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## Features of the hydrobiocenosis of the Kuibyshev reservoir in conditions of local pollution

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**Abstract.** A complex ecological situation develops in the area of the largest reservoir of the Volga cascade – Kuibyshev, especially in the areas of concentration of population and production. In connection with the development of aquaculture, the problems of conservation and reproduction of sterlet in the Kuibyshev reservoir become actual. Taking into account the tasks of preserving water quality in the upper part of the Volga reach of the Kuibyshev Reservoir as a spawning site of sturgeon in the early 20th century, special attention was paid to the impact of waste water discharges from the Mari Pulp and Paper Mill (JSC "MTSBK"). The hydrochemical and hydrobiological characteristics of section of the Volga reach of the Kuibyshev reservoir and secondary settler of JSC "MTSBK" were studied. The change in the qualitative and quantitative characteristics of the hydrobiocenosis in the conditions of functioning water treatment plant was shown.

### Introduction

A complex ecological situation develops in the area of the largest reservoir of the Volga cascade – Kuibyshev, especially in the areas of concentration of population and production. In connection with the development of aquaculture, the problems of conservation and reproduction of sterlet in the Kuibyshev reservoir are actual. Taking into account the tasks of preserving the quality of waters in the upper part of the Volga reach of the Kuibyshev reservoir as a spawning site of sturgeon fish in the early 20th century [1], particular attention was paid to the impact zone of wastewater discharges (JSC "MTSBK"). Investigation of the local contamination site of the Volga Reach in the area of wastewater discharges of JSC "MTSBK" as a model, with a high content of organic substances, makes it possible to trace the process of changing the characteristics of the biocenosis as the content of organic substances decreases: from the maximum contamination zone in the secondary settler, to the section of the Volga reach – less exposed to sewage.

Monitoring of hydrochemical and biotic indicators of the state of water ecosystems of energy objects becomes extremely important. It allows assessing the limits of stability of hydrobiocenoses, outline measures to reduce the negative anthropogenic impact on freshwater bodies.

### Results and discussion

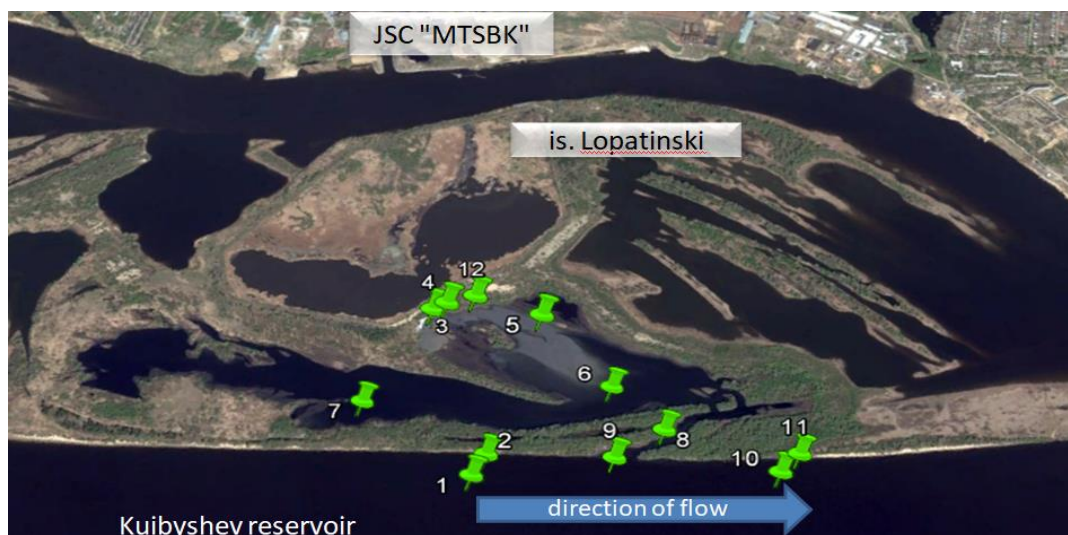
Characteristics of the study area, material and methods of research

The model site of the study is located in the Volga reaches of the Kuibyshev reservoir in the Lopatinskaya Volozhka area. JSC "MTSBK" commissioned in 1938. The secondary settler is a system of inter-island closed gulfs, from which the sewage flows through the canal into the channel part of the



Kuibyshev reservoir where the waters are further diluted by the main stream of the reservoir and the waters of the Ilet River that confluence upstream.

Hydrochemical and hydrobiological tests in the area of the Lopatinskaya Volozhka were conducted every two weeks during the growing seasons of 2011-2014 at the stations indicated in Figure 1. Hydrochemical, hydrobiological studies were carried out by standard methods.



**Figure 1.** Scheme of sampling stations in the area of wastewater discharge of JSC “MTSBK”.

Investigation of the state of water according to physicochemical factors of the environment  
In the zone of maximum organic pollution - wastewater discharges into the secondary settler, the COD varied from 69.4 to 270 mgO<sub>2</sub> / dm<sup>3</sup>. The control stations are characterized by COD values from 19.1 to 27.7 mgO<sub>2</sub>/dm<sup>3</sup>, what indicates a low concentration of organic substances. If the values of BOD<sub>5</sub> are more than 10 mg / l for "dirty" waters, then in the most contaminated sections of the settler the BOD<sub>5</sub> values are on average twenty times higher. At the control points of the Volga reach, the BOD<sub>5</sub> index varied from 1.4 to 2.6, in the zones of self-cleaning processes – 4.02 mgO<sub>2</sub>/l. During the operation of the treatment plant for about 60 years, on the control sites the BOD<sub>5</sub> indicator corresponds to clean and moderately polluted waters. The conducted study of the concentration of biogenic and organic substances in the control area showed an increase (within the limits of the MPC) of the concentrations of ammonium-ion, nitrate ion and phosphate ion as compared to the 2000s [2].

Analysis of the chemical composition of the water of the Volga reaches on the control site, carried out by the X-ray fluorescent method, revealed an excess of the MPC [3]: for strontium by 1.58, for iron by 2, for zinc by 6, and for copper by 40 times. Of the heavy metals in the water of the secondary settler there were Sr>Mn>Fe>Co>Zn>Cu>Rb. In the most polluted section of the secondary settler were noted Mn, Co, Rb, which were not observed in the water of the control section (Table 1).

**Table 1.** Concentrations of heavy metals (in fractions of MPC) in the water of the secondary settler and the Volga Reach.

Site of the study /Index	Elements								
	Sr	Fe	Zn	Mn	Cu	Rb	Co	Ni	Pb
<i>Secondary settler of JSC "MTSBK"</i>									
At wastewater discharge from the primary settler	1,60	3,0	4,0	60,0	30,0	0,05	4,0	-	-
Gulf of the secondary settler	2,2	4,0	355	40,0	-	-	41,0	-	-

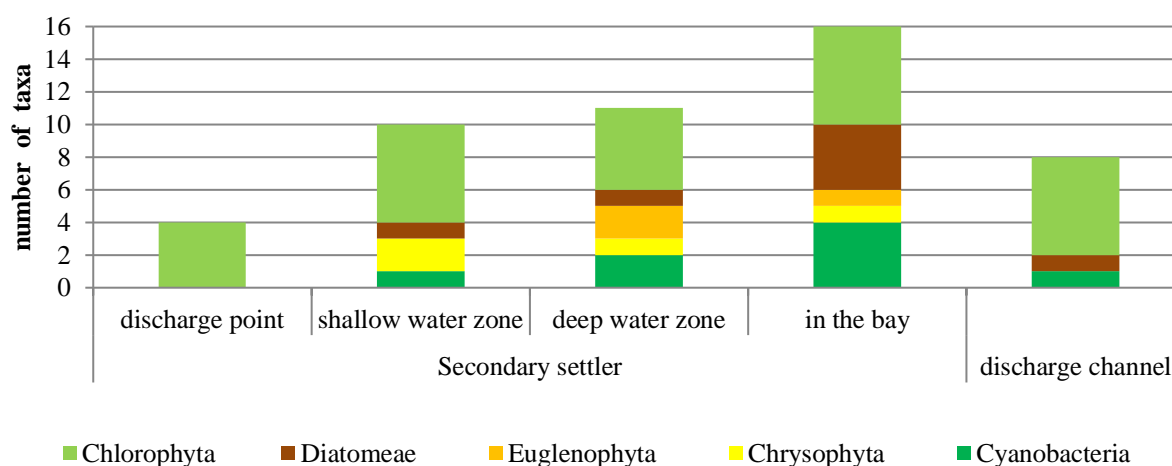
Ending of Table 1

<i>The Volga reach</i>									
The control section (500 m above the mixing zone)	1,58	1,2-2,1	6,0	-	0,75-40,0	-	-	-	-
Water mixing zone	1,68	2,0	48,0	20,0	-	-	-	-	-
Downstream (500 m from the water mixing zone)	1,65	6,0	14,0	10,0	50,0	-	-	3,0	13,3
MPC (mg/l)	0,4	0,1	0,01	0,01	0,001	0,1	0,01	0,01	0,006

Assessment of changes in the state of water by hydrobiological characteristics under conditions of local pollution.

The evaluation of the microbial component of the biocenosis shows that the section of the Volga reach (including the secondary settler) refers to the mesosaprobic zone. In different sections of the settler the total microbial number varied from 9813 to 49000 CFU/ml. Wastewater discharges showed a high number of coliform bacteria: up to 773 070 CFU/100ml. In all soil samples bacteria of these genera were found: *Bakterium*, *Pseudomonas* and *Clostridium*, which are ammonifying, and some members of the genus *Clostridium* – cellulose-destroying bacteria.

In the composition of phytoplankton, 70 species and taxa of algae were found from 6 divisions: in the control section of the Volga reach – 49, in the secondary settling basin – 59 (Figure 2).



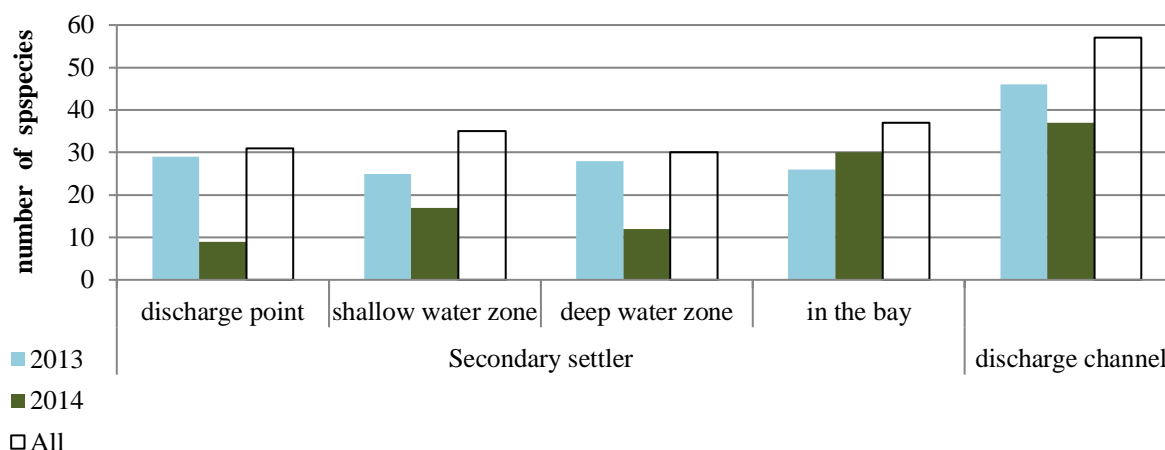
**Figure 2.** Taxonomic diversity of phytoplankton in the secondary settling basin.

In the secondary sedimentation basin, except the wastewater discharge site, cyanobacteria were the most numerous. The greatest abundance and biomass of phytoplankton was noted in the shallow section of the sedimentation basin – up to 708,879 cells/l and 325.78 mg/l, respectively. The basis of abundance was *Aphanothece globosa* Elenkin (up to 57%), 42% of the biomass formed large golden algae *Dinobryon divergens* Imhof. The density indices in the settler basin were dominated by green algae *Chlamydomonas* sp. (12.98), cyanobacteria *Microcystis aeruginosa* f. *flos-aquae* (Wittr.) Elenk. belonged to subdominants (9.99).

In the composition of zooplankton, 110 species and forms were encountered, in the control section of the Volga reach – 63, in the secondary settling basin – 71. The current state of the structure of zooplankton in the control areas of the Volga reach revealed ratio similar to the previous period [4].

In the control plot were well represented predatory species of branchy crustaceans – *Polyphemus pediculus* (Linne, 1778), *Bythotrephes longimanus* (Leydig, 1860), *Leptodora kindtii* (Focke, 1844), which were not observed in areas of wastewater discharges in Volga reach in previous studies [4]. At all stations of the Volga reaches, the *Dreissena veligers* and the bryozoa resting eggs were noted.

The study of zooplankton of the secondary sedimentation basin revealed a reduction in the qualitative (Figure 3) and quantitative indices of its development, there were no rotifers and crustaceans among the dominant species. There was a greater development of the infusoria of *Paramecium caudatum* (Ehrenberg, 1836) and representatives of class *Peritricha* sp., in the area of discharge of water into the secondary settler they amounted to 89.5% of the zooplankton population, small roundworms, annelids and various plankton forms of insect larvae were met.



**Figure 3.** Taxonomic diversity of zooplankton in the secondary settler.

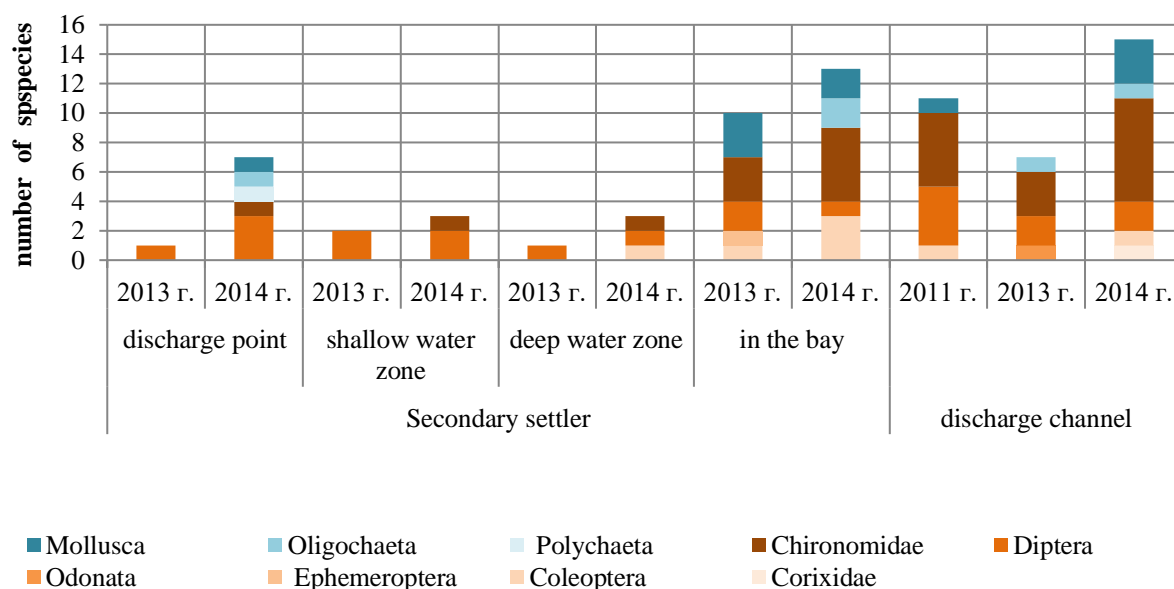
Regularities in the change of zooplankton communities have been revealed: in the most polluted area (polysaprobic zone) the infusoria *Paramecium caudatum* and representatives of the *Peritricha* group predominate, the variability of the species diversity indicators was more than 40%; at the site of reduction of organic contamination ( $\alpha$ -mesosaprobic zone), maximum development of phytoplankton and low development of zooplankton are noted first (the maximum quantity of zooplankton varied from 0.26 to 7.18 thousand specimens/m<sup>3</sup>). With a further decrease in organic contamination ( $\beta$ -mesosaprobic zone), the maximum biomass of zooplankton (up to 76.7 g/m<sup>3</sup>) was noted, first due to the development of *Daphnia pulex*, followed by *Moina macrocopa* and *Ceriodaphnia laticaudata*. In the areas of restoration of water quality from the branching crustaceans can be related to typical forms: *Bosmina longirostris*, *Chydorus sphaericus*, *Daphnia cucullata* (Sars, 1862); among copepods: *Eudiaptomus graciloides* (Lilljeborg, 1888), *Cyclops kolebsis* and *Metacyclops gracilis*, copepodite and naupliar stages of copepods. The coefficients of variation of Shannon species diversity indices [5] at the restoration sites – 13-22%; in the zone of water mixing the variability of species diversity is higher – up to 37%; on these sites are widely represented predatory species of branching crustaceans – *Polyphemus pediculus*, *Bythotrephes longimanus*, *Leptodora kindtii*.

According to the “trophy scale” [6], the entire stretch of the Volga reach can be related to the low class, and the shallow section within the secondary sediment basin - to the elevated class of trophic. The density indices in the secondary sedimentation basin showed an increase in the dominance of *Asplanchna priodonta* (Gosse, 1850) and the change of dominance from *Bosmina longirostris* to *Daphnia pulex* and *Moina macrocopa*.

As a part of the zoobenthos, 160 species and forms were encountered, of which 49 in the control section of the Volga reach. The most commonly noted were mollusks *Lithoglyphus naticoides*, from 2013 their frequency of occurrence - 100% and *Dreissena polymorpha* (Pallas, 1771).

The basis for the abundance of soft benthos (up to 60%) in summer was larvae of chironomids, and in the autumn - oligochaetes (62%). In the coastal zone the zoobenthos population varied up to 0.62-1.12 thousand specimens / m<sup>2</sup>. In 2014 there was a significant increase in the number of polychaetes *Hypania invalida* (Grube, 1860), the maximum of their development occurred at the beginning of August (0.22 thousand specimens/m<sup>2</sup>).

40 species and forms of zoobenthos were encountered in the secondary settler of JSC “MTSBK” (Figure 4), of which the most frequent were *Culex* sp., *Eristalis* sp., *Chironomus* sp. *plumosus* (Linne, 1758), *Glyptotendipes* sp. *griepkoveni* (Kieffer, 1913).



**Figure 4.** Taxonomic diversity of zoobenthos in the secondary settler.

The structure of the main complex of zoobenthos species on the sites of the greatest organic pollution is represented by the forms of insects capable of atmospheric respiration. With the improvement of the state in the ecotope, the diversity and representation of the secondary-water insects breathing dissolved oxygen increased, the control areas were dominated by primary water animals.

In the secondary settling tank, the zoobenthos population varied from 20 to 420 specimens/m<sup>2</sup>, the largest biomass in 2013 in the Gulf (up to 51.02 g/m<sup>2</sup>) and in the channel in 2014 (up to 64.5 g/m<sup>2</sup>). At the remaining stations of the settling basin, the zoobenthos biomass did not exceed 1.76 g/m<sup>2</sup>. According to the quantitative development of the zoobenthos, the class of waters [6] in the secondary sediment basin is estimated as  $\beta$ -oligotrophic and, only in the gulf, as hypertrophic.

The study of the components of hydrobiocenoses and hydrobionts in the areas of wastewater discharges revealed on all sites from 4 to 7 pollutants of heavy metals. Of the highly hazardous heavy metals in the bottom sediments and water, lead was present, from moderately hazardous - Cu, Cr, Zn, Ni. At the wastewater discharge sites, the main pollutants that enter the food chains into the fish are currently copper and zinc. In the Volga reach in the perch, there is an excess of the permissible residual amount for zinc and copper 3.5 and 4.7 times respectively. Lead is also a potential threat, as it accumulates in hydrobionts. The conducted studies revealed a decrease in the presence of copper, mercury and cadmium in hydrobionts in comparison with the end of the twentieth century [7, 8].

## Conclusions

At the wastewater discharge sites in the Volga reach of the Kuibyshev Reservoir, the main pollutants that enter the food chains into the fish are currently Cu and Zn. Pb, Hg and Cd – the characteristic pollutants of hydrobionts at the end of the 20th century are not currently noted in the hydrobionts of the Volga Reach.

The main pollutants in wastewater discharge in the secondary settler of the pulp and paper mill are organic substances. In the secondary settling tank there is a reduction in COD of water from 69.4-265.0 mgO<sub>2</sub> / dm<sup>3</sup> to a level characteristic for the control section of the river (in 2.9-4.4 times). Despite



the 60-year service life of the treatment plant, the studies showed no significant changes in the state of the hydrobiocenosis of the Kuibyshev reservoir downstream of the discharge compared to the control site.

49 species and intraspecific taxa of algae, 88 species and forms of zooplankers, 72 – zoobenthons were encountered in the area of the Kuibyshev reservoir in the area of wastewater discharge of JSC “MTSBK”. The whole studied area of the Volga reach refers to the low trophy class and is estimated as moderately polluted.

In the secondary sedimentation basin, 50 species and intraspecific taxa of algae were encountered, 71 species and forms of zooplankers, 40 – zoobenthons. As the concentration of organic substances decreases in local contamination sites, the change in the prevailing groups of internal communities of hydrobionts proceeds according to the following scheme: bacterioplankton → phytoplankton (in the direction of green → blue-green algae) → zooplankton (due to branchy crustaceans). The structure of the main complex of macro-invertebrate species on the sites of the greatest organic pollution is mainly represented by insect species capable of atmospheric respiration; when the state in the ecotope improves, the diversity and representation of the secondary-water insects increases: forms with breathing dissolved oxygen, replace forms consuming atmospheric air. Primary-water animals prevailed in the control areas and in the restoration zones.

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