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Glony denne w stawie po akumulacji ścieków cukrowniczych*

Benthic algae in a pond after the accumulation of beet-sugar factory wastes

Wpłynęło 10 kwietnia 1976 r.

Abstract — The composition of algae occurring in the mud of a pond used for several years for the accumulation of beet-sugar factory wastes was identified and listed. This is an attached algae community accompanied by typical pond plankton algae originating from sedimentation, a prevalence of diatoms, of benthic or epiphytic species, being characteristic. Green and blue-green algae occurred in smaller amounts.

Algal communities living in the surface layer of the bottom mud of a pond have not so far been the subject of any more detailed investigations, nor are there many papers touching on this subject (among others Lund 1942, cit. Wentzel 1964, Siemińska 1947, Moss, Round 1967, Moss 1969). Interest was taken rather in those algae communities in rivers, lakes, and at seashores. They were also determined in different ways. Davidova (1966) and Tamás (1967, 1968, 1971) called these communities microphytobenthos whereas Stańczykowska et al. (1968) called them phytomicrobenthos or simply microbenthos. On the other hand, Eaton, Moss (1966) and Moss (1968) similarly as Lund (1942), cit. Wentzel (1964) used the term benthic of epipelic algae.

The majority of research workers measured the benthic algae biomass, expressing it in terms of chlorophyll *a* content when giving the total

* Praca wykonana w problemie węzłowym 09. 1. 7.

species composition of the communities, stress being laid, however, on the chemical aspect of the problem. The aim of the present work was to investigate the composition of the algae inhabiting the bottom of a pond, a correlation with chlorophyll *a* values being a certain complement.

Information on the pond

In the years 1967—1972 the pond Zimowy Wielki (Great Winter Pond) was filled with beet-sugar wastes from the nearby factory at Chybie. The investigation was carried out in 1974, thus when no wastes had been discharged from the sugar factory for more than a year. The pond was stocked on 5th April 1974 with 32 000 carp fry with a total weight of 320 kg. The fish were not fed nor was the pond fertilized. On 15th October of the same year 7000 specimens of second year carp fry with a total weight of 1400 kg were caught.

Method

Bottom sediment samples were taken by means of a tube sampler in 3 places in the pond differing as to depth and aquatic vegetation; at the inflow (A), in the middle (B), and at the outflow (C) subsequently the upper layer, about 5 mm thick, was taken off with a spoon from the mud core (after pouring off the excess water). This procedure was usually repeated three times to obtain a sufficient amount of investigation material. After being transported to the laboratory the samples were examined in vivo under the microscope and two samples of similar amounts of sediment were weighed, the first being taken for algae counts, after preservation in formalin solution, and the other used for measurements of dry weight and for chlorophyll *a* extraction. The chlorophyll was determined spectrophotometrically in acetone extract (performed by Dr. M. Bombówna). The adopted investigation method was that often used for examination of the bottom sediment core in determining the fossil algae composition (Eaton, Moss 1966). After careful mixing a drop was taken for microscopic investigation. Algae were counted in three bands of the sample. The amounts of algae were given in recalculation per 1 g dry weight. This concerned blue-green algae and green algae and those diatoms which could be identified without additional preparation usually as to genus only. Since the diatoms constitut-

Tabela I. Skład jakościowy glonów występujących na dnie w stawie Zimowy Wielki w 1974 r.
Stanowiska poboru prób: A - przy dopływie; B- na środku stawu; C - przy odpływie

Table I. Quantitative composition of bottom algae in the pond Zimowy Wielki in 1974
Sampling stations: A - at the inflow; B - at the middle part; C - at the outflow

Taksony / Taxons \ Data / Date	8.IV.			8.V.			3.VI.			2.VII.			1.VIII.			27.VIII.			27.IX.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Beggiatoa alba (Vauch.) Trev.		+		+																	
Beggiatoa sp.					+				+	+		+	+	+	+			+			
Bacteriophyta (nitkowate + filamentous) n. det.															+						
Planktomyces Bekefii Gimesi	+																				
Anabaena sp.				+	+	+						+		+							
Aphanizomenon flos aquae (L.) Ralfs																	+				
Aphanotèce sp.			+																		
Gloeocapsa turgida (Kütz.) Hollerbach				+									+								
Gloeocapsa sp.														+	+						
Gomphosphaeria sp.	+	+		+	+		+	+	+	+	+	+	+	+	+		+				
Lyngbya cryptovaginata Schkorbatoff				+																	
Lyngbya sp.						+								+							
Merismopedia elegans A. Braun				+								+									
- tenuissima Lemm.														+	+			+	+		+
Merismopedia sp.	+	+	+		+	+	+	+	+	+		+		+	+						+
Oscillatoria limosa Agardh				+		+															
- limnetica Lemm.												+									
- subbrevis Schmidle emend. Claus											+										
- tenuis Agardh												+			+						
- terebriformis Agardh													+		+			+			
Oscillatoria sp.	+	+	+			+		+	+		+										+
Phormidium sp.	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+
Pseudoanabaena constricta Schmidle															+						
Hormogonales n. det.											+					+					
Euglena spirogyra Ehrb.				+																	
- tripteris (Duj.) Klebs	+		+						+												
Euglena sp.		+	+							+		+			+		+				
Petalomonas sp.												+	+								
Petalomonas mediocanellata var.minor Shawh. et Jahn.															+						
Peranema sp.					+																
Phacus longicauda (E.) Duj.			+		+																
- pleuronectes (O.F.M.) Duj.			+										+								
- pyrum (E.) Stein			+	+								+									
- triqueter (E.) Duj.	+	+	+	+					+		+			+							
- Wettsteini Dreż.												+									
Phacus sp.										+											
Trachelomonas hispida (Perty) Stein										+											
- lacustris Dreż.	+	+																			
- planctonica Swir. var. oblonga Dreż.			+																		
- volvocina Ehr.	+	+		+	+		+							+	+	+	+				
Dichotomococcus curvatus Korschik.	+	+																			
Dinobryon divergens Imhof				+																	
Flagellata apochromatica					+		+	+		+		+									
Achnanthes conspicua Mayer					+			+	+		+	+	+		+	+	+	+	+	+	+
- exigua Grun.		+		+			+														
- hungarica Grun.	+		+										+	+			+			+	
- Hustedtii Bily et Marvan		+																			
- linearis (W.Sm.) Grun.		+				+													+	+	
- microcephala (Kütz.) Grun.																			+		
- minutissima Kütz.	+		+														+				
Achnanthes sp. div.	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
Amphora ovalis Kütz.	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+
Asterionella formosa Hass.		+																			
Bacillaria paradoxa Gmelin																				+	
Caloneis bacillum (Grun.) Mer.							+						+				+				+
- Schröderi Hust.														+			+			+	+
- silicula (Ehr.) Cl.	+	+		+	+	+							+	+	+	+	+			+	+
- - var. alpina Cl.																				+	
- - var. truncatula Grun.	+	+	+	+	+		+	+	+	+			+		+	+	+			+	+
Caloneis sp.		+																			
Ceratoneis arcus (Ehr.) Kütz.		+	+	+			+							+		+	+	+		+	+
- - var. amphioxys (Rabh.) Grun.										+						+			+		
Cocconeis placentula Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
- - var. euglypta (Ehr.) Cl.																				+	+
- pediculus Ehr.																				+	
Cyclotella Meneghiniana Kütz.	+	+	+	+	+		+	+	+	+	+		+	+	+	+	+	+		+	+
Cyclotella sp.		+	+	+		+			+	+	+	+						+			+

cont. Tab. I.

Taksony / Taxons — Data / Date	8.IV.			8.V.			3.VI.			2.VII.			1.VIII.			27.VIII.			27.IX.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Cymatopleura solea (Bréb.) W. Sm.	+	+	+	+	+	+			+	+	+	+	+	+	+	+		+		+	+
- - var. gracilis Grun.									+												
- solea var. regula (Ehr.) Grun.														+							
Cymbella affinis Kütz.		+																			+
- cistula (Hemp.) Grun.		+											+								
- cymbiformis (Ag. Kütz.) V. H.											+										
- gracilis (Rabh.) Cl.																			+		
- helvetica Kütz.																			+		
- lanceolata (Ehr.) V. H.		+																			
- naviculiformis Auersw.	+									+					+	+				+	
- prostrata (Berkeley) Cl.		+			+				+									+		+	
- turgida (Ehr.) Kütz.	+				+		+		+	+	+			+	+	+				+	
- ventricosa Kütz.	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+		+	+	+
Cymbella sp. div.	+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+		
Denticula sp.							+														+
Diatoma elongatum(Lyngb.) Ag.		+																			
- hiemale (Lyngb.) Heib.																					+
- vulgare Bory	+	+										+		+			+				+
Epithemia zebra (Ehr.) Kütz.														+	+						
Epithemia sp.					+		+													+	
Eunotia arcus Ehr.	+			+			+	+		+	+	+	+	+	+	+		+	+	+	+
- - var. bidens Hust.							+		+												
- diodon Ehr.	+			+		+													+		
- exigua (Bréb.) Rabh.																			+		
- lunaris (Ehr.) Grun.	+	+	+	+	+		+	+		+	+	+	+	+	+	+	+		+	+	
- - var. subarcuata Näg.) Grun.															+						
- monodon Ehr. var. bidens (Greg.) W. Sm.															+						
- praerupta Ehr.	+									+		+					+				
- - var. inflata Grun.	+																				
- sudetica O.F. Müll.															+						
- pectinalis (Dillw.? Kütz.) Rabh.														+							
Eunotia sp.		+		+	+		+		+	+						+	+				+
Fragilaria capucina Desm.				+			+			+	+		+	+	+		+		+	+	+
- construens (Ehr.) Grun.	+	+	+	+		+						+								+	
- intermedia Grun.		+																			
- leptostauron (Ehr.) Hust.	+																				
- pinnata Ehr.													+		+						
- virescens Ralfs					+						+										
Fragilaria sp.	+	+		+	+			+	+												
Frustulia sp.										+		+	+	+							
Gomphonema acuminatum Ehr.	+	+	+	+	+		+	+		+	+			+	+	+	+				
- - var. coronatum (Ehr.) W.Sm.	+	+		+	+		+	+		+			+	+	+	+	+	+		+	
- - var. trigonocephalum (Ehr.) W.Sm.		+			+			+		+				+	+					+	+
- angustatum (Kütz.) Rabh.	+	+	+	+	+		+			+	+		+	+		+		+	+	+	+
- - var. producturn Grun.	+	+	+	+		+	+	+	+	+	+	+				+	+		+	+	
- - var. sarcophagus (Greg.) Grun.																			+		
- augur Ehr.					+																
- constrictum Ehr.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	
- gracile Ehr.	+	+			+		+	+	+	+	+		+	+	+			+	+	+	+
- - var. lanceolatum (Kütz.) Cl.																				+	+
- intricatum Kütz. var. pumilum Grun.																		+			
- lanceolatum Ehr.							+							+							
- - var. insigne (Greg.)				+																	
- longiceps Ehr.															+						
- olivaceum (Lyngb.) Kütz.	+	+		+	+		+	+		+	+		+	+	+	+	+	+	+	+	+
- - var. calcareum Cl.		+			+											+	+		+	+	+
- parvulum (Kütz.) Grun.		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
- - var. micropus (Kütz.) Cl.	+	+	+	+	+	+	+	+	+	+	+			+	+	+	+		+	+	+
- - var. subclavatum Cl.																				+	
- subtile Ehr.					+																
Gomphonema sp.	+	+			+					+	+	+		+		+	+	+		+	+
Gyrosigma acuminatum (Kütz.) Rabh.												+		+	+						+
Hantzschia amphioxys (Ehr.) Grun.																	+			+	+
Melosira granulata (Ehr.) Ralfs		+	+		+			+	+		+	+	+								
- - var. angustissima (O. Müll.) Hust.														+					+		+
- varians Ag.				+																	
Navicula cincta (Ehr.) Kütz.	+	+	+	+	+	+	+		+	+	+		+	+	+	+	+	+	+	+	+
- - var. Heufleri Grun.																				+	
- coccone iformis Greg.																+	+				
- cryptocephala Kütz.	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+		+	+	+	+
- - var. veneta (Kütz.) Grun.								+					+							+	
- cuspidata (Kütz.)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
- - var. ambigua (Ehr.) Cl.	+	+	+							+	+									+	+
- - var. Heribaudii Perag.	+	+	+	+				+		+									+		+
Navicula dicephala (Ehr.) W.Sm.		+	+											+	+						
- exigua (Greg.) O. Müll.														+							

cont. tab. I.

Taksony / Taxons — Data / Date	8.IV.			8.V.			3.VI.			2.VII.			1.VIII.			27.VIII.			27.IX.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Navicula hungarica Grun. var. capitata (Ehr.) Cl.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
- menisculus Schum.	+	+		+			+	+	+		+	+				+			+		+
- placentula (Ehr.) Grun.				+																	
- - var. jenisseyensis (Grun.) Meist.																			+		
- pupula Kütz.	+																				
- radiosa Kütz.	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+		+	+	+
- rhynchocephala Kütz.	+	+		+	+	+	+	+	+	+	+	+	+		+		+	+	+	+	+
- scoliopleuroides Quint										+											
- viridula Kütz.		+		+	+		+	+		+	+		+	+					+	+	
- vitrea (Østr.) Hust.																				+	
Navicula sp. div.	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	
Neidium affine (Ehr.) Cl.														+		+		+	+		+
- affine var. longiceps (Greg.) Cl.							+														
- - var. amphirhynchus (Ehr.) Cl.		+	+	+	+															+	
- bisulcatum (Lagerst.) Cl.										+											
- - f. undulatum O. Müll.	+																				
- dubium (Ehr.) Cl.																				+	
- kozłowii Mer. var. parvum Mer.																+					
- productum (W. Sm.) Cl.														+							
Neidium sp.										+	+	+									
Nitzschia acicularis W. Sm.	+	+	+	+	+	+						+									
- acuta Hantzsch							+											+			+
- amphibia Grun.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
- angustata (W. Sm.) Grun.					+						+										
- capitellata Hust.				+	+								+						+		
- dissipata (Kütz.) Grun.					+		+		+					+					+		+
- gracilis Hantzsch														+						+	
- Heufleriana Grun.					+																
- linearis W. Sm.		+																	+		+
- z sekcji - from section linearis											+	+					+				
- palea (Kütz.) W. Sm.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
- paleacea Grun.	+	+		+	+		+	+	+	+	+	+				+			+	+	
- recta Hantzsch	+	+	+		+	+	+		+	+	+	+	+	+	+		+	+		+	+
- sigmoidea (Ehr.)	+	+	+	+	+	+			+			+						+			+
- stagnorum Rabh.		+					+	+		+	+	+							+	+	+
- sublinearis Hust.																			+		
- vermicularis (Kütz.) Grun.														+							
Nitzschia sp. div.	+	+	+	+	+	+	+		+		+	+	+		+			+	+	+	+
Pinnularia gibba Ehr.		+		+	+									+					+		
- - var. linearis Hust.		+			+		+	+	+					+	+	+				+	
- - var. mesogongyla (Ehr.) Hust.		+								+											
- - var. parva (Ehr.) Grun.																				+	
- - f. subundulata Mayer		+														+					
- interrupta W. Sm.					+			+							+				+		
- maior (Kütz.) Cl.					+																
- mesolepta (Ehr.) W. Sm.	+		+	+			+	+							+	+	+		+	+	
- microstauron (Ehr.) Cl.	+			+	+		+							+	+	+			+	+	
- - f. biundulata O. Müll.		+																			
- - var. diminuta Grun.							+					+									
- subcapitata Greg.				+	+		+		+				+	+	+	+	+	+		+	
- viridis (Nitzsch) Ehr.	+	+	+		+			+		+		+	+	+	+	+		+	+	+	+
- - var. rupestris (Hantzsch) Cl.														+							
- - var. sudetica (Hilse) Hust.					+									+	+				+	+	+
Pinnularia sp.		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
Rhoicosphaenia curvata (Kütz.) Grun.					+																
Rhopalodia gibba (Ehr.) O. Müll.					+								+							+	
- parallela (Grun.) O. Müll.				+																	
Stauroneis phoenicentron Ehr.	+	+			+	+	+									+					
Surirella angustata Kütz.	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+		
- linearis W. Sm.		+											+	+	+						
- ovata Kütz.	+	+	+		+						+		+	+	+	+	+	+	+	+	+
- - var. pseudopinnata Mayer				+	+						+		+	+			+			+	
- robusta Ehr.												+									
- spiralis Kütz.																	+				
Surirella sp.		+							+												+
Synedra acus Kütz.			+	+	+			+	+	+				+	+	+					
- rumpens Kütz.							+														+
- ulna (Nitzsch) Ehr.	+	+	+	+	+	+	+	+		+	+		+		+	+	+		+	+	
- - var. danica (Kütz.) Grun.																			+		
Synedra sp.											+										
Tabellaria fenestrata (Lyngb.) Kütz.		+					+									+					
- flocculosa (Roth) Kütz.		+				+							+	+	+	+		+			
- - var. flocculosa (Roth) Knud.	+	+	+	+	+		+	+	+	+	+	+			+		+		+	+	+
Tabellaria sp.				+															+	+	
Bacillariophyceae n. det.	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+		+

Taksony / Taxons — Data / Date	8.IV.			8.V.			3.VI.			2.VII.			1.VIII.			27.VIII.			27.IX.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Chlamydomonas sp.	+	+	+	+										+	+				+		
Eudorina elegans Ehr.						+															
Pandorina morum (Müll.) Bory				+		+															
Phacotus lenticularis Ehr.		+					+	+	+	+		+	+	+	+		+	+		+	+
Actinastrum Hantzschii Lagerh.					+																
Ankistrodesmus acicularis (A. Br.) Korschik.								+													
- falcatus (Corda) Ralfs				+	+				+		+	+		+	+						
- pseudomirabilis Korschik.	+	+	+		+				+												
Ankistrodesmus sp.		+		+					+	+	+										
Coelastrum microporum Naeg.							+			+				+							
Coelastrum sp.				+	+																
Cracigenia apiculata Schmidle	+	+		+	+							+									
- quadrata Merren		+																			
- tetrapedia (Kirchn.) W. et W.		+	+																	+	
Dictyosphaerium pulchellum Wood	+	+		+	+	+		+				+									
Kirchneriella sp.	+													+	+						
Lagerheimia genevensis Chod.	+	+																			
Oocystis sp.			+				+		+					+							
Pediastrum Boryanum (Turp.) Menegh.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+
- biradiatum Meyen															+						
- duplex Meyen	+	+	+		+	+				+	+			+					+		
- - var. genuinum A. Braun f. gracilis Pascher				+	+														+		
- integrum Naeg.	+																				
- tetras (Ehr.) Ralfs		+			+					+	+										
- - var. tetraodon (Corda) Rbh.	+			+						+	+										
Raphidonema sp.				+																	
Scenedesmus acuminatus (Lagerh.) Chod.	+	+	+	+	+							+									
- - var. biseriatus Reinsch.		+		+		+															
- acutus (Meyen) Chod.	+			+	+	+	+		+	+	+	+		+	+	+	+	+	+	+	
- arcuatus Lemm.		+																			
- armatus (Chod.) G.M. Smith	+	+		+	+		+	+	+		+		+	+	+	+				+	
- bicaudatus (Hansg.)	+	+			+	+		+			+	+	+	+	+		+	+		+	+
- denticulatus Lagerh.	+			+	+		+	+			+		+								
- ecornis (Ralfs.) Chod.				+		+	+	+			+		+		+						
- intermedius Chod.	+												+	+	+	+	+				
- - var. bicaudatus Hortob.															+			+			
- opoliensis P. Richt.				+					+												
- quadricauda Chod.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+
- - var. longispina (Chod.) G.M. Smith	+		+																		
- spinosus Chod.	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Scenedesmus sp.	+		+							+			+	+	+						+
Tetraedron caudatum (Corda) Hansg.				+				+			+	+									
- incus (Teil.) G.M. Smith							+								+						
- limneticum Borge					+																
- minimum (A. Br.) Hansg.		+	+	+	+		+		+	+	+	+			+		+	+		+	
Tetraedron sp.							+														
Tetrastrum glabrum (Roll) Ahlstr. et Tiff.								+													
Troschitzia sp.						+			+					+				+			
Chlorophyta n. det.																					+
Closterium parvulum Naeg.					+	+															
- strigosum Bréb.												+									
Closterium sp.	+											+		+							
Cosmarium bioculatum Bréb. Ralfs var.depressa Char.											+										
- botrytis Menegh.				+	+	+	+					+	+	+	+		+				
- depressum (Naeg.) Lund											+										
- Garrolense Roy et Bisset							+														
- granatum Bréb.	+			+	+	+		+		+	+	+	+	+	+		+	+	+		
- impressulum Elfw.					+																
- margaritaferum Menegh.						+				+	+										
- Meneghini Bréb.							+	+	+	+	+	+	+	+			+	+		+	
- reniforme (Ralfs) Aresch.					+									+							
- suborenatum Hantzsch						+															
- trilobatum Reinsch				+				+													
- undulatum Corda et Ralfs				+			+	+	+	+	+	+	+	+		+	+		+		
Cosmarium sp.	+	+	+				+			+	+	+	+	+	+	+	+	+		+	+
Euastrum sp.										+	+	+									
Staurastrum sp.			+	+		+					+			+	+		+	+	+		
Spirogyra sp.					+													+			

ed the majority of algae, this group was identified on the basis of fixed preparations of specimens digested in chromic acid and fixed in pleurax according to the method given by Siemińska (1964). The algae identified in this way were not presented quantitatively.

Altogether 21 samples were collected at 4 week intervals beginning from 8th April to 27th September 1974. Investigations on *Ciliata* (Grabacka 1977), benthic fauna (Zięba 1977), and phytoplankton (Krzeczkowska-Wołoszyn 1977), and also bacteriological (Starzecka, Ronchetti 1977), biochemical (Zygmuntowa 1977), physico-chemical, and zooplankton studies (M. Lewkowicz, S. Lewkowicz 1977) were carried out simultaneously.

Phytomicrobenthos composition

The specimens encountered in the bottom sediments belonged to several systematic groups.

In the group of bacteria (*Bacteriophyta*) the genus *Beggiatoa*, with one species *B. alba*, occurring in small amounts till 27th August at all sampling places was distinguished.

Of the group of blue-green algae (*Cyanophyta*) 20 taxons (Table I) were identified. These algae occurred constantly, their participation being from 1 to 27 per cent. The greatest numbers, over 5 milion specimens/g dry weight (6 per cent of all the algae), were recorded at the station at the inflow where the genus *Phormidium* constituted 80 per cent of the occurring blue-green algae. The highest percentage was recorded on 1st August at the station at the outflow when the number reached 616 772 specimens/g dry weight and in the group of blue-green algae the participation of *Gomphosphaeria* was 39 per cent. Species of the genus *Gloeocapsa*, *Lyngbya*, *Merismopedia*, *Oscillatoria*, and *Pseudonabaena* were also found in the mud.

Euglenophyta occurred in the benthic communities sporadically and in small numbers forming 1 to 2 per cent of their total, 16 taxons were distinguished belonging to the genera *Euglena*, *Phacus*, *Trachelomonas*, and of the colourless *Flagellata* to the genera *Peranema* and *Petalomonas*.

Chrysophyta, apart from a few *Chrysophyceae*, which did not play any important part among the benthic algae, were represented mainly by the class of diatoms (*Bacillariophyceae*), which constituted 53 to 89 per cent of the phytomicrobenthos (fig. 1). The numbers calculated per 1 g dry weight varied, depending on the date or place of sampling, from 1 134 860 specimens (2nd July) to 63 817 460 specimens (8th April — inflow). 174 taxons were distinguished.

The genus *Achnanthes* (*A. minutissima, A. hungarica, A. conspicua, A. exigua,* and others) occurred the most frequently and most numerously. The numbers of specimens calculated per 1 g dry weight varied from 122 680 (2nd July — outflow) to 25 460 910 (8th April — inflow). Usually larger amounts were found to occur at the inflow or sometimes in the middle of the pond than at the outflow. Their percentage in relation to the total amount of diatoms was from 5 to 46. Although the genus occurred constantly an increase in numbers, was maintained with some variations, from April till the beiginning of July.

The genus *Nitzschia*, including littoral and benthic species, was an important and constant component of benthic algae communities. 16 taxonomic units were distinguished. The number of specimens ranged from 71 560 to 9 391 320 specimens/g dry weight. An increase in number occurred in spring when at the station at the inflow they were 90 times more numerous than at the same station in August. During the investigation period the percentage share varied from 1 to 16. The station at the inflow and the one in the middle of the pond were characterized by a denser settlement than that at the outflow. Among the commonly occurring species were: *N. palea, N. amphibia, N. recta, N. sigmoidea.*

The genus *Gomphonema* was a constant and important component of diatom communities. It contains species frequently encountered at the bottom and on the epiphytes of any type of water body (Siemińska 1964). From the 20 taxons distinguished the following occurred frequently: *G. acuminatum* together with varieties, *G. angustatum* with the variety *productum, G. constrictum, G. gracile,* the prevalent *G. olivaceum,* and *G. parvulum* with the variety *micropus.* In the distribution of this diatom differences consisting in a more frequent occurrence at the inflow and in the middle of the pond were noticed. Numbers ranged from 53 170 to 6 886 970 specimens/g dry weight (Table II), the greatest numbers being recorded in April and at the beginning of June. Participation of the genus *Gomphonema* in the total amount of *Bacillariophyceae* was from 6 to 26 per cent.

The genus *Navicula* contains many species common at the bottom and on the epiphytes of ponds. In the investigated material it was frequent and numerous at all stations, though, in the middle of the pond and at the station at the inflow it was usually most numerous, ranging from 118 270 to 5 408 890 specimens/g dry weight, its percentage participation in the diatoms being from 3 to 34 per cent. The most frequently and most numerously occurring were: *N. cryptocephala, N. rhynchocephala, N. hungarica* var. *capitata, N. cincta, N. cuspidata* with its varieties (craticular forms sometimes being encountered), *N. radiosa,* and *N. viridula.* Within the genus 14 species and 6 varieties were distinguished.

Amphora ovalis occurred constantly, its numbers ranging from 123 950 to 3 339 130 specimens/g dry weight; it appeared most numerously in

Tabela II. Liczniejsze glony występujące na dnie stawu Zimowy Wielki w 1974 r.
Ilości przeliczone na 1 g s. m.; + - obecność w próbie; A - stanowisko poboru:
A - przy dopływie; B - na środku stawu; C - przy odpływie

Table II. More numerous algae occurring on the bottom of the pond Zimowy Wielki in 1974
Number calculated per 1 g of dry weight; + - presence in sample;
sampling stations: A - at the inflow; B - at the middle part; C - at the outflow

Taksen / Taxon — Data / Date	8.IV.			8.V.			3.VI.			2.VII.			1.VIII.			27.VIII.			27.IX.		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Phormidium sp.	4173920	1853040	+	715370	512840	77260	124270	318170	17480			40890	303790	170910	63800	51900	259330	52620	493910	56320	92960
Achnanthes sp. div.	25460910	2117760	542240	5212040	2948830	180270	2671970	8431500	+	3863680	3334400	122680	911370	1538240	180770	2179880	1425830	197320	3556180	506880	309890
Amphora ovalis	3339130	2246380	421740	1226360	1666730	154520	373830	3340780	108600	807330	816580	143130	464620	740030	159510	363310	217760	131550	1185390	884800	123950
Cocconeis sp.	1252170	1453540	421740	510980	1794940	51750	932080	2545360	14480	1211000	952680	40890	625450	826090	21260	1297550	514720	+	1580520	723160	216920
Cyclotella Meneghiniana	2086960	2246380	1445970	306590	641050	128770	+	2227190	28960	57660	340240	20440	71480	56970	21260	36330	+	52620	+	394240	340870
Cymatopleura solea	208690	132140	+	+	+	25750			7240	+	68040	10220	+	28480	53170	+		78930		+	30980
Cymbella sp. div.	1043480	2246380	301240	510980	1025680	128770	683520	3181700	28960	576670	408294	30670	160830	85450	31900	259510	39590	39460	197560	+	+
Gomphonema parvulum	5634790	3435640	421740	408780	641050	180270	1180640	5408890	72400	980330	1292930	71560	339530	569720	42530	519020	158370	131550	+	112640	30980
Gomphonema sp. div.	1252180	1585680	120500	715380	384630	25760	372830	1272680		1441680	680490	30680	71480	333340	10640	882330	98990	13150	987830	1239040	189940
Navicula sp. div.	5008700	1583680	602490	715370	1282100	180270	186410	5408890	181000	576670	816580	388510	339530	512750	414720	467110	277140	223630	1778090	394240	526813
Nitzschia palea	4173920	1321400	301240	715380	1025680	77260	+	472250	7240	403670	272190	+	+	199400	31900	103800	79180	+	98789	112640	154940
Nitzschia sp. div.	5217400	2114240	783240	2350530	897470	154520	372830	+	57920	+	136100	71560	89350	+	138240	+	19800	78930	98780	+	123960
Pinnularia sp. div.	417660	264720	120490	408780	384630	77260	284550	1431760	72400	57660	68050	30670	71480	56970	42530	155700	+	13150	+	168960	90960
Surirella sp. div.	1043480	+	120490	102190	128210	103010	+	+	21720	+	68050	20440	35870	+	31900	+	19790	52620	+	+	30980
Synedra sp. div.	834780	132140	120490	204390	256420	25750	+	477250	7240	+			17870	24480	21260	103800	+		197560	+	
Phacotus lenticularis		794160					62130	159080	7240	115330		40890	125090	28480	31902		217760	13150		56320	30970
Ankistrodesmus sp. div.	2086960	132140	180740	+	128210			159080	7240	+	272190	+		56970	10630						
Scenedesmus quadricauda	2086960	264140	240990	1430750	897470	154520	497112	954510	28960	230660	1020730	10224	+	85450	53170		118780	26310	493915		30980
Pediastrum sp. div.	1878260	528560	+	102190	256420	+	62130	159080	+	173000	272190	20440	17870	56970		155700	19790	13150	197560		30980
Cosmarium sp. div.	208960	264720	+	102197	+	51500	592250	795420	21720	461330	476340	92010	232310	569720	63800	155700	296950	92080	395132	394240	61970

April and June. In the composition of diatoms it constituted 5 to 15 per cent. In the middle of the pond and at the outflow the participation of this diatom in the diatom communities was higher than at the inflow.

The genus *Cocconeis* includes epiphytic species living on aquatic plants. At the investigated station the common *C. placentula* with the variety *euglypta* occurred constantly. The number of cells was from 21 260 (1st August — outflow) to 2 545 360 (3rd June — middle). They were more numerous at stations where the vegetation was abundant (inflow and the middle of the pond) from which they could reach the bottom as the effect of sedimentation. The participation of this genus in the communities was from 1.7 to 18 per cent.

A very common diatom occurring in the mud of the investigated pond was the genus *Cymbella*, characteristic of epiphytic and benthic associations. 10 taxons (Table I) were distinguished in the ponds, the most frequent of them being *C. ventricosa* and *C. turgida*. Their numbers ranged from 28 960 to 246 380 specimens/g dry weight and they were usually more abundant in the middle of the pond and at the inflow. Percentage participation of *Cymbella* in diatom communities was 1.3 to 9.9 per cent.

The littoral species *Cyclotella Meneghiniana* was almost always present in samples in amounts similar to *Cymbella* sp., it being relatively more abundant in spring and in the middle of the pond. Its percentage participation in *Bacillariophyceae* communities ranged from a fraction to 22 per cent.

The genus *Pinnularia* — also littoral — was represented in the investigated material by 15 taxons. The numbers calculated for 1 g dry weight were from 13 150 to 1 131 760 specimens. It was much more numerous in the middle of the pond and at the inflow than at the outflow. The species of this genus were more numerous in spring, reaching a maximum on 3rd June. Among the most common species were: *P. gibba* with its varieties, *P. microstauron*, *P. viridis*, and *P. interrupta*. Among the diatoms their participation was from a fraction to 10 per cent.

The genus *Surirella*, associated with the littoral zone and the benthos, occurred frequently among other diatoms in numbers from 19 790 to 1 043 480 specimens/g dry weight, constituting a fraction to 4 per cent of the class composition. In the initial period of investigation (IV, V) they were more numerous. Most frequently encountered were *S. angustata* and *S. ovata* with the variety *pseudopinnata*, which are common in a pond environment.

6 species of the genus *Fragilaria* were identified, of which only *F. capucina* occurred frequently. Usually more cells were present at the inflow where on 2nd July 1 268 460 specimens/g dry weight were counted, this constituting 10 per cent of the diatom composition at that time.

Other diatoms identified in the bottom sediment were no longer so

numerous and their percentage participation in the total composition of diatoms was smaller.

Cymatopleura solea was frequently found but in smaller numbers (7240 to 208 690 specimens/g dry weight). It occurred relatively more frequently in April at the inflow. Its participation was from a fraction to 5 per cent.

The epiphytic genus *Eunotia* was represented by 12 taxons of which *E. arcus* and *E. lunaris* were more often recorded, other species given in Table I being only sporadic. The numbers of diatoms belonging to this genus were from 21 720 to 403 660 specimens/g dry weight, their participation in class communities being from a fraction to 3 per cent — usually more numerous at the inflow.

3 species and one variety were distinguished in the genus *Synedra*, including mainly littoral species. *S. ulna* and *S. acus* occurred most frequently, usually more numerously in the middle of the pond and at the inflow. A certain intensification in occurrence was visible in spring. Numbers were from 7240 to 834 780 specimens/g dry weight. In the diatom composition their numerical participation was from a fraction to 2 per cent.

Fairly common among the diatoms was the littoral genus *Tabellaria*, mainly *T. flocculosa* var. *flocculosa* in numbers from 68 050 to 461 330 specimens/g dry weight, usually more numerous at the inflow. Their participation was between 0.6 and 4 per cent.

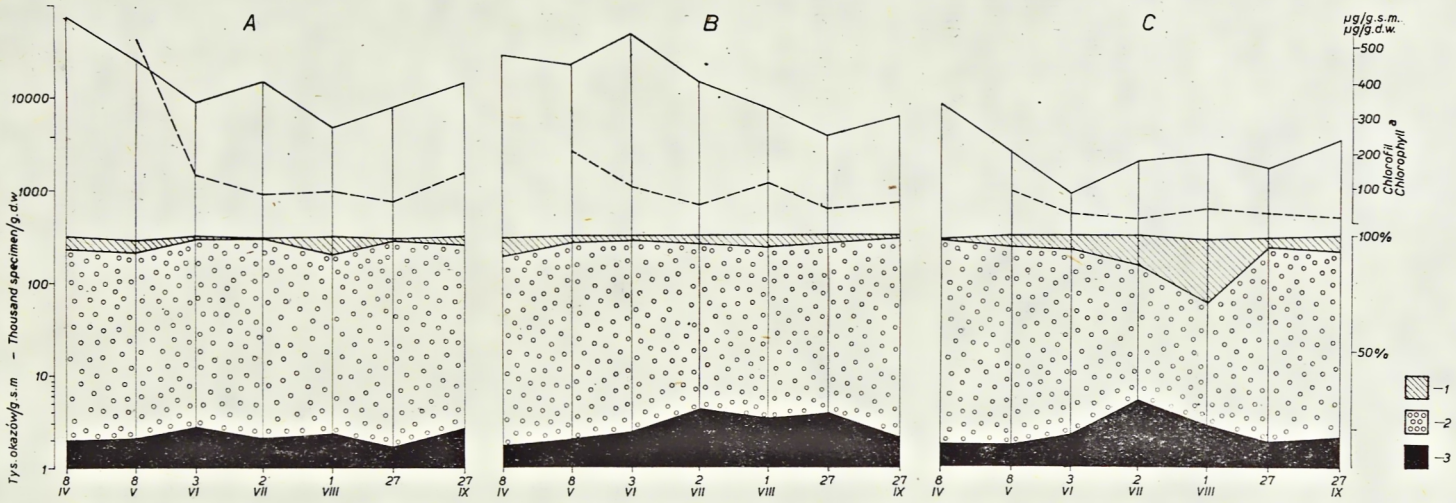
In the investigated material the following species of the genus *Diatoma* occurred: *D. elongatum*, *D. hiemale*, and *D. vulgare* in numbers from 20 250 to 98 780 specimens/g dry weight, this being reflected in their low participation in diatom communities (from a fraction to 1.8 per cent).

The genus *Caloneis*, which includes benthic species, was represented in the pond sediments by species occurring in small numbers, these being mainly *C. silicula* with its varieties.

The epiphytic diatom *Ceratoneis arcus* with the variety *amphioxys* occurred sporadically, its participation being under 1 per cent.

Of the diatoms encountered in the form of single specimens which did not play any important part in the class accumulations of benthic diatoms the following should be mentioned: *Asterionella formosa*, *Denticula* sp., *Epithemia* sp. *Neidium* sp. div., epiphytic species such as *Rhoicosphenia curvata*, *Rhopalodia gibba*, *R. paralella*, *Frustulia* sp., and others listed in Table I.

The group of green algae (*Chlorophyta*) was the second important component of the benthic algae communities. They occurred in all samples throughout the investigation period. Their numbers varied from 123 080 (3rd June — outflow) to 8 973 330 specimens/g dry weight (8th April — inflow). At the stations at the inflow and in the middle of the



Ryc. 1. Udział procentowy poszczególnych grup systematycznych, całkowita ilość glonów dennych (linia pełna) oraz zawartość chlorofilu *a* (linia przerywana) na stanowiskach poboru: przy dopływie (A), środku stawu (B) i odpływie (C) stawu Zimowy Wielki 1974 r.

Fig. 1. Percentage share of particular systematic groups, total number of bottom algae (full line), and content of chlorophyll *a* (broken line) at sampling stations: at the inflow (A), at the middle part (B), at the outflow (C) of the pond Zimowy Wielki in 1974

1 — *Cyanophyta*; 2 — *Bacillariophyceae*; 3 — *Chlorophyta*

pond they were always found to be more abundant than at the station at the outflow (fig. 1).

The green algae were represented by three orders: *Volvocales* (4 taxons), *Chlorococcales* (44 taxons), and *Conjugales* (19 taxons).

Volvocales appeared at intervals in small numbers ranging from 13 150 to 1 058 880 specimens/g dry weight. Their participation in relation to the whole class of green algae was between 2 and 44 per cent. They were less numerous at the station at the outflow than at any other place in the pond. The most frequently recurring species was *Phacotus lenticularis*.

The order *Chlorococcales* constituted the most important group among the green algae living at the bottom. *Chlorococcales* occurred constantly in numbering 65 770 to 8 341 840 specimens/g dry weight and being usually found more numerously at the inflow or in the middle of the pond. The spring season (peak in April) and the early summer were favourable for their development, after which a decrease in their number took place. Their participation in the green algae communities was fairly high, ranging from 44 to even 100 per cent. Among the *Chlorococcales* the genus *Scenedesmus* (mainly *S. quadricauda, S. bicaudatus, S. acutus, S. ecornis*) was always dominant, ranging from 14 to 90 per cent participation in the green algae group, a less important position being held by *Pediastrum* (2 to 23 per cent) and other less abundant genera, such as *Ankistrodesmus, Tetraedron, Crucigenia,* and others usually occurring in the plankton (Table I).

Green algae of the order *Conjugales* also occurred constantly in the bottom sediment, their numbers, however, being smaller than those of *Chlorococcales* and ranging from 21 720 to 795 470 specimens/g dry weight. In the group of green algae they constituted 2.3 to 60 per cent. They were least numerous at the outflow. There was a certain intensification of occurrence in July and August, for which *Cosmarium undulatum, C. granatum, C. Meneghinii* were responsible. The genera *Closterium* and *Staurastrum* were encountered less frequently.

General character of the benthic algae

Among the algae found in the sediment taken from the bottom of the pond epipelic algae occurred whose habitat is the upper mud layer, a great number of diatoms determined as benthic algae, some blue-green and green algae belonging to them. Apart from access of light, the condition of their survival may also be their mobility, which counteracts their burrowing in the bottom sediment (Moss 1968). The investigations carried out by Stańczykowska et al. (1968) showed that

in the Mazurian Lakes the number and biomass of the phytomicrobenthos did not decrease with an increase in depth; algae could occur as deep as 7 cm. The thin layer of mud, about 5 mm thick, taken from the pond Zimowy Wielki could thus also contain living algae. Although the percentage of living and dead algae were not determined in every sample, the percentage of living algae can, however, be estimated as reaching 60 per cent.

The living algae also accumulate at the bottom of the pond, these being mainly epiphytic diatoms falling from the plant substrate, which they overgrow, as well as living and necrotic plankton algae originating from sedimentation. According to Jewell et al. (1971), organic matter originating from algae occurring in three fractions of which the third one is resistant matter decomposing slowly, also accumulates at the bottom. It is to that fraction that cell membranes, diatom valves, etc. belong. Hence, in the sediment samples taken from the bottom living and necrotic algae cells are found whose percentage relation is often variously determined. In Lake Mikołajskie Kowalczewski (1973) found 33 per cent of necrotic algae. Tamás (1971) estimated the relation of living and necrotic algae in the bottom sediment of Lake Balaton as 1 : 1, or in some cases 1 : 4, whereas, Davidova (1966) determined, by means of a luminescent microscope, the percentage share of necrotic diatoms in the bottom sediment of Lake Ładoga as from 80 to 95 per cent.

The amounts of algae and chlorophyll *a* content

In the investigated ecosystems stress has recently been laid on the evaluation of the rate of photosynthetic production of organic matter, i.e. on measurements of primary production. One of the ways of evaluating the biomass of photosynthetizing algae is to measure the chlorophyll *a*. According to Moss (1968), such measurements are very useful in evaluating benthic algae communities which can only with difficulty be separated from the mud and detritus particles. The review and counting of algae in the benthic material also give some difficulty, hence measurements of this pigment are a useful complement. This method was used by many research workers, some of them calculating a correction for the products of chlorophyll degradation (Moss 1968) and others giving the pheophytin percentage (Kowalczewski et al. 1973) apart from the species and quantitative composition of the algae.

In the present investigations the results of analysis presented in fig. 1 show that greatest amounts of chlorophyll *a* (527.9 μg/g dry weight)

always occurred at the inflow or in the middle of the pond (209 μg/g dry weight), whereas at the outflow, where it was deepest (about 2 m), its content decreased (11.3 to 92.0 μg/g dry weight).

The chlorophyll *a* concentration showed at some dates a fairly great dependence on the amount of algae, this being distinctly marked in spring (till the beginning of June). Its highest concentration in the bottom sediment, found at that time, resulted from the abundance of diatoms and green algae. Later on in the year some variations were observed. The correlation with respect to the amount of algae was more or less distinct, after which, in September, a certain increase both in the number of algae and chlorophyll content again occurred, especially in the part of the pond near the inflow.

The fact that not only the number was decisive can be easily recognized by comparing the number of algae and the species dominating at a particular station on three successive dates: 8th May, 3rd June, and 2nd July. As concerns the sum of the phytomicrobenthos the following was found: about 25 million, 9.5 million and 14 million specimens respectively, these changes corresponding with a constant decrease in chlorophyll concentration in the bottom sediment (fig. 1). It follows from the analysis of the number of particular species (Table II) that not the dominant species among the diatoms, *Achnanthes* and *Gomphonema*, must have been decisive in this case, but the numbers of *Scenedesmus quadricauda*, the dominating species among the green algae, which developed after *Pediastrum* and whose number, about 1.5 million specimens/g dry weight on the first date decreased three times and six times on the second and third sampling dates respectively.

Season-long observations seem to indicate that the number and biomass of the algae characterized by a high content of chlorophyll *a* decide its amount in the bottom sediment. It should be noted that the decrease in chlorophyll content during the summer was probably also partly due to constantly rising temperature, which accelerated the biodegradation in the bottom sediment.

Recapitulation

The special composition of algae distinguished in the mud indicates that it is a community of species, mainly attached ones accompanied by plankton algae typical of ponds. The prevalence of diatoms and especially benthic or epiphytic species is characteristic. A similar system of algae was found at the bottom of fertilized ponds and of the control pond

(Krzeczkowska-Wołoszyn, Kyselowa — unpublished data).

In the pond Zimowy Wielki algae occurred in masses till the beginning of July. These amounts were sometimes several times greater than those found at the bottom of the control ponds and even of the fertilized ones investigated in 1973. This may indicate a still continuing effect of the wastes and a stimulating influence of biogenous substances accumulated in the bottom sediments.

A vigorous development of the phytoplankton in spring 1974 was found in this pond by Krzeczkowska-Wołoszyn (1977), maximum amounts of algae occurring in the plankton also on 8th April of that year with the difference that then green algae were dominant. At later dates green algae and diatoms occurred in the plankton in similar amounts or with a slight prevalence of the former.

Apart from the phytoplankton, the algae developing at the bottom influenced, in consequence of their photosynthetic activity, the content of oxygen dissolved in the water. At the time of maximum quantitative intensity of algae at the bottom (8th April) maximum amounts oxygen were found (13.44 mg O_2/l) (M. Lewkowicz, S. Lewkowicz 1977).

Among the attached algae there was here a fairly large number of species which were found in the plankton, this giving evidence of the falling down to the bottom of some plankton and the floating of some benthic species which may occur when accumulations of benthic algae become detached in consequence of being lifted up by oxygen bubbles released in the process of photosynthesis.

The abundantly developing benthic algae constituted the nutrition basis for the microbenthic *Ciliata* and the invertebrate zoobenthos. During the increased occurrence of the phytomicrobenthos Grabacka (1977) reported larger amounts of *Ciliata* feeding on algae.

STRESZCZENIE

Badania przeprowadzono w 1974 r. w stawie Zimowy Wielki po dwuletniej przerwie w akumulacji ścieków z pobliskiej cukrowni. Podstawę badań stanowiła wierzchnia warstwa mułu pobierana sondą rurową z trzech miejsc na stawie (przy dopływie, na środku stawu i przy odpływie). W pobranych próbach oznaczano glony i przeliczano je na 1 g s.m. Okazy spotykane w osadzie dennym należały do kilku grup systematycznych.

Z grupy sinic oznaczono 20 jednostek systematycznych. Glony te występowały stale, udział ich wynosił od 1 do 27% składu. Zwykle spotykano rodzaje: *Phormidium, Gomphosphaeria, Gloeocapsa, Merisnopedia, Lyngbya, Oscillatoria* i *Pseudoanabaena.*

Z euglenin, które spotykano sporadycznie i w małych ilościach, obok gatunków z rodzaju *Euglena, Phacus* i *Trachelomonas* występowały rodzaje *Peranema* i *Petalomonas* zaliczane do bezbarwnych wiciowców.

Chrysofity były głównie reprezentowane przez gromadę okrzemek, które stanowiły od 53 do 89% składu fitomikrobentosu. Ilości w przeliczeniu na g s.m. zmieniały się

zależnie od terminu czy miejsca poboru od 1,5 mln do 63 mln komórek/g s.m. Wyróżniono 174 jednostek systematycznych (tabela I).

Drugi po okrzemkach ważny składnik zbiorowisk glonów żyjących na dnie stanowiły zielenice. Występowały przez cały okres badań. Przy dopływie i na środku stawu było ich więcej niż przy odpływie. Najważniejszą grupę stanowił rząd *Chlorococcales*. Ich udział w zbiorowiskach zielenic był znaczny (44—100%). Zwykle przeważał rodzaj *Scenedesmus*, następnie *Pediastrum*. Spotykano też chlorokokki pospolite w planktonie stawów. Wśród zielenic spotykanych w mule były również należące do rzędu *Conjugales*, jak: *Cosmarium undulatum*, *C. granatum* i *C. Meneghinii*. Ilości ich były mniejsze niż chlorokokków i nie dochodziły do miliona komórek/g s.m.

Ponieważ nie obliczano w niniejszym opracowaniu biomasy fotosyntezujących glonów, posłużono się pomiarami chlorofilu *a*, które wykonała dr M. Bombówna. Największe jego ilości (527,9 μg/g s.m.) występowały zawsze przy dopływie lub na środku stawu (209 μg/g s.m.), natomiast przy odpływie, gdzie było najgłębiej, zawartość jego malała. (11,3—92,0 μg/g s.m.).

Ponieważ w mule badanego stawu glony występowały do początku lipca w bardzo dużych ilościach, może to świadczyć o pewnym jeszcze następczym działaniu ścieków, o stymulującym wpływie zakumulowanych w osadach dna substancjach biogennych.

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