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METHANE FLUXES IN A SHALLOW EUTROPHICATED NATURAL WETLAND AND TROPICAL DRY DECIDUOUS FOREST UNDER INFLUENCING FACTORS IN WESTERN MADHYA PRADESH

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ABSTRACT

Fluxes of methane (CH_4) were measured in situ monthly for two years from a tropical shallow urban pond, receiving influx of agriculture run-off from the surrounding water shed and domestic sewage, located in Ujjain city, Madhya Pradesh. The Tropical Dry Deciduous Forest dominated by *Tectona grandis* (Teak plants) is located 20Km southwards from Indore. Results revealed that the shallow pond is a continuous source of (CH_4) with highest annual methane emission rates (mean 4308.15 Kg ha^{-1} yr^{-1}). In contrast to Wetland, the natural site Tropical Dry Deciduous forest is found to be the strongest sink for methane showing annual methane consumption rates (mean -20.35,-24.55 Kg ha^{-1} yr^{-1}). Several influencing factors like pH, temperature, inorganic nitrogen and organic carbon were studied concomitantly with CH_4 fluxes. CH_4 emissions were positively and significantly correlated with sediment organic matter in wetland and soil moisture in the forest. The study conclude that the shallow tropical water body is a source of CH_4 flux and also point out the importance of natural plant community as key player to act as sink for methane, the important green house gas.

KEYWORDS : Methane, Wetland, Deciduous Forest, Sink, Source

Methane is the abundant organic gas in the atmosphere. It plays an important role in the photochemical reactions of the troposphere and the stratosphere, and changes of its concentration exert a strong influence over the atmospheric chemistry (Thompson and Cicerone, 1986). In addition methane is so called greenhouse gas which has strong absorption bands and trap part of the thermal radiation from the earth's surface (Wang et al, 1976). Although atmospheric methane concentration is about 200 times less than CO_2 it contributes approximately 15% to current "greenhouse" forcing in the atmosphere (Hansen et al, 1989). This is because CH_4 is about 30 times more effective as CO_2 in absorbing infrared (IR) radiation. The atmospheric concentration of this gas has been doubled during the past 200 years, rising over the past 15 years by average of 1% per year (Rudolph, 1994) although slowing down of this growth rate was reported recently (Dlugokencky et al., 1994). Wetlands are the largest single source of atmospheric methane (Meng et al., 2012). Although the major sink for atmospheric methane is its chemical reaction with hydroxyl radicals in the atmosphere (IPCC, 1996) uptake of ambient methane by some soils could be an additional significant sink, representing 1-15% of that oxidized by reaction with hydroxyl radical (Wuebbles and Edmonds, 1991). The residence time of methane in the atmosphere is about 10-20 year (Cicerone & Oremland, 1988). Methane is produced in soil by methanogenic bacteria and is oxidized by methanotrophic bacteria. The study aims to: (i) Quantify methane fluxes periodically in urban shallow pond and forest habitat. (ii) Monitoring physico-chemical factors influencing methane flux in the water column, sediment and soil interface.

MATERIALS AND METHODS

For the study of CH_4 flux measurement in the aquatic ecosystem, We considered the shallow, eutrophicated Solah Sagar Pond, which is a natural and perennial water body situated on Ujjain Sagar road, 5 km from Ujjain city (230 11' N lat and 750 43' E long and 491.7 m amsl). Madhya Pradesh, Central India. The pond is shallow at the margins and the depth gradually increases towards the central area, attaining a maximum depth of approximately 3.5m. The surface area of the pond is about 65,918 m^2 during the rainy season when it is completely filled. It harbours almost natural water, except receiving domestic urban waste water through the earthen channel and agriculture drained water. Basically the pond has been utilized on a lease system for the cultivation of water chestnut (*Trapa bispinosa*, family Trapaceae) and fish farming by the local fisherman (Bhoi) (Billore S.K. et al, 1998). The wetland is kept idle for 1-2 months between weed (*E. crassipes*) removal and crop (*Trapa bispinosa*) sowing. During this period an intensive

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growth of *Ceratophyllum demersum* (submerged plant) and *Lemna minor* (free-floating plant) occurred. The study site Simrol Forest comes under Indore forest division of Madhya Pradesh situated about 110 km away from Ujjain. The forest is Tropical Dry Deciduous Type and is mostly confined to hilly terrains of Deccan plateau. The soil is deep to moderately black cotton soil in plains and valleys. The density of teak forest is moderate varying from 0.6 to 0.8 through stocking of 0.9 densities and above is also noticed in valleys and banks of streams. The average height of tree varied from 19 to 20 meters. *Tectona grandis* enjoys the status of dominant species. Other associates include *Hardwickia binata, Acacia caesia, Sehima sulcatum,* etc. The climate of Ujjain and Indore area is typically monsoonal with hot summer (May-June) and cold winter (January-February). The year can be divided into summer, Rainy and winter seasons. The mean monthly maximum temperature varied from 21.0, 27.5°C (January) to 36.5°C, 46.5°C (May) and the mean minimum temperature varied from 13.0, 9.7°C (January) to 29.50C, 25.8°C (May). Average rainfall amounted to 1015 and 1111.0 mm during the study period.

Sampling Technique

Gas samplings were carried out using closed chamber technique as standardized by National Physical Laboratory (NPL), New Delhi (Parashar, D.C. Gupta et al, 1993). In wetland, a circular motorcycle rubber tube filled with air was attached to the bottom rim of a transparent Perspex chamber made from 6 mm plexi glass sheet to make it float on the surface of the water. The chamber cover is fitted with a sampling port ad a port to which a plastic pressing pump is attached for uniform mixing of air inside the chamber. The sampling port is a hole plugged with a rubber septum through which a 50 ml glass syringe was inserted with hypodermic needle to collect gas samples from the chamber. Gas samples were transferred to pre evacuated, sealed glass vials of 100 ml volume at 0, 10, 20 and 30 min intervals and ambient air sample was also collected near the chamber to compare with 0 min flux at the time of calculation. In the forest aluminium base (54L × 33W × 10H cm) with internal groove size (48L × 27W × 2H cm) were installed manually. The base was embedded in the soil a few hours in advance to ensure that ambient soil atmosphere was maintained in a stabilized condition. The airtight Perspex chamber (50L×30W×50H cm) which fitted into the groove of the aluminium base was put in place at the time of sampling covering an area of $0.1765 m^{-2}$. The air inside the chamber was isolated from the outside atmosphere and the system was made airtight by filling the groove in the aluminium base with water. Flux measurements were made in the late morning at 10 am and afternoon by 3 pm on each sampling day. The temperature inside the Perspex chamber was recorded at the time of sample collection (0, 10, 20, 30 min) using a thermometer (-10 to100^0C range, Co Immersion Zeal, England) fixed on the inside wall of the chamber for calculation of box volume at STP. Water temperature was also measured with a thermometer adjacent to the chamber. The collected gas samples in 100 ml glass vials were brought to the laboratory and analyzed for CH_4 on a gas chromatograph (Nucon series 5700, India) equipped with a Flame Ionization Detector (F.I.D) and a column of stainless steel 1/8" O.D.× 6 feet length packed with molecular sieve 5A, 60/80 mesh column. Injector and detector temperature were maintained at 80,110 and 110^0C respectively. The gas chromatograph was attached with integrator (Oracle 3). Ultrapure nitrogen served as carrier gas (flow rate 30 ml min^{-1}). Hydrogen was taken as the fuel gas and zero air as the supporting gas with flow rates of 30ml min^{-1} and 300 ml min^{-1} respectively. Gas chromatograph was calibrated by repeated injections of methane standards in the nitrogen and ambient air samples. After confirming the peak and retention time for methane in ambient samples, collected gas samples were analysed for methane. Gas chromatograph was also calibrated before and after each set of measurement. Samples analysed at Vikram University were authenticated (in aliquot) at NPL for reconfirmation.

CH_4 Fluxes were calculated as:

CH_4 flux $F(mg\ m^{-2}h^{-1}) = BV_{STP} \times \Delta CH_4 \times 16 \times 1000 \times 60/10^6 \times 22400 \times A \times t$

Where BV_{STP} (Chamber air volume in cc at STP) = $BV \times B.P \times 273/(273+T) \times 760$

Box Volume (BV)= [(H-h) LW-Biomass volume inside box)

Where H= Chamber height, h= channel above soil /chamber above water level

L= chamber length (cm), W=chamber width (cm), B.P= Barometric pressure (mm hg)

T= chamber air temperature at the time of sampling (^{0}C)

Δ CH_4 = change in CH_4 concentration in ppmv from zero minute to the t minute sampling

A= area covered by the box (m^2), t = time in minutes

The physico-chemical characteristics of wetland sediment, water column and forest soil were also analysed. Organic carbon in sediment and soil sample was estimated by dichromate oxidation and titration with ferrous ammonium sulphate. pH was measured using a pH meter equipped with glass electrode (1:25 soil : water ratio, w/v)

RESULTS AND DISCUSSION

The periodic CH_4 flux in the Eutrophicated wetland ecosystem (Solah Sagar Pond) during the 2 years ranged from 718.08 to 2085.39 mg m^{-2} d^{-1} (Fig. 1a). Higher methane emission occurred during the summer and lower during the winter season. Water temperature in the surface 5cm water column ranged from 17 to 31^{0}C, while average temperature was almost same during summer and rainy season, and 9^{0}C lower during winter. Dissolved oxygen in the water column varied from 3.50 to 6.00 mg l^{-1}. Organic matter in the wetland sediment ranged from 4.29% to 6.24%. In the forest soil organic matter varied from 1.03 % to 1.29% respectively whereas soil moisture ranged from 25.00 to 39.50 % d.w. (Table1)

Table 1: Physico-Chemical characteristics of Wetland water column, sediment and forest soil

Parameters		Summer	Rainy	Winter
Pond Water	Water Temperature(^{0}C)	30.50 (2.88)	32.50 (2.00)	20.50 (1.70)
	Dissolved oxygen (mgl $^{-1}$)	3.50 (0.38)	6.00 (0.20)	5.00 (0.45)
	Organic C (mg l^{-1})	780.00 (26.00)	660.00 (21.00)	795.00 (30.00)
	NH_4^+N (mg l^{-1})	1.00 (0.05)	4.90 (2.50)	3.78 (0.60)
Pond Sediment	Sediment pH	7.90 (0.29)	8.20 (0.62)	7.80 (0.13)
	Organic Matter (%)	6.24 (0.81)	5.51 (0.57)	4.29 (0.82)
	NH_4^+-N (mg N 100g^{-1} ODS)	22.50 (6.41)	12.30 (1.94)	20.70 (1.60)
	NO_3^-N (mg N 100g^{-1} ODS)	2.25 (0.44)	4.24 (2.49)	3.75 (0.62)
Forest Soil	Soil Temp(^{0}C)	39.50 (5.75)	28.50 (0.52)	25.00 (1.51)
	Soil Moisture (% d.w.)	10.51 (3.84)	25.31 (1.81)	21.46 (2.08)
	Organic Matter (%)	1.29 (0.02)	1.03 (0.01)	1.13(0.02)
	Microbial Biomass C (mg C 100g^{-1} ODS)	32.17 (5.06)	24.88 (1.24)	-102.98(1.32)

ODS, Oven dry Soil: Values in parenthesis are Standard Deviation

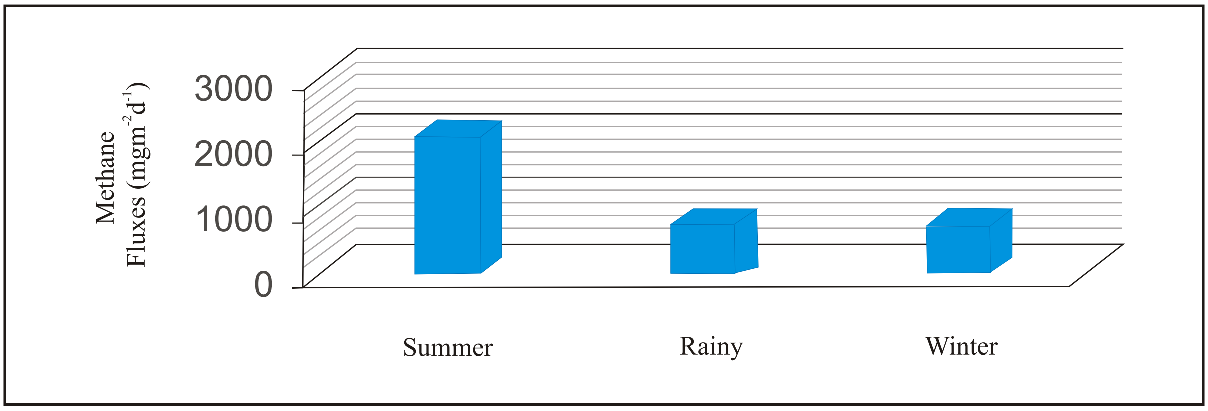

Figure 1(a): Seasonal variations in methane fluxes in wetland

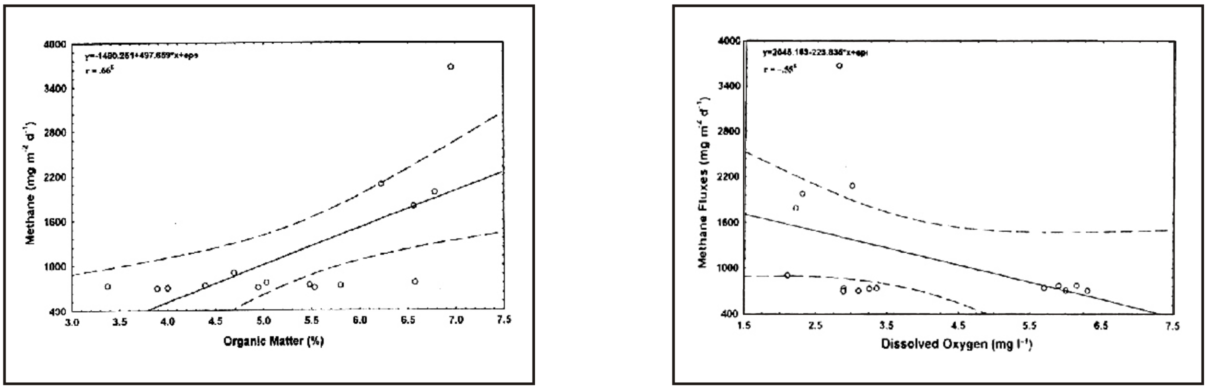

Fig. 1(b,c): Relationship between CH_4 fluxes vs b) sediment organic matter and c) dissolved oxygen Dotted curves show the 95% confidence interval for the regression

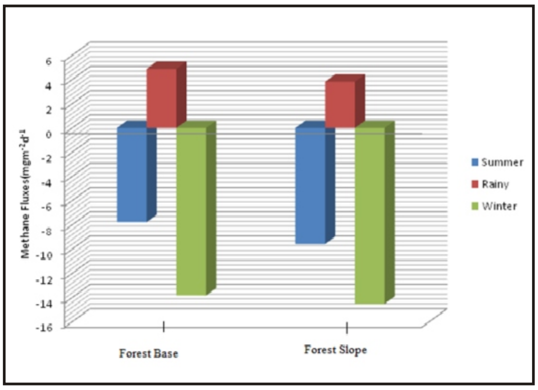

Fig. 2 (a): Seasonal variations in methane fluxes in forest soil. Positive values revealing the emission trend and negative the methane consumption

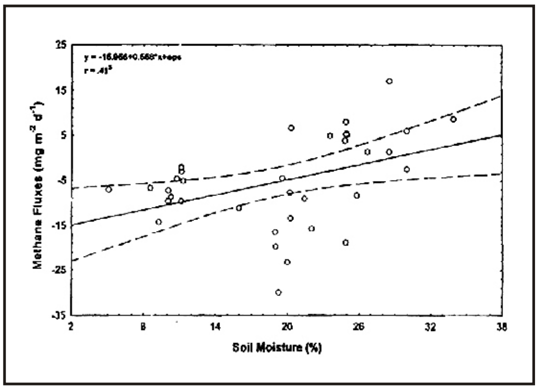

Fig. 2 (b): Relationship between Soil moisture (%) and methane fluxes. Dotted curves show the 95% confidence interval for the regression

Regression analysis indicated significant positive correlation between sediment organic matter Vs. Methane fluxes ($r=0.66, p<0.05, n=15$) (Fig 1 b). Significant negative correlation was observed between dissolved oxygen in water column Vs methane fluxes ($r= -0.55, p<0.05, n=15$) (Fig. 1c). Methane fluxes in forest base and slope ranged -7.78 to 4.88 and -9.58 to 3.82 mg m^{-2} d^{-1} (Fig. 2a). The results indicated that the methane emission occurred during the rainy season (4.88, 3.82 mg m^{-2} d^{-1}) due to anaerobic condition developed on account of days continuously raining for several times, a condition favourable for the methane producing bacteria. In contrast to rainy season, soil remained dry and oxic during summer and winter season, a condition favourable for the functioning of methane consuming bacteria (methanotrophs) attributing to methane consumption during the two seasons. Forest slope showed higher methane consumption than base. Significant negative correlation was observed between soil organic matter Vs methane fluxes ($r = -0.40, p<0.05, n=36$) while significant positive correlation was observed between microbial biomass carbon, NH_4^+N, NO^{-3} N Vs methane fluxes ($r=0.47, p<0.05, n=36; r=0.35, p<0.05, n=36; r=0.47, p<0.05, n=36$) respectively. Soil moisture showed significant positive correlation with methane fluxes ($r=0.41, p<0.05, n=36$) (Fig.2b). Solah Sagar Wetland remained dominantly covered by water chestnut and other free floating submerged and emergent macrophytes throughout the year. These aquatic macrophytes besides their biomass components such as leaves and other plant parts during plant ageing also release organic material by root system (root exudates) to the sediment system which is converted to organic substrates for methane producing bacteria during summer season as temperature increase [ambient 30.5-36.5^{0}C, water column 32.5^{0}c] so did the level of microbial activity, which increased decomposition of organic matter and supply of substrate for methanogens. Optimum temperature for methanogenesis lies between 30-33^{0}C (Oremland 1988). In contrast lower methane production during rainy and winter season attributed to a) relatively low temperature in the rainy and winter seasons, reduced microbial activity slow down the decomposition and supply of substrates for methanogens. b) active growth of the overlying vegetation during rainy and winter season keeping the upper layer of water column as photosynthetic (aerobic) and also the oxidative stage in the rhizosphere which causes methane oxidation. (Burke et al, 1988) also observed lower CH_4 emission rates in denser vegetation which may be due to a greater amount of O_2 transporting to the soil via plants to cause a high CH_4 oxidation rate turbulence due to monsoon rains and wind currents attributed lower rates of methane emission in the rainy and winter seasons. In the forest, methane uptake has been attributed to oxidation of methane by methanotrophic bacteria to methanol by the enzyme methane monoxygenase which is further oxidized by means of dehydrogenases and the bacterial electron respiratory chain to CO_2 (Conrad, 1989). The Simrol forest soil is a drained soil silty clay loam to silty clay. The clay content is 36%. The soil pores spaces in forest sites being replaced by rain water during rainy season on account of days receiving rains and idealistic for an anaerobic conditions. Soil water content increased to 25.31% during rainy season organic matter received on the forest floors in the form of litter during earlier season started decomposing during the rainy season. This decreases the oxygen concentration in soil atmosphere. Rainfall also stimulates heterotrophic activity in soils, decreases the soil oxygen concentration which is an important regulator of methane. A decrease in soil oxygen concentration, results in anaerobic conditions. The methane producing bacteria becomes active in anoxic environment hence leading to methane emission during the rainy season as compared to negative fluxes during the summer and winter season. The study concludes that Wetlands are the largest source of methane emission. The in-situ built up and decomposing organic matter in the sediment plus optimum methanogenesis boost up the fluxes. Mitigation strategies should be adopted. The importance of natural plant communities as key player to act as sink for methane. The natural system forest should be maintained to control methane fluxes and in turn global warming.

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