The role of bioplato in conservation of the ichthyofauna of small river ecosystems

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Abstract. When wastewater enters water bodies, it changes both physical properties and chemical composition of water. Qualitative and quantitative composition of aquatic organisms and the biological structure of phytocenopopulations change as well. A special form of pollution is eutrophication of water bodies. The ability of photosynthetic organisms to accumulate and use substances, primarily phosphorus and nitrogen, makes them actively involved in self-purification of natural waters. The anthropogenic impact on aquatic ecosystems is increasing, therefore, monitoring and global environmental protection systems are of great relevance. The paper deals with a range of issues: the impact of gas station discharges on chemical composition of water is studied and assessed; the concentration of pollutants in water is analyzed before and after a backwater inhabited with higher aquatic plants; the effect of hydrophytes on processes of self-purification of the water body is considered. Solution of the issues made it possible to assess the impact of higher plants on chemical composition of water and self-purification processes, and biota. The impact of higher plants on concentration of pollutants in the water body was analyzed. The study revealed that higher plants reduce an adverse effect of pollutants on the biotic potential of the river ecosystem.

1. Introduction

The conditions of intensified production in various economic sectors expose water bodies to anthropogenic pressure. Water bodies located in urbanized areas run the risk of local pollution, along with the global intake of toxicants during biogeochemical cycles and with atmospheric precipitations [1–5].

In river ecosystems, water quality can be effectively managed through control of the content of biogenic elements using higher aquatic vegetation [6] – macrophytes: Phragmites australis (Cav.) Trin. Ex Steud., Scirpus lacustris Albedens, Typha latifolia L., Typha angustifolia L., Sagittaria sagittifolia L., Potamogeton natans L., and Butomus umbellatus L., etc. These plants are of practical significance since they are used for additional treatment of wastewater from enterprises of light, metallurgical and coal industry, and household and livestock wastewater [7, 8]. Higher aquatic plants absorb a significant amount of biogenic elements (nitrogen, phosphorus, potassium, sulfur, magnesium, etc.) and reduce the level of water body eutrophication, assimilate and process various substances; saturate water with oxygen; create favorable conditions for fish spawning and juvenile feeding; intensify water purification from heavy metals [9, 10]. In water bodies, oil-oxidizing bacteria play a significant role in reduction of the level of oil products in water. The study aimed to assess the
impact of aquatic and shoreline-aquatic vegetation on chemical composition of water and self-purification of water bodies, biota.

2. Objects and methods
The object of the study was the Mamonovka River of fishery significance of the second category (Table 1).

Table 1. Morphology, hydrology and typology of the water body.

| Parameters                        | Category                          | Value                  |
|-----------------------------------|-----------------------------------|------------------------|
| Geology:                          | organo-silicon                    |                         |
| Hydrology:                        | district                          | Baltic                 |
|                                   | pool                              | Baltic Sea             |
| River parameters:                 | площадь водосбора catchment area  | 311.0/124 km²          |
|                                   | river length                       | 51.0/12 km             |
|                                   | channel width                      | from 10.0 to 16.0 m    |
|                                   | current speed (average)            | 0.3 m/s                |
|                                   | height                            | lowland 0–50 m         |
| Water flow rate:                  | average long-term                 | 2.92 m³/s              |
|                                   | minimum for 2000                   | 1.25 m³/s              |
|                                   | maximum urgent (1962)              | 28.6 m³/s              |
| Levels:                           | average – 6.45 m; highest – 7.45 m; lowest – 5.81 m |                         |
|                                   | high flood (1979)                  | 7.76 m                 |
|                                   | summer steady low water level (1969)| 5.75 m                |
| Inflows:                          | quantity                          | 28/6⁰                 |
|                                   | length                            | 58/17⁰                |
| Chemical composition:             | class                              | hydrocarbonate         |
|                                   | type                              | calcium                |
|                                   | medium hardness                   | from 3 to 6 mmol/l     |
| Mineralization degree             | medium                            | 415.0 mg/l             |
| Water pollution degree            | moderately polluted               | quality class III, SCWQI <2.5⁰ |

* The denominator contains data for Kaliningrad region.

For water quality assessment, rivers and reservoirs are divided into several classes with regard to water pollution. Classes are based on intervals of the Specific Combinatory Water Quality Index (SCWQI).

State monitoring of the Mamonovka River is performed by the Kaliningrad Center for Hydrometeorology and Environmental Monitoring at an observation post located 6.2 km from the mouth. The river basin is asymmetric; it is located on the territory of Bagrationovskiy district. Its right-bank part is only 10% of the total area. All major tributaries of the river originate in Poland.

Within the boundaries of the water basin, there is a part of the territory of the Novoselovsky state natural zoological reserve of regional designation, specially protected wetlands, water protection zones and protected shoreline belt and coastal protection belt. The width of the shoreline protection belt in different parts of the water body depends on the bank slope. In accordance with Art. 65 of the Water Code, the width of the water protection zone for the Mamonovka River is 200 m.

The ichthyofauna of the river is mainly inhabited and represented by low-value species – roach and perch. The water body is not of commercial but of recreational value for amateur fishing. There are medium sized spawning grounds in the river with no wintering pits. Fisheries activities are planned for the future.

The studies were conducted in the area of the industrial site of a gas station located outside the water protection zone. Rainwater is discharged from the gas station through storm water inlets into a mud sump with a grease trap equipped with a settling tank, where oil products float up and the suspension settles. Oil products are collected by an oil-and-gas discharge pipe into a separate oil-and-
gas collection well. After the grease trap, clarified water is additionally treated using a filter. Expanded clay is used as a load. Mechanical treatment facilities (MTF) were commissioned in 1996, and the actual capacity of MTF is 62.64 m³/day.

Household wastewater from the gas station enters a septic tank equipped with a filter. In the septic tank, wastewater is clarified, and organic matter is decomposed under anaerobic conditions. The septic tank is a monolithic high density polyethylene tank equipped with a removable filter. A vent line is installed in front of the septic tank, which also serves as a purifier. Clarified water from the septic tank of the settling tank flows to the biofilter-percolator for additional treatment.

The biofilter-percolator is a monolithic reservoir made of high density polyethylene. In the upper part, the biofilter is equipped with a distribution device to distribute the effluent over the entire surface of the filter material. At the bottom of the biofilter, a drainage tray is placed to support the filter material. Pizzalon (highly porous durable material) is used as a filtering material. In the biofilter-percolator, clarified wastewater after the septic tank is subjected to biological oxidation and filtration. To improve the biofilter operation, it is planned to install a vent line on the inlet pipeline and an aeration well on the inlet pipe to provide air access to the filtering material. Biological treatment facilities (BTF) were commissioned in 1996, and the actual capacity of BTF is 0.66 m³/day. Purified settled water is discharged from the biofilter-percolator into the storm collector and further into the Mamonovka River. Waste of the enterprise is mainly of the 4th hazard class (low hazard).

Surface runoff is discharged from the drainage area (0.030 ha of buildings roofs; 0.321 ha of asphalted surfaces and roads; 0.749 ha of lawns) of 1100 ha. Gravity-driven runoff flows through an underground sewer line through outlet No. 1 located 5 km from the river mouth, 54°27'18" N 19°55'25" E, to the watercourse of the river. Key sites are laid out at five points (Figure 1):
site 1 – the very first point 50 m upstream from the outlet point (site 2);
site 2 – the outlet point of the discharged treated wastewater from the gas station;
site 3 – 50 m from the outlet point downstream;
site 4 – water abstraction point from the bioplato;
site 5 – 50 m after the bioplato.

![Figure 1. Location of the wastewater outlet of the gas station and water abstraction points.](image-url)
The study employed field and laboratory research methods. In the field, reconnaissance and route-key methods were used. The abundance, or the number of specimens of the species in the trial area, was assessed using the method of linear assessment in accordance with the O. Drude scale.

Water samples from the Mamonovka River were studied in the laboratory with regard to a number of indicators in accordance with the current standards and methods:
- phosphorus phosphates were analyzed according to GOST 18309-2014. Water. Methods for determination of phosphorus containing substances (method B);
- ammonium nitrogen was investigated according to GOST 33045-2014. Water. Methods for determination of nitrogen containing substances (method A);
- suspended solids were examined according to PND F 14.1:2:4.254-09. Quantitative chemical analysis of water. Methods for measuring mass concentrations of suspended and calcined suspended solids in samples of drinking, natural and wastewaters using the gravimetric method;
- petroleum products were analyzed according to PND F 14.1:2:4.5-95. Methods for measuring the mass concentration of petroleum products in drinking, surface and wastewaters using IR spectrometry;
- ultimate BOD were studied according to PND F 14.1:2:3:4.123-97. Methods for measuring the biochemical oxygen demand after n-days of incubation (ultimate BOD) in surface fresh, underground (ground), drinking, waste and treated wastewaters.

3. Study results
Higher aquatic plants provide continuous biochemical, chemical and physical-chemical utilization and neutralization of substances that pollute water bodies. They serve as bioindicators of the environmental state and exhibit high occurrence, high abundance, ease of collection and processing, and relatively large size.

The plant species selected for study grow in the backwater to form a natural bioplato, and comprise four ecological groups: I – floating unattached plants – duckweed (Lemnaminor L.); II – floating attached plants – yellow pond lily (Nupharluteum (L) Sm.); III – underwater plants – hornwort (Ceratophyllumdemersum L.), Canadian pondweed (Elodeacanadensis Rich.), pierced-leaved clasping-leaved pondweed (Potamogetonperfoliatus L.); IV – emergent plants – rush flower (Butomusumbellatus L.), bur reed, or common (Sparganiumemersum Rehm.), sedge (Carexacuta L.). The dominant species are sedge rush, cornstalk weed, water foxtail, frogbit, common reed, creeping crowfoot, and stinging nettle (Table 2).

| Cenopopulations                  | left bank | Geomorphological profile | right bank |
|----------------------------------|-----------|--------------------------|------------|
|                                  | 60 m upstream | 50m downstream | in bioplato | 50 m upstream | 30m downstream | 60m downstream |
| PotamogetonlutensL.              | cop2       | cop1                     | cop1       | sp           | cop3          |               |
| Acoruscalamus L.                 | cop3       | cop1                     | sol        | cop2         | cop2          | cop2          |
| Elodea canadensisRich u Mich     | cop1       | cop1                     | sol        | cop1         | cop1          | cop2          |
| HydrocharismorsursranaeL.        | cop1       | cop3                     | sp         | cop3         | cop2          | cop1          |
| CeratophyllurnsubmersumL.         | cop1       | cop3                     | cop3       | sp           | sp            |               |
| SpirodelapolyrhizaL.             | sp         | cop3                     | cop1       | cop1         | sol           | sp            |
| Lemna minorL.                    | sol        | cop1                     | sol        | sp           | sol           |               |
| Phragmitesaustralisis(Cav.)      | cop3       | cop1                     | cop1       | sol          | -             | sol           |
| Juncus tenuis Wild.              | sp         | cop1                     | cop1       | sol          | sol           | sp            |
| Carexacutal.                     | sol        | sol                      | cop2       | sol          | sol           | sol           |
| Nupharlutea(L.) Sibthet.Sm       | sp         | sol                      | -          | sp           | sol           | sol           |
| ButomusumbellatiusL.             | sp         | sol                      | cop2       | sol          | -             |               |
| Ranunculus repensL.              | cop2       | cop3                     | sp         | cop3         | cop2          | cop1          |
Myosotis caespitosa L.
Utricularia vulgaris L.
Alopecurus geniculatus L.
Sparganium emersum Rehm.

Aquatic plants occupy the waterside of the water body and serve as a barrier to prevent sewage flows into water bodies and streams. They are essentially $K$-strategists.

The study revealed that the concentration of pollutants in terms of $\text{BOD}_{\text{ultimate}}$, suspended solids, phosphate phosphorus, ammonium nitrogen, oil products in the populations of aquatic and shoreline aquatic plants in the Mamonovka River is higher than that at sites 1 and 5 (Table 3).

Table 3. Effect of aquatic and shoreline aquatic vegetation on self-purification of water bodies, \(\text{mg/dm}^3\)

| Site 1 | Site 4 (in bioplato) | Site 5 (after bioplato) |
|--------|----------------------|-------------------------|
| June-August | Mean value | June-August | Mean value | June-August | Mean value | MPCa |
| Suspended solids | 7.5 7.5 7.45 | 9.9 9.87 9.88 | 7.43 7.41 7.42 | 7.667 |
| $\text{BOD}_{\text{ultimate}}$ | 4.7 4.8 4.75 | 9.4 9.3 9.35 | 4.5 4.6 4.55 | 3.0 |
| Phosphorus phosphates | 0.09 0.09 0.09 | 0.170 0.168 0.169 | 0.09 0.08 0.085 | 0.07 |
| Ammonia nitrogen | 0.53 0.52 0.525 | 0.93 0.91 0.92 | 0.51 0.51 0.51 | 0.40 |
| Petroleum products | 0.07 0.07 0.07 | 0.14 0.13 0.135 | 0.05 0.05 0.05 | 0.05 |

*concentration according to the approved standard for permissible discharge (Table 4)

Table 4. Approved standard for permissible discharge.

| Month | Units of measurement | $\text{BOD}_{\text{ultimate}}$ | Suspended solids | Phosphorus phosphates | Ammonia nitrogen | Petroleum products |
|-------|----------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| January | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00125 | 0.00318 | 0.00003 | 0.00017 | 0.00002 |
| February | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00125 | 0.00318 | 0.00003 | 0.00017 | 0.00002 |
| March | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00125 | 0.00318 | 0.00003 | 0.00017 | 0.00002 |
| April | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00155 | 0.00396 | 0.00004 | 0.00021 | 0.00003 |
| May | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00187 | 0.00478 | 0.00004 | 0.00025 | 0.00003 |
| June | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.00187 | 0.00478 | 0.00004 | 0.00025 | 0.00003 |
| July | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.0018 | 0.0047 | 0.00004 | 0.00025 | 0.00003 |
| August | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.0018 | 0.0047 | 0.00004 | 0.00025 | 0.00003 |
| September | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.0018 | 0.0047 | 0.00004 | 0.00025 | 0.00003 |
| October | g/hour | 46.329 | 118.401 | 1.081 | 6.177 | 0.772 |
| | t/month | 0.0015 | 0.0039 | 0.00004 | 0.00021 | 0.00003 |
At all water abstraction points, the values of BOD$_{\text{ultimate}}$, phosphorus phosphates, ammonium nitrogen and, partially, petroleum products exceed the MPC. This is due to an intense anthropogenic impact on the water body upstream and, as a result, activation of natural processes of biochemical oxidation due to activity of various microorganisms, as well as decomposition of unstable organic compounds contained in the sampled water.

Analysis of water sampled after passing through the bioplat showed that the concentration of these substances at site 5, in comparison with site 1, inevitably decreases.

The combination of analyzed indicators (suspended solids, BOD$_{\text{ultimate}}$, phosphorus phosphates, ammonium nitrogen, petroleum products) corresponds to the beneficial effect of vegetation on self-purification of the water body as a natural sorbent of pollution, which ensures stable and balanced functioning of ichthyofauna.

4. Conclusion

The study revealed phytocenoses of semi-aquatic vegetation, which are dominant in these conditions and represented by edificatory cosmopolitan cenopopulations of *Acorus calamus*, *Phragmites australis*, and *Alopecurus geniculatus* species.

Chemical analysis of water samples showed that after passing through the bioplat water is purified up to or below initial values (site 1). However, the values of BOD$_{\text{ultimate}}$, phosphorus phosphates and ammonium nitrogen required for water bodies of fishery value are not attained due to high anthropogenic impact on the entire drainage area of the Mamonovka River.

The number of plant populations that make up the bioplat must be maintained in the optimal mode in the context of nature conservation measures aimed at improving their habitats as a source that provides a self-regulating effect of the plant component on self-purification of the hydrosphere, since the ability of plants to oxygenate generators is limited.

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