

Autotroph-heterotroph Relationships in Natural Waters

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Souhrn

Biologické zkoušky vod spolu s chemickou charakteristikou umožňují klasifikaci různých typů vod, ale jedno číslo pravidelně nestačí, abychom vodu správně hodnotili. Gabrielův biologický index stanovovaný at původní nebo modifikovanou metodou je cenné kritérium, jež nás může o stavu vody dobře informovat, jsou-li dodrženy nutné předpoklady; není to ovšem metoda a hodnota zcela kvantitativní.

Celková hodnota producentů, resp. fotosyntetisující hmota (autotrofové) proti celkové organické hmotě vůbec [hmota konsumentů plus reducentů (destruentů) plus rozpuštěné organické látky] by tedy byla mnohem lepší mírou pro charakteristiku vody nežli prostý počet nestejnorodých jednotlivých individuí, i když je doplněn přídatnými indexy.

Proto lepší představu o stavu biomasy poskytuje srovnání obsahu chlorofylu (jako charakteristika fotosyntetisující hmoty) s obsahem „organického uhlíku“. Dosavadní běžnou konvenční metodu biologické spotřeby kyslíku je nutno doplnit standardisovanou obdobně konvenční metodou biologické produkce kyslíku.

Literatura uvádí velmi mnoho různých způsobů, jak stanovit „organický uhlík“ a chlorofyl; významnější z nich byly kriticky a experimentálně zhodnoceny v práci ŠESTÁKOVĚ (1955, 1958a, b). Z řady vyzkoušených modifikací se nejlépe osvědčily postupy navržené v textu. Poměr producentů a konsumentů s destruenty je nutno v praxi vždy zjednodušit, musíme se však vždy snažit o to, aby byl vyjádřen co nejpřesněji. Nelze se spokojit číslem nebo rovnicí, nýbrž je nutno vždy podle možnosti respektovat i další faktory, jako jsou např. složení společenstev, vztahy allelobiologické, antibiosa a specifické poměry různých lokalit; je tedy nutno respektovat nejen kvantitativní hodnoty, nýbrž hodnotit i kvalitativní charakter a vztahy různých organismů.

Summary

Biological tests of waters combined with determinations of their chemical nature make it possible to classify different types of waters, but usually one figure does not suffice for a correct evaluation of a given water. GABRIEL'S biological index is a valuable criterion which can give us a good deal of information about the state of the water if the necessary conditions are adhered to; it is not, however, a completely quantitative method and value.

The total body of producers, that is photosynthesizing matter (autotrophs) compared with the total organic matter as a whole [the body of consumers plus reducers (destroyers) plus dissolved organic matter] would be a much better criterion for characterizing the waters than a simple count of various individual bodies, even if this were to be supplemented by the relevant indices.

The usual conventional method, employed hitherto, of a biological oxygen demand must be supplemented by a similarly standardized conventional method of biological production of oxygen.

The literature on the subject gives many different methods for establishing "organic carbon" and chlorophyll; the most important of these have been evaluated critically and experimentally by ŠESTÁK (1955, 1958a, 1958b). Of a number of tested modifications the procedures outlined in this article proved to be the best. The relationship between producers and consumers plus destroyers must always be simplified. We cannot content ourselves with a figure or an equation, but must respect other factors as far as possible.

The evaluation of different waters has for long been the fundamental problem not only in hydrobiology (biological productivity of waters), but also in the field of health services (hygiene, the supply of drinking and other water, spas), agriculture (irrigation) and industry (supply of water for production processes). For practical purposes an easy and simple method is needed, which can provide as rapidly as circumstances permit, a quantitative basis for the evaluation of waters. Chemical and biological tests must, at the same time, complement each other (PRÁT 1947, 1956). The usual methods are described in detail or summarized in various papers; we give references here only to some of the latest works (BULÍČEK 1957; CYRUS and CYRUS 1950; HANUŠKA et al. 1956; JAM 1953; LAPTEV 1955; RAZUMOV 1957; STARMACH 1952, 1955, 1956; SYMON 1948; SYMON et al. 1954; TRNKA et al. 1957; ŽDANOV and RJABOVA 1956; earlier references, not given here, are contained in the papers mentioned).

Biological tests of water are sometimes unfavourably criticized, not for their actual nature, but on account of incorrect procedure in carrying them out (LUTONSKÝ 1956; ŠVEC 1956). It is not, of course, necessary to discuss the fact that careless work can ruin even the most perfect method. It is not, however, possible to agree with the contention that biological tests reflect only the momentary state of water at the time of sampling (ŠVEC 1956, p. 160).

With the exception of cases where there is a rapid and strong external influence (e. g. a sudden inflow in running water or sudden artificial intoxication), biological tests in fact provide evidence of equilibrium attained over periods of varying length before samples are taken; a biological test can show this previous state, which is sometimes different from the momentary, chemically determined state of water (cf. e. g. PRÁT 1947, 1952, 1956).

Many different kinds of biological tests can be used. They are usually combined with chemical and physical data. In many cases productivity is given in terms of photosynthetic assimilation. Analyses of the amount of chlorophyll in water can throw light on a number of questions, but only from one point of view; it is necessary to know not only the capacity of organisms for increasing oxygen production (thereby at the same time, of course, the increase of assimilates), but also the conditions of oxygen consumption, or the amount of oxidizable substances in water. Attempts to use chlorophyll for the determination of the amount of phytoplankton are of an earlier date (for references cf. ŠESTÁK 1955).

The question of establishing types of waters according to their purity, the organisms present and productivity has not as yet been satisfactorily solved. The complexity of these questions is shown in the reports and discussion at the XIII. International Limnological Congress (e. g. ELSTER 1958; HRBÁČEK 1958; OHLE 1958) and in a number of articles in recent volumes of the journal *Limnology and Oceanography* (e. g. OHLE 1956).

For a correct evaluation of the properties of water we must know not only the chlorophyll content, but also the mutual relations between producers, reducers and consumers; their numerical expression was introduced by GABRIEL (1940, 1943, 1946, 1954) as the so-called "biological index". This is based on the counting of centrifuged plankton under the microscope. It is intended to provide information about the self-purifying capacity of the water concerned.

Gabriel's biological index, established either by the original or by a modified method (LUTONSKÝ 1956) is a valuable criterion, which can give us a good deal of information about the state of water if the necessary conditions are adhered to; it is not, however, a completely quantitative method and value. Some of its drawbacks have been pointed out by CABEJSZEKOVA and MALA-
NOWSKI (1955), STANISLAWSKA (1955), TUBOROYSKI (1957).

The principle of the method—the counting of producers, consumers and reducers and the recording of their mutual relationship

$$\left(\frac{2 \times \text{number of producers}}{\text{No. of reducers} + \text{No. of consumers}} \right)$$

—is certainly correct. In practice, however, it is not possible to count individual bacteria or to evaluate zooglae of different sizes; this is the most serious obstacle in the case of reducers or destroyers. New opportunities are offered by the method of determining bacterial mass by means of membrane filters, which is being steadily perfected (POKORNÝ 1957), but it is not easy to incorporate its results into Gabriel's index.

Different algae, e. g. *Chlorella*, *Scenedesmus*, *Eudorina*, *Pediastrum*, *Euglena*, etc., produce very different effects according to their size and photosynthesis intensity, and this applies both when individual cells or colonies are counted. Consumers also show considerable differences in size. Quantitative results are not even given by estimates of biomass volume according to various models (e. g. LOHMANN 1908).

The counting method can only take into account formed particles. Even if the so-called amorphous parts were to be included in the formula of the index (HANUŠKA 1949) the method remains very inaccurate and arbitrary. This is also due to the fact that we cannot distinguish inorganic particles from organic under the microscope without recourse to complicated micro-analysis. Coagulates of bi-valent and tri-valent iron behave very differently in water, but in counting we have to evaluate them equally.

Substances dissolved in water can sometimes, however, be of greater importance for the evaluation of water than the seston. Whatever view may be taken of PÜTTER's theory of dissolved nutrients of water animals, it is not possible to ignore the organic substances dissolved in water. The total content of unformed, dissolved organic substances in water varies considerably and can be quite high. As early as 1942 JUDAY (1942) reported from some lakes in Wisconsin that the amount of dissolved substances in water may exceed the amount of organic matter of water fauna and flora. The relation of the quantity of plankton to the amount of dissolved organic matter was reviewed by SAUNDERS (1957).

Recently LEWIN (1956) has described *Chlamydomonas mexicana*, which can set free in the medium 20 to 25% of its total production of organic matter in the form of dissolved polysaccharides. In the case of the species *Chl. parvula* and *Ch. pterfii*, deliquescent mucus forms 40 to 60% of the total production of organic matter and in older cultures it considerably increases the viscosity of the environment. In the light of these findings and of the literature on the subject LEWIN points out the consequences for plankton succession and for the growth of heterotrophic bacteria, the possibility of forming chelate compounds with metals, and the influence of hydrocolloids on soil properties. SHAPIRO (1957, p. 170) reports far more dissolved organic matter than seston for Linsley Pond. It is, therefore, important that these dissolved substances should be taken into consideration in the classification of waters.

The total body of producers, that is photosynthesizing matter (autotrophs) compared with the total organic matter as a whole [the body of producers plus consumers plus reducers (destroyers) plus dissolved organic matter] would be a much better criterion for characterizing the waters than a simple count of various individual bodies.

A better idea of the state of the biomass-production is, therefore, obtained by means of a comparison of the chlorophyll content (as an indication of photosynthesizing matter) with the "organic carbon" content. This procedure was adopted by VINBERG and ZACHARENKO (1950), but they stated the correlation coefficient only for a limited range of conditions of plankton. REY (1952) suggested the comparison of chlorophyll with protein content. HOGETSU and ICHIMURA (1954) determined the relation of chlorophyll to organic carbon in seston from various depths.

Although none of these experiments has led to definite conclusions they support the view that the relation between the amount of chlorophyll and the amount of organic substances (living, organized and dissolved) can provide a valuable criterion for the estimation of the properties of water.

The calculation of the relation between the amount of chlorophyll and the total amount of organic matter (determined from dry weight or by carbon content) would thus give a better indication of the interrelation of autotroph and heterotroph activity than counting of organisms. Insofar as there is a sufficient amount of plankton or organic matter in a sample it is only necessary to evaporate the water and determine dry weight and deduct the amount of ash. However, some organic substances may be decomposed during

evaporation, thus giving rise to unnecessary experimental errors. For this reason (particularly when there is only a small quantity of organic matter available) it is better to determine the amount by chemical means.

The combustion of organic substances and the determination of freed carbon dioxide by elementary analysis is a relatively complicated and lengthy process; with rising demands on accuracy hydrobiology does indeed require ever more and more complicated laboratory methods (e. g. KAY 1954a, 1954b), but in practice it is usual to use methods of wet oxidizing of carbon, even though the results are not so reliable (*cf.* ŠESTÁK 1955, 1958b). Using these methods we always obtain a lower value for so-called organic carbon, i. e. oxidizable substances, and, which is important, a value which varies according to the chemical nature of the substances. This disadvantage can be compensated by the fact that in hydrobiology we are usually more concerned with the amount of substances capable of oxidation under natural (milder) conditions, with the consumption of oxygen, than with the total amount of all organic matter (including that which is not readily oxidized). On the other hand, however, it is not only the total amount of oxidizable substances and their capacity for oxidation which is important, but also their quality. Thus, for example, humus substances (humic acids) are burned with difficulty and when oxidation conditions are mild, amount of humus is only partially determined (ŠESTÁK 1955, 1958b; SHAPIRO 1957, p. 171); but it is just these compounds which are of considerable importance for the development of organisms, whether positively (PRÁT 1955, 1956) or negatively (dystrophic waters), and they are, therefore, biologically very important.

In practice, however, a simplified conventional method, which gives results that can be easily reproduced, must suffice. If a certain method is uniformly employed it is at least possible to obtain relative results which are comparable.

In order to determine the total amount of oxidizable substances, so-called organic carbon (i. e. carbon in living organisms, carbon in non-living organisms but in an organized state and unorganized dissolved organic compounds), a sample of water is taken direct for analysis. Where it is necessary to supplement and differentiate these values the carbon is determined in the residue on the filter or in the centrifugate (of seston) and dissolved substances in the filtered or centrifuged water.

Many different methods of determining "organic carbon" and chlorophyll are given in the literature; the more important of them have been critically and experimentally reviewed by ŠESTÁK (1955, 1958a, b). Of a number of tested modifications the following procedures have proved the best:

A. Determination of organic carbon

1. Bichromate method for samples with at least 20 mg. C/l:

To 5 ml. of water sample in a thick-walled test-tube SIAL (or PYREX), size 30 × 160 mm., are added 5 ml. of 0.5 N $K_2Cr_2O_7$ solution in conc. H_2SO_4 and the tube is heated for 60 min. in a steam bath in a covered vessel. The contents of the test-tube is then poured into a measuring flask, the volume is made up to 250 ml. and 1 hour after dilution 3 portions of 50 ml. are taken from the sample. To each is added 1.5 ml. of 20% aqueous solution of KI and this is titrated with 0.05 N or 0.025 N solution of $Na_2S_2O_3$ against a starch indicator until the colour disappears. In the given portion 1 ml. of 0.05 N $Na_2S_2O_3$ corresponds to 0.15 mg. of carbon. The average from parallel portions is converted to correspond to 100 ml. of water (multiplication by 100).

It may be mentioned that a similar bichromate procedure was included among the standard methods in the latest edition of the well-known American manual (Standard methods . . ., 1955). It differs from the method recommended above particularly in the lower resultant concentration of bichromate in the mixture during the combustion of the sample (0.04 N), which lasts for 2 hours under reflux, and in the final titration with ferrous-ammonium sulphate using ferroin indicator. For waters containing substances difficult to oxidize, catalysis with silver ions is recommended (this did not prove successful, ŠESTÁK 1955, 1958b). If Ag_2SO_4 is not used for

catalysis it is necessary to deduct a correction for chlorides ($\text{mg. Cl}/1 \times 0.23$). It is also necessary to take into account the possibility of oxidation of iron compounds.

2. The permanganate method according to KUBEL for samples up to 10 mg. C/l.

In a 500 ml. Erlenmeyer flask with a special tube for calming boiling, 5 ml. of 25% H_2SO_4 by volume are added to 100 ml. of the water sample. As soon as the mixture boils, 15 ml. of 0.01 N KMnO_4 are added and the resulting mixture is kept at the boiling point for a further 10 min. Then 15 ml. of 0.01 N oxalic acid are added and the liquid retitrated with 0.01 N permanganate solution until the first pink colour appears. In retitration 1 ml. of 0.01 N KMnO_4 solution corresponds to 0.03 mg. of carbon oxidized in the sample.

"Carbon" as determined by the manganistan method is usually one-fourth to one-fifth (or even less) of the carbon found by the biochromate method and it is necessary to take this into account in calculation.

B. Determination of pigment content (chlorophyll).

A layer 1 to 1.5 cm. thick of glass sand (grains smaller than 100μ , average size of grains 12 to 25μ) is placed on filter paper in a small Büchner funnel and the sample is filtered under suction. The sand with plankton is then poured into a mortar and ground for about 3 min. until coloured stripes are no longer formed; it is then returned to the funnel and extracted with 5 ml. of non-aqueous acetone, then 85% acetone, finally non-aqueous acetone again. The extract is refiltered through the Jena sinter-glass No. G4, made up to 20 ml., measured on a photometer. Extinction is compared with the standard curve and converted in terms of percentage of chlorophyll (pigments) in relation to the organic matter in the sample. Examples of chlorophyll determination are given e. g. by SMITH and BENITEZ (1955), calculation nomographs by DUXBURY and YENTSCH (1956).

Using the methods described above, the relation of "organic carbon" and chlorophyll in samples of algae grown from cultures of the Collection of Autotrophic Organisms of the Czechoslovak Academy of Sciences (PRÁT 1948) was studied. In the survey given in two tables the values obtained by counting cells in a counting chamber have been added for comparison.

There is ample evidence in literature on the subject and in the facts mentioned above that a number of difficulties are met with during the determination

Table 1. *Chlorella vulgaris* var. *viridis* CHODAT. Comparison of results obtained by various methods (average of 2 to 6 determinations). Amount of chlorophyll expressed in extinctions of 10 ml. acetone extract, measured by means of Pulfrich photometer in a 5 cm.-long glass absorption cell. Average concentration of algae 1, 1/2, 1/3, 1/4 and 1/6. Values for diluted samples are given below as percentages.

Concentration	Counting in chamber		Organic carbon				Chlorophyll acc. to S 61 in 5 ml. of sample (method B)	
			KMnO ₄ (A 2)		K ₂ Cr ₂ O ₇ (A 1)			
	No. of cells in 5 ml.	%	mg. C in 5 ml.	%	mg. C in 5 ml.	%	extinc- tion	%
1	11,000,000	100	0.112	100	0.637	100	0.450	100
1/2	5,000,000	45.5	0.054	48.3	0.262	41.2	0.260	57.8
1/3	3,480,000	31.6	0.032	28.6	0.206	32.3	0.150	33.3
1/4	3,300,000	30	0.030	26.7	0.169	26.5	0.096	21.3
1/6	2,240,000	20.3	0.017	13.6	0.075	11.8	—	—

Table 2. Amount of pigments (in extinctions $\times 10^3$) from measurements with filters S 61 and S 47, corresponding to 0.1 mg. C (by bichromate method) and to 1 million algae cells (from count in chamber).

Pigments determined by method B, only for *Chlamydomonas* cultures using 3 times repeated extraction from filters giving lower values (ŠESTÁK 1958a). Pigments measured in acetone extract of 10 ml. volume by means of Pulfrich photometer with 5 cm.-long glass absorption cell. Both cultures of *Scenedesmus* were about 3 months old, grown with the same illumination in liquid medium L 41 (PRÁT 1948). To medium of culture I added soil decoct, which in culture II was replaced by A—Z solution. The difference in chlorophyll content for cultures I and II is significant ($\bar{d} = 5.6$, $t_{11} = 4.78$, $P < 0.001$).

Algal species	Filter S 61		Filter S 47	
	amount of chlorophyll corresponding to			
	0.1 mg. C	1 mil. cells	0.1 mg. C	1 mil. cells
<i>Chlamydomonas gyrus</i>	56	382	231	1390
<i>Chlorella vulgaris</i> var. <i>viridis</i>	71	41	229	133
<i>Scenedesmus obliquus</i> cult. I	47	30.6	164	105
<i>Scenedesmus obliquus</i> cult. II	—	36.2	—	125

of the relation between “organic carbon” and chlorophyll, such as: the percentage content of chlorophyll is not constant even within one algal species, it depends on nutrition, on the amount of ions and organic substances in the environment, on the age of the culture and on other factors; individual groups of algae contain photosynthetic pigments of varying activity (cf., e. g., BLINKS 1955). Photosynthesis is not a linear function of chlorophyll content. Even dead cells continue for a long time to contain some non-decomposed chlorophyll. In view of this the only solution would be to determine photosynthetic intensity directly, or the amount of freed oxygen. As early as 1947 PRÁT pointed out that the existing method of biological oxygen demand would have to be supplemented by the value of biological oxygen production not only using “light” and “dark” bottles in the natural surroundings, but determining photosynthesis in definite quantitatively characterized conditions. While, however, the BOD method is only an agreed test and its different procedures are still under discussion (dilution water, degree of dilution, period of exposure, unnatural experimental conditions), in the determination of photosynthesis a further technically difficult problem arises, i. e. defined, constant and easily reproducible illumination. So long as an acceptable and uncomplicated solution of this has not been found these experiments may serve as a qualitative criterion, but they cannot offer a quantitative evaluation comparable for different experiments. However, even positive or negative results of tests in the light (increase or decrease of oxygen) can give valuable information for different waters.

In the meantime the relation of organic substances (“organic carbon”) in water to the amount of chlorophyll provides at least an approximate value, which can give useful information about the activity of autotrophs and heterotrophs.

If the ratio of chlorophyll to the total organic matter (organized and dissolved) is high, a prevalence of photosynthesis is indicated, that is a high content of producers. If on the other hand the ratio of chlorophyll to total organic matter is low, reducers, destroyers and consumers (or in some cases dissolved organic substances) preponderate. In waters lacking in producers the chlorophyll content drops to nought; in this case the absolute value of organic substances is decisive for the nature of the water.

This means that if there is 2 to 4% of chlorophyll in the dry weight (i. e. about 4 to 8% with regard to the total amount of "carbon"), a high proportion of autotrophs, producers, can be assumed. The lower the chlorophyll content the greater the preponderance of heterotrophs.

This conception is, however, quite schematic and in definite cases it is necessary to evaluate not only the figures obtained, but also to take into account the forms of organic matter and the kinds of organisms they represent. J. HRBÁČEK has called our attention to cases where assimilating phytoplankton is rapidly consumed by strongly reproducing *Daphnia* (grazing activity of the zooplankton). Under such conditions a low or non-existent amount of chlorophyll would be found with a large amount of organic substances (living individuals). These figures would provide incorrect information about the properties of the water. It must be repeated that figures are only an aid, which make it possible to record certain conditions in a quantitative sense, but not absolutely. In every case it is necessary to consider as far as possible all the circumstances in order to give numerical values their true significance. Further, in addition to the quantity the quality of organic substances must be stated, that is they must at least be typified according to the fraction as dissolved (in the filtrate) and organized and these should again be divided at least into living and dead. What is more, this quantitative result must be described qualitatively, for it is impossible to regard a living mass of *Infusoria*, *Rotifera* and *Crustacea* or even molluscs and fish as equivalent to each other. The important part played by fish breeding in influencing the character of reservoirs has been emphasized by HRBÁČEK (1958).

The total nitrogen content could also be taken as a basis for comparison; it would correspond more closely to the living organisms. However, the nitrogen content of organisms shows a much wider range of variation than does carbon content; nitrogen compounds are often difficult to oxidize (ŠESTÁK 1955). Therefore, while in some cases nitrogen content can serve as a suitable supplementary basis, as a general rule it is even less suitable than the amount of oxidizable carbon substances.

The method here suggested is not intended as a substitute for Gabriel's biological index nor for any other form of evaluation, but as a supplement. So long as some other easy and more accurate method has not been worked out Gabriel's biological index remains an important aid for the evaluation of waters.

In hydrobiological literature there is frequent mention of frequency (numerousness) and of production or of weight of the biomass. Gabriel's index determines frequency relations, the method concerned with the relations of organic substances and pigments approaches nearer to actual production.

It has already been emphasized while describing methods that the oxidation methods for the determination of so-called total organic carbon do not give completely quantitative results, that the values obtained can be compared only if a uniform method is used and that they must be regarded as relative. There are also a number of other factors which must always be considered in the assessment of water. It is very difficult to fix the share of chemosynthesis in this complex; although it is not great (KUZNETSOV, 1958), it has to be reckoned with.

With regard to the relation between producers and consumers it has been the custom so far to conceive of it as the preponderance of assimilation (photosynthesis) over dissimilation. But even granting their fundamental significance it is not possible to fit these relations into such a simplified scheme. No equation can be made to fit the influence of one organism on another,

neither allelobiological relations nor the mutual influence of individuals of the same species. This is the case within groups of producers and consumers. Various interspecific relations can act not only on their growth, but also on their activity (POSPÍŠIL 1952). A few notable examples will suffice to illustrate the mutual influence of organisms. As early as 1914 PRÁT (1914) wrote: "Among only slightly developed filaments of algae (*Cladophora*, *Spirogyra*) in a dish there appeared *Saprolegnia* on a mosquito larva. In order to maintain its growth I put dead flies into the dish and after a time I observed that unicellular green algae had appeared on the bodies of the flies among the *Saprolegnia*. The former appeared to be doing well, while *Saprolegnia* stopped growing and finally disappeared. New flies, which were later introduced into the dish, did not become infected with *Saprolegnia*, similarly *Saprolegnia* did not appear on flies put into water from the original culture which had been poured into another dish". — Today the literature on antibiotic influences is voluminous, but relatively little of the work applies to natural conditions in the field (STEEMAN-NIELSEN 1955). With regard to the relations between autotrophs and micro-organisms the work of MENCL (1956a, 1956b) may be mentioned; even if his results are not completely approved, they show the importance of this problem and its significance in relation to the new approach to the assessment of water. Quite a number of cases of symbiosis of autotrophs and micro-organisms are known. The varying mutual influence of different components of plankton and in particular of water flora have often been described (FOTT 1956; KOMÁREK 1955). GORYUNOVA (1955) describes cases, which she refers to as хищничество (robbery) of blue-green algae.

All these interrelations are undoubtedly of great importance in the general balance of biocoenosis, but they cannot be expressed by any equation. We must, however, take them into account.

Although it will now be clear that the relation between producers and consumers plus reducers (destroyers) has always to be simplified in practice, it is not possible to omit this value, rather it is necessary to try to express it as accurately as possible and to take into account other factors as well, as far as circumstances permit.

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К вопросу о взаимоотношениях автотрофов и гетеротрофов в водах

СИЛВЕСТР ПРАТ и ЗДЕНЕК ШЕСТАК

Резюме

На основе многих литературных данных обсуждается потребность использования биологических и химических тестов в классификации разных типов вод. В качестве дополнения тнз. биологического индекса Габриеля

$$\left(\frac{2 \times \text{количество продуцентов}}{\text{количество редуцентов} + \text{количество консументов}} \right),$$

устанавливаемого подсчетом планктонных организмов, рекомендуется сравнение содержания хлорофилла с содержанием органического углерода в данной воде. Для этого рекомендуются методы (определение органического углерода окислением перманганатом или бихроматом, колориметрическое определение хлорофилла), которые экспериментально изучались и оценивались. Обычный метод BOD надо дополнить стандартизированным биологическим методом продукции кислорода.