Ostroumov S. A. Biological filtering and ecological machinery for self-purification and bioremediation in aquatic ecosystems: towards a holistic view. - Rivista di Biologia. 1998; 91(2): 221-232. (published)
PMID: 9857844 [PubMed - indexed for MEDLINE]

BIOLOGICAL FILTERING AND ECOLOGICAL MACHINERY FOR SELF-PURIFICATION AND BIOREMEDIATION IN AQUATIC ECOSYSTEMS: TOWARDS A HOLISTIC VIEW

S.A.Ostroumov

Faculty of Biology, M.V.Lomonosov Moscow University, Moscow 119991, Russia; email: ar55@yandex.ru
1. INTRODUCTION

Natural ecosystems are capable of removal of polluting substances from water through a variety of physical, chemical and biological processes (e.g., Gehm, Bregman [1976]; Konstantinov, [1979]; Skurlatov, [1988]; Koronelli, [1996]). The complex network of these processes is vital to upgrade and maintain the quality of water compatible with providing habitats for a number of aquatic species. Another group of important processes are those which remove excess biogenic elements (primarily N, P) from water or prevent them from being accumulated in water at concentrations above certain levels. The entire system of all these processes is important to maintain a certain level of purity of water, which is an extremely significant condition for making natural water of many water bodies a resource for human consumption. The role of surface water bodies as a resource (vs. groundwater) varies in different regions but it is in general significant.

To verify our understanding of the water purification in an ecosystem, some useful models have been developed (e.g., Vavilin, [1983; 1986]).

2. PROCESSES AND MECHANISMS CONTRIBUTING TO WATER PURIFICATION

Some examples of various processes leading toward upgrading the quality of water and its purification are given in Table 1.

In addition to the summary of the processes and factors leading to the self-purification of an ecosystem, it is noteworthy to consider some elements or structural blocks of aquatic ecosystems which perform part of the functions contributing to the final self-purification. On the basis of abundant literature (e.g., Gehm, Bregman, [1976]; Konstantinov, [1979]; Koronelli, [1996]) and our works (e.g. Ostroumov, [1986]; Telitchenko, Ostroumov, [1990]; Ostroumov, Donkin, [1997]; Ostroumov at al., [1997]), it is useful to consider several functional biofilters which serve as components for the entire self-purification process (Table 2).

The number 1 biofilter is the variety of aquatic animals which are filter-feeders. Among them are bivalves, crustaceans, rotifers, some protists, bryozoans, tunicates, and other organisms. Some aspects of this type of ecosystem biofilter are analyzed in the next section. The second biofilter is represented by the organisms that prevent or slow down the flow of pollutants, organic matter and biogens from the land surrounding the water body into the water. This type of biofilter is comprised of aquatic vegetation next to the shores and the rich community of invertebrates and microorganisms associated with these plants. Biogenes which enter the water (e.g. fertilizers or products of nitrogen fixation by soil microorganisms) are taken up by the aquatic vegetation and serve the trophic chains...
based on it. As a result, a significant part of the biogenes is being accumulated and recycled within the community of peripheral aquatic vegetation, instead of entering the main part of the water.

The third biofilter prevents the re-entry of chemicals from the bottom sediments into the water column. The function of this biofilter is performed by the diverse complex of benthic organisms, including benthic plants. The importance of this function is evident when it is taken into consideration that the sediments are the storage place for both pollutants (e.g. heavy metals and persistent organics) and the biogens. At the expense of light as the source of energy as well as some chemical reactions, the benthic organisms grow and absorb biogens leaking from the sediments. As a result, the biogens are accumulated into the biomass of benthic organisms instead of being immediately released into the water. Thus, benthic organisms bind up part of the biogens and by doing so decrease the reverse flow of them into the water. Also, the benthic community and especially microorganisms supported by it contribute to binding and destroying pollutants that are leaking out from the sediments.

The fourth filter is functionally analogous to pumping the water through a biotechnological device called a bioreactor. The latter is made up of microorganisms immobilized on fibers or on other surfaces; the microorganisms remove and biodegrade pollutants from the water. However, in the case of a natural ecosystem it is not water moving along microorganisms that remain stationary, but vice versa; it is microorganisms that move though the relatively stable water column. The movement of microorganisms is driven by gravitational force, and the movement is sped up by the attachment of bacteria to the bigger particles suspended in the water. The fact that a significant number of functionally active bacteria are attached to various sedentary particles and pellets is well-documented (e.g., Konstantinov, [1979]).

3. HOW POLLUTION MAY INFLUENCE THE WATER PURIFICATION: THE CASE OF WATER BIOFILTERING

Water biofiltering by filter-feeding invertebrates is an extremely important process which influences at least seven other important processes in the ecosystem, all of which are relevant to physical, chemical and biological aspects of water purification (Ostroumov et al., [1997]). Among these are: (1) biofiltering-induced decreasing amount of suspended particles; (2) increasing the transparence of the water column; (3) increasing sunlight and UV penetration into the water; (4) regulation of the plankton species composition; (5) generating pellets of faeces and pseudofaeces; (6) increasing aeration of water column through its better stirring; (7) accelerating of the process of sedimentation of particulate organic matter in the direction of the bottom and increasing accumulation of organics in the sediments. The latter process is important not only for water purification but also for the
biogeochemical flow of carbon from the atmosphere to the bottom deposits of C and, hence, for the CO2 balance in the atmosphere (e.g., Zavarzin, [1984]; Lovelock, Kump, [1994]).

Our data, as well as that found in the literature, give several examples of how pollutants may inhibit the filtering activity of aquatic organisms. The pollutants exercising such effects are as diverse as metals, pesticides, and surfactants (Table 3). In addition, it is known that increasing concentrations of particulate water suspended in the water also inhibits the filtering rate of various aquatic invertebrates (e.g., Alimov, [1981]).

The organisms susceptible to such effects are also diverse and include bivalves (e.g. Ostroumov et al., [1997]), rotifers and many others. E.g., we studied the effects of synthetic surfactants on water biofiltering by the mussel *Mytilus edulis*. Our data demonstrated pronounced effects of an anionic (Table) synthetic surfactant. We have shown (Ostroumov, Donkin, in preparation) that the non-ionic surfactant, Triton X-100, inhibited water filtering by *M. edulis*. Following 60-min filtering period, the number of cells of algae *Isochrysis galbana* which was observed in the beakers with 1 mg/L Triton X-100 was 3143 cells per 0.5 mL, which was over twice as many as the number of cells in the control beakers without any additions of the surfactant. In the control beakers the concentration of cells was 1330 cells per 0.5 mL (Ostroumov, Donkin, in preparation).

In addition, our studies demonstrated the inhibitory effects of cationic surfactant tetradecyl trimethyl ammonium bromide (TDTMA) on water biofiltering by the rotifer *Brachionus angularis* (Kartasheva, Ostroumov, in preparation). At the concentration of 0.5 mg/L, TDTMA inhibited the average filtering rate of *B. angularis* so that it was 44.7% - 72.3% of control on average over the period of filtration 120-285 min, at temperatures 22°C - 24°C. Some other components of the water-purifying machinery of aquatic ecosystems are also susceptible to potential impairment from environmental pollution (see Table 5).

The new data are relevant to understanding how biodiversity is contributing to the stability of the biosphere (Yablokov, Ostroumov, [1983; 1985; 1991]). Our analysis is a step toward a holistic theory of natural bioremediation of aquatic ecosystems.

4. CONCLUDING REMARKS

1. The complex ecological machinery which performs water purification in aquatic systems include at least four types of functional biofilters which consist of aquatic bacteria, algae, plants, and invertebrates.

2. One of these four types of functional biofilters is represented by invertebrates which are filter feeders, e.g. bivalve molluscs and other organisms.
3. An additional aspect of ecological risk from pollutants is their ability to inhibit the water filtering rate and, by doing so, to impair a set of processes leading to water purification.

4. New evidence in support of the above conclusions was obtained in experiments conducted by the authors. We revealed new information testifying to the ability of synthetic surfactants, which may enter water bodies as pollutants (Ostroumov, [1986, 1990, 1991]), to inhibit water biofiltering by bivalves and rotifers.

5. A better understanding of the machinery of self-purification in aquatic ecosystems is a prerequisite for better understanding the structure and functioning of aquatic ecosystems (e.g., Ghilarov, [1987; 1990]; Fedorov, [1979]) and the connection between the functioning of aquatic ecosystems and global biogeochemistry (Zavarsin, [1984]; Lovelock, Kump, [1994]).

ACKNOWLEDGEMENTS. The research was supported by the Internatuional Biospherics Group. The author is grateful to Dr Peter Donkin (Plymouth Marine Laboratory) for hosting and helping his work with mussels; Prof. Lev V. Belousovs (Moscow University) for advice, to Dr. A.G. Dmitrieva for reading and discussing fragments of the first version of the manuscript, Profs. M.E.Vinogradov, V.D.Fedorov, V.N.Maximov, and O.F.Filenko for discussions; Mr. Glenn Kempf for reading fragments of first drafts of the manuscript and discussions.

REFERENCES


Goryunova S. V., Ostroumov S.A. [1986], Effects of an anionic surfactant on green algae and seedlings of vascular plants. *Biologicheskie Nauki (Biological Sciences).* 7: 84-86.(in Russian, with English abstract).

Gutelmaher B.L. [1986], *Metabolism of plancton as the whole.* Leningrad: Nauka 156 p.


Ostroumov S., Donkin P., Staff F. [1997], Inhibition by the anionic surfactant, sodium dodecyl sulphate, of the ability of mussels Mytilus edulis to filter and purify the sea water. Vestnik Moskovskogo Universiteta. Ser. 16. Biologija. (Bulletin of Moscow University. Ser. 16. Biology) 3: 30-36 (in Russian, with English abstract).


Table 1. Examples of processes and factors instrumental in purification, mediation and upgrading the quality of water in natural ecosystems (e.g., Gehm, Bregman [1976]; Konstantinov, [1979]; Ostroumov, [1986]; Skurlatov, [1988]; Koronelli, [1996]).

Table 2. Some types of functional biofilters and organisms involved

Table 3. Inhibitory effects of water pollution on the rate of filtering by aquatic organisms (examples)

Table 4. Anionic surfactant SDS inhibits water filtering by mussels *Mytilus edulis*. The effect is measured as decrease in *Isochrysis galbiana* cell density (per 0.5 ml) during filtering by *Mytilus edulis* at 1 mg/L SDS (After Ostroumov et al., [1997], with some changes). Cell density at the beginning of the experiment: 19533 per 0.5 ml.

Average Coulter count in filtered sea water: 131.7.

Table 5. Components of water-purifying system that are susceptible to environmental pollution (some examples)

**ABSTRACT**


PMID: 9857844 [PubMed - indexed for MEDLINE]

According to one of approaches to the definition of criteria for the phenomenon of life, the key attribute is the ability of the life system for some self-regulating and self-supporting. Part of such holistic functions of aquatic ecosystems as self-regulating and self-supporting is their cleaning the water via a multitude of various mechanisms. The goal of this paper is to present some fundamental elements of the theory of ecosystem self-purification (water self-purification) which emphasizes the importance of the four functional biological filters that are instrumental in purification and upgrading the quality of water in aquatic ecosystems. These functional filters are: (1) direct water filtering by aquatic organisms that are filter-feeders; (2) the filter (represented mainly by communities of aquatic plants/periphyton) which prevents input of pollutants and biogenic elements (N, P) from land into water bodies and water streams; (3) the filter (represented by benthic organisms) which prevents re-entry of pollutants and biogenic elements from the bottom sediments into the water; (4) the filter (represented by microorganisms attached to particles which are suspended in the water) that provides microbiological treatment of the water column. New experimental data by the author reveal the negative role of man-made effects on the ecological machinery which purifies water. The analysis and discussion lead to the holistic theory of the natural process of bioremediation of aquatic ecosystems.
Key words: self-regulating and self-supporting, aquatic ecosystems, theory of ecosystem self-purification, upgrading the quality of water, water filtering by aquatic organisms that are filter-feeders; communities of aquatic plants/periphyton, pollutants and biogenic elements (N, P), benthic organisms, microorganisms attached to particles which are suspended in the water, microbiological treatment of water column, man-made effects, natural process of bioremediation