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Protozoans in ponds filled with sugar factory wastes

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Abstract — The protozoans in the bottom mud of fish ponds used for the treatment of sugar factory wastes were investigated. In the microfauna of protozoans, mainly in the *Ciliata* group, the qualitative and quantitative relations were examined. The course of self-purification of the water in the pond was distinctly reflected in the development of *Ciliata*. It was shown in their succession when three ecologically different associations followed each other. The rate of mineralization of wastes depended on the degree of water pollution and limited the occurrence and disappearance of individual associations of *Ciliata* in the mud of the pond. The enrichment of the environment of the pond with new mineral constituents influenced favourably the number of *Ciliata*.

The question of purification of water from industrial wastes is a constant problem of the national economy. Sugar factory wastes are among food industry sewage waters the most heavily loaded with organic substances, and the problem of their purification is difficult because great quantities of sewage with a high content of organic matter are produced in a short period (that of the sugar campaign). In Poland, up to the present, they are purified by various methods, almost exclusively biological, since they form a very good medium for microorganisms (Zaręba in a collective work 1969). One of these methods was an attempt to utilize them in fish ponds, where they are gradually mineralized, at the same time enriching the water of the pond with new nutrient compounds.

The present work is part of a collective investigation carried out for some years in the Laboratory of Water Biology of the Polish Academy of Sciences in Kraków, on the effect of sugar factory wastes on the biocenosis of fish ponds. The aim of the work was to study the succession of protozoans in the bottom sediments during the process of self-purification of the water in the ponds and to investigate the changes brought about in the microfauna of the bottom by the introduction of wastes of different concentrations from the various technological phases of sugar production. The main subject of these studies was the group *Ciliata*, of which a number of species are fairly sensitive indices of the degree of water pollution, and hence reflect the course of the processes of self-purification of the water.

The terrain and method

The investigations were carried out in the years 1967—1968 in four fish-rearing ponds of the Mnich complex belonging to the Experimental Station of the Laboratory of Water Biology, Polish Academy of Sciences, at Gołysz (Cieszyn district). The introduced wastes came from the sugar factory at Chybie.

The ponds Polny III and Łąkowy were investigated during two years, while the ponds Zimowy Wielki and Żabiniec were used for the treatment of sugar factory wastes in 1968 only. One of the ponds, Polny III, was filled throughout 2 years as it remained under water from December 1966 to October 1968. This pond was filled with undiluted wastes and the remaining 3 ponds with wastes variously diluted with water. The pond Łąkowy was an exception, as it was filled with clean water from the River Bajerka in 1968. A list of the investigated ponds and their more detailed characteristics are given in Table I.

The samples for biological analyses were taken at intervals of 3 weeks from the beginning of March to October (the total number of times being 18) using the mud sucker designed by Starmach (unpublished) which sucks about 75 ml of sediment mixed with bottom water. In the period mentioned above 52 samples were taken. They were taken at two points: from a point at the foot-bridge near the outlet of the pond (mean depth being 1.2 m, only in pond Polny III up to 2 m), and from the opposite shallow littoral part (depth 0.4—0.6 m). The living material was investigated and quantitative and qualitative analyses of the protozoan microfauna were carried out. On the basis of the data obtained from preparations of a given volume of sediment the number of protozoans in 1 ml of the surface layer of mud was calculated.

The succession of microbenthos protozoans in relation to the progressing process of self-purification

The investigated ponds differed mainly in the amount and quality of wastes introduced into them. Detailed information on the kind and concentration of the introduced wastes is given in Table I. After the sugar

Tabela I. Szczegółowe dane dotyczące badanych stawów

Table I. Detailed data concerning the investigated ponds

Nazwa stawu Name of pond	Powierzchnia w ha Area in ha	Rok badań Year of investigation	Rodzaj ścieków Kind of wastes	Okres dopływu ścieków Period of wastes supply	Rozcieńczenie ścieków Wastes dilution	Początkowe ChZT z chwilą napełnienia stawu Initial COD at the moment of filling of the pond
Iolny III	9.0	1967	Dyfuzyjne i z pól irygowanych Diffusion wastes and from drainage fields	1 XII 1966 - 10 I 1967	Bez rozcieńczenia Without dilution	1389 mg O_2/1
		1968	Bez ścieków Without wastes			
Łąkowy	8.1	1967	Większość ścieków z pól filtracyjnych The majority of wastes from the filtration fields	1 - 15 II 1967	4 : 1	913 mg O_2/1
		1968	Bez ścieków Without wastes	-	Woda w rzeki Bajerki Water from the River Bajerka	
Zimowy Wielki	8.0	1968	Mieszane Mixed	XII 1967 - I 1968	1 : 3	931 mg O_2/1
Żabiniec	10.0	1968	Mieszane Mixed	XII 1967 - I 1968	1 : 4	823 mg O_2/1

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factory wastes loaded with very large amounts of organic matter had been introduced into the ponds, the process of biological self-purification continued in the course of the winter and spring. In this period the conditions prevailing in the pond bottom were quite different from those in normally utilized ponds, the mineralization processes of organic compounds occurring by fermentation and decay being verry intensive and hence considerably influencing the chemical relations in the environment. The substances released into the environment in the course of this type of decomposition — carbon dioxide, methane, and hydrogen sulphide — create highly unfavourable conditions for the majority of aquatic animals. The changes in the chemisms of the pond environment in the process of self-purification of the water were investigated in detail (L e w k o w i c z 1973). In this work some physico-chemical measurements of BOD_5, COD, and the percentage of oxygen saturation of the water were used.

The course of self-purification processes of the water was different in individual ponds, this chiefly depending on the initial concentration of the wastes after their introduction to a pond. On this basis of chemical investigations 4 stages were differentiated in the course of self-purification of the water. The first stage, called heterotrophy, was characterized by anaerobic conditions resulting from high intensity of putrefactive processes and high BOD_5 values, in connection with large amounts of organic matter. The next stages (called hyperautotrophy, transition, and stabilization) oxygen was already present and BOD_5 markedly decreased. The phases of the self-purification process were in a measure reflected in certain biological changes, mainly in the relations of phyto- and zooplankton. The development of various groups of phyto- and zooplankton revealed a marked stage-like changeability in the course of the vegetation season and considerable accordance with chemical changes in the environment (K y s e l o w a 1973). This stage-like changeability was not so distinctly reflected in all layers. No distinct stages were found in the bottom microfauna, the effect of wastes on its quantitative and qualitative relations still being considerable (Z i ę b a 1973).

As results from the quantitative and qualitative determinations, the bottom microfauna of the ponds was mainly composed of protozoans and small *Metazoa*. *Ciliata* decidedly held the first place, especially in quantitative ratios, while others such as *Heliozoa* and *Rhizopoda* were in comparison always less numerous. The qualitative differentiation of *Ciliata* was fairly considerable. The total number of determined protozoans was 125 taxons, among which as many as 106 *Ciliata* were recorded. Relatively numerous were the families *Metopidae* and *Oxytrichidae*. *Ciliata* found in the ponds Polny III and Łąkowy are listed in Tables II and III.

All the investigated ponds had fairly similar fauna of *Ciliata*. The numbers of species in individual ponds varied, more species being found

Tabela II. Wykaz orzęsków znalezionych w stawie "Polny III" w roku 1967
Table II. List of Ciliata in the pond "Polny III" in 1967

Zespół - Community	Nazwa gatunku / Name of species \ Data / Date	2.III	29.III	25.IV	29.V	20.VI	7.VII	28.VII	17.VIII	4.IX	12.X
1	Enchelys vermicularis Smith	+	+								
	Paramecium putrinum Clap. et L.	+									
	Trimyena compressum Lackey		+								
2	Caenomorpha lauterborni Kahl						+	+			
	- medusula Perty				+	+	+	+			
	- universalis Levander						+	+			
	Caenomorpha sp.	+						+			
	Dactylochlamys pisciformis Lauterborn					+					
	Lacrymaria cucumis Penard						+				
	Lacrymaria sp.		+								
	Metopus acuminatus Stokes							+			
	- cydonia Kahl							+			
	- es O.F. Müller					+	+	+	+		
	- extensus Kahl						+				
	- fuscus Kahl					+		+			
	- laminarius Kahl fo. minor Kahl					+					
	- micrans					+					
	- ovalis Kahl							+			
	- striatus Mc Murrich								+		
	- tenuis Kahl				+						
	Metopus sp.				+	+	+	+			
	Plagiopyla nasuta Stein					+		+			
	- ovata Kahl						+				
	Epalxis sp.				+						
3	Ancystropodium maupasi Fauré-Fr.						+				
	Aspidisca costata Dujardin							+		+	+
	- lynceus Ehrb.							+			
	Aspidisca sp.							+			
	Chilodonella cucullulus O.F. Müller					+				+	
	- uncinata Ehrb.								+		
	Cinetochilum margaritaceum Perty				+	+		+		+	+
	Codonella cratera Leidy									+	
	Coleps hirtus Nitzsch					+	+	+			
	Colpidium sp.					+	+			+	
	Colpoda cucullulus O.F. Müller					+					
	Cyclidium citrullus Cohn						+			+	
	Cyclotrichum sp.					+					
	Euplotes patella Müller							+			
	Euplotes sp.								+		
	Halteria grandinella O.F. Müller							+	+	+	
	Hemiophrys sp.						+				
	Holophrya sp.					+					
	Lionotus lamella Schewiakoff									+	
	- urticularis							+			
	Lionotus sp.					+	+		+		+
	Oxytricha sp.				+	+	+	+		+	
	Paramecium caudatum Ehrb.					+	+	+	+		
	Paruroleptus lacteus Kahl					+				+	+
	Paruroleptus sp.					+					
	Prorodon ovum Ehrb.-Kahl							+	+	+	
	- teres Ehrb.								+		
	Prorodon sp.				+	+	+	+	+	+	
	Spathidium cithara Penard						+				
	Spathidium sp.						+		+		
	Spirostomum minus Roux									+	
	Stentor coeruleus Ehrb.								+		
	- multiformis Stein								+		
	Trachelophyllum sp.				+			+	+	+	
	Urocentrum turbo O.F. Müller								+		
	Uroleptus sp.					+					
	Urosoma longicirrata					+					
	Urostyla sp.				+		+	+	+		
	Vorticella similis Stokes				+			+			
	Vorticella sp.					+		+		+	

in ponds where great quantities of wastes had been introduced, i. e. Polny III (64 species) and Łąkowy (46 species). Much smaller differentiation was observed in the ponds Zimowy Wielki and Żabiniec, where the wastes were highly diluted. The limiting factor was the fact that in Polny III and Łąkowy no oxygen occurred for a long time and hence in comparison with other ponds greater numbers of forms characteristic for an environment of rotting slime lived there, mainly the representatives of the family

Tabela III. Wykaz orzęsków znalezionych w stawie "Łąkowy" w roku 1967

Table III. List of Ciliata in the pond "Łąkowy" in 1967

Zespół - Community		Nazwa gatunku / Name of species — Data / Date	2.III	29.III	25.IV	29.V	20.VI	7.VII	28.VII	17.VIII	4.IX	12.X
	1	Trimyena compressum Lackey		+								
	2	Atopodinium sp.									+	
		Caenomorpha medusula Perty					+					
		Lacrymaria cucumis Penard		+								
		Lacrymaria sp.		+								
		Metopus acuminatus Stokes										+
		- es O.F. Müller			+	+	+	+	+		+	
		- extensus Kahl							+			
		- undulans Stokes							+	+		
		Metopus sp.			+							
		Perispira strephosoma Stokes								.+		
		Plagiopyla nasuta Stein				+						
		- ovata Kahl				+	+	+				
		Saprodinium sp.								+		
	3	Askenasia volvox Clap. et L.				+						
		Aspidisca costata Dujardin				+		+	+	+	+	+
		- lynceus Ehrb.				+					+	
		Chilodonella cucullulus O.F. Müller					+					
		- turdigula Penard										+
		Chilodonella sp.									+	
		Cinetochilum margaritaceum Perty				+		+		+	+	+
		Coleps amphacanthus Ehrb.									+	
		- hirtus Nitzsch				+		+	+	+	+	+
		Colpidium colpoda Stein	+				+	+				
		Colpoda cucullulus O.F. Müller			+							
		Cyclidium citrullus Cohn							+	+	+	
		Cyclidium sp.									+	
		Didinium sp.						+				
		Euplotes patella Müller fo. alatus Kahl		+								
		Frontonia acuminata Ehrb.									+	
		Halteria grandinella O.F. Müller							+	+	+	
		Holophrya simplex Schewiakoff							+			
		Loxodes striatus Engelmann									+	
		Oxytricha sp.				+	+			+		
		Paramecium caudatum Ehrb.			+	+	+					
		Paruroleptus lacteus Kahl								+	+	
		Paruroleptus sp.				+				+		
		Prorodon ovum Ehrb.-Kahl						+	+	+		
		Prorodon sp.					+	+	+	+	+	
		Stentor roeseli Ehrb.								+		
		Trachelophyllum sp.								+		
		Uroglena volvox	+									
		Uroleptus limnetis Stokes				+				+		
		Uroleptus sp.						+				
		Urostyla sp.		+		+			+		+	+
		Vorticella sp.							+	+		

Metopidae. It was these species which contributed largely to the enrichment of the qualitative composition of *Ciliata* in the ponds mentioned above (Tables II, III). The biological analysis of materials collected in ponds filled with undiluted and variously diluted wastes revealed distinct stages in the course of the process of self-purification, mainly in the *Ciliata* group. During the growing season great changes in the qualitative composition of *Ciliata* and in their numbers were observed, the succession within this group being manifested in the occurrence of three associations of *Ciliata* of different ecological character, which reflected the stages of self-purification processes in the pond. The time of appearance of these associations corresponded to the stages differentiated on the basis of chemical criteria, in spite of the fact that the number of complexes of *Ciliata* did not agree with the number of differentiated stages (4).

The following associations of *Ciliata* were determined:

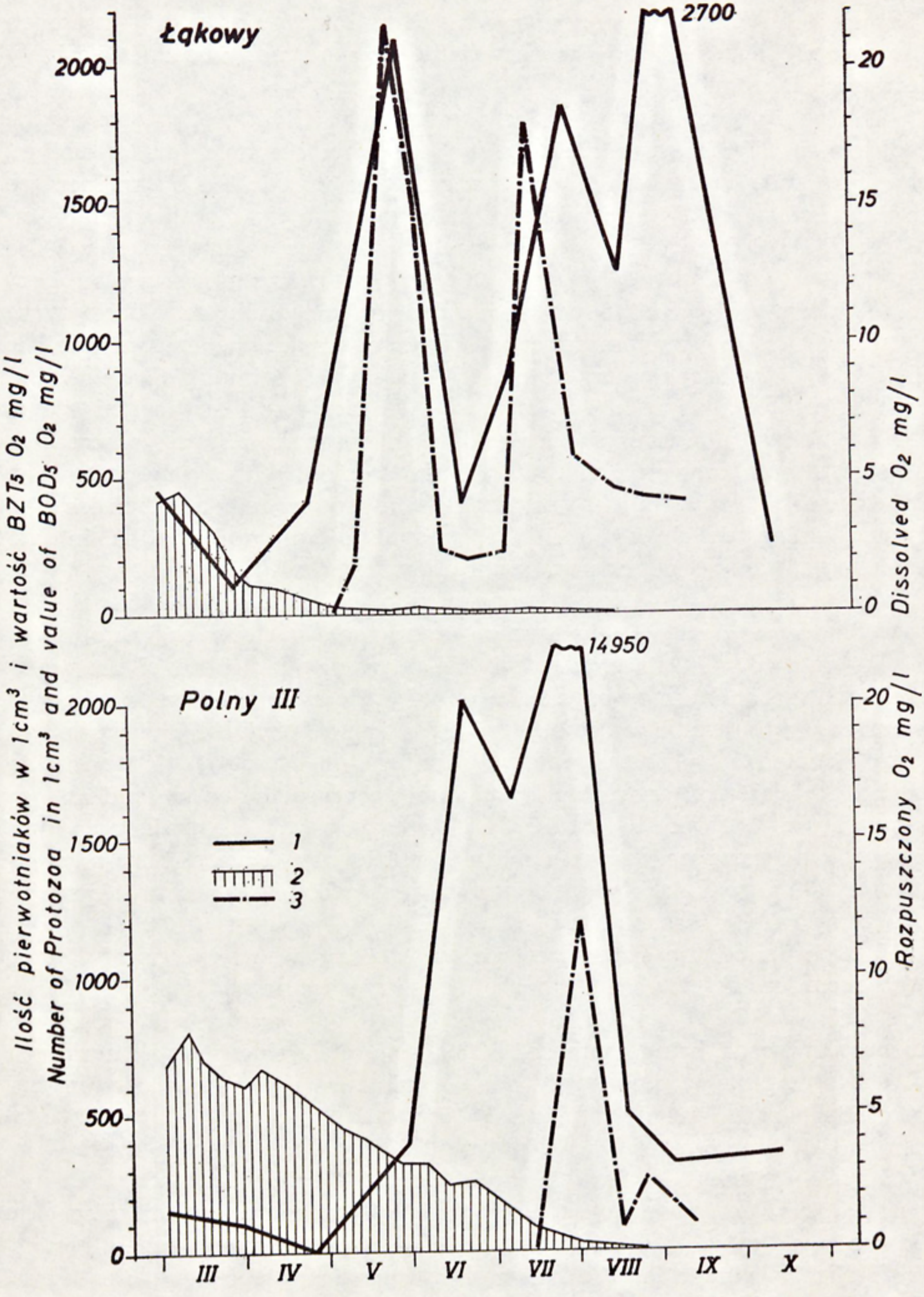
1) the saprophelic complex typical for sewage waters, 2) the association

of saprobionts characteristic for rotting slime in the presence of hydrogen sulphide, 3) the association characteristic for a normally used, intensively fertilized fish pond.

The qualitative changes in the population of *Ciliata*, expressed in the replacement of one association by another, were accompanied by distinct changes in their numbers. These changes were manifested by an increase in the number of *Ciliata* parallel to the decrease in the degree of pollution of the pond. On the other hand, the number of occurring species was the lower, the higher was the degree of pollution. In the initial period (first stage), when the pollution was so strong that no abundant development of life was possible, small numbers of *Ciliata* occurred. The smallest number of species was always recorded in all ponds at the beginning of the season. Just before the appearance of oxygen, i. e. at the end of the first stage, the variability of *Ciliata* species and their numbers distinctly increased. The maximum amounts of *Ciliata* were found a short time after the appearance of oxygen, that is during the second stage. Then as the mineralization developed and the amount of organic matter in the environment decreased the number of *Ciliata* gradually declined (figs 1—2). As in each pond a different concentration of wastes was found, the successive stages in individual ponds lasted for a various lengths of time.

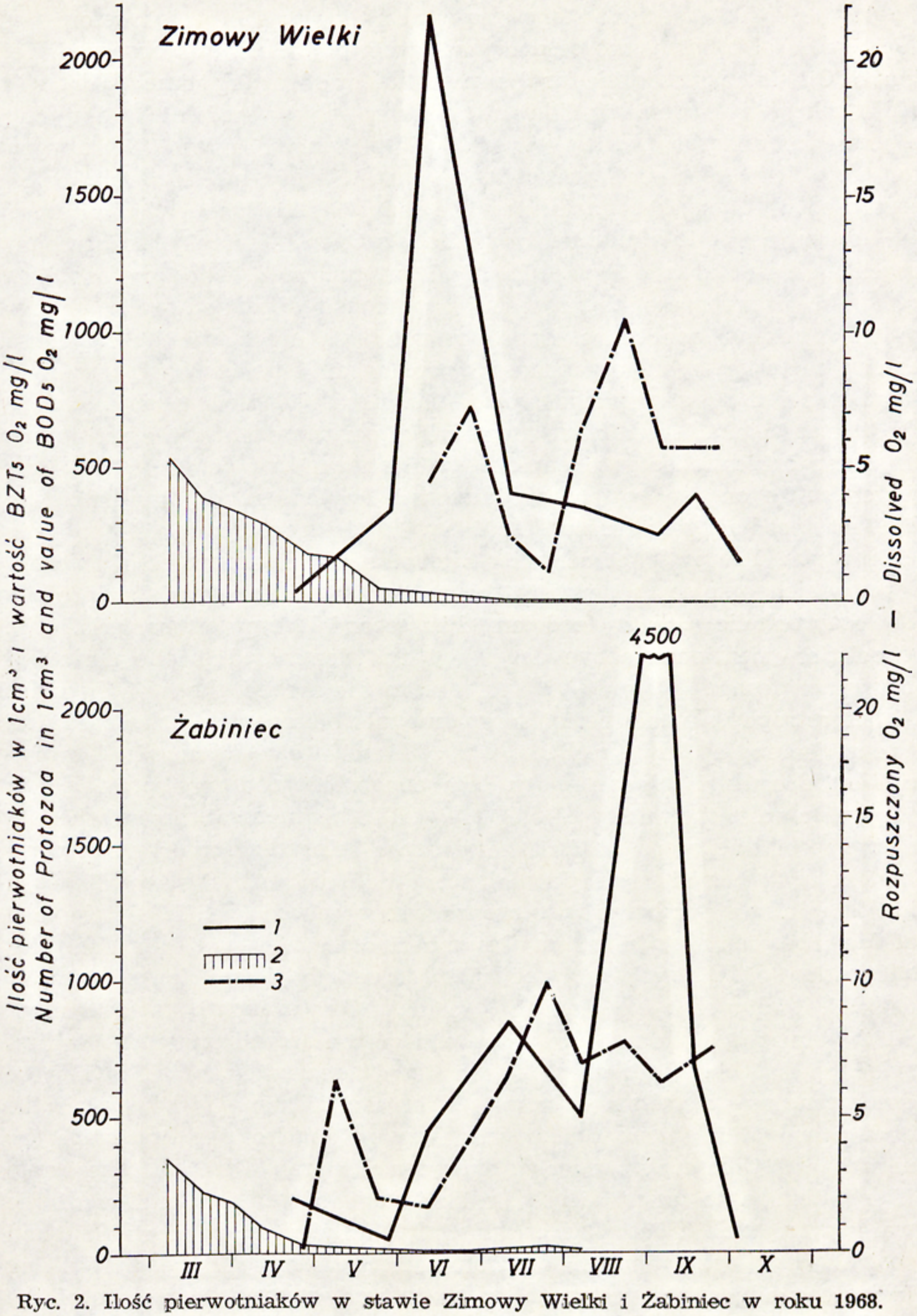
The most distinct limits between the stages of purification of the water and greatest accordance of succession of *Ciliata* with chemical changes occurring in the water were observed in the pond Polny III. The first stage (that of heterotropy) lasted relatively long — up to July 14 1967. In this period the bacterial anaerobic breakdown occurred under ice and at low temperature (Lewkowicz 1973). This stage was characterized by a high load of undecomposed organic matter, which was expressed by a value of over 900 mgO_2/l, lack of oxygen, and weak acid reaction of water at the beginning of the season.

In this period the occurrence of two successive associations of *Ciliata* was recorded. At the beginning of the investigations (March 1967) an association of *Ciliata* typical for sewage water (polysaprophelic) occurred. It was very poor, being composed of 3 species occurring in small numbers, which formed only 2 per cent of the total number of species recorded in this pond during the whole period of investigation. *Enchelys vermicularis* dominated as a typical index of a polysaprophelic zone, according to Liebman (1962). Besides this species only small numbers of *Paramecium putrinum* and *Trimyena compressum* (Table II) were present, these species also being typical for strongly polluted waters. From other groups individual specimens of *Rhizopoda*, Nematodes, and rotifers were found. The above-mentioned association of *Ciliata* occurred during one month only (March 1967), a considerable decrease in BOD_5 being recorded in that period. This association disappeared entirely in the next month. In April some only a very few Nematodes were found in the samples.



Ryc. 1. Ilość pierwotniaków w stawie Łąkowy i Polny III w roku 1967. 1 — ilość pierwotniaków, 2 — wartość BZT_5 O_2 mg/l, 3 — tlen rozpuszczony

Fig. 1. Number of *Protozoa* in the pond Łąkowy and Polny III in 1967. 1 — number of protozoans, 2 — value of BOD_5 O_2 mg/l, 3 — dissolved O_2 mg/l



Ryc. 2. Ilość pierwotniaków w stawie Zimowy Wielki i Żabiniec w roku 1968. 1 — ilość pierwotniaków, 2 — wartość BZT_5 O_2 mg/l, 3 — tlen rozpuszczony

Fig. 2. Number of *Protozoa* in the pond Zimowy Wielki and Żabiniec in 1968. 1 — number of protozoans, 2 — value of BOD_5 O_2 mg/l, 3— dissolved O_2 mg/l

At the end of the first stage (May), and thus in the period before the appearance of oxygen, the second association of *Ciliata* was observed, i.e. that of *Ciliata* characteristic for the environment of rotting slime (W e t z e l 1928), where hydrogen sulphide and methane are released in the decaying processes in anaerobic conditions or in the presence of a very low oxygen content. This association was already qualitatively more varied, being composed of 21 species (mainly of the family *Metopidae*), which formed 14 per cent of the total number of species found in the pond. The dominant species were *Metopus fuscus, Plagiopyla nasuta,* and *Caenomorpha medusula.* The occurrence of this association obviously depended on the change in the nutritive conditions. Saprophelic *Ciliata* are a specialized group among bacteriophagous organisms. According to G r a a f (1957) they may be considered as stenophagous bacteriophages, adapted exclusively to feeding on thiobacteria. Hence the seasonal occurrence of these protozoans in water bodies is easy to explain. It is known that organic substances which settle on the bottom are attacked by the group of putrefactive bacteria, producing hydrogen sulphide with the decomposition of protein compounds. The presence of this gas favours the development of thiobacteria, which oxidize it, deriving the necessary energy from this process. The saprophelic *Ciliata* feed on this second group of bacteria. The association mentioned above developed and dominated in the period of 3 months (from May to July), and thus in the second phase of the stage of heterotrophy. In this period large amounts of organic matter occurred, e.g. at the end of May the BOD_5 was still more than 300 mg O_2/l, but its content decreased fairly rapidly. The anaerobic conditions prevailed in the water up to the middle of July (14. VII). This moment marked the end of the second phase of the first stage, hence being the borderline between the first and second stages. In the second half of the first stage a marked increase in the number of protozoans was observed (fig. 1). At the end of May, besides *Metopidae,* small numbers of certain species of the third association of *Ciliata* were encountered, usually found in a normally utilized, intensively fertilized fish pond. After a month their number notably increased, though up to the end of the second phase of the first stage the species belonging to the third association of *Ciliata* were accompanying organisms only and had practically no influence on the qualitative ratios among *Ciliata.* In the second half of the first stage the numbers of *Ciliata* also revealed a tendency to rapid growth. The group which dominated quantitatively in this stage of self-purification of the water were still *Ciliata,* accompanied by a few species of rotifers and gastrotrichs. Large numbers of protozoans were still observed, resulting from the abundant development of the already-mentioned species of the second association of *Ciliata* of the family *Metopidae* (Table II). The greatest numbers of protozoans were noted at the end of June (20. VI.) when, besides numerous species of the family *Metopidae,* fairly large numbers of the species *Paramecium caudatum,* usually reckoned among the third association, developed. The last species prevailed at the shallow point, while *Metopidae* dominated at the deeper one. This suggests a more rapid progress of chemical changes in shallow regions. It should be added that saprobiontic *Ciliata* were sporadically found in normally used fish ponds, mainly in summer when an oxygen deficit occurred at the bottom, but usually only in shallow and densely overgrown parts of ponds, where large amounts of plant detrituts collected (G r a b a c k a 1965, 1971). Again, *Paramecium caudatum* often occurs in different kinds of polluted water in poly-, alpha-, or mesosaprobic zones (T u r o b o y s k i 1970).

The second stage (of hyperautotrophy) was characterized by the simultaneous occurrence of two associations of *Ciliata,* i.e. the second and the third ones. It was only in this stage that certain species feeding on algae were also encountered. In this period the quantity of organic matter was still great, but the water already contained a certain constant amount of oxygen. The largest number of protozoans in the investigated period was found just two weeks after the appearance of oxygen in the water (fig. 1). These large numbers occurred chiefly owing to a simultaneous numerous occurrence of many species of *Ciliata,* among which *Aspidisca costata* and *Caenomorpha medusula* dominated quantitatively. From *Metazoa* large numbers of gastrotrichs (*Gastrotricha*) developed. The occurrence of such great numbers of protozoans depended on the trophic and environmental conditions. The deciding factor was oxygen, as the majority of species of *Ciliata* are known to be aerobic. In the new conditions considerable amounts of bacteria also developed. According to the majority of authors the here dominating *Aspidisca costata* feeds mainly on bacteria. The numerous occurrence of the species *Caenomorpha medusula* and the presence of a number of other saprobiontic species at this time, especially at the deep point, suggest that in the surface layer of mud oxygen occurred slightly later than at the water surface, or that its amount was initially much smaller than at the bottom of the water. It might account for the differentiation of the fauna of protozoans in the mud at different points of the same pond. The saprobiontic species dissappeared at the end of July.

The third, so-called transition stage lasted in this pond from the middle of August 1967 to the beginning of March 1968. The third association of *Ciliata,* most differentiated qualitatively, composed of 39 species amounting to 60 per cent of their total number, dominated at this time. It presents a community typical for microfauna of an intensively fertilized fish pond. In this stage a marked decrease in BOD_5 was observed, its value amounting to less than 10 mg O_2/l already from the middle of August. The number of protozoans did not decrease significantly before the end of the season (September — October).

In the second year of investigation (1968) the situation in pond the

Polny III was considerably less differentiated. In that year the pond was not treated with wastes. The whole investigated period (from April to October) presented the stage of so-called stabilization, which was revealed in the microfauna by the occurrence of the third association of *Ciliata* only. No consequent effect of wastes on the microfauna was found because the numbers of *Ciliata* were lower than in the previous year. From saprobiontic fauna only two species of *Ciliata* were noted: *Metopus* sp., and *Saprodinium* sp.; they were not numerous and occurred in summer only.

The process of self-purification of the water in the pond Łąkowy was similar in the year 1967 (Table III, fig. 1). Also in the chemical investigations 4 stages were determined, but their length was different, this being probably caused by different loading with organic matter (the wastes introduced into the pond were diluted in the ratio of 4 : 1). In this pond the reduction of organic matter proceeded much faster, hence the self--purification process was shorter. In the microfauna associations of *Ciliata* similar to those in the pond Polny III were determined. Here the first stage of the self-purification process lasted to the end of April only. In this period saprobiontic microfauna prevailed. At the beginning of the investigations (March) only small numbers of one polysaprophelic species occurred. During the next three stages the third association of *Ciliata* dominated quantitatively, being also the most varied one in its qualitative composition, similarly as in the pond Polny III. Saprobionts representing the second association of *Ciliata* occurred almost up to the end of the season, but also in very small numbers. In this pond the greatest numbers of protozoans were noted at the end of May, thus similarly as in other ponds with wastes, also a short time after the occurrence of oxygen in water. The presence of oxygen in water was recorded here on the 12th of investigation in 1968 the third association of *Ciliata* occurred, the September. In the pond Łąkowy the maximum numbers of *Ciliata* were much lower than those in the pond Polny III in 1967.

In the next year of the investigations (1968) the pond Łąkowy was not treated with wastes but filled with pure river water. During the whole season the numbers of protozoans were much smaller than in the parallel period of the previous year. Then no consequent effect of wastes was observed, similarly as in the pond Polny III. During the whole period of investigation in 1968 the third asseociation of *Ciliata* occurred, the saprobiontic *Ciliata* being found sporadically in this pond, chiefly in summer.

In the ponds Zimowy Wielki and Żabiniec, filled with strongly diluted wastes, no changes in the fauna of protozoans were found which would correspond to the stages determined on the basis of the hydrochemical data. Fewer species were found here than in the previously described ponds. No polysaprophelic *Ciliata* were noted. Other saprobionts were scarce and did not dominate quantitatively in any period. Larger amounts of protozoans occurred mainly in summer, this being in the pond Zimowy Wielki in early summer, while in the pond Żabiniec the greatest numbers were recorded in the middle of summer and at the beginning of autumn.

Conclusions

On the basis of the obtained results it may be stated that:

1) The course of self-purification of the water of the pond was distinctly reflected in the development of *Ciliata* of the bottom. It was manifested in their succession, three ecologically different associations of *Ciliata* following each other.

2) Strong pollution of water occurring at the beginning of the experiment resulted in unfavourable conditions for the development of protozoans, this being revealed by a marked decrease in the number of species. At the beginning of the season, when there were very large amounts of organic matter in the ponds and the occurrence of free oxygen in the water was not noted, index, organisms connected with polluted waters of the polysaprophelic zone were living in the slime and gradually disappeared along with the progressing process of self-purification.

3) The period preceding the appearance of oxygen in the water was characterized by the presence of saprophelic fauna typical for rotting slime, where methane and hydrogen sulphide occur.

4) The rate of mineralization of wastes depended on the degree of pollution of the water and limited the occurrence and disappearance of individual associations of *Ciliata* in the mud of the pond.

5) The enrichment of the environment of the pond with new mineral constituents very favourably influenced the increase in the number of *Ciliata*. Maximum numbers of *Ciliata* were always noted within a short period of the appearance of oxygen in the water.

6) Maximum numbers of *Ciliata* found in the ponds filled with undiluted or weakly diluted wastes were many times higher than those noted in normally utilized ponds.

7) No consequent influence of wastes on the bottom microfauna of protozoans in the second year of the investigations was found.

STRESZCZENIE

W przeciągu dwu lat (1967—1968) przeprowadzono badania na czterech stawach karpiowych położonych na terenie kompleksu Mnich, należących do Zakładu Doświadczalnego PAN w Gołyszu i wykorzystywanych do oczyszczania ścieków cu-

krowniczych. Do stawów tych wprowadzono podczas kampanii cukrowniczej ścieki o różnym stężeniu. Jeden ze stawów napełniono ściekami nierozcieńczonymi (Polny III). W okresie zimowo-wiosennym przebiegał silny rozkład ścieków. Procesy fermentacji i gnicia stwarzały w środowisku dennym niekorzystne warunki dla pierwotniaków.

Proces samooczyszczania przebiegał w różnym czasie. Szybkość mineralizacji była związana ze stopniem zanieczyszczenia stawu, stąd najdłużej trwał on w stawie Polny III, napełnionym ściekami nierozcieńczonymi. Przebieg samooczyszczania odbił się na rozwoju mikrofauny pierwotniaków, a głównie grupy orzęsków (*Ciliata*), wśród których wyróżniono trzy kolejno po sobie następujące odmienne ekologicznie zespoły orzęsków. Przy dużej ilości materii organicznej w wodzie brakowało tlenu i wtedy występowały gatunki związane z wodami zanieczyszczonymi, które ustępowały stopniowo w miarę postępowania mineralizacji.

Wyróżniono trzy zespoły orzęsków, tj.: typowy zespół polisaprobowy, który występował w okresie początkowym przy najsilniejszym zanieczyszczeniu wody, zespół saprobiontów występujący przy obecności metanu i siarkowodoru w czasie końcowej fazy etapu beztlenowego oraz zespół charakteryzujący intensywnie nawożony staw rybny, który rozwijał się w mule po pojawieniu się tlenu w wodzie.

Wzbogacenie środowiska stawowego przez produkty mineralizacji ścieków odbiło się korzystnie na liczebności fauny pierwotniaków. Maksymalne ilości pierwotniaków zanotowano w stawie najbardziej zanieczyszczonym w pierwszym roku badań w niedługim czasie po pojawieniu się tlenu w wodzie. Następczego działania ścieków w roku następnym nie stwierdzono.

REFERENCES

Grabacka E., 1965. Mikrofauna dna stawów rybnych w Gołyszu — Microfauna of the bottom of fish ponds in Gołysz. Acta Hydrobiol., 7, 317—328.

Grabacka E., 1971. Orzęski dna odrostowych stawów rybnych Zespołu Gołysz — *Ciliata* of the bottom of rearing fishponds in the Gołysz Complex. Acta Hydrobiol., 13, 5—28.

Graaf F., 1957. The microflora and — fauna of a quaking bog in the nature reserve „Het Hol" near Kortenhoef in the Netherlands. Hydrobiol., 9, 210—317.

Kahl A., 1935. Wimpertiere oder *Ciliata* in Dahl: Die Tierwel Deutschlands. Jena, G. Fischer Verl.

Kyselowa K., 1973. Plankton stawów zasilanych ściekami cukrowniczymi — The plankton of ponds enriched with wastes from beet sugar factories. Acta Hydrobiol., 15, 51—88.

Lewkowicz S., 1973. Zmiany chemiczne w wodzie i powierzchniowej warstwie dna stawów użyźnianych ściekami cukrowniczymi — Chemical changes in the water and accumulative stratum of soils in ponds fertilized with beet sugar factory wastes. Acta Hydrobiol., 15, 1—49.

Liebmann H., 1962. Handbuch der Frischwasser und Abwasserbiologie. 2, Jena, G. Fischer Verl.

Turoboyski L., 1970. Listy organizmów wskaźnikowych spotykanych w wodach powierzchniowych Polski. Mat. Bad., I.G.W., 5, 2.

Wetzel A., 1928. Der Faulschlamm und seine Ciliaten Leitformen. Ztschr. Morphöl. Ökol. Tiere, 13, 179—328.

Zięba J., 1973. Makrobentos stawów ze ściekami cukrowniczymi — Macrbenthos of ponds with sugar factory wastes. Acta Hydrobiol., 15, 113—129.

Praca zbiorowa, 1969., Woda i ścieki w przemyśle spożywczym. Warszawa, Wyd. Nauk.-Techn.

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