Ecotoxicological sensing of the arctic seas

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Abstract. The results of ecotoxicological monitoring - studies of the resistance of marine phytoplankton communities of the Arctic seas to some pollutants are presented. The influence of pollutants on primary productivity was assessed as the most sensitive biological process. It is shown that the method of ecotoxicological sounding makes it possible to identify areas most susceptible to chronic pollution, leading to a decrease in biological productivity.

Phytoplankton is a key component of the aquatic ecosystem because the formation of organic matter in the process of photosynthesis is one of the basic ecological processes in aquatic ecosystems and determines the biological productivity and stability of ecosystems [1, 2]. Among the most important parameters characterizing the state of the phytoplankton community, such as the growth rate of the algal population, chlorophyll content, and changes in the composition of the community, the most sensitive to negative influences is the intensity of photosynthesis (primary production). Photosynthesis of algae is more sensitive than the population growth of algae to a low concentration of some toxicants [3, 4, 5]. The study of changes in production processes under the influence of negative factors (pollutants) gives the most adequate idea of the ecosystem's response to pollution [6, 7].

To assess the resistance of natural phytoplankton communities to negative toxic factors in recent years, a short-term ecotoxicological experiment is often used, based on a quantitative assessment of the response of the phytoplankton community to the introduction of various concentrations of the toxicant [8]. The process of primary production of organic matter was chosen as the target of exposure; toxic metal (copper) and organic toxicants (benzo (a) pyrene and PCBs) served as exposure factors [9]. Copper is an important trace element for phytoplankton, necessary for metabolic and physiological processes [10]. However, at an increased concentration, copper is a potential toxicant that adversely affects the growth, development and reproduction of algae [11].

The experiments were carried out in conditions close to natural ones during marine expeditionary research. For the first time, large-scale ecotoxicological studies of the stability of phytoplankton communities (ecotoxicological sounding) were carried out in the same season (summer succession) in all seas of the Russian Arctic and Subarctic - the Baltic, White, Barents, Kara, Laptev, East Siberian, Chukchi and Bering Seas. The LD50 (the concentration of the toxicant causing a 50% decrease in primary production) was chosen as a measure of resistance. The determination of primary production was carried out by the radiocarbon method [12, 13].

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There were 40 ecotoxicological experiments with copper, 4 experiments with benzo (a) pyrene (BP) and 2 experiments with polychlorinated biphenyls (PCBs) in different Arctic seas. The change in the primary production of phytoplankton communities was estimated in the range of copper concentrations 5-100 μg Cu/L, BP 1-10 μg/L, and PCB 10-50 μg/L.

As a result of the analysis of the data obtained in ecotoxicological experiments carried out with copper, it was found that the average LD50 level for the Arctic seas is 49 ± 27 μg Cu/L (mean ± standard deviation), the range of variation of this parameter is from 5 to 125 μg Cu/l (Table 1).

The highest resistance of phytoplankton to the toxic factor (copper) was found in the Baltic, Kara, Laptev seas (average LD50 from 53 to 69 μg Cu/L). The Baltic Sea is surrounded by developed industrial countries, which is naturally accompanied by a high level of pollution of sea waters, including heavy metals. Under these conditions, phytoplankton adapts to high concentrations of toxicants in the environment and becomes more resistant to their effects, which has been shown in many studies [14, 15]. Similar effects were observed in the Kara and Laptev Seas, where the study areas were in the zone of influence of the powerful Siberian rivers runoff - the Yenisei and Ob in the first case and the Lena in the second.

Table 1. Average values and range of LD50 variation (μg Cu/L) for the primary production of phytoplankton in the Arctic seas

| Sea           | Average LD50 | Minimum LD50 | Maximum LD50 |
|---------------|--------------|--------------|--------------|
| Baltic Sea    | 53           | 35           | 100          |
| White Sea     | 38           | 30           | 45           |
| Barents Sea   | 50           | 50           | 50           |
| Kara Sea      | 69           | 40           | 125          |
| Laptev Sea    | 60           | 50           | 70           |
| East Siberian Sea | 38       | 10           | 75           |
| Chukchi Sea   | 41           | 5            | 120          |
| Bering Sea    | 42           | 10           | 80           |

The lowest resistance of phytoplankton to copper was found in the White and East Siberian Seas (average LD50 <40 μg Cu/L). In the Chukchi Sea, the strongest variability in the toxic effect of copper on phytoplankton was found in different regions of the sea - from 5 to 125 μg / L. It is obvious that the environmental conditions in these areas were significantly different.

Similar experiments with benzo (a) pyrene and PCBs revealed a certain confinement of more resistant phytoplankton to polluted water areas. According to the literature data, in chronic experiments DDT and PCBs inhibit photosynthesis in the concentration range of 1–10 μg/L [16].

The phytoplankton community in the northern shallow part of the Chukchi Sea was found to be least sensitive to the presence of BP (station 106). At the maximum experimental BP concentration of 10 μg/L, the intensity of photosynthesis decreased only to the level of 53% of the control. At the same time, in the Bering Sea (in the Anadyr Bay - stations 115, 131), the minimum experimental concentration of the toxicant of 1 μg/L led to a significant suppression of photosynthesis (Fig. 1). For phytoplankton of the East Siberian Sea, a pronounced toxic effect manifested itself at a BP content of 10 μg/L. Phytoplankton showed the maximum resistance in areas with an increased BP content in natural water.
Figure 1. Influence of various concentrations of BP on primary production (PP, % of control) in the seas of the Eastern Arctic

The results of experiments with PCBs indicate that the nature of the response of phytoplankton from different habitats is similar to the response to BP. In the coastal areas, phytoplankton proved to be resistant to the presence of the maximum experimental concentrations of PCBs (10 µg/L), while in the open sea this concentration had an inhibitory effect (figure 2).

Figure 2. Influence of different concentrations of PCBs on primary production (PP, % of control) in the Chukchi Sea

The ecosystems of the coastal regions of the Chukchi Sea and the shallow water zone in the northern part of the sea turned out to be the most resistant to the impact of the studied pollutants in the eastern Arctic. It should be noted that the phytoplankton communities of the Anadyr Bay of the Bering Sea are highly sensitive to toxicants. A higher resistance of the plankton communities of the Chukchi Sea in comparison with the Bering Sea organisms in the course of ecotoxicological experiments was established earlier [17].

The use of the methodology of ecotoxicological sounding of phytoplankton communities in the pelagic zone of the seas makes it possible to assess the relative tolerance of the studied ecosystems to anthropogenic impact, to carry out zoning and to identify areas with the highest phytoplankton sensitivity to the action of pollutants [18].
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