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# Methane flux and vertical-horizontal distributions of methane in Lake Fukami-ike

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**ABSTRACT:** Lake Fukami-ike is a small eutrophic lake in central Japan and the lake water stratifies from April to October. The methane flux and vertical-horizontal distributions of dissolved methane were studied starting in March 1999. The vertical distribution of dissolved methane indicates the methane is produced in the hypolimnion, and the competition with sulfate-reducing bacteria is clearly seen as hydrogen sulfide concentration increase. High dissolved methane concentrations were often found in the eplimnion and hypolimnion in this lake. The high methane concentrations in the bottom layer were released from the bottom sediments (max. about 26.7 $CH_4$ μl $g^{-1}$), with a corresponding decrease in the acetic acid concentrations. The phenomenon in which there was a high methane concentration and methane flux was often seen in the surface layer. The horizontal dissolved methane distribution in the surface of lake water was not found to be affected by run off from the lake shore.

**Key Words:** eutrophic lake, dissolved methane, methane flux, organic acid

## Introduction

Methane is one of the greenhouse effect gases increasing due to various human activities after industrial revolution, and the present atmosphere concentration is estimated to be 1.714 ppmv (IPCC, 1994; Rodhe, 1990). Much methane gas is produced by some bacteria in anaerobic environments in the decomposition process of some organic matters, and the main substrates of methanogenesis are thought to be $H_2$+$CO_2$ , acetic acid, formic acid, propanic acid and butyric acid (Barber. 1979; Koyama et al., 1973).

Lake Fukami-ike is a small eutrophic lake in Nagano Prefecture, in central Japan, with a maximum depth of 7.7 m and an area of 2.2 ha. The lake is located at the bottom of a basin and is well protected from the wind. The thermocline stratifies from April to October, and an anoxic condition prevails below the 4 m depth. In the 2 m-4.5 m layers, oxic and anoxic boundary layers are formed (Yagi et al., 1983). The methane flux and vertical-horizontal distributions of dissolved methane were studied in lake Fukami-ike starting in March 1999. The purpose of the present study was to clarify the annual changes and features of the vertical distribution of methane in Lake Fukami-ike.

## Materials and Methods

Lake water samples were collected with a polyvinylchloride tube and a handy pump every 25-100 cm of depth. Water temperature was measured with a thermistor thermometer, and dissolved oxygen was determined with a DO meter (Horiba OM-14). Sediment sampled were taken with an Ekman-Birge dredge. In the vertical direction water was collected at the maximum depth (7.7 m). The gas for bubbled methane was collected by the water substitution method at a 1 m depth for 5-6 hours at maximum depth. The horizontal sampling water for the surface was obtained at four sites located at approximately equidistant intervals on a north-south line.

The dissolved methane concentration was analyzed using sample water tightly a glass bottle. With pure air gas replaced in the head-space ion site, the methane flux was determined from the collected gas, which was analyzed with a methane gas chromatograph (KK Sensor Tech GS-15). The organic acids determined ware formic acid, acetic acid, tartaric acid, malic acid, glycolic acid, butyric acid, and propanic acid, measured quantitatively using ion chromatography (Dionex, DX-AQ), after the sample was filtered using filter paper (PTFE 0.45 um Advantec).

The methanogenesis from sediment was measured with about 20 g sediment and distilled water in 50 ml test tube with a screw, and tightly sealed. It was incubated at 20°C, and the daily variation of the methane concentration was determined at in the intervals of the 0, 3, 5, 7, 14, and21 days. The bacteria was cultured by the method of Zeikus (Koga et al., 1987).

## Results and Discussion

Typical vertical distributions of dissolved methane, organic acid and other environmental factors (water temperature; WT, dissolved oxygen; DO, hydrogen sulphide; $H_2S$) are shown in Figure 1. The dissolved methane concentrations in the summer stratification stage increased in proportion to the increase in organic acid from the upper oxic and anoxic boundary layers. However, this dissolved methane tended to decrease with the increase of hydrogen sulfide. Thus, methane production seems to be control led by the sulfate reduction (Suh et al., 1993).

Methanogenesis in the sediment and in the hypolimnion is considered to be the reason that dissolved methane concentrations increased in the bottom layer. The methanogenesis was examined by the method of using methanogenic bacteria cultivated from a depth of 3.5 m (Sept. 01)

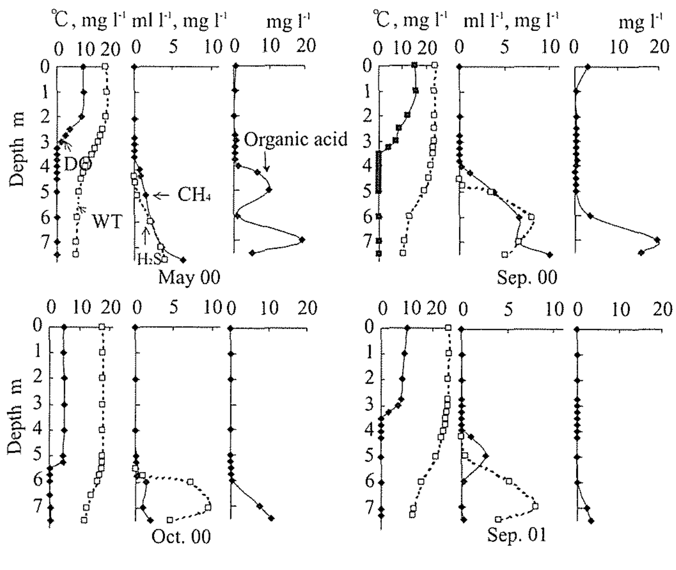


**Fig. 1.** Typical vertical distributions of dissolved methane, organic acid ($\sum$= acetic + formic + propanic + butyric), water temperature (WT), dissolved oxygen (DO) and hydrogen sulphide ($H_2S$)

in the hypolimnion. The methanogenesis was determined to be 2.29μl $l^{-1}$. The production of methane was measured in laboratory experiments and the result is shown in Figure 2. The amount of methane released 26.7 $CH_4$ μl $g^{-1}$ on the 21st day, and the acetic acid decreased in proportion to this increase. This suggests that acetic acid is a substrate of methanation in the hypolimnion (Koyama, 1976).

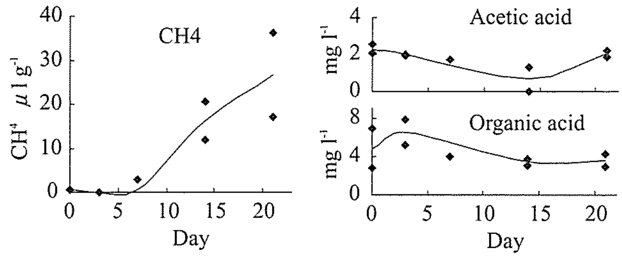


**Fig. 2.** Change of dissolved methane and organic acid (∑=acetic + formic + propanic + butyric + malic) released from incubated bottom sediment.

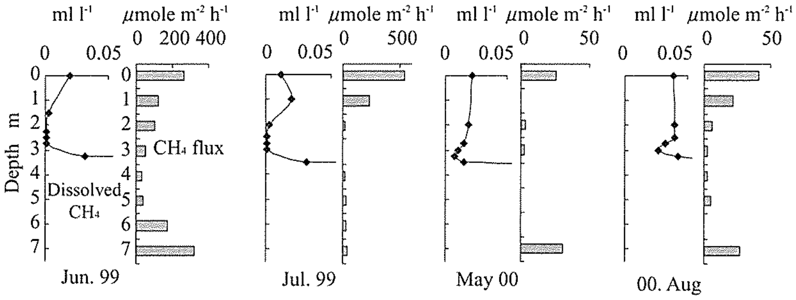


**Fig. 3.** Dissolutions of dissolved methane concentration focused on the epilimnion and methane flux.

The dissolved methane often increased in the epilimnion in the field observations and a similar tendency was confirmed in the methane flux (Fig .3). It is difficult to conclude that the methane formed in the epilimnion. Therefore the horizontal distribution was surveyed in order to examine transfer from the lake shore. It is considered that the higher concentration of dissolved methane in the surface water in the center of the lake than near the shore. While, in October was from the effect of the lake shore. The high methane concentration in the surface water in Lake Fukami-ike is suggested to be affected of zooplankton (Rudd et al., 1978).

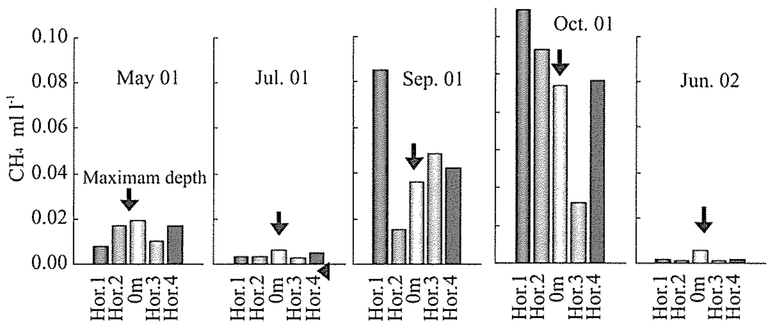


**Fig. 4.** Distributions of the dissolved methane in surface water collected by the method of horizontal sampling.

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