Quaternary Science Advances 14 (2024) 100199

Contents lists available at ScienceDirect

Quaternary Science Advances

journal homepage: www.sciencedirect.com/journal/quaternary-science-advances

# Carbon and nitrogen biogeochemistry of a high-altitude Himalayan lake sediment: Inferences for the late Holocene climate

Abdur Rahman [a,b,c,**], Rayees Ahmad Shah [a,d], M.G. Yadava [a], Sanjeev Kumar [a,*]

[a] Physical Research Laboratory, Ahmedabad, 350009, India
[b] Department of Earth and Environmental Sciences, National Chung Cheng University, Chiayi, 62102, Taiwan
[c] Environment and Disaster Monitoring Center, National Chung Cheng University, Chiayi, 62102, Taiwan
[d] Mantaqi Centre for Science and Society, Islamic University of Science and Technology, Pulwama, 192122, India

ARTICLE INFO

*Keywords:*
Himalaya. Wular Lake
Carbon and nitrogen biogeochemistry
Stable isotopes
Late Holocene

ABSTRACT

A study was conducted to decipher changes in paleoenvironmental conditions of the Kashmir Valley (India) using stable isotopic compositions and elemental concentrations of total organic carbon (TOC) and total nitrogen (TN) in a sediment core from the Wular Lake. The Chronology of the core established through radiocarbon dating estimated the age of the core bottom to be 3752 Cal years BP, covering the late Holocene. Using carbon isotopic compositions of TOC ($\delta^{13}C$), nitrogen isotopic compositions of TN ($\delta^{15}N$), and TOC - TN contents, the study identified changes in biology and associated biogeochemical processes in the Wular Lake during the late Holocene. Changes in C and N biogeochemistry of the lake through the last 3752 Cal years BP suggested overall drier condition during 3752–1500 Cal years BP that transitioned into a wetter condition at around 1500 Cal years BP until at least 295 Cal years BP. Evidence for relatively intense drier events were observed within the dry and wet phases at around 2500 and 500 Cal years BP. Changes in $\delta^{13}C$ and TOC contents in the sediment core revealed that the inorganic C dynamics and productivity (along with organic C contents) in the lake were largely regulated by variations in respired $CO_2$ and $HCO_3^-$ availability along with terrestrial matter supply through the Jhelum River. Similarly, variations in $\delta^{15}N$ and TN contents showed changes in N dynamics of the lake with varying nitrification and decomposition throughout the studied period. Observed dry and wet phases in the region might be due to the weakening and strengthening of the precipitation, which was linked to negative and positive phases of the North Atlantic Oscillation, respectively.

## 1. Introduction

The Himalaya, the highest mountain range situated in the India-Pakistan-China region, provides direct or indirect livelihood to a large population of the world. The hydroclimate over the Himalaya is dominantly controlled by two atmospheric circulations: the Indian summer monsoon and the westerlies. Except the western Himalaya, where the Pir-Panjal range acts as an orographic barrier, the Indian summer monsoon induced precipitation covers almost entire Himalayan range (Zgorzelski, 2004; Dimri et al., 2015). The western Himalayan hydroclimate is dominantly controlled by the westerlies (Ridley et al., 2013; Farhan et al., 2015; Cannon et al., 2018; Zaz et al., 2019), whose intensity is controlled by temperature and pressure gradient between the North Atlantic Ocean surface temperature [also represented as North Atlantic Oscillation (NAO)] and the Himalayan-Tibetan landmass (Lauterbach et al., 2014; Wolff et al., 2017). The westerlies also play a dominant role in precipitation during boreal winter over Europe and the central Asia by transporting moisture from the Mediterranean Sea, Caspian Sea, and Black Sea (Olsen et al., 2012; Caves et al., 2015; Wolff et al., 2017; Bini et al., 2019; Lüdecke et al., 2020). Long-term effects of westerlies on environmental conditions in various northern hemisphere regions, including the western Himalaya, have also been widely reported (Bini et al., 2019; Shah et al., 2020, 2021, 2023; Verma et al., 2023; Wolff et al., 2017).

In the last few decades, several studies have been conducted to understand changes in the western Himalayan environment and variation in the intensity of westerlies during the Holocene period (last 11.7 ka; Berglund, 2004) using various climate and environmental proxies such

* Corresponding author.
** Corresponding author. Physical Research Laboratory, Ahmedabad, 350009, India.
*E-mail addresses:* astabdull@ccu.edu.tw (A. Rahman), sanjeev@prl.res.in (S. Kumar).

https://doi.org/10.1016/j.qsa.2024.100199
Received 20 February 2024; Received in revised form 26 April 2024; Accepted 12 May 2024
Available online 15 May 2024