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Reconstruction of Paleoclimate and Environmental Fluctuations Since the Early Holocene Period Using Organic Matter and C:N Proxy Records: A Review

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ABSTRACT

In this review, the shifts in organic matter (OM) accumulation and C:N ratios in lake sediments to reconstruct paleoclimate and paleo-environmental changes since the early Holocene period are presented. The C:N proxy data of total OM reflect wet climatic conditions during early Holocene (10 to 8.2 kyrs BP) due to enhanced southwest monsoon. This was followed by intermittent arid conditions during the mid and late Holocene period (8.2 to 2.8 kyr BP). Enhanced values of C:N ratio during middle to late Holocene (7.8-2.3 kyrs B.P) indicate periods with lower lake levels and minimum precipitation, while decreased C:N ratio point to stronger SW monsoon and expansion of the lakes. Further, C:N and δ^{13}C results from the lake sediments reveal a detailed and continuous paleo-environmental changes in the relative sources of OM (allochthonous vs autochthonous). Proxy records using such natural archives have also been utilized to reconstruct past extreme events and environmental changes around the lake systems, such as causes for lake desiccation, hydrographic changes, alternations between C_3 and C_4 vegetation and historical disturbances in the catchment area since the early-late Holocene period coupled with the Indian summer monsoon.

INTRODUCTION

Organic rich sediments accumulating at the bottom of suitable climate-sensitive lakes provide continuous and high resolution (inter-annual to decadal scale) records of past climate variability, paleo-environmental changes of the associated catchments (Verschuren, 2003; Baresic et al., 2011). Mineralogical, organic and isotopic composition of lacustrine sediments also provide important information of palaeo-environmental changes, human-induced impacts and help in predicting future trends in environmental evolution following the global and the local/regional factors that influence them.

Production of OM in soils and sediments is directly linked to the intensity of the southwest monsoon (SWM) and is crucial for agricultural productivity, sustainable civilization, land use and land pattern dynamics in India (Staubwasser et al., 2003; Gupta, 2004; Nagasundaram et al., 2014). Early farming and agricultural practices were dependent on the amount and intensity of monsoon rains (Bellwood, 2005; Ruddiman et al., 2008). One of the prime factors for the rise and decline of river valley civilization such as the Harappan was due to the climatic fluctuation, particularly due to the overall decrease in the SW monsoon rains since the middle Holocene period (roughly 7 to 5 kyr BP) (Crawford, 2006). We have compiled from literature, the data on fluctuating OM from early to late Holocene period; data collected on OM and C:N are from six sites (five lakes and one river delta) (Fig.1) that are located in the Indian region receiving rain dominantly from the SWM. Out of these five lakes, two lakes are located on the fringes of the Thar Desert where the climate is mainly controlled by SWM and westerly winds.

The C:N ratio remains constant during periods of higher productivity, but shows variation during periods of lower lake productivity due to the changes in the internal productivity of OM and isotopic changes of carbon and nitrogen in lakes (Routh et al., 2004). Determining the source and amount of OM deposited is useful because it provides a better understanding of the biochemical processes within the lake and its surroundings. The flux and ratio of elements like carbon (C) and nitrogen (N) in an ecosystem are also dependent on the anthropogenic intervention, e.g., land use, management intensity coupled with other environmental factors like precipitation and climatic gradient (Ghaley et al., 2015).

The nature, magnitude and type of organic substances reflected by C:N ratio and δ^{13}C in the lake sediments contribute to a better understanding of paleoclimate and paleoenvironmental records (Meyers, 1994; Meyers and Lallier-Verges, 1999). Since many of a lake's specific nutrient dynamics represent the catchment landscape processes and changes in these processes may serve as indicators of terrestrial processes that are otherwise difficult to detect. OM and C:N ratios in lakes are likely to be altered as a consequence of changes in terrestrial export of nutrients related to climatic fluctuations. Similarly, the change in isotope ratios probably indicates a change in watershed vegetation from C_4 to C_3 plants. Thus, monitoring and understanding the effects of natural and anthropogenic changes in C:N and OM nutrient dynamics is very important because of the multitude of processes operating within and outside the ecosystem. Despite the extensive work on paleolimnological processes, the significance of OM and C:N ratio as climate proxy sources for paleoclimatic reconstruction appears to have remained uncovered so far.

Based on high-resolution geochemical proxy records (C:N, δ^{13}C and OM%) of sediment cores retrieved from lakes, it is aimed to establish the stages of environmental shifts and identify the initial time frame and pattern in which past environment(s) influenced the human activities. Whilst both natural climate change and human-influenced environmental changes are likely to be recorded in the Holocene lake sediments, it is critical to evaluate the influence of human activities on the reliability of sedimentary proxies in inferring the past climate changes (Crawford, 2006; Lu et al., 2009; Li et al., 2012).

ORIGIN AND ACCUMULATION OF OM IN LAKE SEDIMENTS

C:N ratio and δ^{13}C provide information whether OM is derived from terrestrial or lacustrine sources (Meyers and Teranes, 2001; Osleger et al., 2008; Chaudhary et al., 2013). Further, the amount of OM underlying in the sub-surface sediments is a small fraction of that originally ingressed into the surface waters (Ishiwatari and Uzaki, 1987;

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