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## Zmiany ilości chlorofilu w wodzie stawów w ciągu dnia — Changes in chlorophyll amount in water of ponds during the day

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In recent years hydrobiologists have more and more frequently used the chlorophyll method for evaluating numerical relations in the phytoplankton. When the amount of chlorophyll in a given volume of water is known the content of organic substance of algae cells can be estimated. In spite of the fact that the amount of chlorophyll differs in relation to mass for individuals of different species, it is usually assumed that the average relation of phytoplankton as a whole is more or less similar. On this basis, therefore, and on the analysis of chlorophyll amount, the size of the so-called biomass or dry mass of the phytoplankton can be evaluated.

Knowing the amount of chlorophyll, the intensity of solar radiation, and the depth into which light rays penetrate in the reservoir, some hydrobiologists try to calculate the intensity in which organic matter is formed in the cells of algae. On this account studies of chlorophyll content are most desirable.

It would seem sufficient to collect samples for quantitative analysis of chlorophyll at any time of the day in order to determine the amount of phytoplankton at a given depth. It appears, however, that the amount of chlorophyll in phytoplankton of the same station, at least in surface strata and on sunny days, depends on the time of day. Yentsch and Ryther (1957) and Ryther et al. (1958) were the first to remark this and it was confirmed later by Shimada (1958) during his investigation on variations of photosynthesis intensity in the Pacific. It results also from the diagrams of Humphrey (1960) concerning numerical relations in the chlorophyll of Australian waters. Ichimura (1960) analyses the phenomenon on the background of luminary relations. All the above-mentioned authors, with the exception of Ryther et al. (1958) observed a maximum amount of chlorophyll in the morning hours and a minimum amount just before sunset.

It would appear at first sight that this phenomenon is the so-called negative phototropism, when the algae descend to the bottom of the reservoir under the influence of the sun's rays. Experiments were conducted by the present author in a relatively shallow pond (75 cm) with the aim of ascertaining, among other things, whether or not this phenomenon actually occurs. If vertical migrations take place, the average amount of chlorophyll in a stratum of water 75 cm deep should be more or less the same, even if the amount of chlorophyll in the surface water of the reservoir is small.

### Method

Samples of water for determining the chlorophyll amount were collected by means of a Ruttner batometer from the surface of 2—3 levels, on sunny days, every few hours from sunrise to sunset. Simultaneously a sample of water was taken so as to determine the species of algae dominating in the phytoplankton. Samples were collected in ponds in the vicinity of Białystok. The chlorophyll amount was determined on membrane filters by means of the Vinberg and Sivko method (1953).

### Results of investigations

**„Łabędzi pond”.** This pond is situated within the area of the park in the town of Białystok, partly surrounded by trees; maximum depth 1 m. Samples were collected on March 20, 1961 (sunrise at 5<sup>30</sup>, sunset at 17<sup>45</sup>). *Dinobryon cylindricum* Im h. and *Chlamydomonas* sp. dominated in the phytoplankton. Changes in chlorophyll amount for 24 hours are presented in Fig. 1. A mean amount (74  $\mu\text{g/l}$ ) of chlorophyll was observed at 5<sup>30</sup>

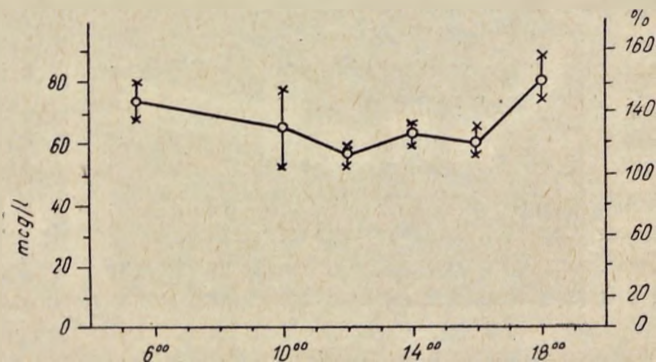


Fig. 1. Changes in chlorophyll amount ( $\mu\text{l} = \text{mcg/l}$ ) in the surface stratum of Łabędzi pond during the day of March 20, 1961

in the surface stratum. At 10<sup>00</sup> the chlorophyll amount diminished to 65  $\mu\text{g/l}$  on the average. The smallest amount of chlorophyll was found on this day at 12<sup>00</sup> (56  $\mu\text{g/l}$ ). From 12<sup>00</sup> o'clock onwards a slow increase of chlorophyll amount was noted and the maximum amount was found immediately after sunset at 18<sup>00</sup> (81  $\mu\text{g/l}$ ).

„Trzy Praczki” pond. This pond is situated in the immediate vicinity of the Łabędzi pond and is not surrounded by trees; its maximum depth is 0,75 m. On March 20, 1961 the same species as in the preceding pond dominated in the phytoplankton. Fig. 2 shows changes in the chlorophyll

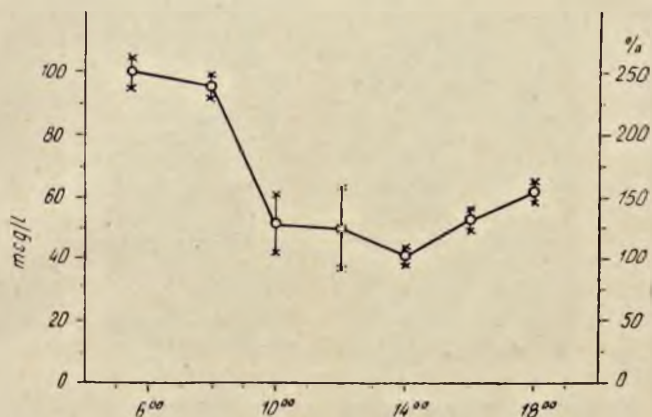


Fig. 2. Changes in chlorophyll amount ( $\mu\text{l} = \text{mcg/l}$ ) in the surface stratum of „Trzy Praczki” pond during the day of March 20, 1961

amount during 24 hours. At 5<sup>30</sup> the chlorophyll amount in the surface stratum was 105  $\mu\text{g/l}$ , and at 8<sup>00</sup> it diminished slightly to an average of 96  $\mu\text{g/l}$ . At 10<sup>00</sup>, however, the amount of chlorophyll diminished considerably (51  $\mu\text{g/l}$  on the average), it remained nearly on the same level at midday (50  $\mu\text{g/l}$ ), and reached its minimum at 14<sup>00</sup> (41  $\mu\text{g/l}$ ). From 14<sup>00</sup> onwards the amount of chlorophyll slowly increased, reaching 62  $\mu\text{g/l}$  at 18<sup>00</sup>.

Observations were carried out on the same small pond during the summer season — August 9, 1961 (sunrise at 5<sup>10</sup>, sunset at 20<sup>06</sup>), (Fig. 3), and vertical stratification for 24 hours was taken into consideration. The following species appeared in the phytoplankton: *Coelastrum microporum* Naeg., *Scenedesmus quadricauda* (Turp.) Bréb., *S. quadricauda* (Turp.) Bréb. var. *dispar* (Bréb.), *S. acuminatum* (Lag.) Chod., *S. arcuatus* Lemm., *S. obliquus* (Turp.) Kütz., *Actinastrum Hantzschii* Lag., *Pediastrum Boryanum* (Turp.) Menegh. var. *longicorne* Rein.

The species *Coelastrum microporum* predominated in quantity. Changes in chlorophyll amount on the surface of the lake are shown in Table III; as can be seen, the amount of chlorophyll at 5<sup>30</sup> was 542  $\mu\text{g/l}$  on the

average. In the afternoon hours, however, the amount of chlorophyll was slightly greater at 13<sup>30</sup> than at 11<sup>20</sup>, but this might have been the influence of a clouded sky from 12<sup>30</sup> to 14<sup>00</sup>.

A slow decrease in chlorophyll amount, from morning until evening, takes place at particular depths in the 24 hour cycle (Fig. 4). When

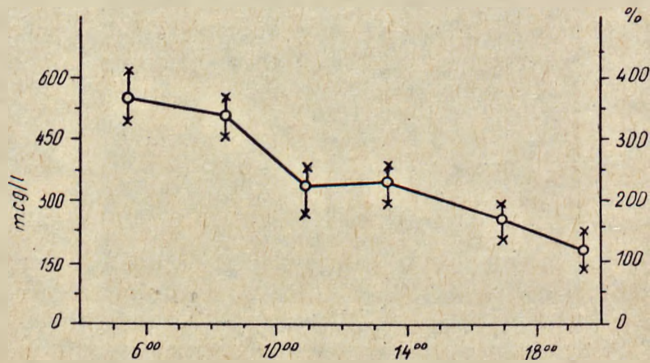


Fig. 3. Changes in chlorophyll amount ( $\mu/l = mcg/l$ ) in the surface stratum of „Trzy Praczkki” pond during the day of August 9, 1961



Fig. 4. Changes in chlorophyll amount at different depths of „Trzy Praczkki” pond. Numbers on columns indicate chlorophyll amount in  $\mu/l = mcg/l$

comparing the mean amount of chlorophyll in an entire column of water at the place where samples were collected in this pond (Table I) in separate hours, we also notice great differences. The mean amount of chlorophyll immediately after sunrise (5<sup>30</sup>) and before sunset (19<sup>30</sup>) diminished by nearly half in the whole column of water.

**Pool on the airfield.** In the past, this pool served as a reservoir for the use of the fire-brigade; at present, partly damaged during the war, it is a watering place for cattle. It is therefore considerably polluted and contains a great amount of organic substance. In the period when

samples were collected (September 22—23, 1961) the species *Euglena*, probably *E. sanguinea* Ehrb., was the only one to be found and it appeared in very great quantities. Samples were collected for analysis of the chlorophyll amount from the surface stratum of the water every

Tab. I

Daily chlorophyll content in the "Trzy Praczki" pond in mcg/l of water at different depths

| Hour \ Depth in m | 5 <sup>30</sup> | 8 <sup>30</sup> | 11 <sup>00</sup> | 13 <sup>00</sup> | 17 <sup>00</sup> | 19 <sup>30</sup> |
|-------------------|-----------------|-----------------|------------------|------------------|------------------|------------------|
| 0,0               | 542             | 510             | 336              | 344              | 264              | 180              |
| 0,25              | 569             | 532             | 548              | 560              | 380              | 272              |
| 0,50              | 569             | 573             | 600              | 600              | 570              | 406              |
| Mean              | 560             | 538,3           | 494,7            | 501,3            | 404,7            | 266              |

mcg =  $\mu\mu$

few hours from sunrise to sunset during two sunny days. It is characteristic for variability in the amount of chlorophyll from the surface stratum of the pool that the changes have a contrary course to that in the previously mentioned ponds. Immediately before sunset the amount of chlorophyll fluctuates in the region of 1 mg/l. But, from 10<sup>00</sup> onwards, the chlorophyll amount increases tenfold, attaining its peak at 16<sup>00</sup>, when the amount of chlorophyll reaches 18 mg/l. This is an extremely high figure and it is probable that such an amount of chlorophyll has not been noted hitherto. Even at sight, during the collecting of samples, considerable differences in the colour of the water could be observed. In the morning hours (6<sup>15</sup>) the water has a grayish colour while before midday and in the afternoon, that is during the period when insolation is at its strongest, the water is dark-green. The amount of chlorophyll diminished just before sunset (Fig. 5).

**The pond near the main road leading to Stanisławów.** This is a pond where fish were reared in the past. Samples of water for analysis of chlorophyll amount were collected on September 22, on a sunny day. In algae *Trachelomonas hispida* (Perty) Stein. decidedly predominated. The amount of chlorophyll in the plankton was more or less the same throughout the day (Fig. 6).

As can be seen from the observations made, considerable changes in the chlorophyll amount in phytoplankton may occur on sunny day in the 24 hour cycle (Table II). These changes may be of three different kinds:

1. The amount of chlorophyll diminishes during the day (Fig. 1, 2, 3, 4).
2. The amount of chlorophyll increases during the day (Fig. 5).
3. The amount of chlorophyll practically does not vary during the day (Fig. 6).

The occurrence of changes in chlorophyll amount during the 24 hours depends probably on the species composition of the phytoplankton (on

sunny days, of course). It is possible, therefore, that on sunny days the greater amounts of chlorophyll observed (Czeczuga 1958) in deeper strata of the epilimnion (Fig. 7) are caused by the influence of light. The sun's rays cause a diminishing of chlorophyll amount in surface waters, which does not occur in deeper strata of water.

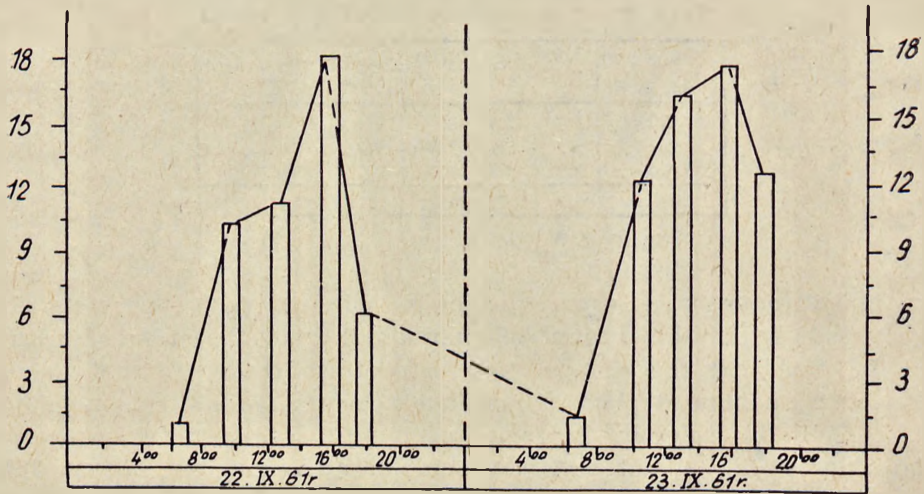


Fig. 5. Changes in chlorophyll amount ( $\mu\text{g/l} = \text{mcg/l}$ ) in the surface stratum of the airfield pool. The hatched section in the upper part of the figure indicates the period from sunset to sunrise

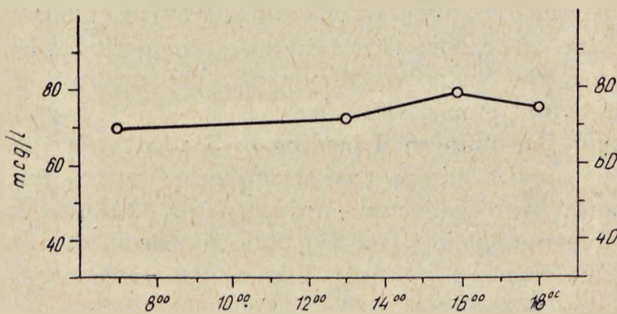


Fig. 6. Changes in chlorophyll amount ( $\mu\text{g/l} = \text{mcg/l}$ ) in the surface stratum of the pond near the Stanisławów main road during the day of September 22, 1961

The decrease in chlorophyll amount in the phytoplankton caused by the action of the sun's rays undoubtedly influences photosynthesis. It has long been known that the course of photosynthesis is always the most intensive at a certain distance from the surface of the reservoir. Even in turbid sewer ponds, with a high chlorophyll content (5—6 mg/l) photosynthesis is the most intensive in a stratum of 15—20 cm below

the surface of the reservoir (Vinberg and Sivko 1960). During intensive insolation photosynthesis can be completely arrested (Sivko 1961).

Tab. II  
Fluctuations range of chlorophyll amount in the surface stratum of water in some ponds near Białystok in mcg/l of water

| The reservoir       | Date       | Chlorophyll amount |         | Ratio |
|---------------------|------------|--------------------|---------|-------|
|                     |            | Maximum            | Minimum |       |
| Labędzi pond        | 20.III. 61 | 81                 | 56      | 1,44  |
| "Trzy praczki" pond | 20.III. 61 | 96                 | 41      | 2,34  |
| The airfield pond   | 9.VIII.61  | 542                | 180     | 3,01  |
|                     | 22.IX. 61  | 18000              | 960     | 18,75 |
|                     | 23.IX. 61  | 17500              | 1340    | 13,06 |

mcg =  $\mu\text{g}$

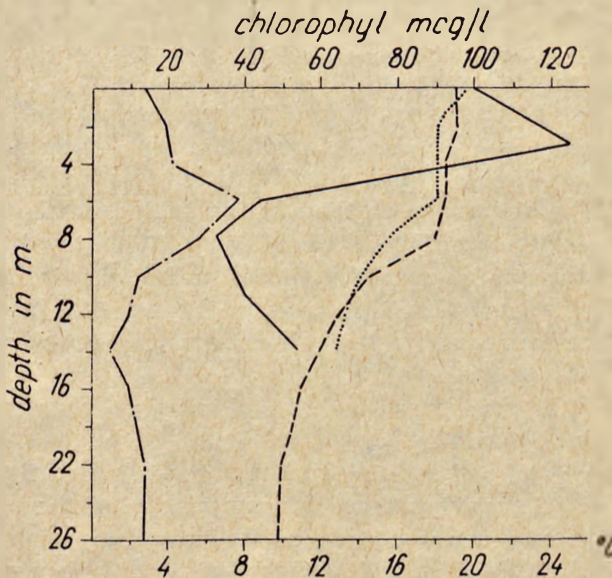


Fig. 7. Chlorophyll in plankton at different depths and the temperature of water in the Kortowskie lake on August 3, 1961 and in the Rajgradzkie lake on August 23, 1961 (— chlorophyll; --- temperature in the Rajgradzkie lake; — chlorophyll; ..... temperature in the Kortowskie lake)

In the case of a chlorophyll increase in the course of the day, as for instance in the presence of the species *Euglena* in the pond, the cause may be the effect of light upon the formation of chlorophyll amount in the cells or the condensation of *Euglena* cells rising to the surface of the water under the influence of positive phototropism. Obviously, this phenomenon demands further study. The supposition concerning the

influence of light on chlorophyll amount is the more probable when the results obtained by Gibor and Meehan (1961) who bred *Euglena* in laboratory conditions are taken into consideration. It is possible that maximum amounts of chlorophyll in the surface stratum of some lakes in the noon hours and on sunny days might also be explained by the influence of light. The Wirbel lake (Province of Olsztyn) (Table III) in

Tab.III  
Chlorophyll amount in plankton and water temperature in the Wirbel lake

| Time of investigation | 26. V. 61 | 11 <sup>30</sup> -12 <sup>00</sup> | 4.VIII.61 | 13 <sup>00</sup> -13 <sup>30</sup> |
|-----------------------|-----------|------------------------------------|-----------|------------------------------------|
| Depth in m            | T °C      | Chlorophyll<br>mcg/l               | T °C      | Chlorophyll<br>mcg/l               |
| 0,0                   | 17,0      | 21,2                               | 17,9      | 170,0                              |
| 1,0                   | 16,2      | 34,0                               | 17,5      | 125,0                              |
| 2,5                   | 14,4      | 42,8                               | 17,2      | 63,7                               |

mcg =  $\mu$ g

which a similar stratification of chlorophyll was observed on August 4, may be given as an example. It is an interesting fact that in the same lake in samples collected in the month of May (on a sunny day, at 11<sup>30</sup>—12<sup>00</sup>) an inverse chlorophyll stratification was found — the amount was greater in the deeper water than at the surface. This might signify that the phytoplankton in the month of May is composed of species in which the chlorophyll amount diminishes under the influence of the sun's rays, while in August, on the contrary, it consists of species in which the chlorophyll amount, under the influence of the sun's rays, probably increases.

It may be that on sunny and windless days no changes in the chlorophyll amount would be observed.

It seems necessary, therefore, that when analysing the amount of chlorophyll in the 24 hours, the species composition of the phytoplankton should be taken into consideration, or at least the species dominating in the given period, as they undoubtedly influence the results obtained.

#### STRESZCZENIE

Badano zmiany ilościowe chlorofilu w cyklu dobowym w planktonie niektórych płytkich stawów okolic Białegostoku. Badania przeprowadzano w słoneczne dni roku 1961.

W okresie badań zaobserwowano trzy typy zmian ilości chlorofilu w powierzchniowej warstwie badanych stawów:

1. Największa ilość chlorofilu występuje w godzinach rannych lub wieczornych, najmniejsza w godzinach popołudniowych (staw Łabędzi, staw „Trzy Praczki”. Ryc. 1, 2, 3, 4). W skład fitoplanktonu wchodziły następujące gatunki: *Dinobryon cylindricum* Imh., *Chlamydomonas* sp., *Coelastrum microporum* Naeg., różne



gatunki *Scenedesmus*, *Actinastrum Hantzschii* Lag. i *Pediastrum Boryanum* (Turp.) Menegh. var. *longicorne* Rein.

2. Największa ilość chlorofilu występuje w godzinach popołudniowych, najmniejsza w godzinach porannych (basen na lotnisku; Ryc. 5). Fitoplankton składał się jedynie z *Euglena*.

3. Występują nieznaczne wahania; w zasadzie ilość chlorofilu nie zmienia się w ciągu doby (staw przy szosie do Stanisławowa; Ryc. 6). W fitoplanktonie występował w dużej ilości *Trachelomonas hispida* (Perty) Stein.

Na podstawie obserwacji ilości chlorofilu na poszczególnych głębokościach w ciągu dnia (Ryc. 4) autor jest skłonny uważać, że w warstwie powierzchniowej następuje zmniejszenie się ilości chlorofilu w ciągu dnia, pod wpływem promieni słonecznych, a nie na skutek fototropizmu ujemnego organizmów. Poszczególne gatunki reagują przy tym odmiennie na intensywność oświetlenia.

Obserwowane często w jeziorach większe ilości chlorofilu w głębszych warstwach wody (3–5 m, Ryc. 7), a nie na powierzchni, można tłumaczyć zgodnie z panującym od dawna poglądem o ceniolubności glonów planktonowych.

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