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**GENERAL BIOLOGY**

# Criteria of Ecological Hazards Due to Anthropogenic Effects on the Biota: Searching for a System

**S. A. Ostroumov**

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Among the multiplicity of characteristics of anthropogenic factors affecting the biota [1–3], researchers distinguish the most important parameters and criteria characterizing negative anthropogenic effects [3, 4], including the effects of chemical factors [5–8]. Development and systematization of these criteria are far from completion.

The purpose of this work is to describe approaches to improvement of a system of criteria of ecological hazards due to anthropogenic effects on the biota and to consider some new experimental data on the effects of surfactant xenobiotics on living organisms.

Criteria of ecological hazards due to chemicals have been developed in terms of the estimation of toxic contamination of ecosystems [1, 2, 4, 6, 8]. The classification of chemicals according to their ecological hazards now accepted in the European Union is based on the following three criteria [9].

(1) Acute toxicity estimated from $LC_{50}$ for three groups of organisms: fish, algae, and daphnia.

(2) Susceptibility of the substance to biological decomposition in water. This is determined with the use of laboratory tests under aerobic conditions. Substances are decomposed by microorganisms, and their decomposition is accompanied by oxygen consumption. If a substance is quickly decomposed (oxidized) by microorganisms, it is not considered to be hazardous to the environment. Exceptions are compounds with a high acute toxicity (with and $LC_{50}$ less than 10 mg/l) and a high bioaccumulation potential (see the next criterion).

(3) The substance's capacity for bioaccumulation. This capacity is considered to be hazardously high if the bioaccumulation factor (BCF) is higher than 100, or the logarithm of the distribution coefficient of the substance in the octanol–water system ($\log P_{ow}$) is higher than 3.

A disadvantage of this set of criteria is an underestimation of other aspects of ecological hazards due to contamination of a water body with the given chemical, e.g., the hazard of a decrease in water $O_2$ concentration due to oxygen consumption by microorganisms during oxidation of xenobiotics. Behavioral changes in living organisms because of interaction of the pollutant with their receptors [1, 10] is also beyond the scope of this system of criteria. Behavioral changes may occur in the absence of bioaccumulation (i.e., when the substance is not hazardous according to criterion 3). Changes in behavior may result in migration of certain species from the ecosystem (emigration) and, hence, to a decrease in biodiversity.

Therefore, more comprehensive sets of criteria should be developed.

In some studies [3, 11, 12], anthropogenic effects on the natural environment are classified in terms of the levels of biological organization. We suggest a new set of criteria (Table 1), in which anthropogenic effects on the biota are systematized based on the same approach.

A characteristic feature of the system of criteria shown in Table 1 is the division of the multiplicity of anthropogenic effects into orderly groups according to four levels of biota disturbance. Most of the traditionally studied toxic effects (an increased mortality, ontogenetic disturbances, organ pathology, etc.) fall in the group corresponding to the level of individual and population responses (level 1). Alterations in primary productivity, water concentration of chlorophyll, etc., correspond to the level of aggregated responses (level 2). Alterations at the level of ecosystem stability and integrity (level 3) are important but have not been sufficiently studied. These are, among others, disturbances in the self-purification capacity of water systems [13], i.e., their ability to sustain the parameters of the aquatic environment. The last group (level 4) comprises alterations in the contribution of ecosystems to biospheric processes, including biogeochemical flows of chemical elements (C, N, P, and S).

This approach agrees with the views of other authors [6, 14] and is useful for developing an adequate system of estimation and classification of anthropogenic effects, including environmental pollutants, with respect to ecological hazards.

An important constituent of the proposed system for analysis of ecological hazards is estimation of hazardous effects on the stability and integrity of an ecosys-

*Moscow State University, Vorob'evy gory, Moscow, 119899 Russia*

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**Table 1.** The level–block approach to analysis of ecological hazards due to anthropogenic effects on the biota

| No. | Disturbance level | Examples of disturbances and their consequences (some of them may be assigned to different levels) |
|---|---|---|
| 1 | Individual and population responses | Toxic effects on individual species (increased mortality, decreased fertility, ontogenetic disturbances, diseases, etc.), changes in morphological and physiological variability, and behavioral changes |
| 2 | Aggregated (superorganismal) responses | Changes in primary productivity, aggregated parameters of biomass, and water chlorophyll and dissolved $O_2$ concentrations |
| 3 | Ecosystem stability and integrity | Rearrangements and/or weakening of plankton–benthos connections; rearrangements and/or weakening of links in the food web |
| | | Changes in the level of bacterial destruction; decrease in water clarification/elimination of particles from water; decrease in water self-purification |
| | | Decrease in regulatory effects because of the loss, migration, or trophi passivity of organisms belonging to higher trophic levels |
| 4 | Ecosystem contribution to biospheric processes | Changes in C flows (e.g., sedimentation of pellets formed by filter-feeding organisms) and N flows (e.g., nitrogen fixation), as well as in flows and cycles of other elements, including S and P; changes in energy (heat etc.) flows |

tem, e.g., the hazard due to weakening the relationship between plankton and benthos. If an anthropogenic effect weakens this relationship in a given ecosystem, the consequences are expected to be unfavorable [13]. An example of such a situation is the decrease in the water filtration rate and elimination of seston by some filter-feeding organisms, such as bivalves, because their filtration activity is one of the important mechanisms of maintaining the plankton–benthos conjugation. It would be important to estimate the possible effect of pollutants on the molluscan filtration activity.

Filtration of water and absorption of phyto- and bacterioplankton and other suspended matter from it by molluscans, as well as formation and excretion of fecal and pseudofecal pellets are important for processes occurring in an aquatic ecosystem [13]. Inhibition of filtration by xenobiotics may, in turn, induce other disturbances at several organizational levels (see Table 1) of the ecosystem. Examples of such disturbances are a decrease in water filtration by other hydrobionts, decrease in water transparency and the resultant decrease in penetration of photosynthetically active radiation and ultraviolet light, deterioration of the conditions for phytobenthos, excessive growth of phyto- and bacterioplankton, disturbances in the regulation of the composition of the algal–bacterial community, increase in detritus formation and siltage of benthic habitats, imbalance of the food web of phytoplankton consumers, decrease in the population growth of filter-feeding organisms, decrease in the number of planktophagous larvae and deformation of the food web, and decrease in $C_{org}$ deposition and concentration in bottom sediments [13].

An important question is whether surfactants, which heavily contaminate environment and have not been sufficiently studied with respect to possible effects on organisms, may suppress filtration [5, 7].

Data obtained by Donkin and myself in experiments on *Mytilus edulis* (unpublished) indicate that surfactants may disturb the plankton–benthos conjugation. Some surfactants, such as a nonionic surfactant Triton X-100 (TX; an alkylphenol derivative), decrease the rates of water filtration and elimination of algae from

**Table 2.** Amount of algae *Isochrysis galbana* in flasks containing mussels *Mytilus edulis* after 90 min of water filtration by the molluscans in the presence or absence of Triton X-100 (TX100, 0.5 mg/l)

| No. of the flask | Presence or absence of TX100 (0.5 mg/l) | Number of algal cells in 0.5 ml of the medium | The average number of algal cells in 0.5 ml of the medium |
|---|---|---|---|
| 1 | + | 427; 451; 468 | 448.7 |
| 3 | + | 335; 338; 362 | 345 |
| 5 | + | 795; 766; 819 | 793.3 |
| 7 | + | 2806; 2743; 2793 | 2780.7 |
| | The average number of cells in 0.5 ml for four flasks with TX100-containing medium (flasks 1, 3, 5, 7) | | 1091.9 (standard error, 298.3) |
| 2 | – | 727; 684; 716 | 709 |
| 4 | – | 347; 337; 348 | 344 |
| 6 | – | 359; 398; 456 | 404.3 |
| 8 | – | 638; 659; 716 | 671 |
| | The average number of cells in 0.5 ml for four control flasks (flasks 2, 4, 6, 8) | | 532.1 (standard error, 48.9) |

Note: The difference between experimental and control values were significant at the 95% significance level according to Student's *t*-test ($p = 0.044$). Conditions: the average initial concentration of cells, 13372 per 0.5 ml; temperature, 16°C. Cells were counted using the Culter counter. The average reading of counter in sea water was 673.7. Sixteen mussels weighing 7.2 to 9.2 g (wet weight with a shell) were used.

water by mussels (Table 2). In the presence of 0.5 mg/l TX, the concentration of algal cells after 90 min of filtration was 1092 cells per 0.5 ml of water versus 532 cells per 0.5 ml of water in the control sample (Table 2). In other words, an excess of algae as a result of filtration suppression was more than twofold (205.3%). If the TX concentration was increased to 2 mg/l, the concentration of algae after filtration was 2635 cells per 0.5 ml versus 556 cells per 0.5 ml in the control sample, i.e., the excess was almost fivefold (473.9%). Thus, inhibition increased with an increase in the surfactant concentration. These results agree with the data on the effects of other chemical compounds [13].

The system of criteria shown in Table 1 simplifies and systematizes the analysis of the ecological role and consequences of disturbance of a given physiological function (in this case, disturbance of water filtration in molluscans). If we go sequentially from level to level, the suggested system will make it possible to follow the range of ecological consequences of a primary disturbance at an individual level that manifests itself at higher levels of organization in an ecologically hazardous form.

In the given example, the change in the organism's physiological activity is the directly observable effect of the xenobiotic. However, we can estimate the ecological hazards more accurately if we consider the processes occurring at levels 3 (a decrease in seston elimination from water and a decrease in the plankton–benthos conjugation) and 4 (a decrease in the formation and excretion of pellets formed from strained algal cells).

Other examples [1, 8, 11, 12, 14] confirm the effectiveness of the approach proposed (Table 1) for the analysis of ecological hazards due to anthropogenic effects on the biota.

The proposed level–block approach to analysis of ecological hazards of anthropogenic alterations in ecosystems allows the multiplicity of anthropogenic effects on the biota to be systematized. This approach may be used to develop criteria for estimation and classification of ecological hazardss due to anthropogenic effects.

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