Short communication

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The 21st century is the virology century

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ABSTRACT. At the present time of global warming and significant pollution of water bodies and watercourses of the Earth, studies of the role of each component in the structure of the aquatic ecosystems are of fundamental and practical importance. The microbial population play a significant role in solving these urgent problems, because microorganisms perform the main function of self-cleaning of water bodies. At the end of the past century, a high number of viruses was detected in the water of the seas and oceans, which significantly exceeds the number of other organisms of the plankton community (Bergh et al., 1989). It was revealed that bacterial viruses (bacteriophages) play a key role in marine ecosystems, regulating the number and structure of bacterial communities, as they are actively involved in biogeochemical processes. To date, the research in this field allows us to consider aquatic viruses an important component of microbial loop, contributing significantly to the functioning of its hosts: bacteria, algae and protozoa. For freshwater ecosystems, such issues of the structural and functional organization of viral communities have been still poorly understood. Since 1997, we have begun to study bacteriophages in oligotrophic abyssal Lake Baikal.

Keywords: bacteriophages, taxonomic diversity, spatial and temporal distribution of the population, neuston, plankton, biofilms, Lake Baikal

In 2015, during the Fourth International Baikal Microbiological Symposium "Microorganisms and Viruses in Aquatic Ecosystems", I finished my key-note presentation entitled "Phages of Lake Baikal: the modern scientific mystery of the nanoworld" with the phrase: "The priority studies of the structure and functioning of phages (viruses) in the aquatic ecosystems are necessary to understand the fundamental and applied aspects of ecology in the 21st century as the century of virology" (Drucker, 2015). Very little time has passed, and today, in the context of the COVID-19 pandemic, the humanity has realized that viruses both harmless and pathogenic are constantly "around us, on us and inside us". All it takes is to list viral pandemics and epidemics of the 21st century: HIV infection, Ebola and Zika viruses, severe acute respiratory syndrome (SARS) known as atypical pneumonia, avian influenza or bird flu (type A virus A (H5N1, H5N2, etc.), swine influenza (type A virus (H1N1), Hunox viral encephalitis, viral hepatitis A, B, D, E, and C, varicella or chickenpox (severe incidence in adults), and Middle East respiratory syndrome (MERS) revealed in 2012.

Viruses are the smallest (measured in nm) and the most numerous organisms on the Earth (Wommack and Colwell, 2000). Their study requires specially equipped and well-isolated laboratories, expensive equipment and, most important, highly qualified virologists. For these reasons, viruses are studied in a small number of laboratories.

Our studies of autochthonous bacteriophages in various biotopes of Lake Baikal have begun in 1997. The first comprehensive microbiological, virological and molecular genetic investigations of phages allowed us to determine their high taxonomic diversity, features of the size range, the pattern of the spatial and temporal distribution of the population to the maximum depths, a great genetic diversity of DNA-containing viral communities in the pelagic zone as well as the structure and composition of the virome in the water column (Drucker et al., 2020).

Bacteriophages detected in long-term studies that were conducted in all seasons of the year both in the communities of various biotopes of Lake Baikal: neuston, plankton and benthos, and free (single) ones in the water column can be considered autochthonous because they were constantly found at different depths up to 1200 m (the maximum depth in the studies). The transmission electron microscopy of oligotrophic abyssal ecosystem has indicated a definite pattern: phages of the family *Siphoviridae* with a long irreducible tail process dominate in the entire water layer as in most other aquatic ecosystems of the world. Tailless

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phages of the families *Microviridae, Leviviridae* and *Tectiviridae* prevail in neuston, whereas in the benthic biofilms from the littoral zone of the lake, we recorded the maximum number of small phages with a shortened tail process of the family *Podoviridae*.

The number of free phage particles in the water of Lake Baikal in different seasons of the year varied from 0.01 to 0.58 $\times 10^6$ ml^{-1}. Phage particles showed the maximum number in the spring and summer-autumn periods in the surface water layer. The minimum number of bacteriophages was recorded in the winter at a depth of 1000 m.

An experimental study of the impact of the Baikal phages on the formation and destruction of the *Pseudomonas aeruginosa* PAO1 biofilm revealed the effect of reducing the biofilm thickness after 24 hours of cultivation compared to the control. We observed the same result during an experimental increase in the multiplicity of its infection with phages.

We proposed a modern scheme of the microbial loop in the ecosystem of Lake Baikal, including viroplankton, virioneuston and viriobenthos.

Bacteriophages in the composition of neuston, biofilms and plankton (free phages) are numerous and important components of aquatic microbial communities.

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