sites remains relatively low. Water temperature (Temp.) also varied among the sites, with relatively higher Temp. observed in the lower DRB. This variation may be linked to broader floodplains and reduced discharge in downstream areas, which enhances solar heating. In addition, it is likely due to the elevation as the higher Temp. is often observed at the lower elevation [11].

4.2. Water Quality Assessment using WQI and HPI

Our findings on the water quality assessments using WQI and HPI support that the DRB is relatively less impacted by anthropogenic activities. Even though sampling sites, which were located right below the settlement (e.g., the Beltes River below Bayanzurkh soum), the water quality condition was assessed as very good. Findings of the overall assessment is likely due to selection of sampling sites further from the settlement areas, waste management implemented by soum centers, unaccessible road conditions, which do not allow, for example, campers to visit and pollute the surrounding areas, and location of the upper DRB belonging to the protected areas (e.g., border zones), which prohibit herders to feed their livestock in the area.

4.3. Implications for Ecosystem Health and Biodiversity

Preserving water quality conditions in this "very good" category is essential for maintaining the ecological integrity of the DRB and ensuring its use for drinking water. If the water quality conditions become unsuitable for drinking, it will affect the distribution of the endangered species such as *Hucho taimen* and their prey, which are indicator species representing the freshwater ecosystem health. Because those species are well-adapted to habitats with relatively lower water temperature and lower concentration of organic compounds (e.g., ammonium and phosphorus). Therefore, it is important to monitor the environmental conditions of those species to detect whether there is an early signs of ecological imbalance.

4.4. Comparison with Other Mongolian River Basins

Our findings on physichemical paramters are supported by other studies conducted along the DRB and other river basins. For example, observed mean DO (8.03 mg/L) and COD_{mn} (3.84 mg/L) measured in DRB were similar to those measured in the Eg River, a tributary of the Selenge River. In the Eg River, DO was 5.0 mg/L while COD_{mn} was 3.2 mg/L[12]. However, the water quality of the DRB was relatively in pristine condition when it is compared with the other river basins such as the Tuul River, which flows through the capital city of Ulaanbaatar and is in the categories of “Polluted” to “highly polluted” below the capital city.

4.5. Study Limitations and Uncertainties

We performed water sampling only once, when streamflow was in a baseflow condition. This is one of the main limitations. Because the result cannot be used to assess spatial variations of environmental conditions along the DRB. It is expected that during the flooding periods, increased discharge could lead to an increase in some physicochemical parameters, including organic compounds and turbidity, which may significantly alter the environmental conditions.

4.6. Recommendations for Management and Monitoring

Our findings on the assessment of important habitat conditions for the taimen fish and its prey species will inform environmental managers, rangers, and decision makers to develop a monitoring program and management plan for the conservation of this endangered species. For example, developing a long-term monitoring program should rely on selecting sites such as the Bayangol River with relatively high concentrations of organic compounds and turbidity. Because the high concentration of those parameters is often linked to intensive livestock grazing along the riverbanks. Without appropriate management, overgrazed areas along the riverbank could eventually contribute to the water quality condition of the major Delgermurun River.

CONCLUSION

Our findings revealed that some of the environmental factors vary across the DRB. For example, elevation and water temperature significantly varied across sites. When assessing water quality conditions using WQI and HPI, all sampling sites remained in the very good category. Our findings can be used to inform future water resource management as we assessed habitat conditions of endangered taimen (*Hucho taimen*) along the DRB and thus, will contribute to the conservation of the DRB ecosystem.

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