Day-time variation in methane emission from two tropical urban wetlands in Chennai, Tamil Nadu, India

Anuradha Verma, V. Subramanian†, R. Ramesh*

School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110 067, India

*Centre for Ocean Management, Anna University, Chennai 600 025, India

Methane emissions from two wetland habitats in Adyar wetlands, on the East Coast were measured during August 1996. Flux data shows that each habitat is a major contributor of methane to the atmosphere. Diurnal variation in emissions was also observed at both the sites. The methane emission was found to be correlated to the soil temperature (integrated to 5 cm). Sulphate concentration and salinity are negatively correlated to the methane emission. The average emission from the Buckingham Canal, a polluted urban freshwater canal, is 30.81 ± 11.15 mg CH_4 m^{-2} h^{-1} and from Adyar Estuary, a degraded mangrove forest, is 39.1 ± 3.28 mg CH_4 m^{-2} h^{-1}.

NATURAL wetlands are estimated to contribute up to 115 Tg of methane per year, which is 21% of the total global emissions[1]. Methane emissions from wetlands show high variability spatially as well as temporally in response to environmental variables as solar radiation, rainfall, salinity, etc. Tropical and sub-tropical swamps represent ~ 30% of global wetlands and produce about 25% of total emissions[2].

A few researches have been carried out in tropics with regard to methane emissions from Wetlands[3-5]. The methane emissions from coastal wetlands of Chennai, East coast of India have been reported earlier with an annual methane emission ranging from 0.02 to 3.20 Tg of methane per year[6,7]. Day-time variation has not been studied so far.

In this work we are reporting our studies on the day-time variation in methane efflux for the same locations reported earlier[6,7]. This will help in understanding the trend of methane emission during the day from these locations. Methane flux data collected in August 1996 in two locations in Adyar wetlands are presented here. This investigation quantifies the day-time methane flux in polluted freshwater canal and an estuary.

The study site is located in Chennai, Tamil Nadu, on the southeast coast of India (Figure 1 *a*, inset). The major waterways in the city are the Cooum and the Adyar Rivers and Buckingham Canal. The Adyar River carries sludge and storm waters and wastes from industrial establishments, slaughterhouses and laundries. The mouth of the river is closed by littoral drift of sand forming a lagoon. The Buckingham Canal, was built parallel to the coast as a salt-water navigation canal. The canal links the mouth of Cooum and Adyar Rivers over a stretch of 8 km. The canal is heavily silted and carries sewage, sludge and urban garbage. One site is located in Adyar Estuary and the other in Buckingham Canal.

For the collection of material, gas samples from the sediment–water interface were collected using 'Closed Chamber' technique[8]. The gas collected was stored and transported in a number of vials and sealed immediately after collection. Triplicate for each sample was made. The perspex chamber inserted had a base of 12″ × 12″ × 3″ and chamber of 12″ × 12″ × 18″ dimensions. The perspex chamber was placed over the base inserted into the sediment column to trap the gases emitting from the sediment–water interface. The base was embedded in the sediment a few hours in advance to ensure that the ambient soil environment is maintained. The gas so collected in the chamber was transferred to the sampling bottles by displacement of water from the sampling bottle by gas from the chamber. The collected gas was stored and transported in glass vials of volume 5 ml (ref. 9). The samples were collected at regular intervals of one hour starting from the time the chamber was placed during the course of the day. The sediment temperature at 5 cm below sediment and atmospheric temperature were also continuously monitored.

The gas samples were analysed in the laboratory at Anna University within 24 h of sampling, using a Hewlett Packard gas chromatograph (GC, model: HP 5890). Column, injector and detector temperatures were maintained at 80°C, 100°C and 90°C respectively, with a flow rate of 30 ml min^{-1}, high purity argon was used as the carrier gas. The gas chromatograph was calibrated, before and after each set of measurement, using 1 ppm CH_4 in N_2 obtained from M/s Mathesons, USA, as primary standard and 2.04 ppm, 2.81 ppm and 10.9 ppm CH_4 in N_2 as secondary standards, obtained from the National Physical Laboratory, New Delhi. Under these conditions, the retention time of CH_4 was 0.65 min and minimum detectable limit was 0.5 ppm. The gas flux was calculated using the formula:

$$F = \frac{\Delta x}{10^6} \times BV_{(STP)} \times \frac{16 \times 10^{-3}}{22400} \times \frac{1}{A} \times \frac{60}{t},$$

where,

F = efflux of methane in mg/m²/h; Δx = change in concentration of methane in ppmv from time '0' min to 't' min;

$$\Delta x = \frac{\text{standard concentration of methane}}{\text{area obtained in GC for standard}} \times \text{area}$$

obtained in gas chromatograph for sample;

†For correspondence. (e-mail: subra@jnuniv.ernet.in)

$BV_{(STP)}$ = box volume at standard temperature and pressure in cm^3; A = area of the box.

Salinity and sulphate were analysed using standard methods[10]. Sediment organic carbon was determined using Eltra carbon analyser.

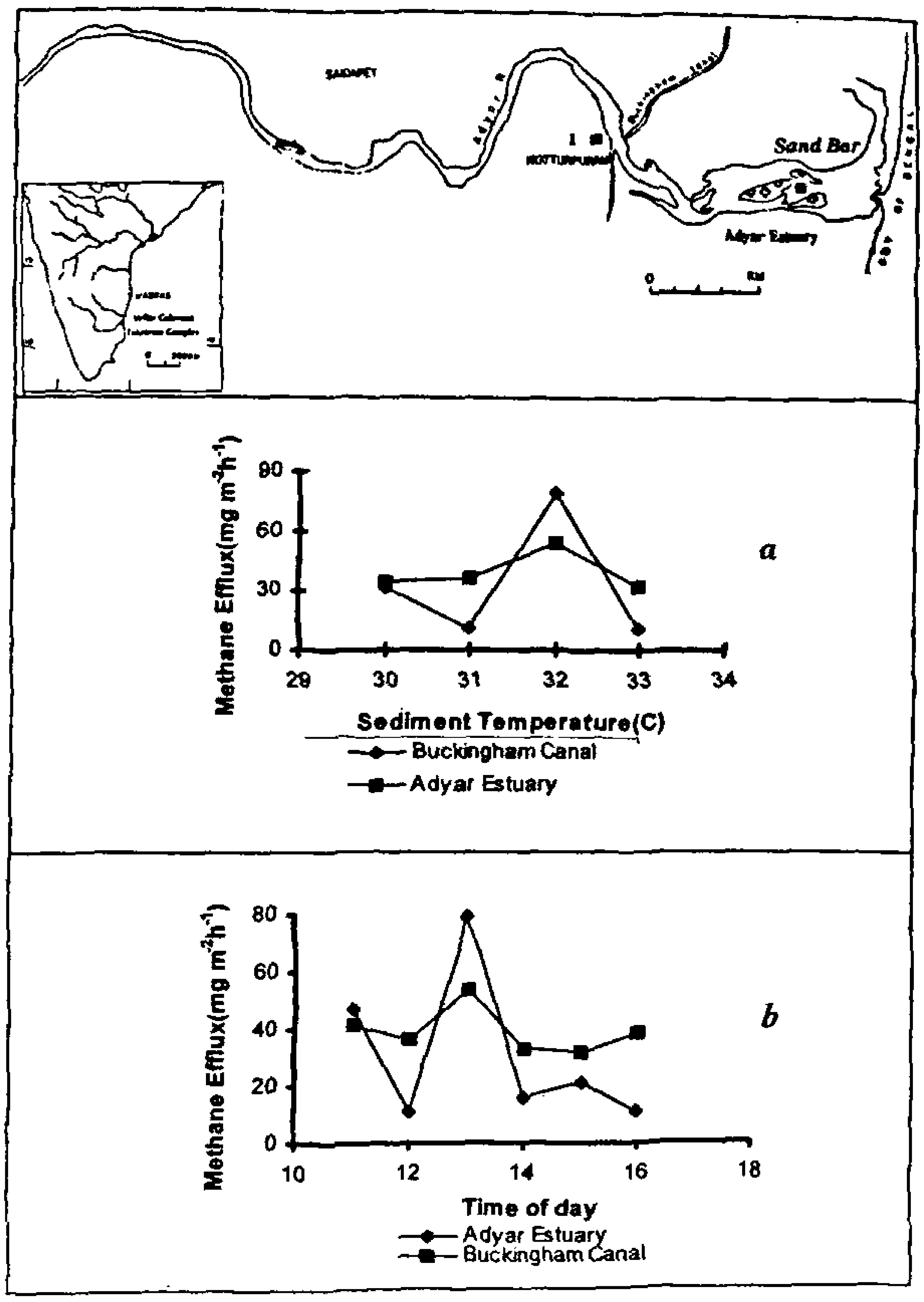

Figure 1. Inset of sampling locations. 1. Kotturpuram (Buckingham Canal). 2. Thesophical Estate (Adyar Estuary). *a*, Variation in methane efflux with sediment temperature. *b*, Diurnal variation in methane efflux.

During monitoring of the methane efflux, while air temperature in the chamber ranged from 31.5°C to 35°C, the sediment temperature ranged from 30°C to 33°C at 5 cm depth from the surface, at both Buckingham Canal and Adyar Estuary.

Methane flux from the sediments was highly variable during the day, both at the Buckingham Canal site and at the Adyar Estuary site (Table 1). At both the locations the peak emission occurred at 13 h when the temperature of sediment was 32°C (Figures 1 *a* and *b*). This effect can be related to the increase in sediment temperature due to solar radiation. Soil temperature highly effects the activity of soil microorganisms and the optimum temperature for methanogens is between 30°C to 33°C (ref. 7). Another effect likely is the plant-mediated effect. The vegetation acts as gas conduits for the emission[11]. The gas transport process in plants is dominated by pressurized bulk flow ventilation driven by solar illumination, which is maximum at noon as observed in the study area. After 13 h as the sediment temperature increased, methane efflux decreased. This is probably due to exceeding of optimum temperature for the microbes.

Silt and clay with 14.6% organic carbon dominate Buckingham Canal sediment. The methane emission at this site is by sporadic ebullitive releases of methane from the sediment, hence a wide range in emission values has been obtained. Adyar Estuary soil is dominated by sand and has 6.54% organic carbon in the first 5 cm of the sediments. Thus, there is a continuous emission of methane from the soil and consequently the range in methane efflux values is low. Thus it appears that sediment texture may be an important factor in gas emissions.

Sulphate content in Adyar Estuary is high, ranging from 2400 to 3200 mg l^{-1}. This is due to tidal influence and partially due to pollution from domestic and industrial effluents. Sulphate content in Buckingham Canal is about 170 mg l^{-1}, which is mainly due to domestic and

Table 1. Variation in sediment temperature and methane efflux during the day

	Buckingham Canal sediment C% = 14.6			Adyar Estuary sediment C% = 6.45		
Time (hours)	Sediment temp. (degree celsius)	Methane efflux ($mg\ m^{-2}\ h^{-1}$)	Water level (cm)	Sediment temp. (degree celsius)	Methane efflux ($mg\ m^{-2}\ h^{-1}$)	Water level (cm)
11.00	30.0	46.83	12.3	30.0	41.26	17.1
12.00	31.0	10.77	11.7	31.0	36.23	15.3
13.00	32.0	78.98	10.5	32.0	53.95	15.0
14.00	32.2	15.91	8.4	32.5	33.05	14.7
15.00	32.5	21.63	10.7	33.0	31.82	14.0
16.00	33.0	10.77	10.7	33.5	38.34	16.0
Mean		30.82			39.11	
Standard deviation		27.15			8.04	
Standard error		11.15			3.28	
CV		88.12%			20.57%	

industrial effluents. Sulphate shows negative correlation with methane emission.

Salinity also shows a negative correlation with methane emission. Salinity is low at Buckingham Canal (0.2 ppt) suggesting no marine influence, but in contrast Adyar estuary (13.93 ppt) has high salinity, thereby showing strong tidal influence. High salinity and sulphate concentration increases competitive interactions of sulphur-reducing bacteria and methanogens. These microbes compete for methane precursors in anaerobic environment[7]. Thus, a higher peak value of methane emission is obtained at Buckingham Canal (78.98 mg $CH_4\,m^{-2}\,h^{-1}$) than at Adyar Estuary (53.95 mg $CH_4\,m^{-2}\,h^{-1}$), at 13 h. But the average high methane efflux in estuary is due to high organic matter content in coastal wetlands of Madras city, a symbiotic co-existence of methanogens and sulphate-reducers[8].

Lower methane emission values in late afternoon at both the sites is due to increase in sediment temperature over the optimum value. Another reason is fall in the water level in the waterways due to low tide, which results in aeration of surface waters and may effect the activity of methanogens in the sediment.

Methane emission values from this study cannot be compared with the values obtained at the same sites by the earlier workers[8] because of different time and day of sampling. The values reported earlier[8] for August 1993–94 for Adyar Estuary is 23.24 ± 0.40 mg $CH_4\,m^{-2}\,h^{-1}$ and for Buckingham Canal is 2.73 ± 0.14 mg $CH_4\,m^{-2}\,h^{-1}$. These values are lower than found in the present study. The probable reason for this year-to-year variation in methane emission values could be due to different environmental conditions at the time of sampling. Further, the values reported earlier[8] are average of fortnightly sampling. The values reported in this paper can be considered to be representative of methane efflux at the study sites on 13–14 August 1996.

Thus, sediment temperature, solar radiation and time of day influence day-time variation in the methane emission in wetlands. Site-specific variability in the emission is due to variation in soil properties, organic matter, salinity and sulphate concentration. Thus for assessing the methane emissions from a wetland, diurnal variations should be considered to provide reliable values. Further refinement of these data needs to be done to understand the dial and spatial variations in methane emissions from an urban wetland that has strong anthropogenic influences, and hence site-specific complexity due to pollutant quality and quantity.

1. Bartlett, K. B. and Harris, R. C., *Chemosphere*, 1993, **26**, 261–320.
2. Mathews, E. and Fung, I., *Global Biogeochemical Cycles*, 1987, **1**, 61–86.
3. Neue, H. U., Wassmann, R., Lantin, R. S., Alberto Ma, C. R., Aduna, J. B. and Javellana, A. M., *Atmos. Environ.*, 1996, **30**, 1751–1754.
4. Gupta, M., Verma, S. D., Parashar, D. C. and Gupta, P. K., *Indian J. Radio Space Phys.*, 1994, **23**, 265–268.
5. Parashar, D. C., Gupta, P. K., Rai, J., Sharma, R. C. and Singh, N., *Chemosphere*, 1993, **26**, 247–250.
6. Purvaja, G. R. and Ramesh, R., Proceedings of International Workshop on Environmental Biogeochemistry, Jawaharlal Nehru University, New Delhi, 1998, pp. 331–346.
7. Ramesh, R., Purvaja, G. R., Parashar, D. C., Gupta, P. K. and Mitra, A. P., *Ambio*, 1997, **26-6**, 369–374.
8. International Atomic Energy Agency Technical Document, IAEA-TECHDOC-674, 1992, pp. 45–84.
9. Subramanian, V. and Verma, A., Patent applied for Govt. of India, 29 July 1998.
10. Alford, D. P., Delaune, R. D. and Lindau, C. W., *Biogeochemistry*, 1997, **37**, 227–236.
11. Sass, R. L., Fisher, F. M., Lewis, S. T., Turner, F. and Jund, M. F., *Global Biogeochem. Cycles*, 1994, **6**, 249–262.

Received 25 October 1998; revised accepted 10 December 1998

Evidence of human occupation and humid climate of 30 Ka in the alluvium of southern Ganga Plain

Indra Bir Singh*[‡], Shikha Sharma*, Maneesh Sharma*, Pradeep Srivastava* and Govindaraja Rajagopalan[†]

*Department of Geology, Lucknow University, Lucknow 226 007, India
[†]Birbal Sahni Institute of Palaeobotany, Lucknow 226 007, India

A stratigraphic horizon in the cliff of Yamuna river at Kalpi has yielded rich vertebrate fossils, namely an elephant tusk (3.54 m long), shoulder blade of elephant, molars of *equus*, *bovids*, *bos*, etc. along with fragments of bones showing definite evidence of human workmanship. Human femurs with unique pencil sharpening are also found in the calcrete conglomerate in Yamuna river bed, which are time equivalent to above horizon. This horizon represents deposit of humid climate around 30 Ka, and is affected by intense seismic event. This is so far the oldest human occupation site in the Ganga Plain.

GANGA Plain Foreland Basin is an actively subsiding basin with a wedge-shaped sediment fill, thinning towards the cratonic southern margin[1]. There is also evidence of upwarping in the peripheral bulge towards the cratonic margin, where rivers have responded by making deep incision[1-3]. There are evidences of neotectonic activity in the form of bending and tilting of beds, block movements, and conjugate system of faults during Middle to Late Holocene[4]. The rivers of southern part of the

[‡]For correspondence