Doklady Biological Sciences, Vol. 372, 2000, pp. 286–289. Translated from Doklady Akademii Nauk, Vol. 372, No. 2, 2000, pp. 279–282.

The Concept of Aquatic Biota as a Labile and Vulnerable Component of the Water Self-Purification System

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Presented by Academician V.N. Bol'shakov June 1, 1999

Received June 24, 1999

Self-purification of water is a complex process including physical, chemical, and biological components [1–3]. The vulnerability of different components of the water self-purification system to anthropogenic factors is as yet insufficiently understood.

The goal of this work was to review the literature and our own unpublished experimental findings concerning potential vulnerability of the biotic component of the water self-purification system to chemical pollutants.

Table 1. Some factors and processes involved in water self-purification (after [2, 3, 9] and other publications)

No. of factor	Factors and processes involved in water self-purification
1	Physical
1.1	Solution and dilution
1.2	Drift over coast
1.3	Migration to nearby waters
1.4	Sorption by suspended particles and subsequent sedimentation
1.5	Sorption by bottom deposits
1.6	Evaporation
2	Chemical
2.1	Hydrolysis
2.2	Photochemical conversion
2.3	Catalytic redox conversion
2.4	Free radical reactions
2.5	Decrease in contaminant toxicity as a result of binding to dissolved organic compounds (DOCs)
2.6	Chemical oxidation of contaminants by oxygen
3	Biological
3.1	Sorption and accumulation of contaminants and biogenic agents by hydrobionts
3.2	Biotransformation: redox reactions, destruction, and conjugation
3.3	Extracellular enzymatic transformation of contaminants
3.4	Removal of suspended particles and contaminants from bulk water as a result of water filtration by hydrobionts
3.5	Removal of contaminants from bulk water as a result of sorption by pellets excreted by hydrobionts
3.6	Prevention or delay of the process of escape of contaminants and biogenic agents from bottom deposits to water
3.7	Biotransformation and sorption of soil contaminants formed as a result of watering with contaminated water

Note: Many factors are interdependent and overlap with each other; in many cases it is impossible to isolate individual factors, and they are considered as individual factors only to illustrate the conceptual analysis.

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0012-4966/00/0506-0286$25.00

Table 2. Examples of possible effects of contaminants on the factors and processes involved in water self-purification (including data obtained by S.A. Ostroumov)

No.	Parameters of surrounding medium, ecosystem, and its components important for implementing the functions listed in Table 1 (see numbers of corresponding items)	The influence of medium contamination by various agents, including surfactant, on water self-purification and relevant ecosystem parameters
1.1	Mixing	Contaminants can reduce the rate of water mixing by filtrators, because surfactant inhibits biofiltration ([3, 12] and unpublished data)
1.3	Hydrological characteristics; hydrodynamic processes (water exchange etc.)	Contaminants can be transported by being absorbed or accumulated by plankton, biogenic particles, and biogenic sediments. Surfactant can exert effects on plankton [4–7]
1.5	Organic carbon (C_{org}) content in deposits; mixing rate	Contaminants, including surfactant, inhibit biofiltration [3], thereby decreasing the pellet formation rate and C_{org} accumulation in bottom deposits
2.1	pH	Contamination may change pH both directly and as a result of photosynthesis modification
2.2	Permeation of visible light and UV radiation	Contaminants inhibit biofiltration [3, 12, 13], thereby increasing medium turbidity
2.3	Concentration of ions, metal complexes, and suspended particles	Contamination changes metal concentration and speciation; biofiltration disorders [3, 12] change the content of suspended particles
2.4	Content of OH-radicals	Contaminants affect plankton, thereby changing the content of OH-radicals; surfactant can either inhibit or stimulate algae and cyanobacteria [4–7]
	Content of hydrogen peroxide	Contaminants affect both count and composition of plankton cells, thereby changing the rates of H_2O_2 evolution and decay
	Redox state of medium	Depends on the rate of exometabolite production by hydrobionts; contaminants may affect hydrobionts
	Content of Cu ions	Contaminants can reduce the rate of water mixing by filtrators, because surfactant inhibits biofiltration ([3, 12] and unpublished data)
2.5	Content and composition of DOC	DOC are formed mainly from organic substances excreted by hydrobionts; hydrobiont functions are sensitive to contaminants
2.6	Content of oxygen dissolved in water	Contaminants, including surfactant, exert effects on phytoplankton (photosynthesis and oxygen evolution)
3.1	Count and composition of hydrobionts, surface properties of hydrobionts, content of DOCs and suspended particles bound competitively to contaminants	Depend on various parameters of aquatic medium, including its pollution, presence of biogenic agents, oxygen concentration, rates of mixing and biofiltration. Surfactant affects green algae [5, 6] and cyanobacteria [4, 5]
3.2	Microbial cell count	The same
3.3	Count and composition of hydrobionts capable of excreting enzymes into the surrounding medium	"
3.4	Count and composition of filtrating hydrobionts	Contaminants inhibit activity of biofiltrators; surfactant may inhibit filtration by mollusks [12]
3.5	Count and composition of hydrobionts capable of excreting pellets; rate of their feeding; rate of water filtration	Contaminants may change the ecosystem parameters and hydrobiont activity. Surfactant may inhibit filtration by hydrobionts [12]
3.6	Phytobenthos, bacteriobenthos	By inhibiting water biofiltration, contaminants can cause a decrease in the rate of plankton and DOC uptake from water and an increase in the water turbidity, thereby decreasing the level of bottom illumination and phytobenthos growth
3.7	Composition and activity of soil organisms; function of root system of plants	Contaminants, including surfactant, can inhibit soil algae and microorganisms [5] and suppress development of plant root systems [9–11]

The data summarized in Table 1 illustrate a significant role of biological processes in the water self-purification system. The efficiency of many abiotic processes shown in Table 1 (e.g., oxidation of various compounds by oxygen, photochemical reactions, etc.) depends on the parameters of water medium, which are themselves largely determined by the aquatic biota activity. For example, the rate of O_2 evolution and production of organic substances by photosynthesizing organisms, rate of water filtration by aquatic inverte-

Table 3. Components of water self-purification system vulnerable to contaminants (certain examples) [3–13] (new experimental findings obtained in collaboration with P. Donkin and R. Weiner are shown)

No.	Organisms as components of water self-purification system	Types of water self-purification processes sensitive to these organisms (numbers as in Tables 1, 2)	Examples of pollutant-induced effects on representatives of these groups of organisms
1	Bacteria (heterotrophic)	3.2, 3.3	TX-100 (1–50 mg/l) inhibited growth of Hyphomonas MHS-3 and VP-6
2	Cyanobacteria	2.4, 2.6, 3.2	[4, 5]
3	Green algae	2.4, 2.5, 2.6, 3.1	[5, 6]
4	Diatomic algae	2.4, 2.5, 2.6, 3.1	[7]
5	Flagellata (Euglena)	2.6, 3.1, 3.2	[8]
6	Vascular plants	2.5,2.6, 3.1, 3.6	[5, 9–11]
7	Invertebrates	1.5, 2.2, 3.4, 3.5, 3.6	SDS (1–4 mg/l) and TX-100 (0.5–4 mg/l) inhibited water filtration and phytoplankton uptake by *Mytilus edulis*; TDTMA (0.5 mg/l) inhibited water filtration by *Brachionus angularis* [12, 13]

Note: (SDS) sodium dodecylsulfate; (TX-100) Triton X-100; (TDTMA) tetradecyltrimethylammonium bromide.

brates, etc., are very important for effective self-purification of water. On the other hand, the functional activity and state of hydrobiont populations are substantially affected by pollutants. These effects were observed in our studies on cyanobacteria [4], green algae [5, 6], diatomic algae [7], flagellata [8], vascular plants [9–11], and invertebrates [12, 13] exposed to synthetic surfactants. Similar effects were observed by other authors in *Mytilus edulis* treated with pesticides [14].

Various effects of contaminants on the aquatic organisms involved in water self-purification are shown in Table 2.

Many groups of hydrobionts contributing to the functional systems of water self-purification are themselves vulnerable to water pollution (Table 3).

An important concept inferred from the literature and our experimental findings assumes that an aggregate of aquatic organisms (aquatic biota) is a labile and potentially vulnerable component of the water self-purification system in aquatic ecosystems. This interpretation of the role of aquatic biota is consistent with the data on the anthropogenic impact on the water self-purification system studied by other researchers [9]. This concept leads to substantial changes in the hierarchy of priorities underlying the principles of protection of biodiversity and environment, including the principles of environmental regulation.

The principles of environmental regulation are based on such important quantitative characteristics as maximum allowable concentrations (MACs) of various pollutants in fish farming water bodies; sources of industrial, drinking, and household water; etc. According to the concept suggested in this work, the MACs for specific substances should be established after a more thorough study taking into account the possible effects on the water self-purification system. In addition to the potential hazard to the microbial component of the water self-purification system, a possible effect on other organisms (e.g., benthos filer feeders) should be taken into consideration. It should be emphasized that both inhibiting and stimulating effects of sublethal concentrations of pollutants are dangerous, because either of them may cause an imbalance in the complicated system of water self-purification (Tables 1, 2).

The concept suggested in this work heightens the level of priority of the sublethal effects of pollutants. The sublethal effects associated with changes in the levels of the functional activity of hydrobiont populations may cause an imbalance in the system of water self-purification.

ACKNOWLEDGMENTS

I am grateful to V.D. Fedorov and other researchers of the Department of Hydrobiology, (Faculty of Biology, Moscow State University), as well as V.V. Malakhov, V.N. Maksimov, A.O. Kasumyan, S.V. Kotelevtsev and other colleagues for their stimulating discussion. This study was supported by the MacArthur Foundation (the program for individual research grants).

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