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In situ accumulation of methane bubbles in a natural wetland soil

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Summary

Natural wetlands are a significant source of atmospheric methane, an important greenhouse gas. Compared with numerous papers on measurements of methane emission from natural wetland surfaces, there are few reports on methane configuration and distribution within wetland soil profiles. By using a newly designed gas sampler, we succeeded in collecting free-phase gas from beneath the water table down to 120 cm in a peat. The volumetric percentage of methane in the gas phase increased with depth and was generally more than 50% beneath the zone within which the water table fluctuates. The volume of the gas phase in the peat beneath the water table was estimated to be from 0 to 19% with significant variation with depth, suggesting uneven distribution of gas bubbles. Using the volume ratio of the gas and liquid phases and methane concentration data in the gas phase, as well as assuming that methane was in equilibrium (based on Henry's Law between the two phases), we calculated that ~60% of the methane accumulates in the form of bubbles. These results suggest the importance of ebullition in methane emission, which might be a major cause for the reportedly large variation of methane emission in both space and time. Most importantly, our results show the need to consider gaseous-phase methane for understanding the production, transport and emission mechanisms of methane in wetlands, which has been overlooked to date.

Introduction

Natural wetlands are a significant source of methane to the atmosphere (Matthews & Fung, 1987; Fung *et al*., 1991; Bartlett & Harriss, 1993; Hein *et al*., 1997). Net methane emission is a complex function of processes that regulate the production, oxidation and transport of the gas to the atmosphere (e.g. Bartlett & Harriss, 1993). Various kinds of biogeochemical factors affect emission, and there has been much work to find key factors responsible for the large variations in both space and time of the emissions (e.g. Harriss *et al*., 1982; Shurpali *et al*., 1993; Whiting & Chanton, 1993; Christensen *et al*., 2003).

In contrast to the numerous papers on measurements of methane emission from the land surface, stored methane within wetland soils has attracted little attention. However, precise knowledge of the configuration and distribution of the methane within soils is essential for understanding methane dynamics in wetland ecosystems. A fundamental question now arises: does the methane in waterlogged peat exist in a gaseous phase as bubbles, or in the dissolved state in the liquid phase?

Conventional wisdom maintains that wetland soils are saturated below the water table, and methane has been thought to exist in a dissolved state. In contrast, in investigating the cause of the anomalously small hydraulic conductivity of catotelm peat, Mathur & Lévesque (1985) developed a new conceptual model in which the hydraulic conductivities were attributed to the occlusion of pores by gas bubbles generated by anaerobic respiration and fermentation. There is support for this concept and subjective evidence for the presence of gaseous-phase methane in some field studies (Dinel *et al*., 1988; Brown *et al*., 1989; Buttler *et al*., 1991). The first quantitative work, in which the volume of the bubbles and the amount of methane in the bubbles were measured, was probably that of Reynolds *et al*. (1992). They did a column experiment using 'grab' samples from a Canadian raised bog, and they showed that the gaseous phase, in which methane seems to be the main constituent, does exist in a 'saturated' column with water. Beckwith & Baird (2001) did a similar experiment using undisturbed peat cores at more realistic temperatures and found that the volumetric gas content increased up to 16% as

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