underlying the observations on the effect of $\Delta t(T)$. Further experimental data are perhaps required to throw light in understanding the changes – structural and others – which are responsible for the present observations. It must be emphasized that the results on the effect of $\Delta t(T)$ are presented in this article primarily from a user's point of view. Kevlar is a fibre with high temperature applications, and exposure to elevated temperatures have been shown to result in several types of deterioration[1,2,5,8]. The results which have emerged from the present study are primarily user-relevant. They provide the useful information that if the fibres are to be used at elevated temperatures, the onset of thermally-induced deterioration can be delayed or their severity can be lessened by splitting a single long exposure into several short exposures. From a judicious choice of the $\Delta t(T)$ values, delaying the decay of the exceptional initial characteristics of the fibre can be successfully achieved. Basically, a 'go slow' approach at elevated temperatures would prove advantageous. Our data also prompt us to suggest that when the high temperature properties are compiled, the role of $\Delta t(T)$ should also be mentioned.

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Methane entrapment in different rice soils of India

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Part of methane produced in submerged paddy field is trapped in the soil, thereby reducing its emission into the atmosphere. Keeping the importance of methane entrapment in view, an experiment was undertaken to study the entrapment of methane in different soils of India. An incubation study was carried out with soils collected from rice fields at ten different locations of India for 60 days to determine the entrapment of methane in the soils during this period. The soils were incubated under submerged condition, at 30°C. Methane entrapment/day as well as the total amount of methane entrapped in the 60-day study period were observed to be different for the different soils. The total entrapment varied from 0.139 to 80.578 µg CH_4 g^{-1} soil, and from 0.212 to 91.959 µg CH_4 g^{-1} soil, when the same soils were treated with rice straw. The soils entrapped 13.04 to 72.32% of the total methane produced, while in the straw treated soils the entrapment ranged from 9.35 to 68.17%. Total and percent entrapment of methane did not show any significant relationship with the sand, silt, or clay content of the soils, while they showed significant correlation with total methane production. This suggests that there could be other factors operating, other than soil texture, which control methane entrapment in submerged soils. This stresses the need for further studies on methane entrapment in soils.

METHANE (CH_4) is one of the important gases contributing to the greenhouse effect. It is increasing at an average global atmospheric concentration of about 0.016 ppmV yr^{-1} (about 1% yr^{-1}) and CH_4 concentration in the troposphere is currently about 1.75 ppmV (ref. 1). Data from polar ice cores indicate an approximately exponential increase in tropospheric methane concentrations over the past 300 years[2]. This increase may be contributing to a rise in global temperature due to relatively high absorption of infrared radiation by CH_4 (ref. 3). Total annual global emission of methane is estimated to be 420–620 Tg yr^{-1} (ref. 4). Wetland rice agriculture is the major anthropogenic source of it, and emissions from this source are estimated at 60–170 Tg yr^{-1}, representing 25% of the worldwide release[5], at 25–100 Tg yr^{-1} (ref. 6) and at 20–150 Tg yr^{-1} (ref. 7). Studies covering the various agroclimatic regions of India have shown that methane emission from Indian rice fields is not more than 4 Tg yr^{-1} (ref. 8).

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Methane emitted to the atmosphere from the soil is only a part of the total methane produced within the soil as there are other factors also which determine the fate of methane within soil. Soil pore spaces trap a portion of the methane produced in the soil, resulting in reduced methane emission. Further, soils from different regions contain different proportions of sand, silt and clay, thereby have different pore size distribution which leads to differences in the amount of methane entrapped. According to Wang *et al.*[9], methane entrapment varied greatly from soil to soil, ranging from 0–99%, and was apparently affected by soil texture. Soils with clayey texture entrapped more methane. A significant positive correlation was found between methane entrapment and clay (0.005–0.001 mm and< 0.001 mm) and a significant negative correlation was found with 1–0.05 mm. According to Neue *et al.*[10], sandy soils showed lower entrapped methane because of their pore size distribution which enhanced ebullition and diffusion.

It is important to evaluate the amount of methane in submerged paddy soils to analyse the relationship between the methane production and its emission into the atmosphere[11]. Holzapfel-Pschorn *et al.*[12] reported that the methane mixing ratio in gas bubbles retained in a planted paddy field was lower than that in non-planted paddy field in mid-July. Watanabe *et al.*[11], reported that the amount of methane that remained in soil at the harvesting stage corresponded to 4–6% of the total methane emitted throughout the growth period. In a pot experiment with a hapludult light clay soil, the amount of methane in soil in the rice planted treatments continuously increased until the harvesting stage, which suggested that the decrease of methane emission rates during the ripening stage was not due to low production of methane[13]. This shows that part of methane which remains in the soil can be significant and may be instrumental in reducing the emission of methane into the atmosphere. Thus higher entrapment of methane may lead to lower emission of it into the atmosphere.

Majority of studies to date have focussed on methane emission from rice soils. But, not much information is available on the methane entrapment in different rice soils of different areas. A laboratory incubation study was taken up therefore to obtain information on entrapment of methane in different soils from ten different rice growing areas of India, and an effort has been made to correlate the entrapment of methane with sand, silt and clay content of the soils.

Ten soils were collected from different rice growing areas (Table 1). Representative samples of all the soils were drawn from 0–30 cm depth. Each soil was sampled from 15 well-distributed points on the fields by tube auger. All the samples were mixed thoroughly to make a composite sample. Composite samples were brought to the laboratory in ice boxes and were stored in the refrigerator immediately. Before start of the incubation study, the soils were air dried and passed through a 2 mm sieve. Soil particle size analysis was carried out by Hydrometer Method (Piper, 1967) to determine its texture. Content of organic carbon in the soil was determined by Walkley and Black Method[15] (Table 2).

For the treatment of soils two sets of soils were taken, each comprising ten different soils in triplicate. One set was taken as the control (without treatment with rice straw), and another set was treated with dried rice straw @ 1 g/kg of soil.

The incubation study was carried out in a BOD incubator at 30°C for a period of 60 days. Spoutless glass beakers (250 ml) were used for the incubation study. Each soil (40 g) was taken in triplicate and was flooded with 80 ml water. Magnetic bars were put into the beakers to stir the soil with a magnetic stirrer. The beakers were fitted with rubber corks at the mouth and were sealed with sealant to ensure that there was no leakage. The corks had three holes, each of 8 mm diameter. Two glass tubes (8 mm dia. each), fitted with rubber septa at the outer end were inserted in two holes for gas inlet and outlet. A platinum electrode was fixed in the other hole to facilitate Eh (redox potential) measurement.

For the sampling procedure, the gas samples from the headspace were periodically drawn at regular intervals of 24 h and 72 h alternately throughout the experiment. A set of gas samples was taken out without disturbing the soil in beaker. Another set of gas samples was drawn from the headspace after stirring the soil with magnetic stirrer (stirring was done to drive out a part of methane produced which remained entrapped within the soil). The latter set represented the gas which was already present in the headspace plus the gas which was entrapped in the soil. Subtraction of the former from the latter represented the entrapped methane within the soil. The entrapped amount of methane of 24 h and 72 h periods was added up to find out the total entrapment during the 60 day incubation period. The gas samples were drawn with a plastic disposable syringe fitted with a 24 gauge needle and a three-way valve to prevent

Table 1. Collected soil types of rice growing areas

Soil type	Location	District	State
Alluvial	Moran	Sibsagar	Assam
Alluvial	BCKV	Nadia	West Bengal
Black	Sakoli	Bhandara	Maharashtra
Alluvial	Gulawati	Ghaziabad	Uttar Pradesh
Alluvial	IARI	Delhi	Delhi
Alluvial	Zarifa	Karnal	Haryana
Alluvial	Kuttanad	Kottayam	Kerala
Black	Nagpur	Nagpur	Maharastra
Alluvial	Bhanwapur	Sitapur	Uttar Pradesh
Red	Erode	Periyar	Tamil Nadu

Table 2. Physico-chemical characteristics of the soils

Location	Soil type	Organic carbon (%)	Sand (%)	Silt (%)	Clay (%)	Textural name
Moran	Alluvial	1.58	77.415	9.00	13.585	Sandy loam
BCKV	Alluvial	0.52	68.885	10.11	21.005	Sandy clay loam
Sakoli	Black	0.62	82.436	3.33	14.234	Sandy loam
Gulawati	Alluvial	0.38	80.371	5.31	14.319	Sandy loam
IARI	Alluvial	0.53	70.415	11.50	18.085	Sandy loam
Zarifa	Alluvial	0.88	74.887	8.01	17.103	Sandy loam
Kuttanad	Alluvial	1.47	77.179	2.40	20.421	Sandy clay loam
Nagpur	Black	0.52	27.072	13.80	59.128	Clayey
Bhanwapur	Alluvial	0.59	70.371	14.00	15.629	Sandy loam
Erode	Red	0.68	88.458	1.04	10.502	Sandy

diffusion of the gas sample. To ensure that the syringe was air tight, a CH_4 standard of 5 ppm was taken into the syringe and was analysed after 10 min . The concentration of methane was found to remain at 5 ppm. During the sampling, care was taken to mix the headspace thoroughly by pushing the plunger of the syringe up and down for at least ten times. After taking both set of samples, the beakers were flushed with nitrogen gas immediately for three min. A set of six beakers were attached in series with three-way valves and plastic tubes to facilitate flushing of six beakers at a time by a single source of nitrogen gas. Flushing of beakers was a necessary follow-up operation to drive out all traces of methane from the beaker to ensure that the next sample of the gas is totally free of any traces of previously formed methane.

The gas samples were analysed by a Hewlett Packard gas-chromatograph fitted with a FID detector. Porapak N column was used for the analysis of methane. Nitrogen was used as the carrier gas with a flow rate of 20 ml min^{-1}. Hydrogen was taken as the fuel gas and zero air as the supporting gas with flow rates of 25 ml min^{-1} and 250 ml min^{-1} respectively. Column, injector and detector temperatures were kept at 50, 120 and 120°C respectively. A 9.03 ppmV methane sample in nitrogen prepared by Scott Specialty Gases, Deerfield, was used as a standard for the gas analyses.

Results on methane entrapment in different soils show that the entrapment in the 60-day period varied from 0.139 $\mu g\ g^{-1}$ (Nagpur) to 80.578 $\mu g\ g^{-1}$ soil (Moran). Soil of Moran showed the highest methane entrapment, followed by soils of Kuttanad, Zarifa, Sakoli, Erode, IARI, Gulawati, Bhanwapur, BCKV, and Nagpur (Table 3).

If entrapped methane is taken as the percentage of the total methane produced, then too soil of Moran showed had the highest entrapment (72.32%), followed by Kuttanad, Nagpur, Sakoli, Zarifa, IARI, Erode, Bhanwapur, BCKV, and Gulawati. Methane entrapment day^{-1} varied from 0.000072 (Gulawati) to 4.49 $\mu g\ g^{-1}$ soil (Moran) in control, and 0.00024 (BCKV) to 6.27 $\mu g\ g^{-1}$ soil (Moran) with straw treatment. In all the soils, as the Eh values dropped, the entrapment of methane increased. This was perhaps due to the increase in methane production with the reduction in Eh values.

Table 3. Total and per cent entrapment of methane

Soils	Treatment	Total CH_4 production ($\mu g\ g^{-1}$ soil)	Total CH_4 entrapment ($\mu g\ g^{-1}$ soil)	Entrapment (%)
Moran	Control	111.403	80.578	72.32
	Straw	134.879	91.959	68.17
Kuttanad	Control	100.148	47.417	47.34
	Straw	126.646	63.854	50.42
Gulawati	Control	3.346	0.436	13.04
	Straw	15.352	5.115	33.32
Sakoli	Control	15.067	3.811	25.29
	Straw	23.266	5.305	22.86
Bhanwapur	Control	2.245	0.360	16.05
	Straw	13.541	2.331	17.22
Zarifa	Control	20.257	5.812	25.69
	Straw	39.217	16.276	41.50
Erode	Control	15.589	3.314	21.20
	Straw	45.253	4.234	9.35
Nagpur	Control	0.321	0.139	43.23
	Straw	0.511	0.212	41.56
BCKV	Control	1.059	0.142	13.44
	Straw	8.428	1.616	19.17
IARI	Control	7.152	1.661	23.22
	Straw	22.841	6.311	27.63

According to Wang *et al.*[9], more the clay in the soil more the entrapment is. But no significant relationship was found between either the total or percent methane entrapment and silt, sand or clay content in the soil. The soil of Moran, having low content of clay, entrapped the highest percentage of methane (72.32%). On the other hand, soil of Nagpur with very high clay content (59.12%) had trapped only 43.23% of the produced methane. Thus, it appears that there could be other factors operating as well which may influence methane entrapment. Perhaps presence of methane oxidizers in the soil significantly modified the amount of methane entrapped in submerged condition. Methanotrophy (by both aerobic and anaerobic methane oxidizing bacteria) in soils is an important sink, and serves as a negative feedback on atmospheric methane increases[16]. Methane oxidation takes place in floodwater–soil interphase[17]. In this study, strictly anaerobic condition was created by incubating the soils in purely nitrogen-saturated environment. There is evidence that certain habitats exist where anaerobic oxidation of methane occurs[18–20]. According to Conrad and Rothfuss[21], about 81% of the methane produced in anoxic layers could be oxidized in soil cores from flooded rice fields. Here methane oxidizers might have oxidized the amount of entrapped methane sufficiently to produce a nonsignificant correlation of total methane entrapment with sand, silt and clay content of the soils. Methane fluxes in clayey soil may be reduced more because the entrapped methane remains longer in clayey soils due to lower diffusion and may be oxidized before it can escape to the atmosphere. In the clayey soil of Nagpur, low entrapment could be due to higher oxidation of methane.

In this study, most of the soils were sandy loam and the range of sand, silt and clay was not very wide. For the study of methane entrapment in relation to soil texture, it seems appropriate to carry out experiments with soils having wide range of sand, silt and clay contents. Otherwise, if sand, silt and clay contents of the soils can be kept constant, and methane production is made to vary, strong conclusions can be drawn on the effect of soil texture and methane production on entrapment. In the experiment under discussion, results show variation among different soils with respect to the entrapment day^{-1} as well as total entrapment of methane in 60 days. Total entrapment as well as the percent entrapment in different soils has been influenced by total production of methane. A significant correlation was observed between the total production and total entrapment of methane both in control(without rice straw treatment) and with rice straw treatment (values of r being 0.97 and 0.96 respectively, $P < 0.05$) (Figures 1, 2). There was significant positive correlation between the total methane produced and percent methane entrapped in both the control and straw-treated soil (values of r being 0.85 and 0.70 respectively, $P < 0.05$). On the other hand, total production of methane had significant positive correlation with organic carbon of the soils ($r = 0.97$, $P < 0.05$). This implies that organic carbon content in the soil had indirectly influenced methane entrapment by controlling methane production. It has been reported that in a study conducted with 20 soil samples collected from 20 rice growing regions of Philippines, organic carbon in the soil was found to have a significant positive correlation with methane production[22]. Total entrapment was higher in straw-treated soils in all the soils since the total production of methane was higher in the rice straw-treated soils. This is expected, as the total production of methane tends to be higher with straw treatment in the soils[23–32,34]. The entrapment day^{-1} was also higher in all the soils with rice straw treatment. This is also expected as the methane flux increases with rice straw treatment. Yagi and Minami[33] have shown that the highest CH_4 fluxes from a Japanese rice paddy were due to addition of rice straw. In our studies, since soils with higher methane production trapped higher amounts of methane, wide differences were observed between total entrapment by different soils. So, the percent entrapment appears to be a better indicator of the entrapment capacity of a soil than the absolute entrapment of methane. The emission will largely depend on the entrapment within the soil. The methane emission from any soil can be predicted if its percent methane entrapment and production potential is known. Similarly, if entrapment and emission data are available, production potential can be predicted by adding up entrapment and emission. The study of entrapment in different soils, its relationship with the soils, physical, chemical and biological properties therefore holds much significance in the studies of methane production and emission from the soil.

Methane entrapment is an important aspect in the studies of methane production and its emission from

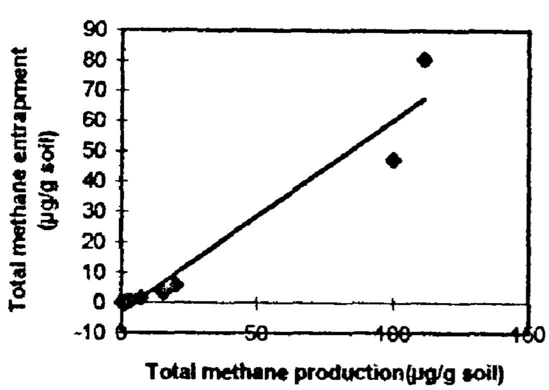

Figure 1. Relationship between total methane production and methane entrapment in control.

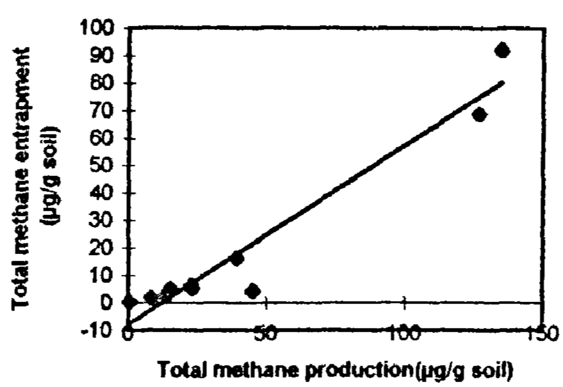

Figure 2. Relationship between total methane production and entrapment with rice straw treatment.

different soils. The study failed to establish any kind of relationship between soil texture and methane entrapment. This indicates the possibility of the involvement of other factors apart from sand, silt and clay content in determining the entrapment pattern of a soil. This emphasizes a need to find out the factors which affect the entrapment of methane in submerged rice soils. Experiments should be carried out with all the different types of rice soils of India to find out the extents of entrapment by these soils, and the effects of different properties of soils on methane entrapment. This will help in understanding the production and emission characteristics of different soils.

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Coastal morphological influence for tropical cyclone track deviation along Andhra coast: GIS and remote sensing-based approach

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World-wide attention has been focussed on the need for better disaster mitigation programmes towards all the natural hazards. Tropical cyclone is one such natural hazard that needs better disaster management and prediction. GIS and remote sensing are two powerful tools for monitoring such disasters. Presented here is a case study where IRS-1C WiFS data coupled with historical database from Indian Meteorological Department is effectively used to demonstrate for better monitoring of tropical cyclone crossing the Andhra coast.

Bay of Bengal is one of the six regions in the world where severe tropical cyclones usually originate in the months of May, November, and December. They are well known for their extreme destructive potential and impact on human activities. Associated with the severe cyclones are strong winds, storm surges along the coast, and there is heavy rainfall which results in destruction to life and property. Proper prediction of this natural disaster requires understanding of its genesis, movement,