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Short term diurnal and temporal measurement of methane emission in relation to organic carbon, phosphate and sulphate content of two rice fields of central Gujarat, India

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Abstract: *Methane emission from two rice fields of Lambhvel village, Anand district, central Gujarat, India, was measured for whole cultivation period during pre-summer season. Along with the methane emission, soil chemistry of the two rice fields (Organic carbon, PO_4^{-2} and SO_4^{-2}) was determined. The methane emission ranged from 105.67 to 720.64 mg $m^{-2}hr^{-1}$, having maximum emission during noon period (11 am to 1 pm) of the day at the rice field 1. Besides, at rice field 2, the methane emission ranged between 201.59 to 430.94 mg $m^{-2}hr^{-1}$, having maximum peak during same period (11 am to 1 pm) of the day. The results of the current investigation confirm that the methane emission vary substantially between two rice fields, and suggest that soil chemistry and flood water depth might control the methane emission in both the rice fields and suppressed by the phosphate and sulphate concentrations. The greater methane emission was gradually declined from first trip to fourth trip. Correlation analysis, ANOVA and F-test showed that the methane emission from both the sites has positive correlation with organic carbon and negative correlation with sulfate and phosphate content of the soil and the details of these reasons are discussed in this paper.*

Key words: *Methane emission, Rice fields, Soil organic carbon, Phosphate, Sulphate*

PDF of full length paper is available with author ***(*istares2005@yahoo.com)***

Introduction

Wetland rice fields have recently been identified as major source of atmosphere methane. Atmospheric methane (CH_4) is recognized as one of the most important greenhouse gases. Flooding rice field cuts off the oxygen supply from the atmosphere to the soil, which results in anaerobic fermentation of soil organic matter. Methane is a major end product of anaerobic fermentation of organic matter (Dubey, 2001). It is released from submerged soils to the atmosphere by diffusion and ebullition and through roots and stems of rice plants. Recent global estimates of emission rates from wetland rice fields range from 20 to Tg/yr (IPCC, 1992), which corresponds to 6-29% of the total annual anthropogenic methane emission. Once in the atmosphere, methane absorbs terrestrial infrared radiation that would otherwise escape to space. This property can contribute to the warming of the atmosphere. Besides, methane (CH_4) contributes 15-20% to the global warming (IPCC, 1996) and has an atmospheric lifetime of 12 ± 3 years and a Global Warming Potential (GWP) of 23 over 100 years (IPCC, 1996). Methane concentrations have more than doubled since the pre-industrial era(Dentener *et al.,* 2005).The largest present anthropogenic sources of methane are rice fields, cattle and biomass burning (Khalil and Shearer, 2000).

Rice cultivation is an important agricultural priority worldwide, because rice is the major cereal crop, feeding two-thirds of the global population and is expected to continue to feed large numbers of the ever-growing population. In most soils, production or consumption of methane is regulated by interactions among soil redox potential, carbon source, electron acceptors and soil properties (Li, 2007). The use of organic fertilizers, water management and certain soil characteristics significantly affect methane emissions have emerged from the recent research. Use of organic fertilizers and incorporation of rice straw into the soil leads to high emissions compared to fields fertilized with chemical fertilizers and nutrient amendments (Schutz *et al.*, 1989; Cicerone *et al.*, 1992; Lindau and Bollich, 1993; Chen *et al.*, 1993; Denier van der Gon and Neue, 1995). If standing water is maintained in the fields throughout the growing season, higher methane emissions occur than the field is intermittently flooded (Sass *et al.*, 1992; Husin *et al.*, 1995; Yagi *et al.*, 1996). Intermittent flooding can occur by controlled irrigation, or the prevailing climatology of rainfall. Mineral fertilizers influence methane production and sulfate containing fertilizer decrease methane production (Neue *et al.*, 1997). The rates of CH_4 emissions are positively correlated with the dynamics of dissolved organic carbon (DOC) in the root zone (Lu *et al.*, 2000).

As methane contributes to the global warming, rice fields are the major sources of methane, it requires interdisciplinary research in relation to methane emission from rice fields and factors controlling, so as to suggest mitigation option for methane emission. So far, no attempts have been carried out in the State of Gujarat on these lines. Keeping the significance in mind, the aim of the present investigation is to evaluate short term diurnal and temporal emission of methane, to correlate the methane emission with organic carbon, sulphate, and phosphate content of soil of rice fields near Lambhvel village, central Gujarat, India.

Materials and Methods

Present study was carried out in two selected rice fields, with a gap of 300 feet of Lambhvel village, central Gujarat to study the diurnal as well as temporal variation of methane fluxes in relation to the soil chemistry and other environmental factors. In both the rice fields the nature, composition of the soil, sowing time of the saplings, amount and application of fertilizers remain more or less identical. However, both the rice fields were differ from one another by irrigation pattern *i.e.* rice field1 was irrigated by well water where as rice field 2 was irrigated by canal water.

Descriptions of sites: The experiments were conducted for the complete harvesting period in two selected rice fields, Rice field 1and Rice Field 2 situated on 22° 35'N, 72° 56.8'E for and 22° 35'N, 72° 56.7'E, respectively in a village Lambhavel, about 5 km from Vallabh Vidyanagar, in central Gujarat, India. The rice fields were irrigated to maintain standing water, although sometime dry condition was experienced due to high temperature in pre-summer season. The sowing of rice sapling was carried out using age-old practice. Common variety of rice *Oryza sativa* L. (regular and hybrid) was planted in the first week of February, and was regularly watered.

Methane emission measurements: Methane (CH_4) emission was measured by static chamber technique followed by the method of Khalil and Rasmussen (1991). The chamber was designed with an area of approximately 1 m^2, to permit the rise and collection of the emitted gas. The static chamber was made up of transparent plastic. The lower edge of the chamber was kept immersed inside the flood-water to avoid the gas leakage (Fig. 1). Chamber was provided with two permanent gas releasing taps on its both the sides. Gas samples were drawn from the chamber using rubber air bladders. Then the gas samples were sucked by syringe equipped with three-way

Fig. 1: Static chamber used for gas sampling

Table - 1: Correlation coefficient (r) between methane emission and organic carbon phosphate and sulphate contents of the soil in the rice field (RF)1

RF-1	Organic carbon	Sulphate	Phosphate	CH_4 emission
Organic carbon	0	0	0	0
Sulphate	-0.62416548	0	0	0
Phosphate	-0.73386252	0.1392413	0	0
CH_4 emission	0.82278897	-0.3328711	-0.4162328	0

Table - 2: Correlation coefficient (r) between methane emission and organic carbon phosphate, and sulphate contents of the soil in the rice field (RF)2

RF-2	Organic carbon	Sulphate	Phosphate	CH_4 emission
Organic carbon	0	0	0	0
Sulphate	-0.531583052	0	0	0
Phosphate	-0.272731675	0.9485513	0	0
CH_4 emission	0.997093894	-0.476362	-0.2185757	0

Table - 3: ANOVA - Single factor among studied parameters of rice field 1

Groups	Count	Sum	Average	Variance
14.50269	19	139.48	7.34	48.03
0.416954194	19	8.48	0.45	0.03
0.07	19	1.56	0.08	0.00
389.938146	19	5202.04	273.79	37868.07

Source of variation	SS	DF	MS	F	p-value	F crit
Between groups	1048471.40	3	349490.47	36.87	0.00	2.73
Within groups	682490.26	72	9479.03			
Total	**1730961.663**	**75**				

Table - 4: ANOVA - single factor among studied parameters of rice field 2

Groups	Count	Sum	Average	Variance
20.58003	19	366.24	19.28	20.29
0.287091017	19	6.63	0.35	0.07
0.1	19	1.10	0.06	0.00
398.9044559	19	5284.28	278.12	24788.38

Source of variation	SS	DF	MS	F	p-value	F crit
Between groups	1055466.70	3	351822.23	56.73	0.00	2.73
Within groups	446557.35	72	6202.19			
Total	**1502024.04**	**75**				

Table - 5: Unilateral F - test (Two sample variances) of methane emission between two rice fields

Methane emission	RF1	RF2
Mean	273.79	278.12
Variance	37868.07	24788.38
Observations	19	19
DF	18	18
F	1.528	
P(F<=f) one-tail	0.189	
F Critical one-tail	2.217	

Table - 6: Unilateral F - test (Two sample variances) of organic carbon content between two rice fields

Organic carbon	RF1	RF2
Mean	0.08	0.06
Variance	0.00	0.00
Observations	19	19
DF	18	18
F	1.075	
P(F<=f) one-tail	0.440	
F Critical one-tail	2.217	

Table - 7: Unilateral F- test (Two sample variances) of sulphate content between two rice fields

Sulphate	RF1	RF2
Mean	7.34	19.28
Variance	48.03	20.29
Observations	19	19
DF	18	18
F	2.367	
P(F<=f) one-tail	0.038	
F Critical one-tail	2.217	

Table - 8: Unilateral F - test (Two sample variances) of phosphate content between two rice fields

Phosphate	RF1	RF2
Mean	0.45	0.35
Variance	0.03	0.07
Observations	19	19
DF	18	18
F	0.502	
P(F<=f) one-tail	0.077	
F Critical one-tail	0.451	

cock, into evacuated sealed vials. Vials were sealed with the self-closing rubber septum. After taking gas sample, the chamber was evacuated using air bladders. In case of dry condition, the chamber was directly placed in the rice fields while the lower edge of the chamber was inserted into the moist soil to avoid the gas leakage (Fig.1).

The methane gas samples were collected from February last week to first week of April'07 at every 15 days interval, from both the rice fields periodically during four trips. The gaseous samples were collected at 9 o'clock followed by subsequent collection at the interval of every two hours till 5 o'clock. Immediately after collection, gas samples were transported to the laboratory at normal pressure. Methane gas concentrations were determined with Perkin Elmer Autosystem Gas Chromatograph equipped with FID (Flame Ionization Detector) in Sophisticated Instrumentation Centre for Applied Research and Testing (SICART), Vallabh Vidya Nagar, Gujarat, India. The temperature settings administered were 60°C, 110°C, and 150°C for column, injector and detector of GC, respectively. The calculations for methane gas have been made by the following formula and gas concentration is represented in mg $m^{-2}hr^{-1}$.

Methane emission (mg $m^{-2}hr^{-1}$) =

$$\frac{[(P_s \times C_s / P_{std}) \times V_v / V_a] \times V_h}{A \times H}$$

Where,

P_s = Peak area for sample in gas chromatograph

C_s = Concentration of the standard methane gas (mg l^{-1})

P_{std} = Peak area for standard in gas chromatograph

V_v = Volume of the vial (ml)

V_a = Volume of air sampled (ml)

V_h = Volume of head space of the chamber, *i.e.* [length*breadth*height of the chamber] (ml)

A = Area covered by the chamber (m^2)

H = Enclosure period (hr)

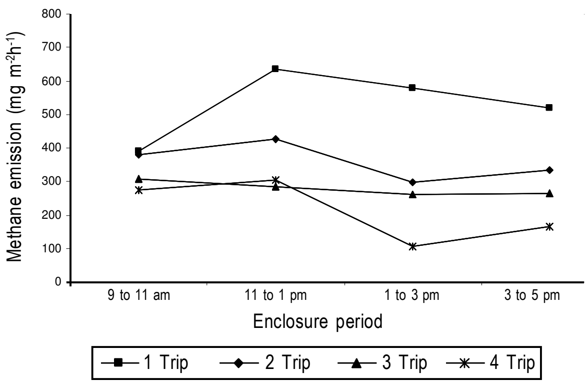

Fig. 2: Diurnal fluctuation of methane emission content from rice field 1

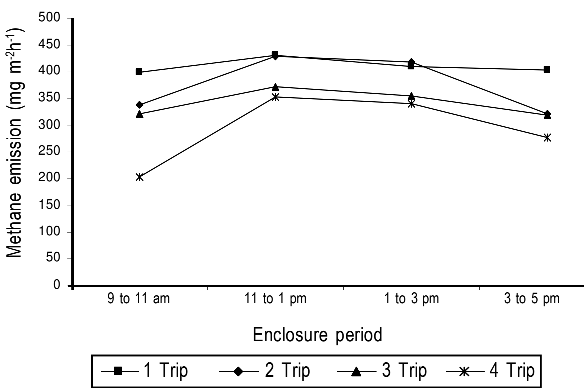

Fig. 3: Diurnal fluctuation of methane emission content from rice field 2

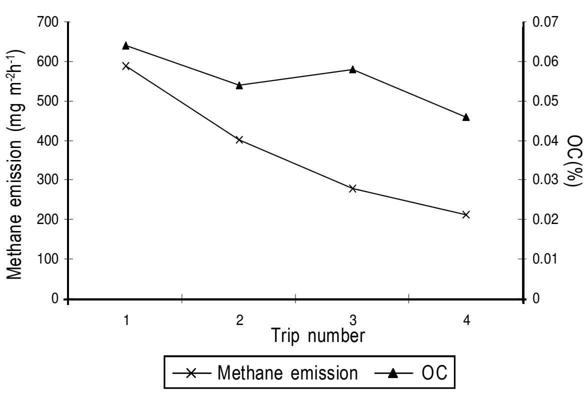

Fig. 4: Average value of organic carbon (OC) and methane emission content from rice field 1

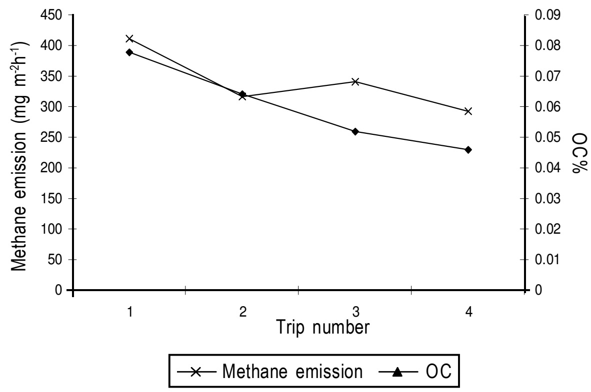

Fig. 5: Average value of organic carbon (OC) and methane emission content from rice field 2

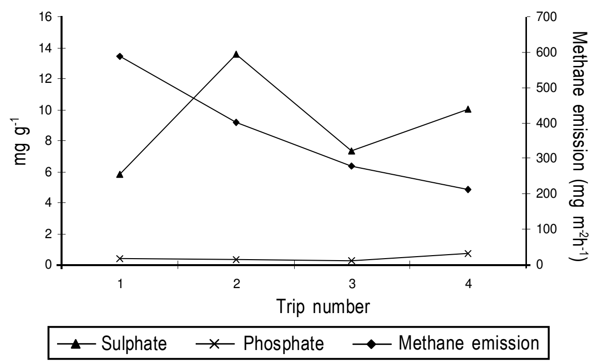

Fig. 6: Average value of sulphate and phosphate content of soil and methane emission from rice field 1

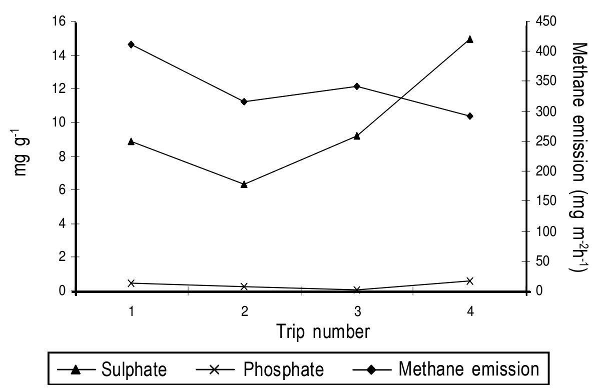

Fig. 7: Average value of sulphate and phosphate content of soil and methane emission from rice field 2

Soil collection: Soil samples were collected simultaneously at two hours intervals from both the rice fields at same place where the methane gas collected. Soil samples were collected with help of spade and stored in polyethylene bags. These were immediately brought to the laboratory and air dried and further used for determination of organic carbon (OC), sulphate and phosphate content using the standard methodology of Trivedy *et al.* (1987) and Maiti (2003). The experimental data was analyzed statistically for correlation coefficient (r), single factor ANOVA between all the parameters of two rice fields, and two-sample variances F-test between same parameter of two rice fields.

Results and Discussion

Methane emission from the rice field 1 was found in the range of 105.67 mg $m^{-2}hr^{-1}$ to 720.64 mg $m^{-2}hr^{-1}$ (Fig. 2). The maximum flux was found during first trip at the second exposure period *i.e.* 11.00 am from 1.00 pm. The lowest emission was observed during the fourth trip at third exposure period *i.e.* 1.00 to 3.00 pm. While, methane emission for the rice field 2 ranged between 201.59 to 430.94 mg m^{-2} hr^{-1}. The maximum emission was found during the first trip between 11.00 am to 1.00 pm enclosure period (Fig. 3). The lowest emission was noticed during the fourth trip between 9.00 to 11.00 am. However in all the visits methane emission was observed greater at the enclosure period between 11.00 am to 1.00 pm. Methane emission was found to decline gradually from first trip to fourth trip which might be due to moderate temperature, light intensity and fertilizers used. At the initial stage the fields were fertilized with the organic manure followed by chemical fertilizer in later stage. This result was very well corroborated with the findings of Schutz *et al.* (1989), Lindau and Bollich (1993). From this it can be accomplished that the rate of methane emission was influenced by the temperature, light intensity and organic manure and fertilizers used in the rice field. Further, it has been reported by Sass *et al.* (1992), Husin *et al.* (1995), Yagi *et al.* (1996) that higher methane flux occurred, if the rice field is flooded with water during growing period than the rice field is poorly irrigated. In present study too, similar findings were observed that the methane emission was higher when rice field was more flooded with water during first two trips than when it was poorly irrigated at later two trips (Fig. 2,3). This finding is very well substantiated the results of Wenyan *et al.* (2006) stating that the standing water depth affects the methane emission.

Moreover, organic carbon content of the soil also exhibited similar pattern with the methane emission and was observed in the range between 0.03 to 0.1%. Organic carbon content was recorded higher during first and third trip while second and fourth trip showed less value of organic carbon content from rice field 1. Where as organic carbon of the soil was found in the range of 0.04 to 0.1% in rice field 2. It showed the similar pattern as in rice field 1. Fig. 4 and 5 shows the relation of average of five values of methane emission and organic carbon content in both the rice fields. Organic carbon content goes parallel with the methane emission content. Organic carbon content in the initial trips was greater due to application of the organic manure in the fields during the initial stage of the rice cultivation practice. These results are positively correlated with the observations of Lu *et al.* (2000).

On the other hand, the methane emission was also influenced by the phosphate and sulphate content of soil. Phosphate and sulphate content of soil ranged between 0.12 to 0.69 mg g^{-1} and 2.95 to 16.03 mg g^{-1}, respectively in rice field 1 while phosphate and sulphate contents of soil ranged from 0.06 to 1.09 mg g^{-1} and 13.57 to 30.75 mg g^{-1}, respectively in rice field 2 (Fig. 6,7). In both the rice fields increasing sulphate concentration of soil decreased the flux of methane. Similar observation was reported by Setyanto *et al.* (2002) while studying methane emission in rice fields of Pati district, Java. Subsequent to SO_4^{2-} reduction, methanogens might start producing methane this could be the cause in the current study that the lower content of sulphate enhanced the methane emission in both the rice fields. The organic carbon content in rice field 1 and 2 was more or less same. However, the phosphate and sulphate content of the soil in rice field 2 was higher, than the field 1 which suppressed the methane flux, perhaps this could be the reason that methane emission from rice field 1 was higher than the field 2.

The correlation coefficient (r) showed that the methane emission has much positive correlation with the organic carbon content (0.822 and 0.997 for rice field 1 and 2, respectively) and the negative correlation with the phosphate (-0.416 and -0.219 for rice field 1 and 2 respectively) and sulphate (-0.332 and -0.476 for rice field 1 and 2 respectively) content of the soil in the rice field 1 and rice field 2. (Table 1, 2). The results of single factor ANOVA showed that the values of the studied parameters differed significantly for both the rice fields (F_{RF-1} 36.87; $p < 1.0$; $\alpha = 0.05$) and (F_{RF-2} 56.73; $p < 1.0$; $\alpha = 0.05$). Similar correlation was established using two-sample variances F-test among studied parameters for the whole experiment (F_{SO4} 2.367; $p < 1.0$; $\alpha = 0.05$), (F_{PO4} 0.502; $p < 1.0$; $\alpha = 0.05$), (F_{OC} 1.075; $p < 1.0$; $\alpha = 0.05$) and (F_{CH4} 1.528; $p < 1.0$; $\alpha = 0.05$) (Tables 3 to 8). Significance test (t-test) between studied rice fields for the methane emission showed that t value of the study is -0.343.

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References

Chen, Z.L., D.B. Li, K.S. Shao and B.J. Wang: Features of CH_4 emission from rice paddy fields in Beijing and Nanjing. *Chemosphere,* **26**, 239-245 (1993).

Cicerone, R.J., C.C. Delwiche, S.C. Tyler and P.R. Zimmerman: Methane emissions from California rice paddies with varied treatments. *Glob. Biogeo. Cyc.,* **6**, 233-248 (1992).

Denier van der Gon, H. A. C. and H. U. Neue: Influence of organic matter incorporation on the methane emission from a wetland rice field. *Glob. Biogeo. Cyc.,* **9**, 11-22 (1995).

Dubey, S.K.: Methane emission and rice agriculture. *Cur. Sci.,* ***81***, 345-346 (2001).

Dentener, F., D. Stevenson, J. Cofala, R. Mechler, M. Amann, P. Bergamaschi, F. Raes and R. Derwent: The impact of air pollutant and methane emission controls on tropospheric ozone and radiative forcing: CTM calculations for the period 1990-2030. *Atmos. Chem. Phys.,* **5**, 1731-1755 (2005).

Husin, Y.A., D. Murdiyarso, M.A.K. Khaill, R.A. Rasmussen, M.J. Shearer, S. Sabiham, A. Sunar and H. Adijuwana: Methane flux from Indonesian wetland rice: The effects of water management and rice variety. *Chemosphere,* **31**, 3153-3180 (1995).

IPCC: Climate change: The Supplementary Report to The IPCC scientific Assessment, Cambridge University Press, New York (1992).

IPCC: XII Summary for Policy Makers, The Scientific Basis of Climate Change. Cambridge University Press, Cambridge, UK (1996).

Khalil, M.A.K. and R.A. Rasmussen: Methane emission from the rice field in China. *Environ. Sci. Technol.,* **25**, 979-981 (1991).

Khalil, M.A.K. and M.J. Shearer: Sources of Methane: An overview. *In*: Atmospheric methane, its role in the global environment (*Ed.*: M.A.K. Khalil). Springer-Verlag, Berlin. pp. 98-111 (2000).

Lindau, C.W. and P.K. Bollich: Methane emissions from Lousiana first and ratoon crop rice. *Soil Sci.,* **156**, 42-48 (1993).

Lu, Y., R. Wassmann, H.U. Neue and C. Huang: Dynamics of dissolved organic carbon and methane emissions in a flooded rice soil. *Soil Sci. Soc. Am. J.,* **64**, 2011-2017 (2000).

Li, C.: Quantifying greenhouse gas emissions from soils: Scientific basis and modeling approach. *Soil Sci. Plant Nut.,* **53**, 344-352 (2007).

Maiti, S.K.: Handbook of Methods in Environmental Science. Vol. II. Soil, Solid Wastes and Air Analysis. ABD Publications. Jaipur. India (2003).

Neue, H.U., R. Wassmann, H.K. Kludze, W. Bujun and R.S. Lantin: Factors and processes controlling methane emissions from rice fields *Nut. Cycl. Agroeco.,* **49**, 111-117 (1997).

Sass, R.L., F.M. Fisher, Y.B. Wang, F.T. Turner and M.F. Jund: Methane emission from rice fields: The effect of floodwater management. *Glob. Biogeo. Cyc.,* **6**, 249-262 (1992).

Schutz, H., A. Holzaptel-Pschorn, R. Conrad, H. Rennenberg and W Seiler: A three-year continuous record on the influence of day time season and fertilizer treatment on methane emission rates from an Italian rice paddy. *J. Geophysics Resour.,* **94**, 16405-16416 (1989).

Setyanto, P., A.B. Rosenani, A.K. Makarim, I.C. Fauziah, A. Bidin and Suharsih: Soil controlling factors of methane gas production from flooded rice fields in Pati district, central Java. *Indo. J. Agric. Sci*., **3**, 1-11 (2002).

Trivedy, R.K., P.K. Goel and C.L. Trishal: Practical Methods in Ecology and Environmental Science. Series in Methodology – 2. Enviro Media Publications, Karad (Maharashtra), India (1987).

Wenyan, Y., C. Song and J. Zhang: Dynamics of methane emissions from a freshwater marsh of northeast China. *Sci. Total Environ.,* **371**, 286-292 (2006).

Yagi, K., H. Tsuruta, K. Kanda and K. Minami: Effect of water management on methane emission from a Japanese rice paddy field: Automated methane monitoring. *Glob. Biogeo. Cyc.,* **10**, 255-267 (1996).