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SHORT COMMUNICATIONS

Microbial Processes of Methane Transformation in the Shallow-Water Zone of the Rybinsk Reservoir

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Investigations of the methane cycle in freshwater systems, where methane is the major end product of anaerobic decomposition of organic matter, have revealed the ecological significance of CH_4 not only in mud but also in water [1]. The main focus of the investigation was the hypolimnion of deep stratified water bodies. In the surface water of some lakes, the processes of the CH_4 cycle have also been recorded [2, 3]. However, such data are still scarce for the littoral zone of inland water bodies [4, 5] and virtually absent for coastal shallow-water areas of reservoirs. The present study was aimed at investigation of the distribution and dynamics of methane and assessment of the microbial processes involved in its transformation in different types of shallow waters of the Rybinsk Reservoir.

The concentration of methane in the water was determined by the phase equilibrium method [6] with a Chrom-5 gas chromatograph and using PID and Porapak-N as sorbents. The processes of methane oxidation and methane generation were estimated from changes in the methane content in *in situ* incubated experimental flasks. The experimental setup was as described in [4]; allyl thiourea (ATU) was used as an inhibitor of methane oxidation [7]. Three series of flasks (three replicates in each series) were filled with the investigated water and closed with silicone stoppers. A control series was immediately fixed with mercuric chloride. The second and third series (an ATU solution was added to one series using syringes to 1 mg/l) were incubated in dark bags for 12–24 h and fixed [5].

Observations were made every ten-days from May to November at permanent coastal stations representing typical shallow-water areas of the Rybinsk Reservoir and, for comparison, in the deep-water-channel part of the Volga Stretch. It was found that the content of methane in the water of different areas varied widely during the vegetation period, specifically, from 0.9 to 126 μl CH_4/l. The minimum concentrations were recorded in the open parts of the reservoir (the Volga Stretch and open shallow-water areas), whereas the maximum concentrations were found in the protected littoral zone, especially in summer in vegetation stands (see table).

The microbial processes of CH_4 oxidation in water took place everywhere but with abrupt spatial and seasonal fluctuations (0.01 to 24 μl CH_4/(l day)). The oxygen consumption attained 10% of BOD-1. The maximum methanotroph activity was recorded in summer in the protected littoral zone in areas with submerged vegetation, and the minimum activity was observed in open the shallow-water areas and in the channel part of the reservoir (see table). An inhibitor analysis showed that, for some areas, CH_4 generation may also occur in aer-

Concentrations of methane and its oxidation and generation rates in water taken from different areas of the Rybinsk Reservoir at particular stages of the vegetation period

Sites (depth at the station)	May	June	July	August	September	October	November
Overgrown shallow-water zone (1 m)	23–28 / 0.07	26–38 / 0.8–3.6	10–80 / 3.0–14 (0.05–0.39)	38–126 / 0.3–24 (0.1–5.21)	18–45 / 0.2–0.8 (0.1)	–	–
Protected shallow-water zone (1 m)	26–28 / 0.08	24–66 / 3.6–5.1	15–92 / 1.3–8.2 (0.05–0.22)	44–110 / 1.1–7.7 (0.1–1.17)	12–24 / 0.2–0.4	9.8 / 0.7	10.4 / 0.04
Open shallow-water zone (1–2 m)	21–33 / 0.08	10–22 / 1.4–4.2	1.5–56 / 0.01–1.5	3.2–28 / 0.6–2.1	6–13 / 0.1–0.2	2.5–7.0 / 0.3–0.9	3.2 / 0.02
Channel of the Volga Stretch (14 m)	14–16 / 0.10	8.5–17 / 0.1–0.4	1.5–24 / 0.3	0.9–30 / 0.2–1.2	4.3–8.1 / 0.1–0.3	3.1–6.2 / 0.11	–

Note: The numerator shows methane concentration, CH_4 μ/l; the denominator shows methane oxidation and, in parentheses, methane generation, μl CH_4/(l day). The dashes stand for "no data."

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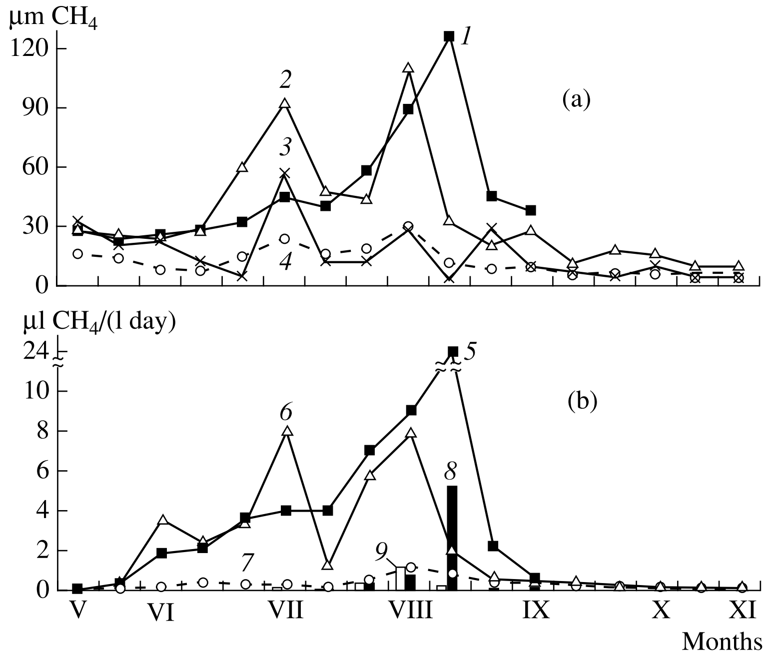

Fig. 1. Seasonal dynamics of (a) the methane content and (b) the rates of its transformation processes in surface waters of different parts of the Rybinsk Reservoir. The methane content is shown for the (*1*) overgrown shallow-water zone, (*2*) protected shallow-water zone, (*3*) open shallow-water zone, and (*4*) channel of the Volga Stretch. Methane oxidation is illustrated for the (*5*) overgrown shallow-water zone, (*6*) protected shallow-water zone, and (*7*) channel of the Volga Stretch, and methane generation, for the (*8*) overgrown shallow-water zone and (*9*) protected shallow-water zone.

ated coastal waters. In the overgrown shallow-water areas, the intensity of methane generation increased in late summer to 1.17–5.21 µl CH_4/(l day), a value usually reached only in highly eutrophic lakes [8]. In this case, consumption of C_{org} was 3.5–9.7 µl CH_4/(l day), corresponding to 50–90% of the bacterial assimilation of CO_2 or to 10% of phytoplankton production (our unpublished data). The above-presented values of methane oxidation and methane generation demonstrate the ecological significance of methane and of the processes involved in its transformation in water for the coastal biotopes of the reservoir.

The seasonal dynamics of the methane cycle in shallow water bodies has not been investigated. In the coastal waters of the Rybinsk Reservoir, we revealed significant variations in the content of methane and in the rates of its oxidation and generation during the vegetation period (see figure); these variations evidently reflect ecotopic flows of C_{org}. The curves representing methane oxidation in the protected shallow-water zone had two expressed summer maximums, obviously related to the dynamics of phytoplankton development. In the overgrown coastal zone, there was one maximum in early autumn, at the end of period of vegetation of higher aquatic plants. The rate of methane oxidation was found to depend on its concentration, and methanogenesis was recorded only in the period during which macrophytes died off and the water was enriched with organic detritus.

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REFERENCES

1. King, G.M., Ecological Aspects of Methane Oxidation, a Key Determinant of Global Methane Dynamics, *Adv. Microbiol. Ecol.*, 1992, vol. 3, pp. 355–390.
2. Utsumi, M., Nojiri, Y., Nakamura, T., Nozawa, T., Otsuki, A., and Seki, H., Oxidation of Dissolved Methane in a Eutrophic Shallow Lake: Lake Kasumigaura, Japan, *Limnol. Oceanogr.*, 1998, vol. 43, no. 1, pp. 10–17.
3. Pimenov, N.V., Rusanov, I.I., Karnachuk, O.V., Rogozin, D.Yu., Bryantseva, I.A., Lunina, O.N., Yusupov, S.K., Parnachev, V.P., and Ivanov, M.V., Microbial Processes of the Carbon and Sulfur Cycles in Lake Shira (Khakasia), *Mikrobiologiya*, 2003, vol. 72, no. 2, pp. 259–267.
4. Boon, P.I. and Sorrel, B.K., Biogeochemistry of Billabong Sediments. 1. The Effect of Macrophytes, *Freshwat. Biol.*, 1991, vol. 26, no. 2, pp. 209–226.
5. Dzyuban, A.N., Methane and Microbial Processes of Its Transformation in the Water of the Upper Volga Reservoirs, *Vodn. Resur.*, 2002, vol. 29, no. 1, pp. 68–78.
6. Naguib, M., A Rapid Method for the Quantitative Estimation of Dissolved Methane and Its Application in Ecological Research, *Arch. Hydrobiol.*, 1978, vol. 82, pp. 66–73.
7. Bange, H.W., Dahlke, S., Ramesh, R., Meyer-Reil, L., Rapsomanikis, S., and Andreeae, M.O., Seasonal Study of Methane and Nitrous Oxide in the Coastal Waters of the Southern Baltic Sea, *Estuar. Coast. Shelf Sci.*, 1998, vol. 47, no. 6, pp. 807–817.
8. Dzyuban, A.N., Intensity of the Microbiological Processes of the Methane Cycle in Different Types of Baltic Lakes, *Mikrobiologiya*, 2002, vol. 71, no. 1, pp. 111–118.