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GENERAL BIOLOGY

A New Type of Effect of Potentially Hazardous Substances: Uncouplers of Pelagial–Benthal Coupling

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Hydrobionts are mediators of "biogenic migration of atoms in the biosphere" [1]. This migration is partly implemented in the framework of pelagial–benthal coupling. Trophic activity of bottom filter feeders results in consumption of the organic matter of plankton synthesized in pelagic zones (see, e.g., [2]). Even the organic matter that is not assimilated by fulter feeders is involved in pelagial–benthal coupling. Suspended matter of aquatic ecosystems (including pellets of invertebrates) is subjected to gravitational sedimentation [2, 3]. The pellets of invertebrates are formed as a result of excretion of unassimilated and undigested food of phytophagous invertebrates. The degree of food assimilation in different taxa of invertebrates ranges from 1 to 98% [4, 5]. The mean percentage of food assimilability averaged over many groups of organisms is 16.2–89.6% (Table 1). Therefore, the rest of the food matter (10.4–83.8%) remains unassimilated and settles to the bottom with pellets. Thus, pellets of invertebrates are able to transport a fraction of organic matter synthesized in the pelagic zone by photosynthetic organisms from this zone to the bottom layers of aquatic ecosystems, i.e., to the habitat of benthic organisms (the benthal).

The goal of this work was to determine whether there is a potential hazard of disturbance of the pelagial–benthal coupling induced by water pollution. It should be noted that such a hazard of the pollution-induced disturbance of ecosystems has been almost entirely ignored thus far.

Bivalve mollusks were objects of this study. Because bivalve mollusks are involved in elimination and sedimentation of particles suspended in bulk water, these organisms are components of the pelagial–benthal coupling [6–11].

The effect of potassium bichromate, a xenobiotic, on the rate of elimination of suspended particles by the Black Sea mussel *Mytilus galloprovincialis* was studied. Experimental methods were described elsewhere [10, 11]. Mussels (kindly provided by of A.V. Pirkova and A.Ya. Stolbov) were grown in water headers in the outskirts of the city of Sevastopol. The mean body weights (raw weights with shell) of experimental (treated with potassium bichromate) and control mollusks were 6.53 and 6.59 g, respectively. Both control and experimental tanks contained 13 specimens of mussel each. Each tank contained 500 ml of sea water (18ppt). The initial concentration of the yeast *Saccharomyces cerevisiae* (SAF-Moment, S.I. Lesaffre, 59703 Marcq-France) suspension in tanks was 40 mg dry weight per liter. The water temperature was 23.4°C. The optical density was measured spectrophotometrrically using a SF-26 LOMO spectrophotometer and cuvettes with an optical path length of 10 mm. Similar experiments were performed with the oyster *Crassostrea gigas*, which was also grown under mariculture conditions.

The results of our experiments showed that potassium bichromate is capable of inhibiting the filtration activity of mollusks (Table 2). This reduces the amount of food available for the digestive system of the mollusks. The decrease in the amount of food removed from water (i.e., the ration decrease) was accompanied by a visually observed decrease in the rate of formation of pellets. The amount of pellets in the end of the experiment in tanks containing potassium bichromate solution in water (0.05 mg/l) was significantly less than in control tanks. It was found in our experiments that oysters (*C. gigas*) were significantly less sensitive to potassium bichromate than mussels (*M. galloprovincialis*).

A similar decrease in the amount of suspended particles (plankton cells) eliminated from water was observed in our experiments with other xenobiotics, including surfactants, synthetic washing mixtures (SWMs), and liquid washing mixtures (LWMs) (Table 3). In all cases studied, we found that inhibitors of filtration activity caused a decrease in the rate of formation of pellets. Only a few examples of such effects are shown in Table 3. Inhibition of filtration processes was also reported by J. Widdows, P. Donkin, D. Page, A.V. Mitin, and some other researchers [9, 10].

In addition to experimental studies on plankton elimination from water by marine and freshwater

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Table 1. Food assimilability and mean percentage of unassimilated food matter in different groups of invertebrates

Group of organisms	Assimilability, range of variation, %	Assimilability, mean value (calculated in this work), %	Unassimilated matter, mean value (calculated in this work), %	References, comments
Rotatoria	48–80	64	36	For *Brachionus calyciflorus* [4]
Bryozoa	41.6	41.6	58.4	*Plumatella fungosa*; data of I.A. Skal'skaya cited from [4]
Gastropoda	42–82	62	38	[4], Efficiency of transfer of chemical elements in pellets of the pond snail *L. stagnalis* was quantitatively assessed in [12, 13]
Bivalvia	4.8–90	47.4	52.6	[4, 7], Under natural conditions, food assimilability by the mussels *M. galloprovincialis* was less than under laboratory conditions [7]; efficiency of transfer of chemical elements in pellets of Unionidae was quantitatively assessed in [13]
Cladocera	50.5–85.5	68	32	[4, 5]
Copepoda	30–88	59	41	[4, 5]
Mysidacea	84.2–95	89.6	10.4	[4]
Isopoda	68	68	32	Hog slater *Asellus aquaticus* [4]
Amphipoda	5.5–98	51.75	48.25	[4]
Decapoda	38.7–96.1	67.4	32.6	[4]
Odonata*	20–97.2	58.6	41.4	[4]
Ephemeroptera*	41–72	56.5	43.5	[4]
Plecoptera*	9–73	41	59	[4]
Trichoptera*	5–51	28	72	[4]
Diptera*	1–31.4	16.2	83.8	*Cricotopus silvestris*, Rodova and Sorokin, 1965, cited from [4]
Range of mean values	–	16.2–89.6	10.4–83.8	Based on the data shown in the table for specific groups of organisms

* Larvae.

bivalve mollusks, we also studied the processes of pellet formation by the pond snail *Lymnaea stagnalis* fed on dying phytomass (floating fragments of leaves of higher plants simulating natural leaf debris) [10, 12, 13]. The mollusks *L. stagnalis* excreted pellets of undigested organic matter. These pellets rapidly sedimented to the bottom, thereby contributing to coupling between pelagic and benthic parts of the ecosystem. It follows from the results of studies on *L. stagnalis* feeding under model conditions that 1 g of consumed plant biomass gave rise to formation of 143.6–153.2 mg of pellets (dry weight). The carbon content in the pellets was 96.9–106.8 mg (67.5–69.7%). Note that the rates of pellet formation by mollusks fed on the phytomass of leaves of plants of entirely different species were close to each other. These experiments also showed that pollutants are can decrease the rate of pellet formation, thereby decreasing the flow of matter to the bottom part of the aquatic ecosystem. Consumed phytomass (floating fragments of plant leaves) is at the upper layers of bulk water (i.e., in the pelagic part of the ecosystem). Therefore, these experiments also illustrate the possibility of uncoupling of the pelagial–benthal coupling.

Thus, the trophic activity of mollusks and the related transfer of matter and energy along the trophic chain (phytomass–phytophages–pellets excreted by phytophages) were inhibited by xenobiotics. Because pellets are sedimented to the bottom and significantly contribute to the pelagial–benthal coupling, the pollution-induced inhibition of filtration, as well as other factors described in [14, 15], are evidence for a new type of potential ecological hazard connected with chemical pollution. Chemical pollutants may behave as uncouplers of the pelagial–benthal coupling. It was shown in the preceding works [9–11] that surfactants and detergents (LWMs and SWMs) are potential uncouplers of the pelagial–benthal coupling in both freshwater and marine ecosystems. The results of this study show that compounds of heavy metals (chromium) can also inhibit the pelagial–benthal coupling. Although the chemical structures of the compounds tested in this work differed from one another, all of the compounds shared a common feature of ecologically

Table 2. Effect of potassium bichromate (0.05 mg/l) on the optical density decrease (550 nm) of a suspension of *S. cerevisiae* cells during filtration by the mussels *M. galloprovincialis*

Experiment no.	Time, min	Mussels + Cr A	Mussels – Cr (control) B	Without mussels – Cr (control) C	A/B, %
1	5	0.202	0.177	0.287	114.12
2	15	0.195	0.111	0.224	175.68
3	25	0.144	0.085	0.218	169.41
4	35	0.148	0.084	0.218	176.19
5	45	0.166	0.062	0.272	267.74

Table 3. Xenobiotic-induced decrease in the amount of suspended particles (plankton cells) eliminated from water by fulter feeders

Species of fulter feeder	Xenobiotic	Reference
Mytilus edulis	Potassium bichromate	This work (Table 2)
M. edulis	Pesticides	Donkin et al., 1997, cited from [10]
M. edulis	Sodium dodecylsulfate (SDS)	[8]
M. edulis	Triton X-100	[8]
Crassostrea gigas	Sodium dodecylsulfate (SDS)	[10, 11]
C. gigas	TDTMA	[10, 11]
M. galloprovincialis, C. gigas	SWM1(L)	[10, 11]
M. galloprovincialis, C. gigas	LWM1 (E)	[10, 11]
M. galloprovincialis, C. gigas	LWM2 (F)	[10, 11]
M. galloprovincialis	SWM2 (I)	[10, 11]
M. galloprovincialis	AHC	[9, 10]
M. galloprovincialis × *M. edulis* (hybrids)	TDTMA	Widdows, Ostroumov (unpublished data)
Unionidae (several species)	Surfactants, detergents	[9, 10]
Brachionus calyciflorus	TDTMA	Walz, Rusche, Ostroumov (unpublished data)

Note: TDTMA, tetradecylcetyltrimethylammonium bromide; SWM1 (L), Lanza-automat (Benckiser); SWM2 (I), IXI Bio-Plus (Cussons); LWM1 (E), dish-washing liquid E (Cussons International, Ltd.); LWM2 (F), dish-washing liquid Fairy (Procter and Gamble, Ltd.), AHC, Avon Hair Care. The data shown in the table are far from complete inventory of polluting agents and species of fulter feeders inhibited by pollutants.

hazardous impact on hydrobionts (fulter feeders). The ecological hazard of these compounds is related to inhibition of pelagial–benthal coupling.

The results of this work, along with experimental data on the behavior of fulter feeders provide a basis for the following prognosis. Further research and experimental studies are expected to provide new evidence that sublethal concentrations of chemical pollutants induce a significant decrease in the filtration capacity of freshwater and marine fulter feeders. This is observed as a decrease in the rate of elimination of suspended matter from water and in the amount of pellets (faeces and pseudofaeces) excreted by these organisms into water. As a result, the amount of pellets (and sedimented matter) accumulated at the bottom of an experimental tank or a natural water body (lake, pond, etc.) are less than in the control (in the absence of pollutants).

According to the terminology suggested by V.I. Vernadsky, the process of inhibition of activity of fulter feeders related to pelagial–benthal uncoupling and decrease in the flow rate of matter from pelagic to the benthic zone may be called a decrease in the rate of migration of atoms from the pelagic to the benthic zone. The uncoupling process considered above is an anthropogenic violation of two basic laws (empirical rules or biogeochemical principles [1]) of the biosphere functioning:

(1) biogenic migration of atoms of chemical elements in the biosphere always tends toward its maximum expression;

(2) on the geological time scale, the evolution of species gives rise to the forms of life that are stable in the biosphere, and is so directed that the biogenic migration of atoms in the biosphere increases [1].

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REFERENCES

1. Vernadsky, V.I., *Khimicheskoe stroenie biosfery Zemli i ee okruzheniya* (The Chemical Structure of Earth's Biosphere and Its Environment), Moscow: Nauka, 1965.
2. Alimov, A.F., *Elementy teorii funktsionirovaniya vodnykh ekosistem* (Principles of Functioning of Water Ecosystems), St. Petersburg: Nauka, 2000.
3. Izrael', Yu.A. and Tsyban', A.V., *Antropogennaya ekologiya okeana* (Anthropogenic Ecology of the Ocean), Leningrad: Gidrometeoizdat, 1989.
4. Monakov, A.V., *Pitanie presnovodnykh bespozvonochnykh* (Nutrition of Freshwater Invertebrates), Moscow: IPEE, 1998.
5. Sushchenya, L.M., *Kolichestvennye zakonomernosti pitaniya rakoobraznykh* (Quantitative Patterns of Nutrition in Crustaceans), Minsk: Nauka i Tekhnika, 1975.
6. Alimov, A.F., *Funktsional'naya ekologiya presnovodnykh dvustvorchatykh mollyuskov* (Functional Ecology of Freshwater Bivalves), Leningrad: Nauka, 1981.
7. Shul'man, G.E. and Finenko, G.A., *Bioenergetika gidrobiontov* (Bioenergetics of Hydrobionts), Kiev: Naukova Dumka, 1990.
8. Ostroumov, S.A., Donkin, P., and Staff, F., *Dokl. Akad. Nauk*, 1998, vol. 362, no. 4, pp. 574–576.
9. Ostroumov, S.A., *Biologicheskie effekty poverkhnostno-aktivnykh veshchestv v svyazi s antropogennymi vozdeistviyami na biosferu* (Biological Effects of Surfactants As Related to Anthropogenic Impacts on the Biosphere), Moscow: MAKS, 2000.
10. Ostroumov, S.A., Biological Effects of Surfactants As Related to Anthropogenic Impacts on Organisms, *Doctoral (Biol.) Dissertation*, Moscow: Mosk. Gos. Univ., 2000.
11. Ostroumov, S.A., *Dokl. Akad. Nauk*, 2001, vol. 378, no. 2, pp. 283–285.
12. Ostroumov, S.A. and Kolesnikov, M.P., *Dokl. Akad. Nauk*, 2000, vol. 373, no. 2, pp. 278–280.
13. Ostroumov, S.A. and Kolesnikov, M.P., *Dokl. Akad. Nauk*, 2001, vol. 379, no. 3, pp. 426–429.
14. Ostroumov, S.A., *Dokl. Akad. Nauk*, 2000, vol. 375, no. 6, pp. 847–849.
15. Ostroumov, S.A., *Dokl. Akad. Nauk*, 2001, vol. 381, no. 5, pp. 709–712.