ANNAL. BIOL. TIHANY | 39 | 115—121 | HUNGARIA 1972

STUDIES ON THE PHOTOSYNTHETIC PIGMENTS AND THEIR DECOMPOSITION IN THE SEDIMENT OF LAKE BALATON AND LAKE BELSŐ

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Received: 1st February, 1972

HARGRAVE (1969) and HICKMAN (1971) have provided evidence on the importance of microphytobenthos in the organic matter production of shallow lakes. The high chlorophyll content of the turbulent water in Lake Balaton (FELFÖLDY, 1963) and the large numbers of algae on the sediment surface (TAMÁS, 1971) indicate the important role of microphytobenthos in the primary production of Lake Balaton.

There are no data in the literature on the pigment content of the sediment of Lake Balaton. Besides information on the chlorophyll content and environmental factors, the knowledge on the physiological condition of pigments is also essential in the study of organic matter production by photosynthesis. Besides these questions, the rate of decomposition of plant pigments was also examined in the aerobic and semi-anaerobic sediments of Lake Balaton and Lake Belső.

Materials and methods

The examinations were carried out at four points of the transversal section between Balatonfüred and Zamárdi (for a detailed description of the transversal section see OLÁH, 1969) in April, 1970 and June, 1971. The depth of water at the sampling stations in the open water (1., 2.) was 370—380 cm, at the sandy southern shore (3.) 35 cm, and at the northern shore at 50 m distance off the reeds (4.) 200 cm. At the sampling stations in the centre of Lake Belső (1., 2.) the depth of water was 430 and 440 cm. The samples were taken by means of an intact core sampler and an Eckman dredge.

Extraction was started in the first hour following collection. For extraction 30 ml 90 per cent acetone solution was added to 5 g mud (wet weight) sample and this mixture was kept in darkness for 14—16 hrs at +4°C and shaken repeatedly. The extraction of pigments was repeated twice by using 10 ml solvent on each occasion. Because of the high carbonate content of the sediment addition of $MgCO_3$ was not necessary. Following extraction the extract was either filtered or centrifuged. The values obtained at 750 nm wavelength did not show any difference between the two processes. The absorption spectra were measured with a "Sepctromom 360" spectrophotometer. Having established the original spectra, the destruction of the pigments follow-

ed by the addition of 3 drops of N HCl solution (Moss, 1967) and the reading was repeated.

Amounts of chlorophylls and plant carotenoids were estimated by the equation of Parsons-Strickland (Strickland and Parsons, 1968) (later referred to as PS-chlorophyll and PS-carotenoids). Relative amounts of the destruction products of chlorophylls, i.e. the phaeo-pigments were determined by the ratios proposed by Moss (1967) and Tietjen (1970) and their absolute amounts by using the equation recommended by Lorenzen (1967). The estimates of pigments are given in μg/wet mud g unit. In the samples examined 1 g wet mud is equivalent to 0,34±0,11 g dry matter.

Results

Pigment content

High values for chlorophyll-a were obtained on the mud surface in the open water along the Balatonfüred-Zamárdi transversal section *(Table 1)*.

TABLE I.

PS-chlorophyll-a content at 0—2 cm (A), 2—5 cm (B) and 8—12 cm (C) depths of mud in the open water of Lake Balaton and Lake Belső (μg/g wet weight)

	A		B		C	
	sampling stations					
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
Lake Balaton:						
August 10, 1970	2.97	3.41	1.90	2.11	0.41	0.47
June 3, 1971	4.99	7.14	2.13	2.24	0.48	0.46
June 17, 1971	4.99	5.80	2.09	2.16	0.51	0.47
Lake Belső:						
April 2, 1970	6.64	6.16	5.47	5.86	5.10	5.14

The value of 29—71 mg/m² obtained is as high as that for chlorophyll-a in eutrophized ponds (Hickman, 1971). In Lake Balaton the diatoms are the dominating elements of the microphytobenthos (Tamás, 1971). During May, i.e. the period of maximum growth of diatoms (Tamás, 1968) the values for pigment content may be even higher in the areas examined. In the highly eutrophic Lake Belső the chlorophyll-a content of the superficial layer of mud was as high as 66 mg/m². The vertical distribution of the pigments in the mud of the two lakes was different. In Lake Balaton the pigment content of the mud rapidly decreased with depth as opposed to Lake Belső where there was no considerable decrease even at a depth of 8—12 cm.

The high value of chllorophyll-c compared to those of chlorophyll-a and -b in both lakes well illustrate the important role of diatoms *(Table 2)*.

The vertical distribution in the mud of carotenoids is similar to that of chlorophyll-a *(Table 3)*. The differences in the pigment content of deeper layers between the two lakes are considerably higher.

TABLE II.

PS-chlorophyll-a, -b, and -c content on the mud surface in the open water of Lake Balaton and Lake Belső (μg/g wet weight)

	a	b	c
Lake Balaton:			
June 3, 1971	4.99	0.90	1.40
June 17, 1971	4.99	1.03	2.44
Lake Belső:			
April 2, 1970	6.64	1.28	4.44

TABLE III.

Amounts of PS-plant carotenoids at 0—2 cm (A), 2—5 cm (B) and 8—12 cm (C) depths of mud in the open water of Lake Balaton and Lake Belső (μg/g wet weight)

	A		B		C	
	sampling stations					
	No. 1	No. 2	No. 1	No. 2	No. 1	No. 2
Lake Balaton:						
April 10, 1970	5.2	5.0	3.6	3.8	2.0	1.8
June 3, 1971	7.7	9.7	4.6	5.3	2.19	2.36
June 17, 1971	7.4	8.0	4.2	4.8	2.24	2.29
Lake Belső:						
April 2, 1970	14.9	14.8	11.6	11.9	10.2	9.8

Amounts of carotenoids and chlorophyll-a *(Table 4)* are much higher near the shore than in the open water of the Balatonfüred—Zamárdi transversal section, which conforms to the spatial distribution of microphytobenthos (TAMÁS, 1971).

TABLE IV.

Amounts of PS-plant carotenoids and chlorophyll-a on the mud surface in the open water (sampling stations No. 1 and 2), at the southern shore (sampling station No. 3) and at the northern shore (sampling station No. 4).(μg/g wet weight)

Sampling places:	1	2	3	4
April 10, 1970				
carotenoids	5.2	5.0	7.9	8.5
chlorophyll-a	2.9	3.4	5.7	6.1

Condition of pigments

In the two lakes the condition of the pigments in the surface layer of the bottom deposit may be determined on the basis of their absorption spectra. The absorption spectra characterizing the examined mud samples clearly show that in Lake Belső, unlike in Lake Balaton, the pigments on the mud surface consist mainly of chlorophyll destruction products *(Fig. 1)*.

The relative amounts of phaeo-pigments on the mud surface are estimated on the basis of the ratio recommended by Moss (430 : 410 nm, 1967). With extracts originating from the mud surface of Lake Balaton the values for this ratio are generally more than 1 (1,04—1,12) and decrease to 0,78 following acidification. In the case of extracts from the mud surface of Lake Belső the

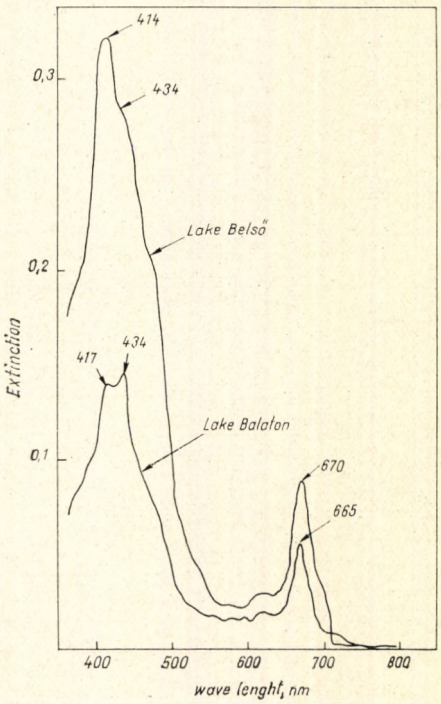

Fig. 1. Adsorption spectra of acetone extracts from the sediment of Lake Balaton and Lake Belső

value for the same ratio was 0,86 even before acidification. It is seen from the above that in Lake Belső most of the pigments on the mud surface are destructed, while in Lake Balaton there is a dominating majority of active pigments capable of photosynthesis in the upper layer of the sediment. Similar condition of pigments on the mud surface in the two lakes is indicated by the ratios of TIETJEN *(Table 5)*. The higher absorption values at 502, 532 and 414 nm in the case of Lake Belső are indicative of the presence of destructed pigments. ORR and GRADY (1957), GORHAM (1960) and TIETJEN (1970) have observed high absorption at these wavelengths in different conditions of destruction of pigments. As shown by the equations of LORENZEN (1967) the absolute amounts of phaeo-pigments and photosynthesizing chlorophyll-a are very different in the two lakes. On the mud surface in Lake Balaton the amount of chlorophyll-a was 4,2 μg/g, while that of phaeo-pigments only 3,2 μg/g, and at 2—5 cm depth of mud these values were 1,3 and 4,5 μg/g respectively. The amount of phaeo-pigments in the superficial layer of the mud in Lake Belső was 8,9 μg/g, whereas that of chlorophyll-a only 1,3 μg /g. At a depth of

TABLE V.

TIETJEN-*ratios at 0—2 cm (A) and 2—5 cm (B) depths of mud in Lake Balaton and Lake Belső*

		532/580	502/580	434/414	434/474
Lake Balaton:					
April 10, 1970	A	1.40	2.46	1.04	1.69
	B	1.50	2.85	1.04	1.45
Lake Belső:					
April 2, 1970	A	2.18	4.56	0.86	1.36
	B	2.11	4.29	0.87	1.31

2—5 cm of mud the amounts of pigments did not change considerably: phaeo-pigments = 7,7 μg/g, chlorophyll-a = 1,1 μg/g. As the chlorophyll-a and phaeo-pigment determinations show the pigments occur for the most part in destructed condition on the mud surface in Lake Belső, while in Lake Balaton the proportion of active chlorophyll-a on the mud surface was also considerable.

Discussion

ENTZ (1954) and TAMÁS (1966, 1967, 1968, 1971) were the first to call attention to the high quantity of diatoms on the mud surface in Lake Balaton. The pigment content analyses carried out by FELFÖLDY (1963) have shown that the total chlorophyll content of a 3,5 m deep water column below 1 m^2 of water surface in the lake is never higher than 50 mg when the lake is calm and its impurities settled. A value of 140 mg was obtained when the water was heavily agitated and stirred to the bottom. These data provide evidence for the important role of benthic diatoms in Lake Balaton. According to the data obtained the total chlorophyll content for 1 m^2 surface of mud was 85 mg. This value may even increase during periods of maximum growth of diatoms. The above show that besides macrophytes and phytoplankton also the microphytobenthos may play an important role in the primary production.

The oxidized sediment surface in Lake Balaton (OLÁH, 1971) and the high degree of oxygen saturation are due to the constant oxygen supply from the atmosphere and the oxygen production of the photosynthesizing "diatom carpet". At high redox potentials the complete decomposition of chlorophylls and carotenoids takes place at a higher rate (FOGG and BELCHER, 1961) and consequently the accumulation of destruction products in deeper layers of the sediment is not considerable. Because of that the amounts of phaeo-pigments, as estimated by using the equation of LORENZEN, on the mud surface in Lake Balaton may be related besides the rapid destruction of pigments also to the destruction products of the chlorophyll in the alimentary canals of zoobenthic organisms. Phaeo-pigment production under bad light conditions must also be considered with pure algal cultures and natural algal populations (YENTSCH, 1965).

In the superficial layer of mud in Lake Belső the amount of photosynthetically active chlorophyll is low because of lack of light. The high amounts of phaeopigments are suggested to originate from the phytoplankton. Owing

to low redox potential (OLÁH, 1971) light and oxygen deficiency, the process of the complete destruction of pigments slows down. This contributes to the high content of destruction products of chlorophyll in the deeper sediment layers.

Summary

1. In the examination period the chlorophyll-a content of the mud surface in Lake Balaton was 29—71 mg/m². The MOSS and TIETJEN ratios as well as the absorption spectra and the phaeo-pigment content computed by using the equation of LORENZEN showed that a large proportion of the pigments was in an active condition. These results suggest that the contribution of the microphytobenthos to the primary production of the lake is considerable.

2. The chlorophyll-a content of the superficial layer of the mud in the highly eutrophic Lake Belső was 66 mg/m², with a highest proportion of phaeopigments. In the upper 12 cm layer of mud the pigments were of homogeneous distribution. The phaeo-pigments are suggested to originate from the rich phytoplankton, and their destruction is retarded by the semi-anaerobic condition of the watersediment interface.

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ADATOK A BALATON ÉS BELSŐ-TÓ ÜLEDÉKÉNEK FOTOSZINTETIKUS PIGMENT TARTALMÁHOZ ÉS LEBOMLÁSÁHOZ

Oláh János

Összefoglalás

1. A vizsgált periódusban a Balaton iszapfelszínén a klorofill-a tartalom 29—71 mg/m² volt. A MOSS és TIETJEN arányok, az abszorpció spektrumok és a LORENZEN képlettel számított feo-pigment tartalom alapján a pigmentek nagy része aktív állapotban van. Ez arra utal, hogy a mikrofitobentosz elsődleges termelése jelentős a tóban.

2. Az erősen eutróf Belső-tó iszapfelszíne 66 mg/m² pigmentet tartalmazott, amelynek döntő többségét feo-pigmentek alkották. Az iszap felső 12 cm-e a pigmentek szempontjából homogén volt. A feo-pigment a gazdag fitoplanktonból származhat és lebomlását a víz-üledék határ szemi-anaerob állapota lassítja.