Open access • Book Chapter • DOI:10.1007/BF00547187

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Published on: 01 May 1994 - Environmental Monitoring and Assessment (Springer, Dordrecht)

Topics: Atmospheric methane, Methane and Soil water

CONSUMPTION OF METHANE BY SOILS

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Abstract. Measurements of the methane flux and methane concentration profiles in soil air are presented. The flux of methane from the soil is calculated by two methods: a) Direct by placing a static open chamber at the soil surface. b) Indirect, using the ^{222}Rn concentrations profile and the ^{222}Rn flux in the soil surface in parallel with the methane concentration (^{222}Rn calibrated fluxes). The methane flux has been determined in two kinds of soils (sandy and loamy) in the surroundings of Málaga (SPAIN). The directly measured methane fluxes at all investigated sites is higher than methane fluxes derived from "Rn calibrated fluxes". Atmospheric methane is consumed by soils, mean direct flux to the atmosphere were - 0.33 g $m^{-2}yr-1$. The direct methane flux is the same within the measuring error in sandy and loamy soils. The influence of the soil parameters on the methane flux indicates that microbial decomposition of methane is primarily controlled by the transport of methane.

1.- Introduction

Methane is an important trace gas because it absorbs the Earth's infra-red radiation and contributes to the greenhouse warming of the Earth´s environment. It has a 11-times (IPCC, 1992) higher greenhouse warming potential than CO_2 which is the main contributor to this effect. Even though its concentration is only about 1.7 ppmv, its contribution to the change in the total greenhouse warming during the last 10 years is found to be 17% (IPCC 1990). Methane is a biogenic gas produced globally by both biotic and abiotic processes. Oxidation of methane does occur in aerated soils by methanotrophic bacteria (Haber et al. 1983). Flux measurements in tropical (Keller et al., 1983) and subtropical soils (Seiler et al., 1984) have indicated that the total methane destruction rate in these regions plays a rather unimportant role, and may attribute less than 5% to the total global methane sink. Flux measurements in the temperate zone and at different kinds of soil are, however, still very sparse.

The methane flux at the soil surface and the methane concentration in the soil air depend on both, the destruction rate by microbial decomposition, and the gas transfer in the soil air by molecular diffusion. In this paper, gas transport in the soil is determined using the radioactive noble gas ^{222}Rn as a transport tracer (Dörr and Münnich, 1990). With measurements of the ^{222}Rn concentration profile and the ^{222}Rn flux at the soil surface in parallel to the methane concentration profile in the soil air, it is possible to determine the methane flux across the soil/atmosphere interface by indirect (^{222}Rn calibrated fluxes). Direct methane fluxes are measured by placing a chamber at the soil surface and observing the methane concentration change with time. This method may yield unreliable flux data due to a considerable disturbance of the steady state concentration profile in the soil. The indirect method does very slightly disturb the steady state conditions. Using the mentioned methods, we have determined the methane flux in two kinds of soils (sandy and loamy) in the surroundings of Málaga over a period of about seven months for sandy soil

Environmental Monitoring and Assessment 31: 125–130, 1994.

and one year for loamy soil. The results and a discussion on this methane sink on the global methane budget are presented here.

2.- Material and methods

2.1. THE CHAMBER

The chamber used consists of a cylindrical container 0.55 m in diameter and 0.28 m high. The chamber was made of stainless steel with a sampling tube. A small electric fan inside the chamber was used to maintain a uniform mixing of emitted gases. The fan is operated a few minutes before the accumulation period is finished. Equal pressure between the environment and the interior of the chamber was maintained through an orifice of 3 mm diameter. The chamber is placed 1-2 cm deep in the soil.

2.2. METHANE

Methane was measured by injecting 10 cm^3 samples into a flame ionization detector gas chromatograph, heated at 240 °C and equipped with a 800/100 mesh, 6 foots (2 m) long, 1/8" (3 mm) diameter Chromosorb 102 packed column. Calibration was obtained using the standard samples. The accuracy of the measurements, including the uncertainty on the standard concentration (1%) and the reproducibility (0.2%) of the analysis, is estimated to be better than 1.5 %.

2.3. RADON

Radon was measured by counting the alpha particles emitted by the radon and its daughter products ^{218}Po and ^{214}Bi when they reach radioactive equilibrium. The precision of the measurement was about 5% taking only the statistical error into account (Carretero, 1994).

2.4. INTERSTITIAL AIR

Measurements of methane and Rn soil concentrations were made inserting some stainless-steel sampling tubes into the soil. The 10 mm diameter tubes terminated in a 3.5 cm diameter, 6 cm long, named as "Filtration chamber" which was designed to permit the aspiration of interstitial air from the soil. The chamber was filled with glass fibres to prevent the aspiration of soil or clay particles. The upper ends of the tubes were sealed except for the time that samples were being taken. A small purging took place before the sampling.

The air samples of the chamber and the interstitial air were taken in pre-evacuated 1 ℓ glass flasks. First we have measured the Rn concentration and after the methane concentrations. The glass flasks are cylindrical, coated with a film of SZn(Ag).

2.5. LOCATION

All samples were taken in an area located in the city of Málaga. The two sampling sites are located on a loamy, uncultivated, bare soil and on bare sandy soil.

3. Results and discussion

3.1. SOIL PROPERTIES

Granulometric soil analyses were carried out by the sieve method, Jiménez and de Justo (1975). Porosity was determined in the laboratory from real and apparent density measurements of a soil sample obtained by perforation of the soil with a core sampler which is a hollow cylinder whose volume is known. Permeability was determined in situ assuming Darcy´s law and measuring the flow for a fixed pressure drop. Table 1 shows some properties of the soils.

Table 1. Properties of the soils

Soil	Sandy	Loamy
Density (g/cm^3)	1.75 ± 0.06	1.76 ± 0.18
Porosity	36.4 ± 0.4	35.1± 0.4
Permeability (m/s)	2.32×10^{-6}	5.90×10^{-7}
Organic matter (C_{org} by weight %)	1.82	2.85

3.2 THE METHANE FLUX BY THE INDIRECT METHOD

In sandy soil, measurements of air soil concentrations were made inserting tubes into the soil at depths: 5, 10, 15, 45, 60, 85 and 105 cm. In loamy soil the tubes into the soil were at depths: 5, 10, 18, 47, 75, 150 and 222 cm. Two mean concentration profiles of methane in sandy and loamy soils are given in Fig.1 (upper part). A steep concentration decrease with depth can be observed. At about 60 cm depth methane concentration has already decreased to nearly zero which must be attributed to the occurrence of a sink of methane in these soils. The observed concentration profiles in these soils can be explained using the model according to Born et al (1990). In this model C(z) the methane concentration in the soil air decreases exponentially with depth:

$$C(z)=C_0 e^{-\frac{z}{z_{CH_4}}}$$

The solid lines in Fig.1 are exponential fits to measured data points. The methane flux J(z=0) from the atmosphere into the soil is calculated with Fick's laws:

$$J(z=0)=-P_{CH_4} \times \nabla C(z=0)$$

where P_{CH4} is the permeability of methane in the soil air and depends on the soil para-

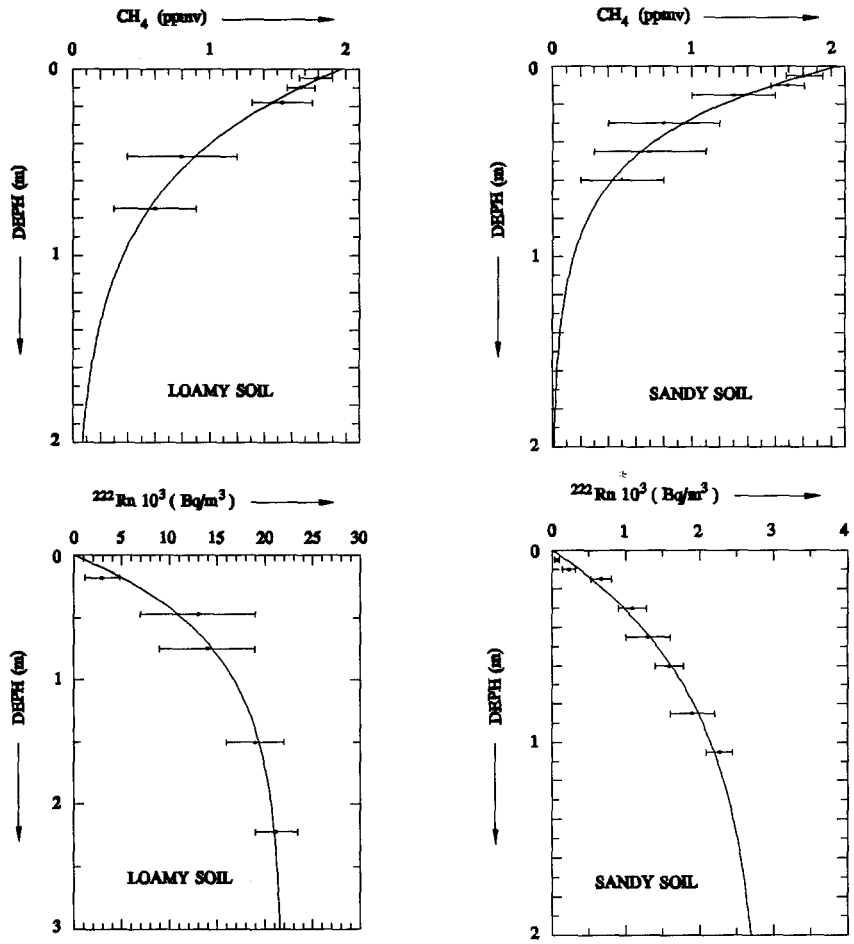

FIGURE 1.- Upper part: Concentration profiles of methane in the soil air. Lower part: Corresponding ^{222}Rn profiles in the soil at the same locations.

meters: porosity, soil moisture, tortuosity and as well as the molecular diffusion coefficient of methane in air is *a priori* not known. We have calculated the permeability at a site from the parallel observed Rn profile (compare Fig.1, lower part) and from a direct Rn flux measurement at the soil surface. Assuming that the permeability can be expressed as a product of the molecular diffusion coefficient D_0 and a function describing the soil parameter only (Dörr and Münnich , 1990), the methane permeability is:

$$P_{CH_4} = \frac{D_{0,CH_4}}{D_{0,Rn}} \times P_{Rn}$$

Where,

$$P_{Rn} = \frac{J_{Rn}(z = 0)}{\nabla C_{Rn}(z = 0)}$$

3.3. THE METHANE FLUX BY THE DIRECT METHOD

Soil gas flux is measured directly by the accumulation method, Wilkening et al. (1975). The concentration change was measured after an accumulation period of 30 min to 1 h. The flux density is calculated from:

$$J = H\frac{\Delta C}{\Delta t}$$

Where ΔC is the concentration increase during Δt and H is the height of the chamber.

3.4. RESULTS

In table 2, the mean methane fluxes and the number of measurements are given.

Table 2. Average methane fluxes.

Mean flux(g m^{-2} yr^{-1})	Sandy	Loamy	No. of measurements
Indirect	0.18 ± 0.07	0.03 ± 0.01	30
Direct	0.36 ± 0.18	0.31 ± 0.15	24

The mean methane fluxes show no obvious correspondence with soil organic matter content at the individual sites (see Table 1). There are few differences in the absolute values at different soils: at the sandy soil we observe the highest direct flux with a mean of 0.36g $m^{-2}yr^{-1}$. At the loamy soil, the mean methane flux is 0.31 g m^{-2} yr^{-1}. The flux from the indirect method at two sites yields smaller average fluxes than those obtained using the direct method. This may be to due to the fact that there is a convective component of flux operating in addition to diffusion.

The fluxes are taken over a period nearly half a year between February and June. The soil temperature has been comprised between 18 and 25°C. We have not found a correlation between the methane fluxes and soil temperature at 15 cm depth in the studied soils as well as Keller et al. (1983). Born et al. (1990), have found a correlation between the methane flux and permeability of methane in soil air. This correlation probably indicates that microbial activity is mainly controlled by the gas transport in the soil air rather than by soil temperature.

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