BIOGEOCHEMICAL FLUXES OF NUTRIENTS AND CARBON FROM VEMBANADLAKE, SOUTHWEST COAST OF INDIA

PANEER SELVAN A

NOVEMBER 2012

ABSTRACT

Coastal ecosystems play a pivotal role in marine primary productivity and encompass rich biodiversity which include mangroves, salt marshes, estuaries and lagoons. These ecosystems provide services like coastal protection, fish resources, habitat linkages and medicinal/genetic resources. Nutrient and carbon cycling in these ecosystems is important in determining food production, climate regulation and overall stability and health of the ecosystem. In recent decades, these areas have been characterised by increasing population density and intense anthropogenic activities. These in turn have enhanced the loading of nutrients, carbon and trace metals and also spiked sedimentation rate in coastal ecosystems. Recent studies have found that these altered environmental conditions, affect the normal biogeochemical processes and the release/sequestration of nutrients and carbon (CO_2 and CH_4).

In this study the focus is on understanding the fluxes of nutrients and carbon in an anthropogenic stressed coastal ecosystem 'Vembanad Lake' situated in the southwest coast of India. The lake consists of two arms with varying dimensions, bathymetry and drainage area. Six perennial rivers join at different parts of the lake during its travel to the ocean, and the two openings to the sea makes it a complex system. Since the climate regime in this region is controlled by the seasonal monsoon, studies were carried out over two years (2008 and 2009) and two sampling seasons a year; in addition sediment cores were studied to provide past information. Widely tested LOICZ budget model was used to calculate the fluxes of nutrients and carbon. Further, the lake status was assessed using Pollution Load Index from the sediments.

Surface water of the lake displayed spatial heterogeneity and high seasonal variability for the physico-chemical parameters as well as nutrients. In the DIN pool, nitrate was the dominant form during wet season transforming to ammonia indicated by increased ammonium levels during the dry season. DIP distribution showed an internal source in the lake whereas DSi pattern was largely governed by the freshwater discharge. The distribution of nutrients generally displayed non-conservative behaviour, and showed a spatial shift of phosphorus limitation in freshwater region to nitrogen limitation in the regions with higher salinity.

From LOICZ budget model, significant seasonal variation was noted with predominance of monsoonal flux as the nutrient influx varied in time. The residence time of the lake varied seasonally being about four times longer in the dry season than during the wet season. On an annual basis, the whole lake acts as source for DIP and sink for DIN and DSi. Net addition of 15.6 x 10^6 mol P yr^{-1} for DIP and net removal of 38.9 x 10^6 mol N yr^{-1} and 83.2 x 10^6 mol Si yr^{-1} for DIN and DSi respectively were noted in the lake. The consumption of DIN in the lake during both the seasons indicated existence of denitrification processes. From the estimated NEM values, the lake is seen as being predominantly heterotrophic, with seasonal variation in magnitude. On an annual basis, NEM is -8.29 mol C m^{-2} yr^{-1} suggesting the prevalence of respiration processes in the lake. For carbon species, an addition of 0.62 x 10^9 mol C yr^{-1} was recorded for the DIC budget and a removal was noticed for DOC budget.

The entire lake water column was supersaturated with both CO_2 and CH_4 during both seasons, and spatial variation was significant for CO_2. Wet season saturation values for both CO_2 and CH_4 are higher compared to the dry season. Concomitantly, the air-water flux rates of these gases also follow the pattern similar to the saturation distribution in the lake. Tidal pattern of $p$$CO_2$ showed a diel variation in photosynthesis and respiration during dry season. Significant gradient of $p$$CO_2$ was observed against both the salinity and pH during both seasons. The efflux of CO_2 recorded during wet season was 268 mmol C m^{-2} d^{-1}, significantly higher than the dry season value of 107 mmol C m^{-2} d^{-1}. High spatial and seasonal variation of $p$$CO_2$ seems to be regulated by river discharge, metabolic activities, land use pattern and anthropogenic activities. Weak inverse relationship with salinity was observed for CH_4 during dry season. High CH_4 values are found in areas with high organic sediment content received through sewage wastes, industrial effluents and hydrophytes. Seasonal pattern of CH_4 showed the influence of rivers and dominance of surface runoff from the adjacent wetlands and agriculture fields as a source. Overall, the annual integrated air-water CO_2 and CH_4 fluxes from the lake are estimated to be 73.3 mol C m^{-2} yr^{-1} and 98.2 mmol C m^{-2} yr^{-1}.

Spatial distribution pattern of the sediment nutrients showed significant variation, but no significant seasonal variation was observed. Elemental ratio in sediments point to the enrichment of allochthonous organic matter in some stations. Three factors obtained from the PCA reveal distinct origins or accumulation mechanisms controlling the chemical composition in the lake. Further, Cluster analysis segregates the lake environment into three sectors with different levels of accumulation and sediment texture. It confirms that the sediment geochemistry in the lake is mainly controlled by the granulometry. Heavy metal distribution in the lake sediment follows the order Mn>Zn>Cr>Ni>Pb>Cu>Co>Cd. The results of pollution load index reveal that the sediment was heavily polluted in the northern arm and moderately polluted in the extreme end and port region of the southern arm of the lake. The ^{210}Pb-derived sedimentation rates from the cores collected in this lake are between 0.65 and 1.14 cm yr^{-1}. Textural profile along the cores reveals that different energy conditions exist in the lake. The accumulation rates of nutrients in the sediment depth profiles have been computed using sedimentation rates and their distribution is discussed. It can be seen that the decline in nutrient (C, N and P) concentration with depth may be due to the recent increase in human activities.

The lake seems to be a high potential source for both the CO_2 and CH_4 gas to the atmosphere. The stronger mineralisation of allochthonous waste from anthropogenic activities in the form of sewage and effluents transported through rivers, results in the release of higher quantities of greenhouse gases. Increased stress from human perturbation on the biogeochemical processes of this lake during the recent decade is further evidenced by the pollution load index values in the surficial sediment and the nutrient variation detected in the vertical geochemical profile.