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Comparative Evaluation of Migrating Anthropogenic Impurities in Ecosystems of the Middle Ob Region through Bioindication and Chemical Analysis

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Abstract

The study considers the influence of chemical substances contained in naturalwater bodies of Nizhnevartovsk region on the survival and fertility performance of *Ceriodaphnia affinis* used as a test object. Based on the data of chemical and toxicological analysis of the Ob River samples, the authors have carried out a correlation analysis of all examined indicators. The results of correlation analysis revealed significant positive and negative correlation between biotesting indicators and chemical substances in the examined water samples.

Keywords

Survival performance; Fertility performance; Test object; *Ceriodaphnia affinis;* Correlation analysis; Biotesting; The Ob River; Concentration of chemicals

Introduction

Most part of the North Western Siberia can be classified as wetlands, with lakes, marshes, and rivers with floodplains occupying more than half of the territory. The Ob River floodplain is a unique natural complex, a combination of wide and small canals, lakes, ridges, which creates excellent conditions for large biomass reserves [1]. Today, the issues of pollutants migrating and accumulating in ecosystems and their impact on the biological processes are becoming more and more urgent [2,3].

The water ecosystems are of particular interest when quality characteristics of environment assessed, and their condition can be indicator of the pollution of the territory in the whole region. In this regard the study of aquatic ecosystems' features can be used to assess their stability and protection.

The search for sensitive test-objects is an important problem in environmental studies; it allows to assess the risk of natural water in advance and to take the necessary measures to prevent their pollution [2].

In the last few decades a large number of studies were dedicated to investigate surface water pollution by chemical substances, to identify average concentration level of individual pollutants in the ecosystem components, and to evaluate their impact on the hydrobionts.

Being an integral method for assessing aquatic toxicity, biotesting is used in addition to chemical analysis. However, it is rather difficult to interpret biotesting results, both in terms of survival and fertility performance, because the standard methods of hydro-chemical analysis do not take into account the nature of combined interactions of substances in the samples, and not all chemical substances are defined. The most sensitive test-object, which proposed to be used in assessment of the potential risk of natural waters is *Ceriodaphnia affinis,* it allows to evaluate chronic toxicity of tested water sample in shorter period of time (7 days) [1,2,3,4].

The purpose of this study was to evaluate sensitivity of test object *Ceriodaphnia affinis* to chemical substances contained in natural waters of the Nizhnevartovsk region.

≥ 50% of *Ceriodaphnia affinis in* tested water within 48 hours, provided that the controls mortality is ≤ 10%.

The chronic toxic effect of the investigated water on *Ceriodaphnia affinis* is determined by their death and the change in fertility over a period of 7 or more days (until the third generation of offspring in the control sample) in the tested natural waters compared to the control sample. The criterion of chronic toxicity is the death of 20% of the test organisms and (or) significant variation in fertility among survivors in comparison with controls. In the course of the study the account of death of *Ceriodaphnia affinis* in the experimental and control samples is carried out every hour during the first day, then 2 times a day every day.

The bio-testing for definition of chronic toxic action is carried out with observance of requirements to the temperature, duration of the photoperiod and quality of the cultivation water [4].

The contents of copper, manganese, and iron in surface waters was determined by atomic absorption spectrometry, the content of ammonium and phenol by photometric method, the concentration of nitrate and chloride by ion chromatography.

The studies were conducted in summer and autumn, with sampling in June and September. The data was statistically analyzed using Statistica 11.5 software and Microsoft Office XP Excel 2005.

Results and Discussion

During the study period, chronic toxicity of surface waters by the criterion of survival of *Ceriodaphnia affinis*, mortality did not exceed 10%. Therefore, the concentration of chemical substances in the Ob River causes no chronic toxic effect on the test objects.

The studies conducted in 2004- 2006, in 2009, 2011 and 2012 showed no chronic toxic effect on the average fertility performance of *Ceriodaphnia affinis*. The water samples studied in 2007, 2008 and 2010 showed certain toxic effect on the fertility performance of *Ceriodaphnia affinis*: the studies in 2007 revealed more than 30% fertility stimulation, while in 2008 and 2010 the results showed inhibition of fertility, in comparison with the control group (Figure 1).

Figure 2 shows the data on the average fertility performance of *Ceriodaphnia affinis* studied in the autumn period. According to

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the studies of average fertility performance of *Ceriodaphnia affinis*, conducted in 2006 and 2012, the analyzed water had more than 30% chronic toxic effect on *Ceriodaphnia affinis*, while in other no toxic effects on tested objects were observed.

The analysis of ammonia content in the sampled water (Figure 3) showed excessive levels of the maximum permissible concentration (MPC) of ammonia in the autumn periods of 2005 and 2012, amounting to 0.83 mg/l and 0.76 mg/l, respectively. The study showed maximum concentrations of ammonia in the summer period of 2010, amounting to 1.2 mg/l. In other periods, the studies showed relatively low ammonia concentrations not exceeding MPC (0.5 mg/l) and amounting to 0.06-0.3 mg/l.

The study in autumn and in summer revealed iron concentrations in the tested water samples exceeding the MPC level and amounting to 0.1 mg/l (Figure 4). The minimum iron concentration was observed in September 2008, the maximum, amounting to 7.19 mg/l, in September 2010. The annual dynamics of iron concentration in the tested water samples shows a slight increase in iron concentration in the summer, with the exception of studies of 2004 and 2010.

Copper concentration study shows the levels exceeding the MPC for the entire period of study, with the exception of water samples selected in the summers of 2010 and 2012, amounting to 0.001 mg/l (Figure 5). In the summers of 2004-2009 and in the autumns of 2010-2012, the studies show increased levels of copper concentration. Maximum concentrations of copper, amounting to 0.008 mg/l, were observed in the summers of 2004, 2006, 2009.

The studies of manganese concentration (Figure 6) in the Ob River show the levels exceeding the MPC standards for the entire study period. Maximum concentrations of manganese were observed in the autumns of 2004, amounting to 0.24 mg/l, and 2010, amounting to 0.5 mg/l; as well as in the summer of 2012, amounting to 0.47 mg/l. The annual dynamics of manganese concentrations in the water showed no significant fluctuations.

Figure 7 shows nitrate concentrations in the water samples, which are rather low, amounting to 40 mg/l, which is 40 or more times lower than the MPC standards. The studies show a trend of increased nitrate concentration in autumn, except in 2004, 2011 and 2012.

During the study period the concentration of chlorides in the Ob River waters was in the range of 1.0-8.9 mg/l, which is 30 to 300 times lower than the level of MPC standards (Figure 8). In summer the studies show a tendency for the increasing chloride concentration.

As a result, the overall study of the Ob River water samples held in 2004-2012 showed that the concentrations of such elements as ammonium, copper, iron, and manganese exceed the MPC standards, while the concentration levels for other substances do not exceed the MPC standards.

Based on the data of chemical and toxicological analysis of water samples, the researchers carried out a correlation analysis of indicators in all samples examined (Tables 1 and 2).

The results of the correlation analysis show significant positive and negative correlations between biotesting indicators and some chemical substances in tested water samples. The studies have shown a positive correlation between survival performance of *Ceriodaphnia affinis* and copper concentration (r=0.542), nitrates (r=0.456) and chlorides (r=0.475) in water, with the increased concentration of these substances, the mortality of the test objects is reduced.

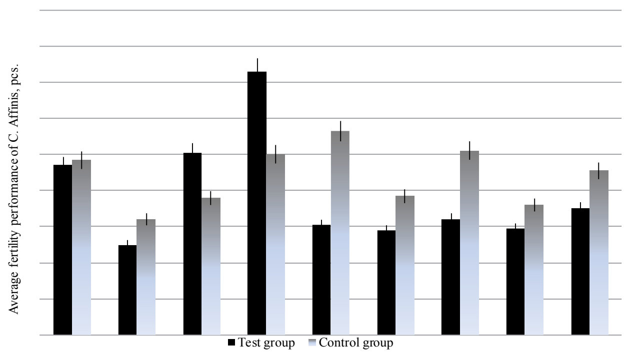

Figure 1: Average fertility performance of *Ceriodaphnia affinis* in summer.

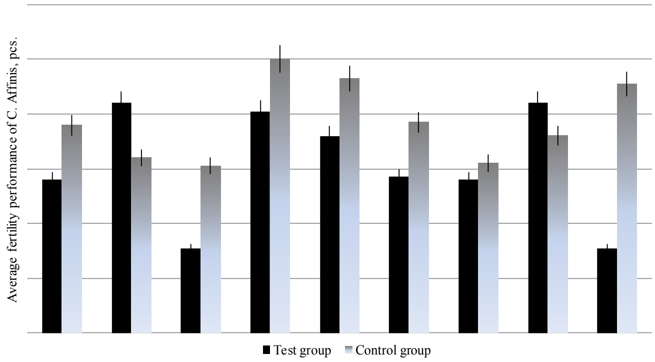

Figure 2: Average fertility performance of *Ceriodaphnia affinis* in autumn.

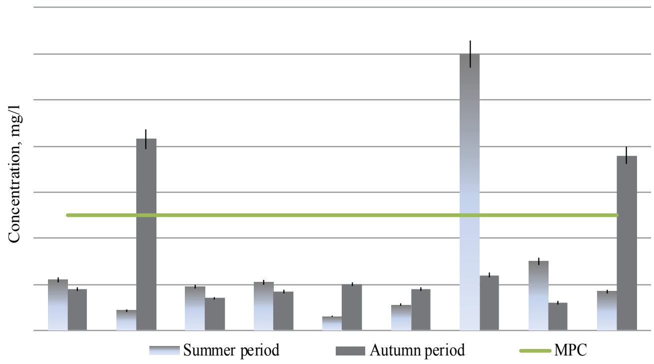

Figure 3: Ammonia concentration in the Ob River throughout the entire period of study.

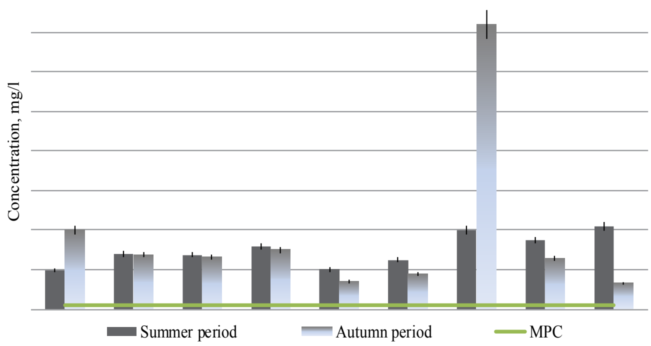

Figure 4: Iron concentration in the Ob River throughout the entire period of study.

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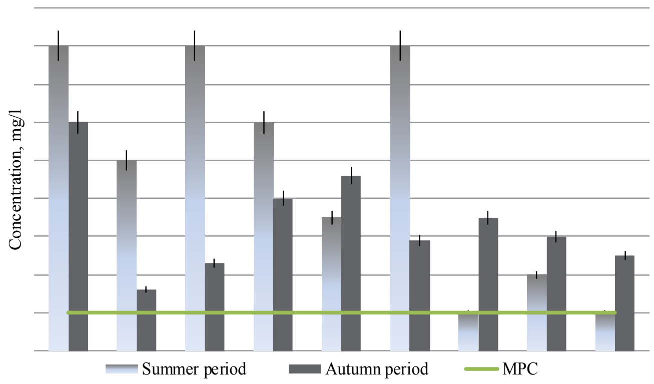

Figure 5: Copper concentration in the Ob River throughout the entire period of study.

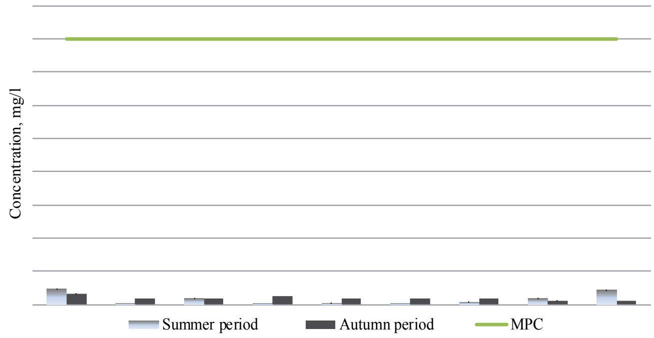

Figure 7: Nitrate concentration in the Ob River throughout the entire period of study.

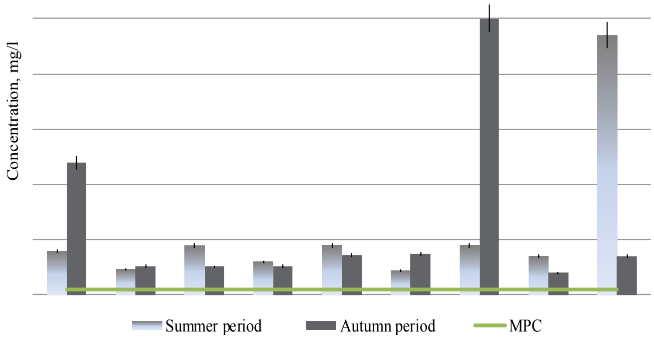

Figure 6: Manganese concentration in the Ob River throughout the entire period of study.

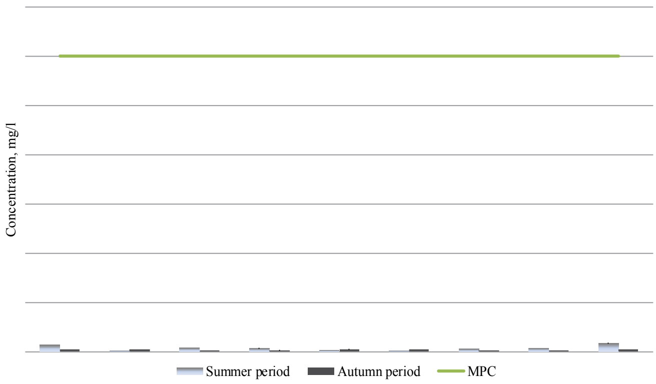

Figure 8: Chloride concentration in the Ob River throughout the entire period of study.

Table 1: The results of chemical and toxicological studies.

Study period(year)			2004	2005	2006	2007	2008	2009	2010	2011	2012	MPC
Concentration of tested substances (mg/l)	manganese	summer	0,079	0,047	0,089	0,06	0,09	0,04	0,09	0,07	0,47	0,01
		fall	0,24	0,05	0,05	0,05	0,07	0,07	0,5	0,04	0,07	
	ammonium	summer	0,22	0,09	0,19	0,21	0,06	0,11	1,2	0,3	0,17	0,5
		fall	0,24	0,05	0,05	0,05	0,07	0,07	0,5	0,04	0,07	
	iron	summer	0,98	1,4	1,37	1,6	1	1,25	2	1,75	2,1	0,1
		fall	2	1,37	1,31	1,5	0,7	0,88	7,19	1,28	0,66	
	copper	summer	0,008	0,005	0,008	0,006	0,004	0,008	0,001	0,002	0,001	0,001
		fall	0,006	0,002	0,002	0,004	0,005	0,003	0,004	0,003	0,003	
	nitrate	summer	2,36	0,2	0,94	0,13	0,21	0,1	0,38	0,92	2,2	40
		fall	1,66	1	1	1,36	1	1	1	0,56	0,5	
	chloride	summer	7,1	1,2	4,2	3,7	1,9	1,2	3,1	3,9	8,9	300
		fall	2,9	2,68	1,81	1,51	2,5	2,22	1	1,24	2	
Median fertility C.affinis (ct.)	sample	summer	9,4	5	10,1	14,6	6,1	5,8	6,4	5,9	7	-
		fall	5,6	8,4	3,1	8,1	7,2	5,7	5,6	8,4	3,1	
	controls	summer	9,7	6,4	7,6	10	11	7,7	10	7,2	9,1	
		fall	7,6	6,4	6,1	10	9,3	7,7	6,2	7,2	9,1	
Survival rate C.affinis (ct.)	sample	summer	10	9	10	10	9	9	10	10	10	
		fall	10	10	9	10	9	10	10	10	10	
	controls	summer	10	10	10	10	10	9	9	10	9	
		fall	10	10	10	9	10	10	10	9	10	

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Table 2: Revealed significant correlations.

Correlations	Correlation coefficient	P
Ammonium, mg/l - Average fertility performance of test objects, pcs.	-0.377	0.03
Iron, mg/l - Average fertility performance of test objects, pcs.	-0.454	0.03
Manganese, mg/l - Average fertility performance of test objects, pcs.	-0.364	0.03
Nitrates, mg/l - Average fertility performance of test objects, pcs.	0.309	0.03
Copper, mg/l – Survival performance of test objects, %	0.542	0.02
Nitrates, mg/l – Survival performance of test objects, %	0.456	0.04
Chlorides, mg/l – Survival performance of test objects, %	0.475	0.03
Iron, mg/l – Phosphates, mg/l	0.507	0.04
Iron, mg/l – Ammonium, mg/l	0.787	0.03
Manganese, mg/l – Ammonium, mg/l	0.790	0.02
Manganese, mg/l – Iron, mg/l	0.775	0.04
Manganese, mg/l – Nitrites, mg/l	0.491	0.03
Phenol, mg/l – Manganese, mg/l	0.653	0.04
Phenol, mg/l – Nitrites, mg l	0.785	0.03
Phenol, mg/l – Nitrates, mg/l	0.525	0.02
Chlorides, mg/l – Nitrites, mg/l	0.546	0.03
Chlorides, mg/l – Nitrates, mg/l	0.696	0.03
Chlorides, mg/l – Phenol, mg/l	0.697	0.03
Copper, mg/l - Nitrites, mg l	0.489	0.03

A negative correlation was observed between the fertility performance of test objects and concentrations of ammonium (r=-0.377), iron (r=-0.454), manganese (r=-0.364), i.e. with an increase in the level of substances in water samples correlates with the inhibition of fertility. At the same time, a positive correlation between fertility performance and increasing level of nitrates (r=0.309) in the water is observed, which means the increase of the nitrate concentration level correlates with the increased fertility performance of *Ceriodaphnia affinis*. Therefore, increasing concentrations of ammonium, iron, manganese, copper, and chlorides increase the survival performance of test objects and inhibit fertility, while higher nitrate concentrations improves the survival and fertility performance of *Ceriodaphnia affinis*. Correlation analysis data suggest credible positive correlations between concentrations of some chemical substances under study, such as ammonium and iron (r=0.787), ammonium and manganese (r=0.790), iron and manganese (r=0.775), iron and phosphates (r=0.507), phenol and manganese (r=0.653), phenol and nitrates (r=0.525), phenol and nitrites (r=0.785), chlorides and nitrates (r=0.696), chlorides and nitrates (r=0.546), chlorides and phenols (r=0.697), manganese nitrites (r=0.491), copper and nitrites (r=0.489).

In general, the results showed moderate credible negative and positive correlation between the survival and fertility performance of *Ceriodaphnia affinis* and concentrations of ammonium, iron, manganese, copper, nitrates and chlorides in water amounting to 0.364 <r <0.542, and credible significant positive correlation between the studied chemical substances, amounting to 0.489 <r <0.79.

The test with use of the test-object *Ceriodaphnia affinis* showed itself as express and informative method for toxicity assessment of natural water bodies in the Nizhnevartovsk region. Correlation analysis allows for interpretation of the results of bio-testing and chemical analysis. Obtained with this test object data along with the results of chemical analysis allow to adequately assess the degree of pollution of the territory.

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