ECOLOGICAL INDICATORS OF WATER QUALITY IN SMALL RIVERS

by

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At the present time hydrobiological indicators are widely used for the control of surface water quality. Results of the applying of methods suggested at the 1st Soviet-American seminar (1975), development of improved methods and estimation of their usefulness for various conditions are presented in this report.

Among the criteria permitting an estimation of the degree and character of changes in water quality and their connection with the functioning of river ecosystems in general, the biological tests of natural waters appears to be the most universal one and is being carried out in two main directions – ecological and physiological (23).

It is well known that localisation of aquatic organisms is determined by their demands on the environment, mainly, for oxygen and organic matter in the water (4). The study of the ecological needs of a certain complex of species permits the revelation of the specific properties of the environment. This fact lies at the base of the method for estimating the water quality according to indicator organisms providing for the establishment of the indicator significance of individual species of aquatic organisms, by means of which, with the aid of mathematical averaging, the degree of pollution for part of a watercourse or a whole water body is calculated.

Thus, for ecological indication are taken – such indices as structure (spatial, trophic, sex, age) of hydrobiont populations or the presence of indicator organisms (indicator species) and their quantitative correlation. This method is intended to reveal the consequences of anthropogenic activity and first of all, to reveal the degree of pollution in rivers by unstable organic compounds. Ecological indication in the best cases can give answers to such questions as the degree and character of the pollution, the distribution of pollution in a water body and the condition of the aquatic ecosystem on a seasonal scale. It follows that water, the quality of which is stated as unsatisfactory according to ecological tests can hardly be used for economic aims, but ecologically good water cannot always be considered as such from the point of view of health (13). In the latter case, specific microbiological, toxicological and chemical tests are necessary. Ecological indication can have its peculiarities according to the character of the disturbance to or of the anthropogenic effect on an aquatic ecosystem. Various consequences should be distinguished, depending on the character and intensity of the effect (24):

1. eutrophication of waters – enrichment of water with biogenic substances in concentrations which increase fish productivity;

2. polytrophication – enrichment of waters with biogenic substances in quantities which cannot be consumed and transformed in the trophic chain of the aquatic ecosystem. It results in a decreased fish productivity due to mass development of autotrophic production which cannot be absorbed by heterotrophic organisms;

3. pollution of waters — introduction of a whole series of substances not characteristic for biotic processes in fresh-water ecosystems (10);

4. poisoning of waters with substances of organic or mineral origin (heavy metals, acids etc). as well as with wastes from the food industry or the metabolic products of agricultural animals (24). Some authors (10) consider eutrophication should not be separated from pollution caused by discharge of waste water into rivers from industrial complexes and settlements. However, this feature is not characteristic for the small rivers of Latvia. We consider that these two features — eutrophication and pollution — should be separated in as much as the intense effect of industrial wastes greatly lowers the role of biogenic substances as stimulators for the growth of aquatic organisms.

In ecological investigations of rivers special attention is being paid to studies on oxygen balance — the comparison of production processes and the demand of oxygen in rivers. Under natural conditions the level of oxygen in rivers can practically be considered as a constant factor because the saturation with oxygen is ensured by atmospheric aeration due to the water current. A negative side of this phenomenon is the narrow range of tolerance of river animals, their susceptibility to oxygen deficiency (8). Therefore river biocenoses are especially susceptible to any organic pollution which decreases the store of dissolved oxygen.

At the present time in many European countries the method for the estimation of water quality has evolved from, (mainly), the degree of saprobity according to indicator organisms, and the Pantle — Buck's method (20) is being applied in Sladecek's modification (21). This method is subject to unfounded, in our view, criticism according to the following considerations: the system of saprobity as an empirical system can be applied within the framework of those initial data which are taken as a basis for this system and are suitable for it (16). Regional factors are often neglected in the saprobiological investigations:

1. historically determined formation of watercourses with diverse contents of nutrients (18) and the fact that the presence of biogenic substances is regulated by the geology and topography of the catchment area and the supply of water (14);

2. past distribution of hydrobionts (many species occupy a certain area and they cannot be taken as indicators in other areas) and the character of the drainage region (18).

Many Soviet scientists have noted that the lists of indicator species made for western Europe need some modifications to fit the climatic conditions of the Soviet Union (7). These corrections include the comparison of the list of indicator species with the registered regional features. When estimating the indicator significance of an individual indicator species, its saprobic valency is considered as the first stage indicating how this species is characterising one or other zone of saprobity. Saprobic valencies (a) of the indicator species in the four general zones of saprobity (from oligo- to polysaprobic, while xenosaprobity and pollution exceeding polysaprobity has not been observed in the small rivers of Latvia) are calculated with the help of formula suggested by Cimdins (15).

$$a = \frac{N.D_i}{\sum_{p}^{o} N.D_i} \;.\; 10 \; ; \qquad a;\; N.D_i \in [o,p]$$

where N — number of specimens,

Di — occurrence of species in space (I),

$$D_i = \frac{n_i}{N_i} .100$$

where n_i — number of samples with species "i",

N_i — total number of samples.

(N.Di) — ecological amplitude of indicator species (15). Indicative weight "g" and saprobic value "s" are estimated according to the distribution of saprobic valencies in the zones of saprobity (21). Thus, on the basis of our data the indicator significance of indicator species was established for various types of small rivers (swift and slow current) under the same climatic conditions. The saprobic values established by us are somewhat higher than those for the western Europe (11), illustrating the peculiarities of small rivers under the physical and geographical conditions of the USSR (15). River areas having diverse degrees of saprobity were separated according to hydrochemical data, taking as a basis the classification by Bilinkina and Drachev (5) with some modifications, taking into account the regional peculiarities. The specific electroconductivity of the water and the BOD_5 of the sediment were introduced in the classification system of surface waters according to hydrochemical indicators (15). The saprobic index of river areas was determined according to Pantle-Buck, using the indicator significances (s) calculated by us:

$$S = \frac{\sum (h.s)}{\sum h}$$

(20), where h — frequency of occurrence of specimens of a species, evaluated according to a 6 level scale (from 1-9), while the value of frequency "h" is estimated, as a relative value. Usually it was estimated as the number N of specimens of one species in per cent from the number of all the species. Instead of the numerical value, the ecological amplitude (N.Di) is suggested which lowers the significance of random occurrences (15). The saprobic index, S, is given with an accuracy of 0.1, thus the arithmetical mean is obtained for which the mean standard deviation and the confidence interval is calculated according to the "t" test for the statistical significance of 95 per cent (11, 15). To calculate the saprobic indices no less than 12 indicator species are needed with the sum of frequency values, Σh, at least 30 (23). Along with the saprobic index some more indices have been calculated, the estimation of which is less labour-consuming. These are indices of species deficiency by Kothe (19) and Hellawell (12), coefficients of species similarity by Jaccard (17) and Sorensen (22). It has been established that the indices of species deficiency can vary greatly according to the relief of drainage area and the gradient of the river bed. Usually, in polluted water the species deficiency (according to Kothe's index) reaches 75-80 per cent. In estuarine areas, where self-purification takes place according to chemical indicators (15), this index is 30-40 per cent. The indices of similarity of species composition characterise very well the disturbance of the spatial structure of background state for river biocenoses under the influence of pollution and heightened water discharge. In streams of high current velocity, Sorensen's coefficient between the benthic biocenoses and periphyton is 0.3-0.4 in clean areas and above 0.5 in polluted regions (15). These coefficients give only an approximate idea about the environmental conditions as they depend on the type of biotope and the number of species in the biocenoses of the regions to be compared. The fitness of Shannon's index (25) for characterising the changes in species diversity under the influence of pollution is not yet clear. Differences in diversity with time are mainly connected with the hydrological character of watercourses as well as with the seasonal development of separate species of aquatic organisms. Greater discharge of water during floods increases the plankton diversity and at the same time decreases its amount in the near-bottom layer and in overgrowths. High species diversity in plankton is a result of organisms carried in from soil; when the flood water decreases the species diversity sharply decreases, many species perish due to the inadequate habitat for their ecological demands. To find out the effect of pollution, Shannon's index of species diversity is applied in a spatial analysis along the whole length of the river. In the background areas this index surpasses 4, in polluted areas 0.8-1.0, in areas where biological self-purification takes place according to chemical indicators, 2-3 (15).

The Woodiwiss (3) biotic index, where autecological reactions of key organisms (macroinvertebrates) are being applied, appears to be very valuable for estimating the quality of river water. In rivers of other regions this index, apparently, can be applied using other key organisms, but in general acting according to the Woodiwiss method. In some degree it relates also to the coefficients of Parele (9).

$$D_1 = \frac{T}{B}; \; D_2 = \frac{T}{O}; \; D_3 = \frac{S}{O}; \; D_4 = \frac{S}{T}$$

where O — all oligochaetes including tubificidae;

B — all benthic organisms, including oligochaetes;

T — all the tubificidae;

S — a separate species of tubificidae.

Coefficients D_1, D_2 indicate the general saprobity of the investigated watercourse. Coefficients D_3, D_4 indicate the range of indication of a separate tubificid species in the community; if the difference between D_3 and D_4 is not large, then the pollution is severe (9). The numerical value of these coefficients characterising various degrees of pollution can change for watercourses of other regions. The coefficient D_2 for watercourses in the Latvian SSR can be considered as a standard; its values for various zones of pollution are as follows:

highly polluted zone — 0.80 — 1.00;

polluted zone — 0.55 — 0.80;

slightly polluted zone — 0.30 — 0.55;

relatively clean zone — $<$ 0.30 (9)

At the end of this review it should be noted that hydrobiological analysis can be used with two different aims:

1. to obtain data on water quality in a given time, and

2. to obtain data characterising the real condition of water ecosystems which is intended for a long storage and a consequent usage for studying long-period changes (2). Ecological indication is fully suitable for reaching the second aim, and on the basis of detailed background monitoring can be successfully applied also for the estimation of water quality in a given time.

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*Editor's note. References preceded by an asterisk are from the Russian language report of the first UK/USSR seminar held at Valdai, USSR, 12-14 July 1976. The report in English was published in 1978 and entitled: Elaboration of the Scientific Bases for Monitoring the Quality of Surface Water by Hydrobiological Indicators. Department of the Environment, Central Unit on Environmental Pollution, Pollution Report No. 3, London.

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