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The chemistry of river–lake systems in the context of permafrost occurrence (Mongolia, Valley of the Lakes). Part I. Analysis of ion and trace metal concentrations

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ABSTRACT

This study provides a description of water chemistry in river–lake systems located in central Mongolia, at the borderline of permafrost occurrence. The analysis involved water samples collected from two river–lake systems: Baydrag River–Böön Tsagaan Lake system, and Shargalyuut/Tuyn Rivers–Orog Lake system. In the water samples, ions and trace elements were detected and quantified. Additionally, the parameters of pH, electrical conductivity (SEC), total dissolved solids (TDS) and total organic carbon (TOC) were determined. Principal Component Analysis (PCA) was performed on the sample results. Water chemistry is mostly influenced by geochemical and hydrometeorological processes. Permafrost thawing could increase the concentration of nitrogen (NH_4^+, NO_3^-) as well as Na^+ and Ca^{2+}, Cl^- and SO_4^{2-}. However, it may also be an effect of other factors such as livestock farming. Seasonal drying out of lakes (e.g., Lake Orog) may also influence water chemistry by deflation of evaporites from exposed lake beds and, at the same time, with lower concentration of chemical compounds in water. The PCA shows that water samples can be divided into two groups. The first group contains lake samples, where water chemistry is shaped by prevailing evaporation processes, whereas the second includes samples from rivers and springs. Water chemistry of the latter is predominantly influenced by geochemical and hydrometeorological processes.

1. Introduction

Hydrological processes in permafrost regions are controlled by thickness of the active layer and total thickness of the underlying permafrost (White et al., 2007). The presence of permafrost can greatly affect the geochemistry of Northern Hemisphere watersheds, changing the seasonal fluxes of nutrients including carbon and nitrogen (e.g., Carey, 2003; O'Donnell and Jones, 2006; Petrone et al., 2006; Frey et al., 2007; Frey and McClelland, 2009; Keller et al., 2010; Bagard et al., 2011; Cheng and Jin, 2012; Douglas et al., 2013; Larouche et al., 2015; Manasypov et al., 2015). Recent monitoring observations indicate widespread permafrost degradation in the Northern Hemisphere (Christiansen et al., 2010; Romanovsky et al., 2010; Smith et al., 2010; Zhao et al., 2010; Slater and Lawrence, 2013). Rapid changes of permafrost have also been observed at the southern range of permafrost appearance (Zhang et al., 2008; Schaefer et al., 2011). The interaction between permafrost degradation and watershed hydrological changes can help us predict the response of aquatic ecosystems to climate changes (McClelland et al., 2007; Koch et al., 2013; Abbott et al., 2015). As temperatures increase at higher latitudes, large amounts of carbon, nitrogen and other chemical compounds stored in permafrost may start to become available for transport to aquatic ecosystems. There is a growing understanding of the potential effects of permafrost degradation on aquatic biogeochemical cycles in Arctic regions such as Alaska (Petrone et al., 2006; McClelland et al., 2007; Douglas et al., 2013), Canada (Zhang et al., 2008; Kokelj et al., 2009; Stotler et al., 2009; Olefeldt et al., 2014), and Russia (Frey et al., 2007; Bagard et al., 2011; Manasypov et al., 2015). However, there is no information concerning surface water chemistry (in the context of permafrost occurrence) in Mongolia.

Detailed hydrological and hydrochemical investigations have been carried out in individual regions of Mongolia (e.g., Ma et al., 2003; Lange et al., 2015). Only a few hydrological and hydrochemical studies have covered the entire country (Glazik, 1995; Davaa et al., 2007; Batsukh et al., 2008; Davaa and Oyunbaatar, 2012; Demeusy, 2012). A significant issue is the impact of strip mining in river valleys on water chemistry and volume of water resources (Farrington, 2000;

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Stubblefield et al., 2005; Thorslund et al., 2014). However, the chemical status of lakes and rivers still constitutes an understudied element of the environment of Central Mongolia.

This paper aims at defining chemical features of water within the river–lake systems located in Central Mongolia, at the boundary of permafrost occurrence (Fig. 1): Baydrag river–Böön Tsagaan Lake system (the Baydrag–Böön Tsagaan System) and Shargalyuut/Tuyn Rivers–Orog Lake system (the Shargalyuut/Tuyn–Orog System). The main aim of the research involved establishing relationships between rivers, their sources and lake water chemistry. The source of all rivers is located in the continuous and discontinuous permafrost zones. Both lakes (Böön Tsagaan and Orog) constitute terminal parts of rivers. The river mouths – lakes – are located in an area where permafrost is absent and where evapotranspiration over infiltration (both in the aqueous

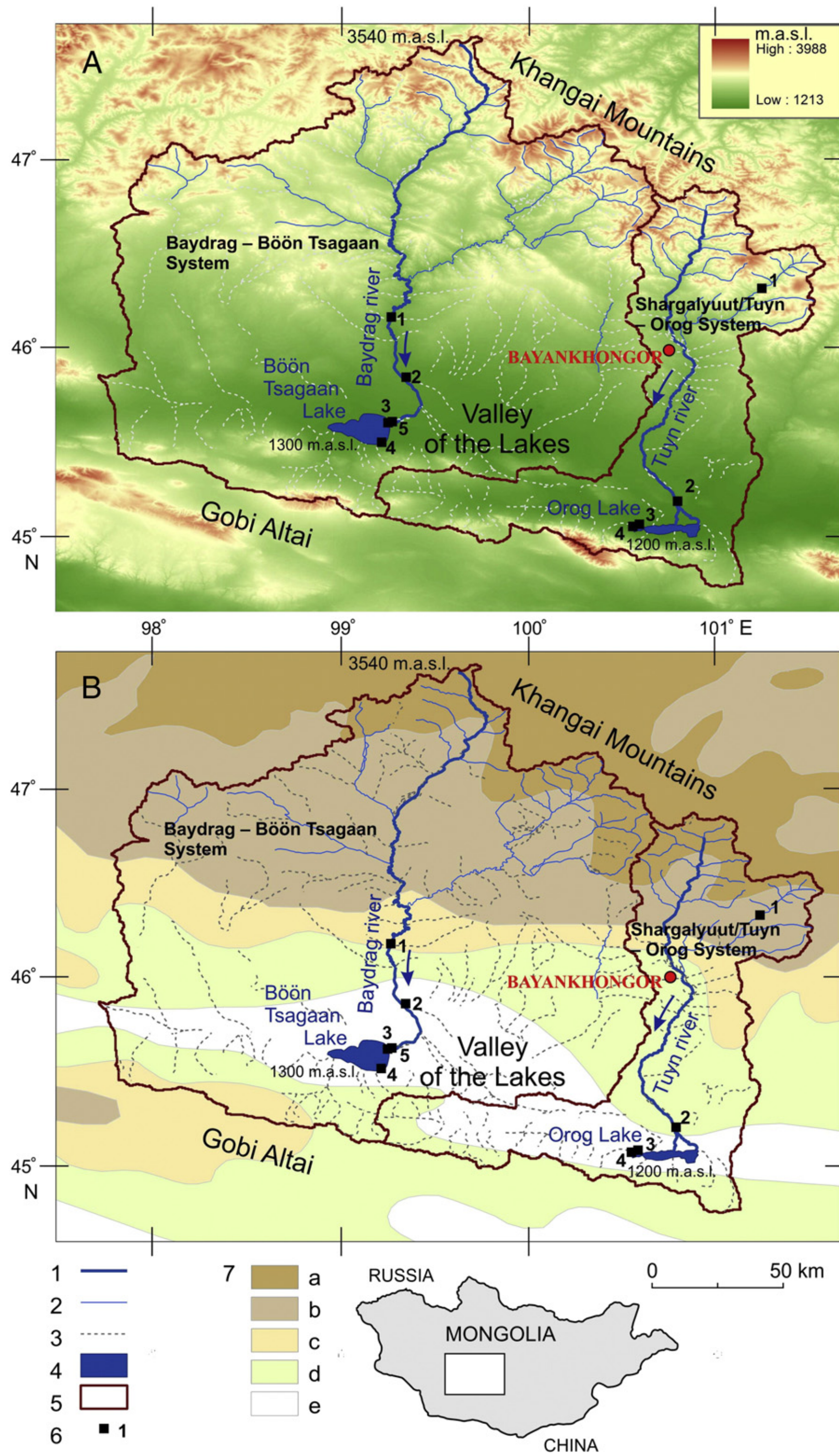

Fig. 1. Location of the research area against the background of (A) digital elevation model (DEM) and (B) permafrost occurrence in Mongolia. Locations: 1 — the Baydrag and the Tuyn rivers, 2 — perennial tributaries of main rivers, 3 — intermittent streams, 4 — researched lakes, 5 — watersheds of the Baydrag and the Tuyn basins, 6 — sampling points, 7 — zones of: (a) continuous and discontinuous, (b) insular, (c) sparsely insular, (d) sporadic permafrost occurrence, (e) seasonally frozen ground (DEM based on Jarvis et al., 2008, 1–5 and 7 based on Sharkhuu, 2000; Sodnom and Yanshin, 2005; Lehner et al., 2008).