

Relationship between Chlorophyll *a* Content and Some Phytoplankton Characteristics in Fish Ponds and Adjacent Watercourses*¹

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Relationship between phytoplankton characteristics (biomass, taxonomic structure, and dimensional composition) and chlorophyll *a* content in fish ponds of the “Vileyka” fish farm and in adjacent watercourses, including the Smerdiya and Viliya rivers, is analyzed in the paper.

KEYWORDS: *phytoplankton, biomass, dimensional composition, chlorophyll.*

Introduction

The intensity of phytoplankton development is one of the main hydrobiological indices reflecting the state of aquatic ecosystems. Relationship was established between the intensity of phytoplankton development and the concentration of photosynthetic pigments in the water [1, 3, 10]. In recent years, the method of assessing the intensity of phytoplankton development in terms of chlorophyll *a* content is widely used [14].

Many publications are dealt with the study of relationship between phytoplankton biomass and chlorophyll *a* content in natural water bodies and watercourses [1, 3, 9, 10, 12, 19, 20]. However, in fish ponds this relationship is not clearly understood. Fish ponds receive organic and mineral fertilizers and fish food. As a consequence, their productivity and the degree of eutrophication increase [2, 7, 16].

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The main objective of the present work was to study relationship between phytoplankton biomass, its taxonomic structure, dimensional composition, and the content of chlorophyll *a* and seston in the water of fish ponds and adjacent rivers connected with them, and also to assess a possibility of the calculation of phytoplankton biomass in terms of chlorophyll *a*.

Material and Methods

Investigations were carried out in 2010–2011 in three fish ponds of the “Vileyka” fish farm (the Minsk region), and also in the Smerdiya and Viliya rivers. The area of the studied fish ponds is 0.1–0.3 km². The Smerdiya River 14 km long is the left bank tributary of the Viliya River. The Viliya River 498 km long is the right bank tributary of the Neman River. The fish ponds of the “Vileyka” fish farm form the cascade. In spring, they are supplied with the water from the Smerdiya River, and also from the Viliya River (under conditions of water deficiency). From the fish ponds, the water incomes into the Smerdiya River and then into the Viliya River.

In the Smerdiya River, the samples were taken at four stations: the first station was dislocated upstream of the fish farm, the second station – in the place of water release, the third station – 0.5 km downstream from the place of water release, and fourth station – 2.7 km downstream from the place of water release. In the Viliya River, the samples were collected in 2010 at two stations located in the place of water intake and downstream of the mouth of the Smerdiya River. In addition, in 2011 samples were taken upstream of the Viliya Reservoir (45 km upstream of the fish farm), and also upstream and downstream of the town of Smorgon (32 and 40 km downstream of the fish farm). The samples of water were taken monthly during the vegetation season (April – October) from the under-surface layer of water. In the fish ponds and in the Viliya River, the samples of water were taken using the Lyakhnovich – Shcherbakov tube.

The samples of phytoplankton of 0.5 L volume were fixed by the method of Utermel in the modification of T.M. Mikheyeva [4] and then concentrated by the method of sedimentation. The numbers of phytoplankton were calculated using the Fuchs – Rosenthal chamber. The biomass of algae was determined by the count cell-volume method [5, 13]. The content of suspended matter was determined gravimetrically. The average individual mass of algae cells was calculated as the ratio between the total biomass of phytoplankton and its numbers. The samples of water were filtered through the nucleus filters (with the openings of 1 μm in diameter) and then dried to the constant mass at 70°C. The same filters were used in determining the content of chlorophyll *a* (without correction to the presence of phaeopigments). Analysis was carried out by the method of spectrophotometry with the extraction of pigments in 90% acetone [8, 18]. The content of seston and chlorophyll *a* was determined in 3–6 replicas at each station.

The obtained data were statistically processed using the MS Excel and Statistica 8.0 Programs. The Spearman coefficient of rank correlation was also used. In this case, $p = 0.05$.

Results and Discussion

In the fish ponds of the fish farm, the intensity of phytoplankton development was essentially higher than that in the Smerdiya River (the main source of its water supply) (Table 1). In the Viliya River, its biomass was closely similar to that observed in the fish ponds. In the Smerdiya River,

Table 1

Phytoplankton structure and seston and chlorophyll *a* content in the studied water bodies and watercourses

Indices	Fish ponds (<i>n</i> = 12–25)	Smerdiya River (<i>n</i> = 16–30)	Viliya River (<i>n</i> = 21–33)
Biomass (<i>B</i>), mg/L	7.6/6.8/4.99	2.8/1.3/5.1	6.3/4.6/4.4
Chlorophyta, %	53.6/57.5/28.0	35.1/33.8/28.1	4.8/3.0/6.1
Cyanophyta, %	19.9/9.1/23.9	14.5/8.3/22.4	30.4/31.7/28.9
Bacillariophyta, %	14.5/6.3/19.3	25.6/20.1/24.4	53.0/59.1/32.0
Others, %	12.0/5.6/19.6	24.8/21.0/26.7	11.8/1.9/19.9
Numbers (<i>N</i>), million cells/L	35.5/22.0/40.9	6.0/3.3/6.9	3.9/3.6/2.4
Average individual mass of algae cells (<i>B/N</i>), 10 ⁻⁹ g	0.5/0.5/0.3	0.6/0.3/0.6	2.0/1.6/1.5
Seston, mg/L	16.8/15.9/6.9	9.9/5.4/11.6	10.1/8.9/4.5
Chlorophyll <i>a</i> , µg/L	80.6/70.6/53.3	17.0/5.8/22.5	21.2/18.4/11.1
Chlorophyll <i>a</i> in seston, %	0.4/0.4/0.2	0.2/0.1/0.1	0.2/0.2/0.1
Chlorophyll <i>a</i> in biomass, %	1.2/0.7/1.4	0.8/0.6/0.8	0.4/0.4/0.3

Note. The average/median/standard deviations are given for all stations per vegetation season.

phytoplankton biomass varied over a wide range, which is typical to small rivers. In this case, its average per season biomass was rather low.

All the three studied ecosystems essentially differed in the taxonomic structure of phytoplankton biomass. In the studied fish ponds, mainly Chlorophyta prevailed in terms of their biomass. On the average over the period of investigations, their contribution accounted for 54%. The contribution of Cyanophyta was 20%, whereas that of Bacillariophyta – about 15%. A high intensity of Chlorophyta development was observed during the whole vegetation season. The maximal intensity of Bacillariophyta development was registered in April – May, whereas the peak of Cyanophyta biomass was observed in summer. In the Smerdiya River, the distribution of algae biomass over their divisions was more uniform. In this case, Chlorophyta somewhat prevailed. Mainly Bacillariophyta (typical representatives of phytoplankton of river ecosystems) dominated in the Viliya River in spring and early summer. Cyanophyta predominated in late summer and autumn at a high concentration of nutrients and at a rather high temperature of water.

In the ponds, the numbers of phytoplankton were essentially higher than those in the rivers. In this case, in the ponds and in the Smerdiya River the individual mass of organisms proved to be several times lower than that in the Viliya River characterized by a predominance of large-sized forms.

At the studied stations, the content of seston ranged from 1 to 30 mg/L. Its minimal content was observed in August in the Smerdiya River in the place of water release, whereas the maximal content of seston was registered in the ponds in August – September. On the whole, in the rivers the content of seston was lower than that in the ponds (Table 1).

The concentration of chlorophyll *a* varied over a wide range: from 1 (the Smerdiya River, June) to 162 µg/L (the fish pond, September). On the whole, seasonal dynamics of chlorophyll *a* content correlated well those of seston. Both indices increased by September. In the ponds on the average per vegetation season, the content of chlorophyll proved to be essentially higher than that in the Smerdiya and Viliya rivers. In the studied fish ponds in seston and in phytoplankton biomass, the specific content of chlorophyll was somewhat higher than that in the rivers.

Literature data [3, 10] suggest that a relative content of chlorophyll in phytoplankton biomass varies over a wide range – from 0.02 to 9.70%. In some rivers of Belarus, this index accounts for 0.22–1.12% [6]. In this case, in the contaminated sections it is higher. Only some publications are dealt with the study of relationship between the content of chlorophyll and phytoplankton biomass in fish ponds [2, 16, 20]. Thus, in the fish ponds of the first group in the organic matter of algae the content of chlorophyll accounted for 1.1–1.7%, whereas in the fish ponds of the second group it was 0.8–0.9% [2]. In fish ponds of Belarus [7], the content of chlorophyll in phytoplankton biomass accounted for 0.09–0.46% (on the average 0.26%), which is essentially lower than that obtained as a result of original investigations.

It has been found that in the Smerdiya and Viliya rivers phytoplankton biomass correlates well with chlorophyll content (Table 2). In fish ponds, such correlation was not observed. On the whole, the concentration of chlorophyll in the water increased with increasing phytoplankton total biomass ($r = 0.70$). However, in fish ponds phytoplankton biomass in terms of chlorophyll content is rather difficult to assess.

In both studied rivers, the specific content of chlorophyll *a* correlated well with phytoplankton biomass. In the fish ponds, this correlation was not statistically valid (Table 2). In this case, the coefficient of correlation was negative. The specific content of chlorophyll decreased with increasing the total biomass of phytoplankton, which is supported by literature data [1, 2, 9, 10, 20]. On the whole, the coefficient of correlation was not high (-0.44). However, it was statistically valid ($p \leq 0.05$).

At present the reasons of the difference in the specific content of chlorophyll in phytoplankton are not clearly understood. For the most part it is accounted for by changes in the taxonomic structure of phytoplankton, that is by changes in the complex of dominant species differing in the specific content of chlorophyll [12, 19]. It is thought that in green algae the content of chlorophyll is 4–6 times higher than that in Cyanophyta and Bacillariophyta. A predominance of Chlorophyta in phytoplankton is responsible for a high relative content of chlorophyll in the total biomass of phytoplankton [1, 3]. However, a set of publications [9, 10, 15, 20] suggests that in studies of surface water bodies such relationship is not registered, or the content of chlorophyll decreases with increasing the contribution of Cyanophyta to 95%. In this case, chlorophyll content does not correlate with the contribution of green algae [16].

In the studied rivers, relationship between the contribution of Chlorophyta to the total biomass of phytoplankton and the specific content of chlorophyll was not established. In fish ponds, the co-

Table 2

Coefficients of correlation between phytoplankton biomass and seston and chlorophyll *a* content in the studied water bodies and watercourses

Indices	Fish ponds (<i>n</i> = 12)	Smerdiya River (<i>n</i> = 16)	Viliya River (<i>n</i> = 21)
Seston / biomass	0.07	0.45	0.52*
Chlorophyll <i>a</i> / biomass	0.27	0.81*	0.62*
Chlorophyll <i>a</i> in biomass/biomass	-0.31	-0.54*	-0.60*
Chlorophyll <i>a</i> / seston	0.83*	0.71*	0.85*
Chlorophyll <i>a</i> in biomass/seston	0.71*	0.20	0.19

*Statistically valid coefficients of correlation with $p \leq 0.05$.

Table 3

Coefficients of correlation between the average individual mass of algae cells and phytoplankton biomass and chlorophyll *a* content in biomass in studied water bodies and watercourses

Indices	Fish ponds (<i>n</i> = 12)	Smerdiya River (<i>n</i> = 16)	Viliya River (<i>n</i> = 21)
Average individual mass of algae cells/phytoplankton biomass	0.01	0.79*	0.68*
Average individual mass of algae cells/chlorophyll <i>a</i> content in biomass	-0.61*	-0.81*	-0.22

*Statistically valid coefficients of correlation with $p \leq 0.05$.

efficient of correlation between these indices was rather high and statistically valid. However, it was negative ($r = -0.60$). Thus, the specific content of chlorophyll decreased with increasing phytoplankton biomass. In fish ponds during the whole period of investigations, Chlorophyta prevailed in terms of their biomass (on the average 54%). Thus, a relative content of chlorophyll depended inversely on phytoplankton biomass. On the whole, in the studied ecosystems relationship between the taxonomic structure of phytoplankton and the specific content of chlorophyll in algae biomass was not established. It should be noted that in fish ponds the contribution of Chlorophyta increased with decreasing the contribution of Cyanophyta ($r = -0.45$), whereas in the Smerdiya and Viliya rivers the increase in the contribution of Cyanophyta was accompanied by the decrease in the contribution of Bacillariophyta ($r = -0.37$ and -0.77 , respectively).

In addition it is thought that the specific content of chlorophyll in phytoplankton depends on the difference in the individual dimensions of its representatives. The increase in their dimensions rather often is accompanied by the decrease in a relative content of chlorophyll [2, 11, 12, 17].

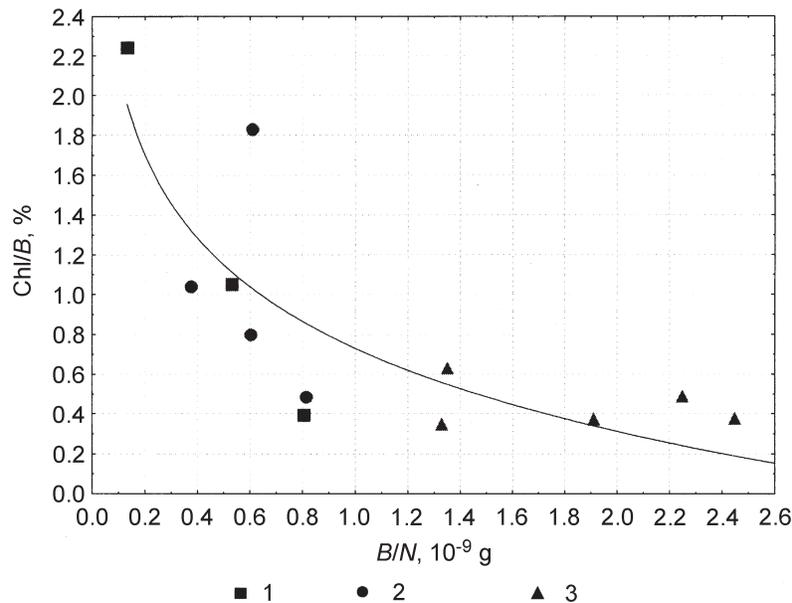


Fig. 1. Relationship between the specific content of chlorophyll *a* in phytoplankton biomass (Chl/B , %) and the average individual mass of algae cells (B/N , 10^{-9} g): 1 – fish ponds; 2 – the Smerdiya River; 3 – the Viliya River (on the average over the studied stations).

In the studied fish ponds and in the Smerdiya River, the average individual mass of algae cells depended inversely on a relative content of chlorophyll (Table 3). It should be noted that this correlation was rather close and statistically valid. In the Viliya River, such relationship was also observed. However, the coefficient of correlation was not statistically valid. On the whole, a relative content of chlorophyll decreased with increasing the average individual mass of algae cells. This relationship is approximated well by regression curve (Fig. 1). In this case, the coefficient of correlation is 0.76 with $p = 0.0045$.

Conclusion

The obtained data suggest that in the studied watercourses and fish ponds the specific content of chlorophyll decreased with increasing phytoplankton biomass. In the ponds in terms of chlorophyll content, phytoplankton biomass should be assessed with caution. To characterize the intensity of phytoplankton development, both these indices should be used. The specific content of chlorophyll in phytoplankton decreased with increasing the average individual mass of organisms. In this case, relationship between changes in the taxonomic structure of phytoplankton and the specific content of chlorophyll in biomass was not established.

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