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RESPONSE OF PHYTOPLANKTON COMMUNITIES OF THE BERING AND CHUKCHI SEAS TO CERTAIN ORGANIC POLLUTANTS AND HEAVY METALS

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Abstract: The purpose of this work is to study and compare the response of plankton communities of the Bering and Chukchi Seas to cadmium, copper, benzo(a) pyrene and polychlorinated biphenyls. Ecotoxicological experiments were carried out during the Third Soviet–US expedition on board of the research vessel ACADEMIC KOROLEV in 1988. The primary production of organic substance was used as a criterion to measure the toxicity. Critical concentrations (LC_{50}) obtained from "dose-effect" curves were used as the response of the community. The strongest influence on the phytoplankton primary production in the Bering and Chukchi Seas was found to be caused by benzo(a)pyrene (BaP) followed by copper (Cu), polychlorinated biphenyls (PCBs), and cadmium (Cd). Average values of LC_{50} for every station are presented. Based on the data, the present state of the Bering and Chukchi Seas ecosystems, concerning the influence of chemical pollution on phytoplankton, is discussed.

1. Introduction

In the last few years, an ever-growing anthropogenic impact on marine ecosystems and the adverse effects resulting from this impact have led to global negative consequences in these ecosystems. Since marine environmental pollution continues to occur, it is necessary to conduct ecotoxicological research on the effects of contaminants on plankton.

The aim of this work was to study of the resistance of phytoplankton communities of the Bering and Chukchi Seas to copper (Cu), cadmium (Cd), benzo(a)pyrene (BaP) and polychlorinated biphenyls (PCBs).

The values of "critical" or "lethal" concentration 50 (LC_{50}) were used as criteria of toxicity. The "critical concentration concept" means that the concentration content of a pollutant in the aqueous medium does not initiate nonreversible changes in the ecosystem.

Although several research projects have been done in the Bering Sea, its oceanographic, hydrochemical and biological parameters have been studied insufficiently compared to the Baltic, Mediterranean and Black Seas for example. Even the areas investigated so far are characterised by the absence of local sources of intensive pollution and slow gradual accumulation of toxicants. It is one of the most undisturbed and

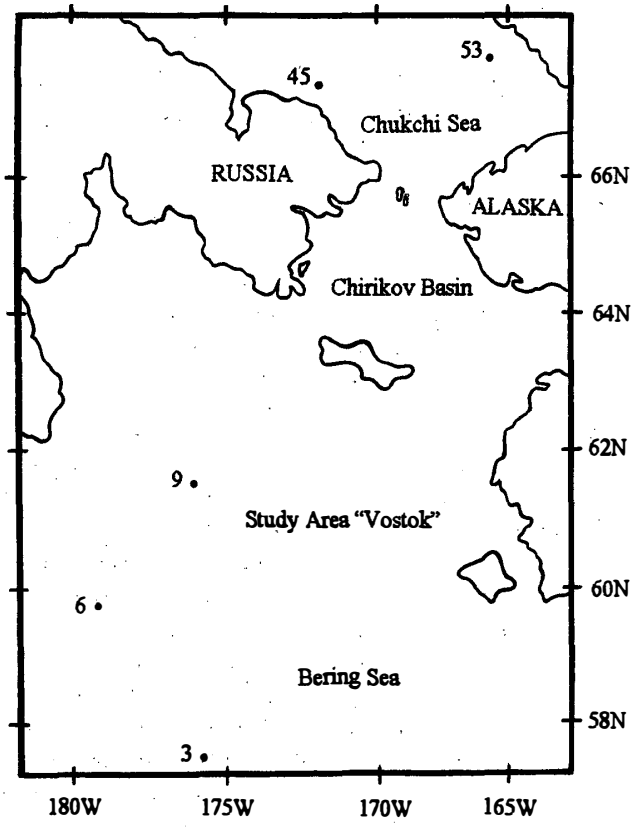


Fig. 1. Location of ecological station in the Bering and Chukchi Seas.

Table 1. Concentration levels of benzo(a)pyrene (BaP), polychlorinated biphenyls (PCBs), copper (Cu) and cadmium (Cd) in marine water of the Bering and Chukchi Seas (ng/l) (August, 1988) (IRHA et al., 1992; VOLODKOVICH and BELYAEVA, 1992; CHERNYAK et al., 1992; KOLOBOVA and MANYAKHINA, 1992).

Compound	Bering Sea	Chukchi Sea
Benzo(a)pyrene	2–5	0.8–3
PCBs	0.2–0.3	0.1–0.2
Cu	80	140
Cd	20–650	10–130

productive regions with an annual harvest of about 1 million tons of fish and a high level of primary production. The annual primary production in the Bering Sea is about 270000000 tons of carbon (MCROY and GOERING, 1976). Contaminant monitoring of such productive regions as the Bering Sea and the southern Chukchi Sea, therefore, seems to be quite important.

Distribution of BaP (benzo(a)pyrene) in the Bering Sea has "spotted" character (IZRAEL and TSYBAN, 1983). In August 1988, the registered level of BaP in the Bering Sea varied from 2 to 5 ng/*l* (Table 1) (IRHA *et al.*, 1992). The highest concentration was found in the photic zone: in the study area "Vostok" and "Chirikov" basin it was up to 64 ng/*l*; and in Bering Strait 85 ng/*l* (Fig. 1) (VOLODKOVICH and BELYAEVA, 1992). In the southern Chukchi Sea in 1988 the concentration of BaP was between 0.8–3 ng/*l*

(Table 1). The highest concentration was found in the central portion of the sea —15–16 ng/*l*, reaching a maximum level near the Alaskan coast (VOLODKOVICH and BELYAEVA, 1992).

LC_{50} ("lethal" concentration 50) of BaP for the Bering and Chukchi Seas were up to 1–2 μg/*l* and 0.75 μg/*l* (KORSAK *et al.*, 1992) respectively.

Regarding PCBs, the average concentrations in Bering Sea water were 0.2–0.3 ng/*l* (Table 1), with the highest level of 0.5 ng/*l* at 100 m depth (CHERNYAK *et al.*, 1992). In the Chukchi Sea, the concentration of PCBs in water in 1988 was about 0.1–0.2 ng/*l* (Table 1), with the highest concentration of 0.4 ng/*l* registered at 20–30 m depth (CHERNYAK *et al.*, 1992).

LC_{50} ("lethal" concentration 50) values of PCBs for the Bering and Chukchi Seas were up to 5–40 μg/*l* (IZRAEL and TSYBAN, 1989) and 35 μg/*l* (KORSAK *et al.*, 1992) respectively.

Heavy metals are another class of pollutants transported to marine ecosystems by rivers. Their levels in marine water vary considerably depending on the presence of anthropogenic sources, geological and geographical features of the region and so on. Small amounts of certain metals in the environment ave necessary for the development of organisms. It should be noted that the amount of copper limits the production of organic material in marine ecosystems. Mostly copper is incorporated by phytoplankton, macrophytes and some species of crustaceans. However, heightened content of copper in the environment inhibits different processes in living things.

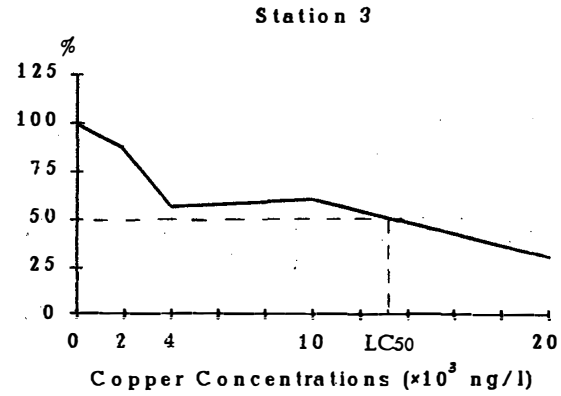
In 1988, the concentration of copper in Bering Sea water varied from 10 ng/*l* to 460 ng/*l* with an average of 80 ng/*l* (Table 1). In the Chukchi Sea it was about 140 ng/*l* (Table 1) (KOLOBOVA and MANYAKHINA, 1992).

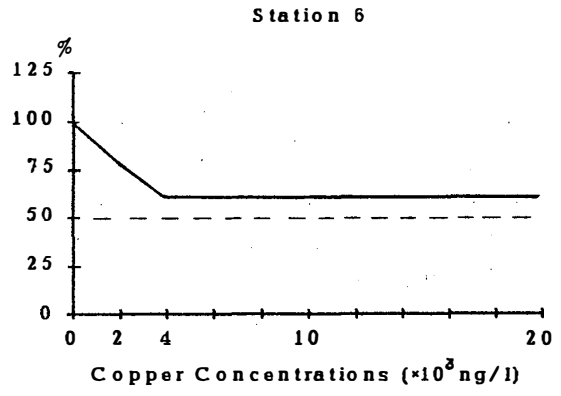
Similarly, the concentration of cadmium in the Bering Sea water was estimated to be from 20 to 650 ng/*l*, while in the Chukchi Sea it varied from 10 to 130 ng/*l* (Table 1) (KOLOBOVA and MANYAKHINA, 1992).

2. Materials and Methods

In the Bering Sea ecotoxicological experiments were conducted at three stations (Fig. 1). Similarly, samples from two stations, No. 53 and 45, in the Chukchi Sea were analysed (Fig. 1). The data obtained in 1988 by the third Joint US-USSR Bering and Chukchi Seas expedition has been used.

The general procedure of the experimental work was as follows. Water samples for the experiments were collected generally in the morning, at the surface layer with a 5-*l* plastic Niskin sampler. To examine each toxicant a sample was dispensed to five 150 m*l* glass bottles for every toxicant–one bottle for control/blank and four others for injection of different concentrations of toxicant. The experimental additions of 0.1, 1, 5, and 10 μg of BaP/*l*; 1, 10, 20, and 50 μg of PCB/*l*; 2, 4, 10, and 20 μg of Cu/*l* (in the form of $Cu(NO_3)_2$); 10, 20, 40, and 60 μg of Cd/*l* (in the form of $CdSO_4$) were done within 30 min after collection. Primary production of phytoplankton was measured by the ^{14}C-technique, using ^{14}C-$NaHCO_3$ (EGOROV *et al.*, 1984). The experimental bottles were placed in a shipboard deck incubator with flowing seawater under a natural illumination for 24 hours. At the end of incubation, samples were filtered on Millipore membrane





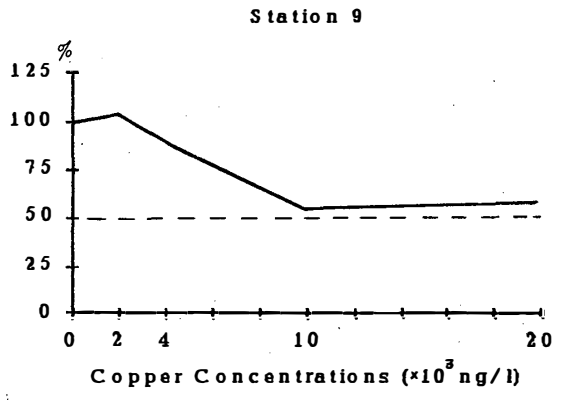
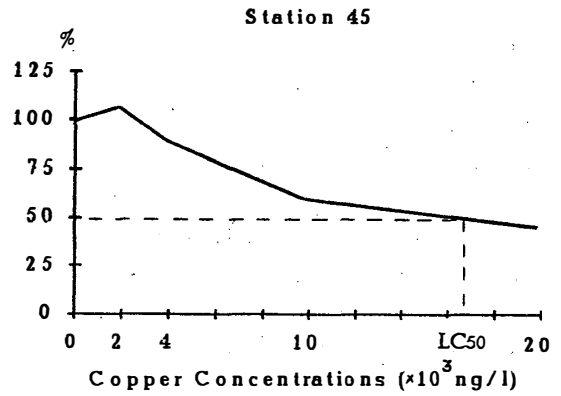


Fig. 2. Effects of Cu concentrations on primary production in the Bering (Stns. 3, 6, 9) Sea.



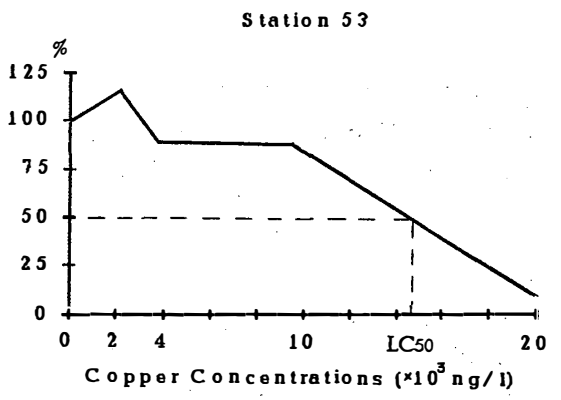
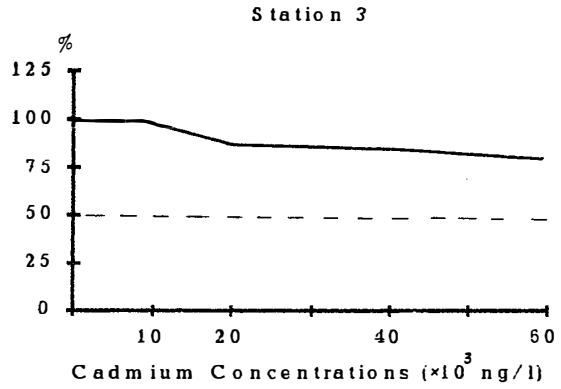
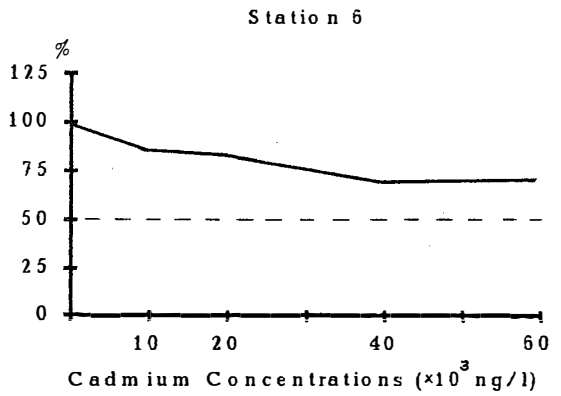


Fig. 3. Effects of Cu concentrations on primary production in the Chukchi (Stns. 45 and 53) Sea.

filters, 0.8 μm pore size and 20 mm in diameter. Radioactivity of the ^{14}C labelled phytoplankton retained on the filters and of ^{14}C isotope solutions was measured with the use of a scintillation counter "Rack-β", then curves were plotted based on the data on activity of the sediments. These curves represent change of primary production value depending on concentration of studied toxicant. The value LC_{50} was estimated using the "Dose-effect" curves according LIFTSHITS and KORSAK (1988).





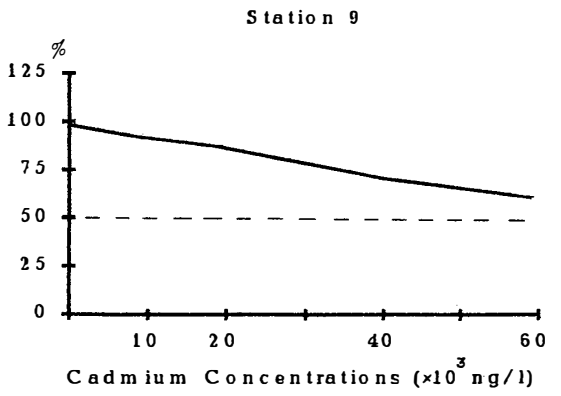
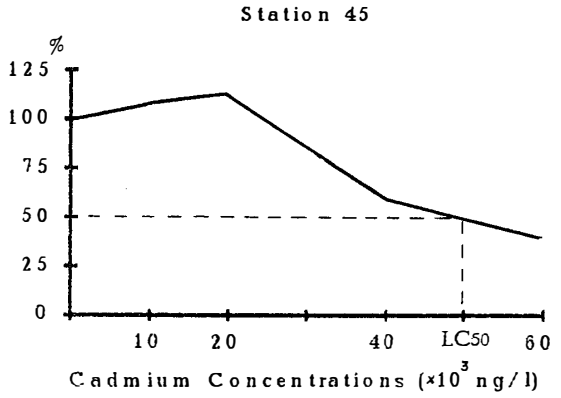


Fig. 4. Effects of Cd concentrations on primary production in the Bering (Stns. 3, 6, 9) Sea.



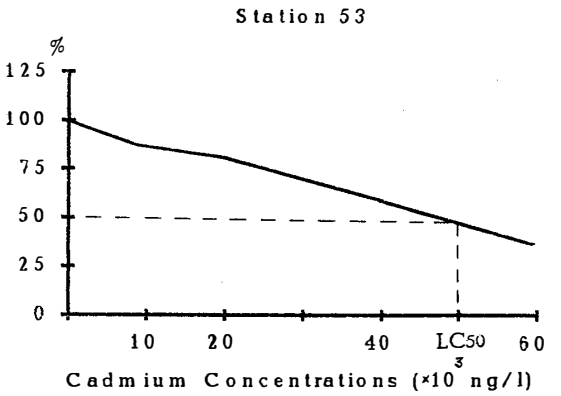


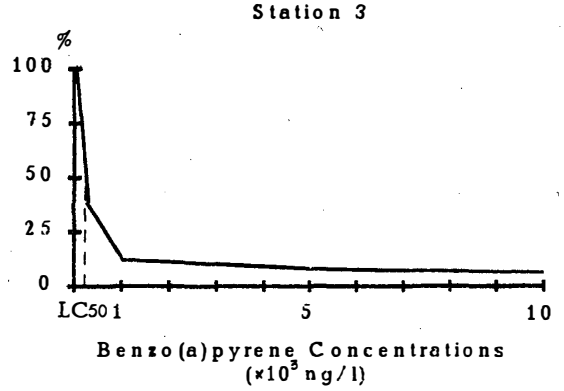
Fig. 5. Effects of Cd concentrations on primary production in the Chukchi (Stns. 45 and 53) Sea.

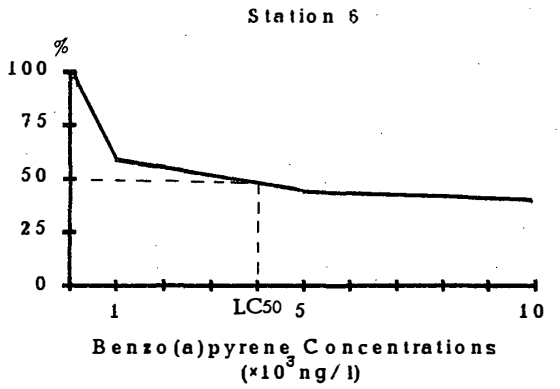
3. Results and Discussion

Data obtained in 1988 indicated comparatively high resistance of phytoplankton communities of the Bering and Chukchi Seas at the end of the phenological summer to the beginning of autumn.

The critical concentrations 50 of BaP, PCBs, Cu and Cd in the Bering and Chukchi Seas are presented in Figs. 2–9.

In the Bering Sea, the critical concentration 50 (LC_{50}) of copper, estimated on stations 6 and 9, was more than 20 $\mu g/l$, and was 13 $\mu g/l$ on station 3 (Fig. 2). LC_{50} of





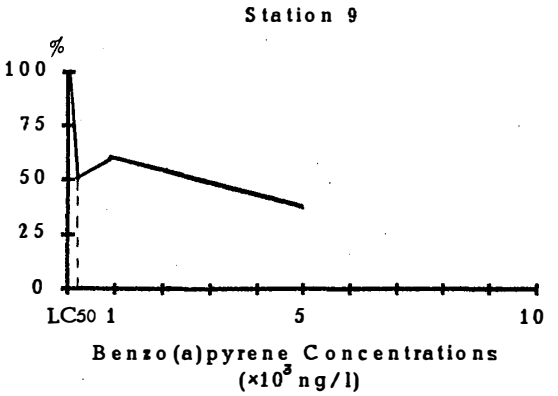
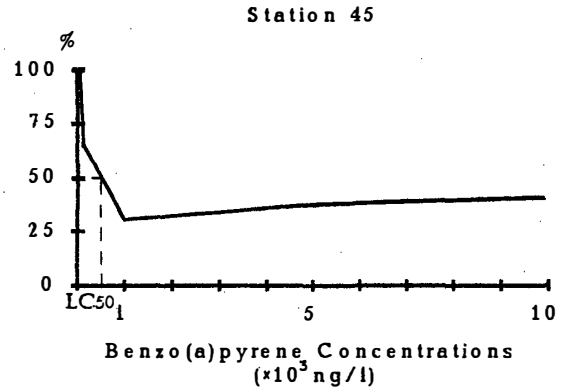


Fig. 6. Effects of benzo(a)pyrene concentrations on primary production in the Bering (Stns. 3, 6, 9) Sea.



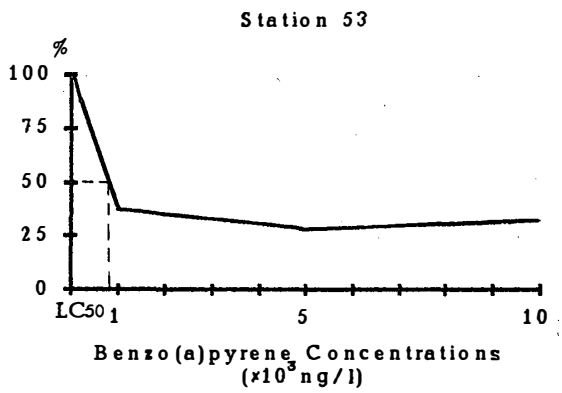


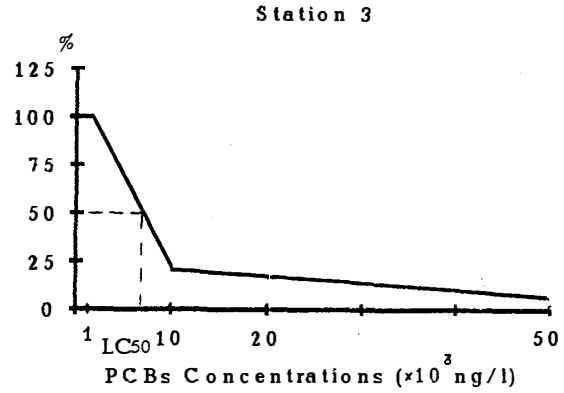
Fig. 7. Effects of benzo(a)pyrene concentrations on primary production in the Chukchi (Stns. 45 and 53) Sea.

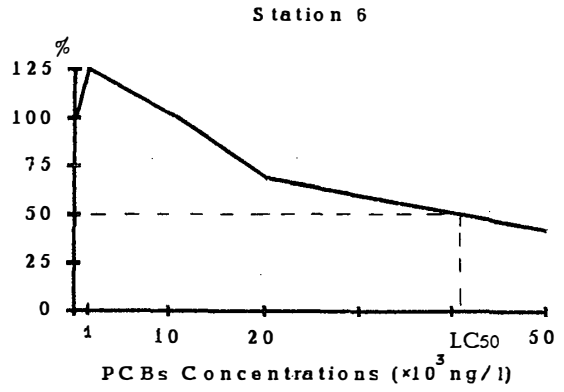
copper at stations 45 and 53 in the Chukchi Sea averaged 16 $\mu g/l$ (Fig. 3).

LC_{50} for cadmium for all stations at the Bering Sea exceeded 60 $\mu g/l$ (Fig. 4), where as that for Chukchi Sea was estimated to be 50 $\mu g/l$ (Fig. 5).

LC_{50} for BaP on stations of the Bering Sea varied from 0.1 $\mu g/l$ to 4.2 $\mu g/l$, with an average value of LC_{50} of 1.1 $\mu g/l$ (Fig. 6). LC_{50} of BaP at both stations in the Chukchi Sea varied from 0.4 $\mu g/l$ to 0.8 $\mu g/l$, averaging 0.6 $\mu g/l$ (Fig. 7).

In the Bering Sea LC_{50} for PCBs varied considerably from station to station. At stations 3 and 9, it was about 8 $\mu g/l$, while at station 6, it was estimated to be 47 $\mu g/l$ (Fig. 8). LC_{50} of this contaminant in the Chukchi Sea varied from 28 $\mu g/l$ to 35 $\mu g/l$, averaging 31.5 $\mu g/l$ (Fig. 9).





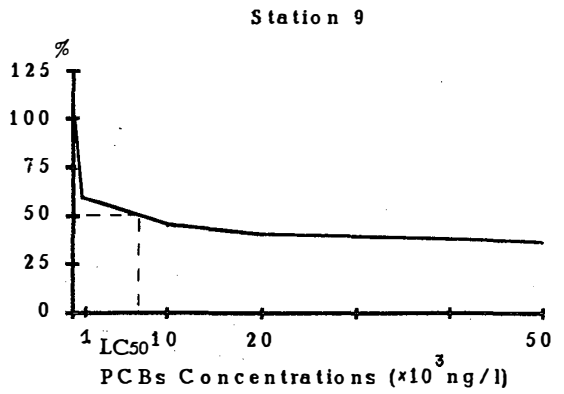
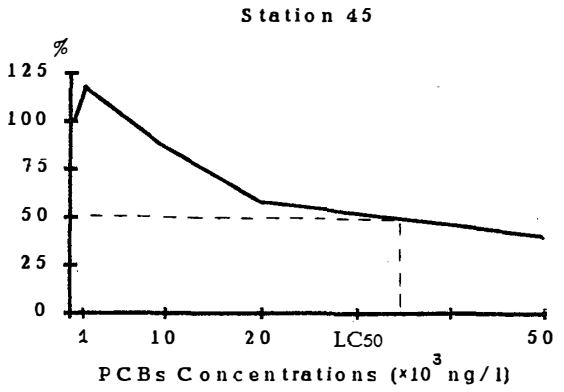


Fig. 8. Effects of PCBs concentrations on primary production in the Bering (Stns. 3, 6, 9) Sea.



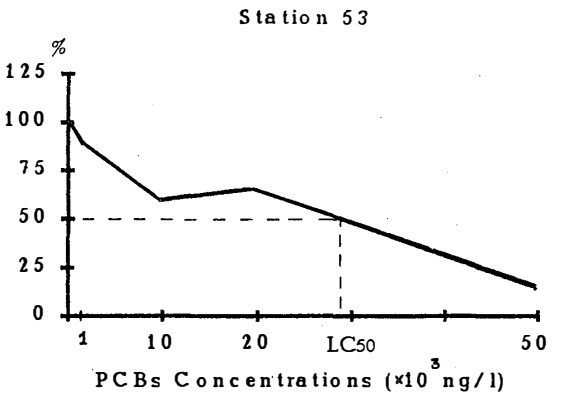


Fig. 9. Effects of PCBs concentrations on primary production in the Chukchi (Stns. 45 and 53) Sea.

BaP was found to exert greater toxic effects on phytoplankton community in the Bering and Chukchi Seas, followed by copper, PCBs and cadmium (Table 2).

Phytoplankton of the Bering Sea was found to be more resistant to copper than in the Chukchi Sea. At two of three stations in the Bering Sea, the value of LC_{50} of copper exceeded the maximum of added concentration of 20 $\mu g/l$. In the Chukchi Sea, the average LC_{50} of copper was estimated to be 16 $\mu g/l$, which was more by two orders of magnitude than the concentration level of this metal in the sea (Tables 1 and 2).

Phytoplankton communities of the Chukchi Sea are much more sensitive to BaP than communities of the Bering Sea. LC_{50} of BaP for phytoplankton of the Bering Sea was more than two times of the Chukchi Sea. The value of LC_{50} of BaP was more by

Table 2. The values of "critical" concentration (LC_{50}) of some pollutants in the Bering and Chukchi Seas ecosystems ($\times 10^3$ ng/l) (Numerator— "critical" concentrations limits of pollutants, denominator—average values).

Compound	Bering Sea	Chukchi Sea
Benzo(a)pyrene	(0,1–4,2)/1,4	(0,4–0,8)/0,6
PCBs	(7–47)/21	(28–35)/31,5
Cu	13–>20/>16,5	(15–17)/16
Cd	>60/>60	50/50

three orders than the concentration of this compound in water in the study area (Tables 1 and 2).

The phytoplankton in both seas have been found to be resistant to PCBs and cadmium. Communities of the Bering Sea showed higher resistance to cadmium (LC_{50} more than 60 $\mu g/l$) than communities of the Chukchi Sea (LC_{50} equal to 50 $\mu g/l$). In contrast phytoplankton of the Chukchi Sea seemed to be more resistant to PCBs (LC_{50} is 31.5 $\mu g/l$) than the Bering Sea ones (LC_{50} is 21 $\mu g/l$) (Table 2).

LC_{50} of PCBs was more by five orders than its concentration in sea water. Therefore, the present status of PCBs contamination in the Bering and Chukchi Seas may not be of concern with respect to toxic effects on plankton (Tables 1 and 2).

Comparing the data obtained in the Bering and Chukchi Seas in 1988 and similar experiments performed in the Baltic Sea in 1987, it should be noted that the ranges of LC_{50} of the investigated pollutants were very similar (LIFTSHITS and KORSAK, 1988; KORSAK and TIMOSHENKOVA, 1990). It is evident that the resistance of the plankton community of the Baltic Sea to BaP and PCBs was lower than in the Bering Sea (KORSAK and TIMOSHENKOVA, 1990; LIFTSHITS and KORSAK, 1988). On the other hand, the resistance of plankton of the Bering and Chukchi Seas to Cu and Cd was much lower than that in the Baltic Sea (LIFTSHITS and KORSAK 1988; KORSAK and TIMOSHENKOVA, 1990). These differences are probably very significant because the temperature of the Bering/Chukchi Sea water was 10°C lower than during the research in the Baltic Sea.

Probably, differences of resistance of phytoplankton communities may be due to their different structures and different levels of adaptation of various species composing the communities. Apparently, while evaluating the response of phytoplankton community to certain pollutants, one should take into consideration LC_{50} based on the ecological situation during seasonal succession. It is known that depending on the stage of succession of phytoplankton community, resistance to certain pollutants can vary two-three times.

Moreover, the level of impact of heavy metals can be changed because of formation of metal-organic complexes in marine water.

4. Conclusion

The toxic effects of contaminants on phytoplankton communities in the Bering and Chukchi Seas can be arranged in the following sequence: BaP > Cu > PCBs > Cd.

Phytoplankton communities of the Bering Sea are more resistant to the influence of copper, BaP and cadmium than communities of the Chukchi Sea. The most precarious situation is with copper pollution because the critical concentration determined for the

both seas was more by two orders than the concentration found in the water.

The highest resistance was shown to PCBs by phytoplankton assemblages of the Chukchi Sea. PCBs concentration in the Chukchi Sea water was five orders of magnitude lower than that found to exert toxic effects on phytoplankton.

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