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ASSESSMENT OF LAKES EUTROPHIZATION RATE ON THE BASIS OF CATCHMENT AREA EVALUATION

It is an attempt at assessment of natural receptivity of lakes to degradation and at a definition of the role of the catchment area in making active or slowing down the process. On the one hand, the catchment is evaluated as a supplier of the matter; on the other hand, the lake into which the matter is carried.

What will be the condition of lakes in the nearest future is to be determined by the rate and intensity of eutrophization observed in an excessive growth of fertility of the lakes' waters. It is a result of uncontrolled, or insufficiently controlled, inflow of biogeneous compounds from natural and anthropogenic external sources and direct interference of man in the internal structure of the lake's ecosystem. A trophic condition of a lake and a given condition of cleanness of its water is a reflection of both natural and anthropogenic pressure on the reservoir. The direction of "natural" eutrophization of lakes is defined by physico-geographical structure of its catchment area and a complex of natural resistance features of a lake (Fig.1). Catchment area is a permanent supplier of the reservoir with various forms of the matter whose amount and delivery rate depend upon its physicogeographical characteristics. But a lake, according to natural resistance calculated by a set of morphometric parameters of the lake's bowl and dynamics of its water, is more or less susceptible to the influence of its catchment. A resultant of factors which favour eutrophization has a different value for each lake. An equal force of the impact of catchment on a lake expressed by the amount of the matter flowing from the catchment area has a different effect when a lake is susceptible to external influence. On the contrary, in the case of the same category of the lake receptivity to degradation, a difference in estimates of the state of their eutrophization should be expected, as catchment affects lakes to varying extent. Hence each catchment reservoir complex should be taken into consideration separately to make it possible to foresee the direction of natural eutrophization of a lake. A natural susceptibility of a lake to degradation and the assessment of the role of its catchment in this process may be expressed as groups of susceptibility (catchment) and categories of resistance (lake) according to the system suggested by Bajkiewicz-Grabowska (1981, 1987). In this system a catchment is evaluated as a supplier of the reservoir with the matter, and a lake

Fig. 1.

as a receiver of this matter. An extent of impact of catchment on the lake is assessed on the basis of characteristics of the entire catchment of a lake and of its direct catchment. The features describing a degree of the effect of the entire catchment upon a lake include: lake index (quotient of the whole surface of the lake's catchment and of the surface of the reservoir) and a balance type of a lake (flowing through, running off, no runoff) indicating a connection by the natural course of water and by the same token a possible source of delivery of the matter (Fig.1). The extent of the impact of direct catchment from which the load of the matter comes to the lake depends on such physico-geographical characteristics as: (1) volume of the catchment effectively participating in a delivery of the matter (measured by a degree of a lack of the surface runoff), (2) an average decline of a catchment whose volume determines the intensity of surface runoff, (3) density of a river network which is an indicator of direct and rapid transportation of the matter, (4) soil permeability that determines transportation of underground waters, (5) way of land use that determines the amount and form of bioelements in the surface runoff.

An impact of catchment on the rate of delivery of the matter to a lake is assessed by applying bonitation of each of the above-mentioned features in the interval of 0 to 3 points, where 0 indicates a very weak influence on delivery of the matter and lack of possibility of its reaching a lake, and 3 stands for a great influence and fast delivery of the matter to a reservoir (Table 1). A final result is an arithmetic mean of the points which were obtained from evaluation of specific features which qualify a catchment to be in one of the following groups:

I — average value is smaller or equals 1.0; catchment strongly limiting surface runoff and showing lack of delivery of the matter to a lake;

II — average value ranges from 1.1 to 1.4; catchment with little susceptibility to activating the load deposited in its area and small probability of its reaching a reservoir;

III — average value ranges from 1.5 to 1.9; catchment with mean susceptibility or with moderate capacity of delivery of the matter;

IV — average value is equal to or exceeds 2.0; catchment is marked by a great capacity of delivering the matter to a lake.

This assessment reveals those features which favour the delivery of the matter to a lake and those which act as a barrier to this process.

The features which determine the lake's resistance to the impact of its catchment area are as follows: (1) mean depth, (2) a quotient of the volume of a lake and its shoreline length, (3) percentage of thermal stratification of waters, (4) a quotient of an active bottom surface and of epilimnion volume, (5) rate of annual water exchange in a lake, (6) Schindler's coefficient or a quotient of an area receiving pollutants and the amount of water dissolving them.

Table 1

Evaluation of the catchment according to sources of biogenic material supply

Characteristics	Number of points			
	0	1	2	3
Lake's coefficient	≤ 10	10 - 40	40 - 150	> 150
The type of lake's water balance	-	with outflow	without water exchange	with inflow and outflow
Catchment morphometry: — channel network density (km ²) — the average slope of catchment (%)	$\leq 0,5$	0.5 - 1.0	1.0 - 1.5	> 1.5
	≤ 5	5 - 10	10 - 20	> 20
Geology of the catchment	clay	sandy-clay	clay-sandy	sandy
The land use of the catchment	forest, swamp, agriculture and forest meadow and agriculture and forest	forest and agriculture, meadow and agriculture	agriculture, meadow and forest and rural settlement	forest and rural settlement, meadow and agriculture and rural settlement, agriculture with rural settlement

The particular features which influence the process under study are given points from 0 (high resistance) to 3 (lack of resistance to the catchment's influence). The final estimate is an arithmetic mean of points obtained from the assessment of the particular features of resistance of a lake (Table 2). The average which is smaller or equal to 0.8 indicates that a lake belongs to the Ist category (highly resistant to external influence), from 0.9 to 1.6 — to the IInd category (of average resistance), from 1.7 to 2.4 — to the IIIrd category (of little resistance) and above 2.4 — to the IVth category (non-resistant or strongly exposed to external influence).

Table 2

The evaluation of a lake's receptivity to degradation

Characteristics	Number of points			
	0	1	2	3
The mean depth (m)	> 10	5 - 10	3 - 5	3 >
Volume of lake (10^3 m^3)				
Shoreline length (m)	> 5	3 - 5	1 - 3	1 >
Thermal stratification (%)	> 35	20 - 35	10 - 20	10 >
Area of active bed (m^2)				
Volume of epilimnion (m^3)	0.10 <	0.10 - 0.15	0.15 - 0.30	0.30 <
Schindler's coefficient	10 <	10 - 30	30 - 100	100 <
Rate of annual water exchange	> 10	5 - 10	1 - 5	1 >

On the basis of the above-mentioned assessment a lake and its catchment can be classified under one of the four groups of catchment-lake system which differ in the rate of natural eutrophization.

The first group represents such an ecological catchment-lake relationship in which natural feature of a reservoir (Ist or IInd category of resistance) as well as of its catchment (1st or 2nd group of susceptibility) do not favour eutrophization of the lake waters; the lake is resistant to external influence, its catchment being little active in delivering the matter to the reservoir. Such a system has therefore a chance of maintaining eutrophization at a low level. The second group represents such an arrangement in which catchment-lake relations are disadvantageous to the reservoir (great capacity of activating a surface load — 3rd or 4th group of susceptibility) but they are balanced by a high resistance of the lake itself to external influence (Ist or IInd category of resistance). In effect, the rate of natural eutrophization of the lake is moderate. The third group represents the ecological catchment-lake system in which advantageous catchment conditions (the catchment is little active in activating surface load; 1st or 2nd group of susceptibility) are observed but the lake itself is prone to external influence (IIIrd or IVth category of resistance). Eutrophization in this group proceeds moderately but interference in catchment conditions (for example, land irrigation works, changes in land use, development of tourism) can lead quite rapidly to degradation of the lake waters. The fourth group is such an ecological catchment-lake system whose natural conditions are disadvantageous to clean lake waters. The reservoirs are characterized by the 3rd or 4th group of susceptibility of a catchment and IIIrd or IVth category of resistance. The natural features of the catchment favour surface runoff and the lake itself is highly susceptible to external influence. This causes a rapid eutrophization of the lake.

The assessment of the rate of natural eutrophization of lakes presented in this paper has been recently used for the evaluation of ecological condition of the Polish lakes (e.g. Bajkiewicz-Grabowska, Malczyk 1988; Bajkiewicz-Grabowska 1987; Hilbricht-Ilkowska 1989).

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