Short communication

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Distribution and morphology of colorless sulfur bacterium of the genus *Thiothrix* in water reservoirs of Baikal rift zone

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ABSTRACT. The habitats of colorless sulfur bacteria of the genus *Thiothrix* have been investigated in 7 hot springs of the Baikal rift zone. The intensity of their development depended on the distance from the outlet of thermal water to the surface and the flow rate of water. The most massive fouling of *Thiothrix* was observed at the border of mixing thermal and river water (Umhei, Alla). Slight *Thiothrix* fouling was observed at a significant distance from the thermal water outlet of the Goryachinsk spring.

Keywords: colorless sulfur bacteria, *Thiothrix*

1. Introduction

In the Baikal rift zone, there are a large number of hot springs (Borisenko and Zamana, 1978), where colorless sulfur bacteria live. In Lake Baikal, they are found in sites with an increased content of organic matter and intensive processes of sulfate reduction and methane generation (Namsaraev and Zemskaya, 2000). Sulfur bacteria of the genera *Thioploca* and *Thiothrix* have been identified in the lake. *Thioploca* is widespread throughout the lake (Namsaraev et al., 1994; Zemskaya et al., 2009). *Thiothrix* forms extensive white mats in the coastal zone in bay Zmeevaya (Chernitsyna et al., 2019) and hot spring Kotelnikovskii (Kompantseva and Gorlenko, 1988). In the Barguzin valley, bacteria of the genus *Thiothrix* were found in hot springs Khoito-Gol (Tatarinov et al., 2010), Seya, Alla and Bolsherechenskii (Namsaraev, 2003).

The purpose of this study was to determine the distribution of the colorless sulfur bacterium of *Thiothrix* genus and its morphological characteristics in hot springs which differing by physicochemical parameters.

2. Material and methods

Thiothrix (white fouling) were sampled during 2019-2020 in hot springs: Zmeevii, Kotelnikovskii, Davsha (Baikal coast), Umhei, Alla, Kuchiger, Goryachinsk (Barguzinskaya valley) (Fig., Table 1). Physicochemical characteristics were measured at the outlet of hot water and at the development sites of *Thiothrix* (ProfLine pH 3310, Germany; Table 2).

Photos of *Thiothrix* were done using Axiovert 200 microscope (Zeiss, Germany). Also samples were stained with DAFI (10 μg/ml), washed with phosphate buffer (0,1M) and fixed in a 4% formaldehyde solution. Samples were viewed on a scanning laser confocal microscope LSM-710 (Carl Zeiss, Germany) in the CIC "Ultramicroanalysis".

Anion concentrations were measured by means of liquid chromatography, on a Milichrom-2A chromatograph with a relative error of 5–10% (Baram et al., 1999). The samples for cation analysis were stored in polystyrene vials pre-acidified with 50μL of ultrapure concentrated HNO_3 and stored at 4°C prior to analysis. Cation (Ca^{2+}, Mg^{2+}) concentrations were determined by means of atomic absorption on an AAS-30 Carl Zeiss Jena spectrophotometer, as well as by flame emission methods (for Na^+ and K^+; Fomin, 2000) with a relative error of 3–5% (Table 2).

3. Results and discussion

Bacterial foiling of Thiothrix cover plants, stones and are found on animals in the coastal zone of bay Zmeevaya. There are no visible *Thiothrix* foiling in baths at high temperatures; *Thiothrix* flocs of different density were found along the coast at a distance of up to 2 m from the bank line.

In the other hot springs, sulfur colorless bacteria are also found on stones and plants in the zone where there is a stream of water, that, in our opinion, provides oxygen access. This can be seen in Goryachinsk spring,

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Table 1. Chemical characteristics of thermal waters of studied springs (Borisenko and Zamana, 1978; Namsaraev et al., 2007; own data).

spring	outlet			mat of Thiothrix			miner-aliza-tion, g/l	Characteristics of water
	T, ⁰C	pH	Eh, mV	T, ⁰C	pH	Eh, mV		
Zmevii	45	9.6	-441	18.0	8.3	-231	0.477	hydrocarbonate-sulfate-sodium, Ra, H_2S, CH_4, N_2, silicic acid
Kotelnikovskii	60-80	9.2	-137	32	9.5	-120	0.32	fluorid-hydrocarbonate- sodium, Ra, H_2S
Davsha	40	9.2	-67	33.5	9.2	+4.6	0.46	chloride-sulfate-sodium, silicic acid, N_2, F
Kuchiger	47	9.7	-380	37.5	9.47	-350	0.3	fluorid-hydrocarbonate-sulfate, Ra, H_2S, silicic acid
Alla	54÷73	9.7	-446	22.1	8.8	-258	0.3	sulfate-hydrocarbonate sodium, H_2S, N_2
Umhei	44	9.6	-388	15÷19	8.6-9.0	-274÷-185	0.36	fluorid-hydrocarbonate-sulfate, Ra, H_2S
Goryachinsk	51.4	9.0	-	19.2	7.3	-292	0.53	carbonate-sulfate-sodium, H_2S, silicic acid

where *Thiothrix* fouling is found at a significant distance from the outlet of thermal water from the ground (after the pond), in a site where the water temperature decreased to 18⁰C, but there is a water current. No fouling of sulfur bacteria was visually detected in the stagnant pond formed by the thermal water. Probably, low water temperature and distance from the outlet also affects the morphology of bacteria: in this area *Thiothrix* is represented by the smallest sizes of flocs.

4. Conclusions

Colorless sulfur bacteria are involved in the accumulation and crystallization of sulfur and play an important role in the ecosystem, since at night the oxidation of sulfur compounds is the main point of oxygen consumption (Zavarzin, 2003). Various researchers have suggested that these bacteria protect organisms (for example, plants, small animals) from the

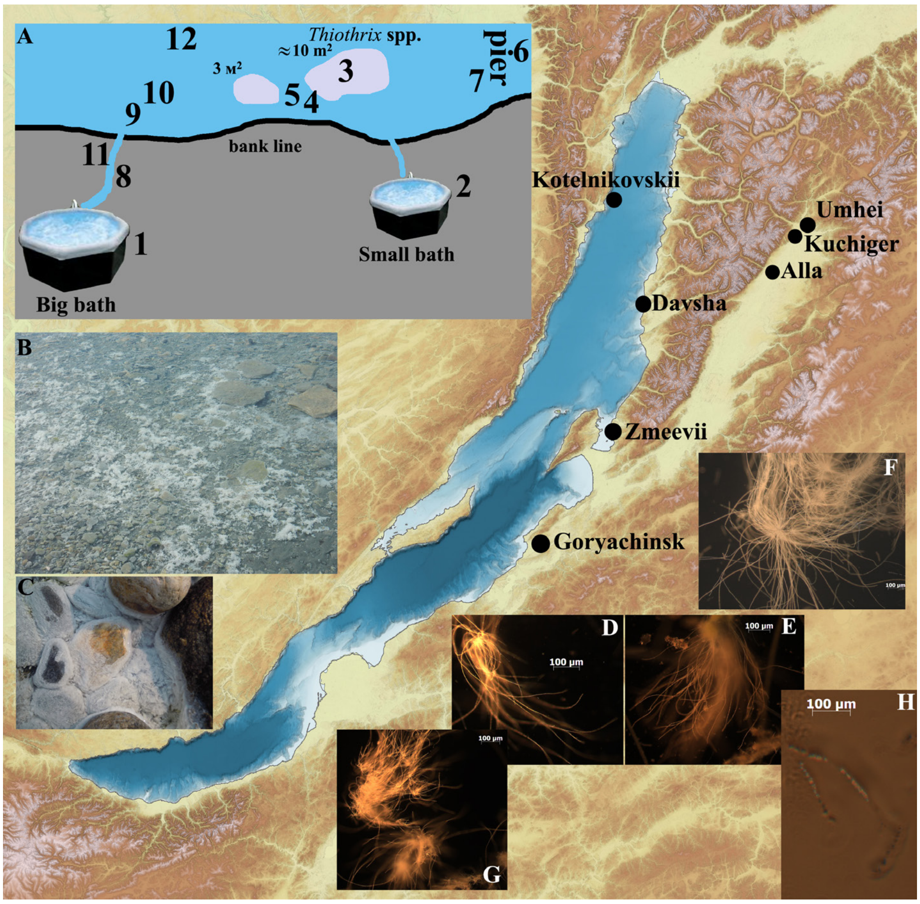

Fig. Schematic map of the locality of sampling stations (map - ASTER GDEM (v.2) and INTAS Project 99-1669 Team). A – schematic map of sampling in bay Zmeevaya. B, C – foiling on stones in Zmeevaya bay and Umhei spring, respectively. View of *Thiothrix* (10x): D - Alla, E - Goryachinsk, F - Umhei, G - Kuchiger, H - Alla (100x).

Table 2. Physical and chemical profiles of water in Zmeevaya bay (concentration of ion - mg/l).

site	T, ^{0}C	pH	Eh, мВ	HCO_3^-	Cl^-	NO_3^-	SO_4^{2-}	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+
1	42.6	9.6	-441	3280	16.2	10.9	92	-	-	-	-	-
2	39.0	9.2	-442.6	3078	13.0	7.9	76	-	-	-	-	-
3	18.8	8.5	-230	47.2	0.51	0.14	8.90	2.50	0.90	13.1	0.98	0.06
4	18.5	8.4	-152.7	81.3	0.35	0.06	6.86	4.70	0.60	20.0	1.36	0.06
5	19.4	8.9	-198.8	75.7	21.4	0.00	60.9	40.9	1.20	18.8	0.61	0.34
6	23.8	9.1	-420	71.9	5.48	0.00	7.06	15.0	1.20	11.5	1.90	0.22
7	18.0	8.3	-231	59.0	3.71	0.19	16.2	2.60	0.70	20.5	1.23	0.10
8	32.9	9.6	-360	84.1	27.8	0.00	60.5	51.7	1.20	16.1	0.05	0.14
9	21.6	9.0	-285	86.4	14.8	0.00	43.6	36.4	2.80	15.2	0.98	0.26
10	19.9	8.9	-210	70.1	0.27	0.13	5.22	2.90	1.30	17.9	1.35	0.06
11	32.3	9.6	-426	-	-	-	-	-	-	-	-	-
12	19.1	7.8	+150	69.0	0.26	0.00	5.21	3.40	1.00	16.3	2.98	0.01

aggressive action of hydrogen sulfide. Thus, the sulfide-oxidizing *Beggiatoa* protects the rhizosphere of rice plants from the toxic effect of sulfide (Joshi and Hollis, 1977). However, by covering plants with a dense layer, sulfur bacteria can prevent photosynthesis.

At present time we analyze microbiomes of *Thiothrix* fouling from all hot springs. To clarify the phylogenetic position and determine metabolism in sulfur, nitrogen and carbon cycles, full-genome studies of *Thiothrix* from the water reservoirs of the Baikal rift zone are planned in the future.

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