Methane Generation in Holocene Permafrost Deposits of the Lena Delta, and its Implication for the Global Methane Budget

INTRODUCTION

Wet tundra environments of the Arctic are natural sources of the climate relevant trace gas methane. These environments represent the largest accessible carbon pool where more than 14 % of the global terrestrial carbon is accumulated. Microbial processes, which are responsible for the decomposition of organic matter and the generation of greenhouse gases, is influenced by changing environmental conditions. For the understanding and assessment of recent and future carbon dynamics in high latitudes we studied the methane concentration, the quantity and quality of organic matter, and the activity and biomass of methanogenic communities in permafrost deposits of the Lena Delta, Siberian Arctic.

RESULTS

Abiotic parameters of the Holocene permafrost deposits from Samoylov Island: (a) Sediment texture, (b) bore hole temperature and calendar years BP of selected sediment layers, (c) total organic carbon (TOC), (d) humification index [HIX, dimensionless] and (e) C/N ratio. Units I-IV based on constrained incremental sum of squares (CONISS) analysis of the different grain size fractions.

Vertical profiles of methane concentration (a) and methane production rates determined at 5°C without any additional substrate (b) as well as with acetate (c) or hydrogen (d) as methanogenic substrates. Methane production were only determined in the core units characterized by high concentrations of methane.

CONCLUSIONS

This work shows for the first time that microorganisms, particularly methanogenic archaea, do not only survive in permafrost habitats but also can be metabolic active under in situ conditions. Furthermore, we show that a slight increase of the temperature can lead to a substantial increase of methanogenic activity. In case of permafrost degradation, this would lead to an extensive expansion of the methane deposits with their subsequent impacts on total methane emission.

STUDY SITE

The study site Samoylov Island with the Russian-German Research Station Samoylov, is located in the active part of the Lena Delta, which represents an area of typical polygonal tundra. This part of the delta was formed during the Holocene with an age of about 9300 years BP. Continuous permafrost, which occurs throughout the investigation area, extends to depths of about 100 to 300 m. The delta is characterized by an arctic continental climate with low mean annual air temperature of -14.7 °C (Tmin = -47.8 °C, Tmax = +18.3 °C) and low summer precipitation of < 198 mm.

Lipid biomarker profiles within the Holocene permafrost deposits of Samoylov Island: (a) Total biomarker [bacteria and archaea], (b) ester-linked phospholipid fatty acids [EL-PLFA, bacteria], (c) phospholipid ether lipids [PLEL, archaea] and (d) percentage of PLEL [archaea] on total biomass. Significant amounts of archaeal biomarker (PLEL) were detected in Unit I and II, which were also characterized by high concentrations of methane.

Methanogenesis in permafrost soils at subzero temperatures. Soil samples were incubated at -3°C (a) and -6°C (b) with hydrogen (circles) or acetate (squares) as a substrate. The bore temperature in the upper two units with high methane concentrations varied in this temperature range.