The theory of the hydrobiological mechanism of water self-purification in water bodies: from theory to practice

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Abstract.
New data on effects of chemicals (surfactants) on water filtration by aquatic invertebrates are reported. The basics of the new theory of the polyfunctional role of biota in self-purification of water in aquatic ecosystems (lakes, rivers, man-made reservoirs) are formulated. The theory covers the following: sources of energy for the mechanisms of self-purification; the main functional blocks of the mechanism of water self-purification; the system of the main processes that are involved; analysis of the degree of participation of the main groups of aquatic organisms; degree of reliability and the main mechanisms providing the reliability of water self-purification; biotic regulation of the processes; the attitude of the mechanism of self-purification towards the external influences/impacts; applications and conclusions relevant to the practice of sustainable use of water resources, including some new approaches in preventing eutrophication and chemical pollution.

Key Words: pollution, water quality, water self-purification, lakes, rivers

Introduction.
Sustainable use of aquatic resources is based on the ability of aquatic ecosystems to maintain a certain level of water quality. Water self-purification in both freshwater and marine ecosystems is based on a number of interconnected processes (e.g., Wetzel, 1983; Spellman, 1996; Ostroumov 1998, 2000). It is important to analyze the list of those processes and to find out whether at least some of them are vulnerable to manmade stress (Ostroumov, 2004).

Materials and Methods.
We have found and studied some negative effects of several chemical pollutants on the process of water filtration by aquatic organisms (bivalves and rotifers). The process of water filtration is a part of the system of processes leading to water purification in aquatic ecosystems. The details of the methods were described in the paper (Ostroumov, 2002a).

Results.
Our data demonstrated that water filtration by bivalves and rotifers was inhibited by several chemicals including surfactants and detergents. Among the surfactants that produced the inhibitory effect were the following:

- sodium dodecyl sulphate (SDS);
- tetradecyltrimethylammonium bromide (TDTMA);
- Triton X-100.

Discussion.
We consider our experimental data within the context of the general theory of the mechanism for water purification that was developed in our publications, e.g., (Ostroumov, 2002b, 2004).

The list of the main processes leading to water purification includes:

(1) physical and physico-chemical processes, including: (1.1) solution and dilution of pollutants; (1.2) export of pollutants to the adjacent land areas; (1.3) export of pollutants to the adjacent water bodies; (1.4) sorption of pollutants onto suspended particles and further

sedimentation of the latter; (1.5) sorption of pollutants by sediments; (1.6) evaporation of pollutants;
(2) chemical processes, including: (2.1) hydrolysis of pollutants; (2.2) photochemical transformations; (2.3) redox-catalytic transformations; (2.4) transformations including free radicals; (2.5) binding of pollutants by dissolved organic matter, which may lead to decreasing toxicity; (2.6) chemical oxidation of pollutants by oxygen;
(3) biological processes, including: (3.1) sorption, uptake and accumulation of pollutants by organisms; (3.2) biotransformations (redox reactions, degradation, conjugation), mineralization of organic matter; (3.3) transformation of pollutants by extracellular enzymes; (3.4) removal of suspended matter and pollutants from the water column in the process of water filtering by filter-feeders; (3.5) removal of pollutants from the water in the process of sorption by pellets excreted by aquatic organisms; (3.6) uptake of nutrients (including P, N, and organic molecules) by organisms; (3.7) biotransformation and sorption of pollutants in soil (and removal of nutrients), important when polluted waters are in contact with terrestrial ecosystems; (3.8) a network of regulatory processes when certain organisms control or influence other organisms involved in water purification.

Aquatic organisms are involved in physical, physico-chemical and chemical processes 1.1-1.6 and 2.1-2.6 directly or through excretion of oxygen or organic metabolites, production of suspended matter, affecting turbidity, temperature of water or other parameters of the ecosystem. As a result, living organisms are the core component of the multitude of processes of the ecological machinery working towards improving water quality. This component performs eight vital functions directly (3.1-3.8) and is involved indirectly in some of the other twelve functions (1.1-1.6 and 2.1-2.6) so that its role is clearly polyfunctional.

Our data on the effects of some chemicals on bivalves and rotifers have shown that the chemicals (surfactants) inhibited one oth important processes listed above, i.e. the process 3.4, namely water filtration by invertebrates and the removal of suspended matter from the water column (Ostroumov, 2002a).

Living organisms of aquatic bodies (both autotrophs and heterotrophs) are diverse in terms of taxonomy. Among them, autotrophs (phytoplankton; higher plants) generate oxygen that is involved in the processes 2.6 and 2.4 above. Heterotrophs (bacteria, fungi, invertebrates, fish) perform some of processes 3.1, 3.2, 3.4, 3.5 and some others. Virtually all aquatic biodiversity is involved.

Given this polyfunctional role of aquatic organisms, in one of our publications we compared aquatic ecosystems to 'large-scale diversified bioreactors with a function of water purification' (Ostroumov, 2000).

What is interesting about the biomachinery of water purification is the fact that it is an energy-saving device. It is using the energy of the sun (autotrophs) and the energy of organic matter which is being oxidized in the process of being removed from water by heterotrophs.

Some interesting examples of how various organisms are incorporated in that polyfunctional activity were given by authors of the preceding papers in this volume.

The importance of aquatic organisms in performing key functions in the hydrosphere provides an additional convincing rationale for protecting biodiversity.

The efficiency of the entire complex of those processes leading to water purification in ecosystems is a prerequisite for the sustainable use of aquatic resources. Man-made effects on any of those processes (we have shown effects of surfactants on water filtration by bivalves; some of the experiments were carried out together with Dr. P. Donkin) may impair the efficiency of water self-purification (Ostroumov, 1998; Ostroumov et al., 1998; Ostroumov & Fedorov, 1999; Ostroumov, 2001a, 2001b, 2002a,b, 2004).

Conclusions.

1.We postulate and predict that further studies will provide new examples of how important biodiversity is in performing many vital ecological processes leading to upgrading water quality.

By doing so, the multifunctional participation of biodiversity supports the sustainable use of water as one of key resources for mankind.

2.The body of new data and ideas presented in this volume will hopefully serve towards following interconnected and partially overlapping goals:

(1) prioritization of efforts on research and management in the area of aquatic resources and aquatic environment;

(2) biodiversity studies and protection;

(3) sustainable use of aquatic bioresources;

(4) advancement of aquaculture and mariculture;

(5) decreasing costs and increasing efficiencies in wastewater treatment using ecosystems; combatting eutrophication;

(6) understanding the role of biota in biogeochemical flows of chemical elements and in buffering global change.

References.

Ostroumov SA (1998) Biological filtering and ecological machinery for self-purification and bioremediation in aquatic ecosystems: towards a holistic view. Rivista di Biologia/ Biology Forum 91: 247-258.

Ostroumov SA (2000) Aquatic ecosystem: a large-scale, diversified bioreactor with the function of water self-purification (Vodnaja ekosistema: krupnorazmernyj diversifitzirovannyj bioreaktor s funktzijej samoochishchenija vody). Doklady Biological Sciences 374: 514-516 (the Russian edition: Doklady Akademii Nauk 374: 427-429).

Ostroumov SA (2001a) Amphiphilic chemical inhibits the ability of molluscs to filter water and to remove the cells of phytoplankton (Amfifil'noe veshchestvo podavljaet sposobnost' molluskov filtrovat' vodu i udalat' iz nee kletki fitoplanktona). Izvestia RAN. Ser. Biology 1: 108-116.

Ostroumov SA (2001b) Effects of amphiphilic chemicals on marine organisms filter-feeders (Vozdeistvie amfifil'nykh veshchestv na morskikh gidrobiontov-filtratorov). Doklady Akademii Nauk 378: 283-285.

Ostroumov SA (2002a) Inhibitory analysis of top-down control: new keys to studying eutrophication, algal blooms, and water self-purification. Hydrobiologia 469: 117-129.

Ostroumov SA (2002b) Polyfunctional role of biodiversity in processes leading to water purification: current conceptualizations and concluding remarks. Hydrobiologia 469: 203-204

Ostroumov SA (2004) On biotic self-purification of aquatic ecosystems. Elements of theory (O bioticheskom samoochishchenii vodnykh ekoistem. Elementy teorii). Doklady Akademii Nauk 396: 136-141.

Ostroumov SA, Donkin P, Staff F (1998) Filtration inhibition induced by two classes of synthetic surfactants in the bivalve mollusc (Narushenije filtratzii dvustvorchatymi molluskami pod vozdejstvijem poverkhnostno-aktivnykh veshchestv dvukh klassov). Doklady Akademii Nauk 362: 574-576.

Ostroumov SA, Fedorov VD (1999) The main components of self-purification of ecosystems and its possible impairment as a result of chemical pollution (Osnovnyje komponenty samoochishchenija ekosistem i vozmozhnost' ego narushenija v rezultate khimicheskogo zagrjaznenija). Bulletin of Moscow University. Ser. 16. Biology (Vestnik Moskovskogo Universiteta. Ser. 16. Biologija) 1: 24-32.

Spellman FR (1996) Stream Ecology and Self-purification. Technomic Publishing Co., Lancaster, Basel. 133 pp.

Wetzel RG (1983) Limnology. Saunders College Publishing, Fort Worth. 858 pp.