METHANE CYCLING IN A NATURAL BRACKISH WATER LAKE

A CASE STUDYON PULICAT LAKE, SOUTH INDIA

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ABSTRACT

Concern about the steadily increasing atmospheric CH_4 concentration from terrestrial and aquatic environments has stimulated research to quantify their sources and sinks. The net flux of CH_4 to the atmosphere is controlled by the balance of CH_4 oxidation and production. Tropical natural wetlands in recent times have been of great environmental concern due to human intervention such as urbanization, intensification of agriculture etc. The present study focuses on the biogeochemical pathways of methane and its cycling from a coastal lagoon (Pulicat Lake) in South India. Two major zones viz. the algal and unvegetated, were studied in detail for CH_4 cycling in this ecosystem.

The first aspect of the study deals with the various processes of methane formation including the methanogenic stimulation by competitive and non-competitive substrates, sequential reduction of electron acceptors (SO_4, Fe) and the effect of methanogenic inhibitors on CH_4 production. Non-competitive substrates such as methanol and competitive substrates such as glucose, hydrogen and molybdate play a key role in inducing methanogenesis. A distinct increase in CH_4 production occurred with a consistent decline in SO_4 and Fe. Iron reduction was obvious only during the first 48 hrs of incubation. Dose response studies of 2-bromoethane sulfonic acid (BES) on CH_4 production showed a decrease in production rates with increasing concentrations of BES from 5mM to 100 mM in the upper (0 - 4 cm) and lower layers (10 - 20 cm). Inhibition of CH_4 production with 200 u M $CHC1_3$ and 1% CH_2F_2 showed higher suppression of CH_4 production in the unvegetated zone when compared to the algal zone.

The second aspect of the work deals with CH_4 production along the profile and *in vitro* CH_4 production by algae/sea grass and sediment slurries. The active methane-producing zones were found to be in the upper sediment layer (0-2 cm) with a cumulative rate of 0.084 and 0.056 nmol $gdwt^{-1}$ h^{-1} $layer^{-1}$) in the unvegetated and algal zones respectively. Soil temperature and organic matter showed a positive correlation with CH_4 production rates while redox potential, dissolved oxygen, salinity and sulfate showed a negative correlation. Higher CH_4 production rates were observed in the green algae (1.01 nmol $gdwt^{-1}$ h^{-1}) when compared to sea grass (0.468 nmol $gdwt^{-1}$ h^{-1}). The green algae were subjected to a salinity range varying from 0‰ (fresh water) to 45‰ (hypersaline) in addition to a control. The order of increasing production was in the salinity range of ***45‰*** < 35‰ < ***25‰*** < ***15‰*** < ***7‰*** < freshwater < control. *In vitro* CH_4 production rates in the sediment slurries in the upper layers (0-2 and 2-4 cm) bear significant correlation with the results obtained in the vertical profile and CH_4 in soil pore water. Production rates were higher in the lower salinity ranges as observed for the algal treatments.

The third aspect of the research work provides an insight into the phenomenon of CH_4 oxidation (in *vitro)* in the algae/sea grass and sediment upper layers (0-2 and 2-4 cm). High CH_4 consumption rate was observed in the control for *Chaetomorpha* (77%) when compared to *Halophila ovalis* (66%). CH_4 consumption was extremely high on treatment with seawater in the sea grass when compared to the green algae. High consumption rates are attributed to the suppression of CH_4 production at high salinity ranges and increased respiration of algae/sea grass, releases sufficient oxygen to aid CH_4 oxidation. In the sediment slurries treated with seawater, it was observed that the algal zone exhibited high oxidation potential when compared to the unvegetated zone during summer while it was the reverse during monsoon. The CH_4 oxidation in the algae and sea grass of Pulicat Lake followed a typical Michaelis-Menten saturation curve during post-monsoon. A K_m value > 9000 ppmv was observed which is in the range observed for methanotrophic bacteria (590 to 54,100 ppmv) indicating its presence in the algae/sea grass.

Finally, the spatial and temporal variation of CH_4 fluxes have been measured. Spatially, the concentrations of CH_4 in both dissolved form and in soil pore water were higher

within the lake ecosystem in comparison to the Buckingham Canal and the Bay of Bengal. Dissolved CH_4 was negatively correlated with salinity (-0.63) and sulfate (-0.7), while soil pore water CH_4 concentrations showed positive correlation with H_2S (>0.8) and with total organic carbon and nitrogen in soil. The temporal variations of CH4 fluxes were studied as (i) chamber fluxes from the sediment-water interface; and (ii) bubble ebullition and (iii) sediment core fluxes from the boundary layer. The CH_4 fluxes were high in the unvegetated zone when compared to the algal zone. The annual $_{CH4}$ emission from Pulicat Lake was 0.026 x 10^9 g yr^{-1} ranging from 0.005 to 0.011 x 10^9 g yr^{-1}. Based on the minimum and maximum values of CH_4 emission obtained from Pulicat Lake, a first order estimate of 0.012 to 0.024 Tg CH4 yr^{-1} is predicted to be emitted from the lagoonal ecosystems of India. The bubble ebullition rates were found to be high in the unvegetated zone (82% during summer) when compared to the algal zone. The aerobic-anaerobic flux (control) rates displayed a lower oxidation potential in the algal zone (42%) when compared to the unvegetated zone (45%). Similarly, the inhibition of CH_4 flux by CH_2F_2 under aerobic conditions revealed lower emission rates in the algal zone compared to the unvegetated zone and the percentage of CH_4 oxidized was similar to that observed in the control.

To summarize, the Pulicat Lake contributes only a minor source of CH_4 to the atmosphere. The data obtained from the lake was used to compute the emission inventory for the lakes occurring globally and is found to range from 0.7 to 1.35 Tg CH_4 $yr^{-}1$. **C**H_4 production was found to be very low, and the active methane-producing zones were restricted to the top 4 cm of the sediment. CH_4 consumption was high possibly due to the suppression of CH_4 production at high salinity ranges, increased respiration of algae/sea grass and bioturbation. The unvegetated zone showed higher production, emission and bubble ebullition rates when compared to the algal zone.

Thus, on an overall basis, CH_4 production and emission continued to occur in the Pulicat Lake sediments. Increases in the concentration of CH_4 can be expected in the future if there is a continuation of the current rate of human change due to intensified human mediated disturbances .