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Ecology of some waters in the forest-agricultural basin of the River Brynica near the Upper Silesian Industrial Region*

8. *Ciliata* in bottom sediments

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A b s t r a c t — The *Ciliata* in the microbenthos of a number of water bodies were investigated, namely: the dam reservoir at Kozłowa Góra, two recreational water bodies (the artificial Lake Chechło-Nakło, and the Świerklaniec park pond), and the middle section of the River Brynica. The catchment basin of the River Brynica together with the mentioned water bodies are situated in a forest-agricultural area adjoining the Upper Silesian Industrial Region. On the basis of analysis of the bottom *Ciliata* species the River Brynica and the examined water bodies were classified as slightly polluted, and the park pond as strongly eutrophicated.

K e y w o r d s: rivers, dam reservoirs, lakes, ponds, microbenthos, *Ciliata*, pollution.

1. Introduction

The present study constitutes part of a collective work undertaken by the Laboratory of Water Biology (at present Institute of Freshwater Biology) of the Polish Academy of Sciences on the effect of industrial pollution on the surface waters of the forest-agricultural territories of Upper Silesia in the region of Tarnowskie Góry. Detailed information concerning the aim of this study together with a description of the

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catchment basin was given by Zięba (1985) referring to the chemical mechanism of the waters — by Bombówna (1985), and the water and bottom microelements — by Reczyńska-Dutka (1985a, b). The present work concerned the qualitative and quantitative investigation of the *Ciliata* communities in the bottom sediments of the examined waters lying within the range of industrial atmospheric pollution, as well as the assessment of water purity.

2. Study area and methods

The area of investigation was the catchment basin of the River Brynica, i.e. the River Brynica with the water-supply dam reservoir at Kozłowa Góra, and two recreational water bodies: the artificial Lake Chechło-Nakło and the Świerklaniec park pond. 7 sampling stations, whose location is given in fig. 1, were established on these waters. Certain hydrographic data concerning the above stations are given in Table I.

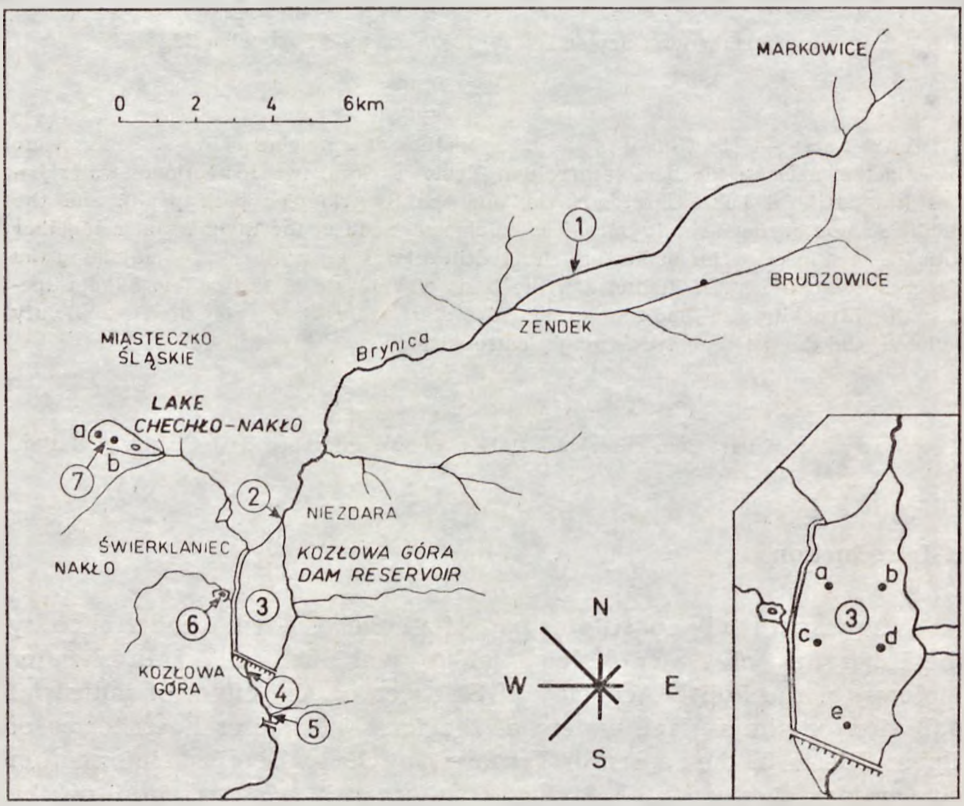

Fig. 1. Distribution of the investigated stations and wind rose. Stations: 1—7

Table I. Brief description of the investigated stations

Station	No.	Situation	Width of the riverbed (m) area (km²)	Depth (m)	Current	Plants	Character of the bottom
River Brynica	1	at Zendek	0.5-1.5	0.2-0.5	medium	single tufts of submersed plants	sand, in places muddy sand
	2	at Niezdara	3.0-4.0	0.2-0.7	slow	single tufts of submersed and emergent plants	muddy sand, in places sand and mud
Dam reservoir at Kozłowa Góra	3	at Kozłowa Góra					
	a b	upper section	mean 4.62	0.5-1.8		none	mud, in places muddy sand
	c d	lower section	maximum up to 6.21	1.8-3.0		none	mud
	e	near the dam		up to 5.0		none	mud
River Brynica	4	near the dam	1.0-1.2	0.2	medium	none	bed lined with stones
	5	below the dam - 1.5 km	2.0-3.0	0.3-0.7	slow	numerous emergent plants	sand, muddy sand and detritus
Park pond	6	at Świerklaniec, inshore	0.06	1.2-1.5		tufts of the submersed plants	mud and detrirus
Lake Chechło-Nakło	7 a	at Chechło inshore	0.66	0.3-0.6		single tufts of emergent plants	sand and muddy sand
	b	central zone		2.3-2.5		tufts of Charasp.	muddy sand

On the River Brynica there were 4 sampling stations. Station 1 is situated in the middle course of the river on a forested territory in the village of Zendek. Station 2 was on the backwaters of the dam reservoir in the village of Niezdara. The remaining stations on the river were below the reservoir. In this section the river changes into a narrow ditch, the part close to the dam being wholly lined with concrete (station 4). Further on the Brynica flows through meadow-covered lowland (station 5), forming a narrow ditch collects various run-off and wastes, mainly organic, from the neighbouring villages.

Stations 3a, 3b, 3c, 3d, and 3e were situated by the dam reservoir at Kozłowa Góra. The water samples were taken here from two places: from a point close to the dam, at a distance of some ten to twenty metres from the dam (station 3e), and from places near the shore in the western and eastern parts of the reservoir (stations 3c and 3d). The remaining two stations were situated in the Świerklaniec park pond close to the shore (station 6), on the premises of the landing place for water sports and in the western part of Lake Chechło-Nakło close to the shore.

The Brynica catchment basin is an area of forest-agricultural character, adjoining the strongly and polluted Upper Silesian Industrial Region. The Brynica catchment basin is therefore an area in which the natural environment is endangered with respect to its biology, mainly owing to atmospheric pollution. Among the described stations, Nos 2, 5, and 6 receive the agricultural run-off and wastes from the neighbouring territories.

Materials for the study of the microbenthos were collected from May 1976 till May 1979, at 2—3 month intervals. When collecting the material

a Starmach's mud sucker was used (unpublished data). Using this device, 75 cm^3 mud samples were taken of sediment mixed with the bottom water layer. The material was examined by microscopic analysis *in vivo*. The qualitative analysis was carried out on the basis of Kahl's (1935) and Liebmann's (1962) keys. The relative number of *Ciliata* was estimated by the assessment method applying a 4-degree scale (1 — very few, i.e. 1—2 specimens under the cover glass, 2 — few — 3 to 10 specimens, 3 — numerous — 10 to 30 specimens, 4 — mass occurrence — more than 30 specimens). In addition, the number of animal specimens in 1 cm^3 of bottom sediment was estimated by calculating the number of specimens in a microscopic preparation made of 0.02 cm^3 of mud mixed with water.

For numerical calculation of the degree of water pollution by means of *Ciliata*, the saprobic index after the Pantle-Buck method (1955) was employed. The frequency of occurrence of species was classifed in three groups. Species encountered only once or very rarely were classified as random (in accordance with the above assessment method), numerous as frequent, and the remainder as appearing in mass numbers. When calculating the annual average figures from the numbers of *Ciliata* at the particular stations the results from 1977 and 1978 were taken as the basis. The results from 1976 and 1979 could not be regarded as representative for this purpose since they included samples collected on two or three dates only.

3. Results

3.1. Characteristics of the *Ciliata* from the particular stations

In the examined material altogether 86 species of *Ciliata* were found. The distribution of the particular species at he investigated stations is given in Table II. The quantitative ratios in this group of *Protozoa* are illustrated by means of the annual averages (fig. 2).

The River Brynica in its middle section (station 1) was relatively pure, as a rule with small numbers of *Protozoa* in the mud throughout the investigation period. The dominating group were the *Ciliata* whose annual average were always under 500 specimens in 1 ml. In the *Ciliata* community were found species belonging to the β-mesosaprobic zone, the α-mesosaprobic zone, or ascribed to both these zones. The species appropriate to the β-mesosaprobic zone prevailed. The *Ciliata* community found here is an indication of little or moderately polluted waters. Most frequent, though represented in small numbers, were the species *Aspidisca costata* and *Cinetochilum margaritaceum*. The *Ciliata* characteristic of a strongly

Table II. Distribution of ciliate at investigated stations in the period 1976-1979

Species	Stations							Species	Stations						
	1	2	3	4	5	6	7a		1	2	3	4	5	6	7a
			code								code				
Askenasia volvox Clap. et L.			•					Metopus spiralis Smith						•	•
Aspidisca costata Dujardin	•	•	•	•	•	•		- undulans Stokes		•					
- lynceus Ehrb	•	•	•	•	•	•	•	- sp.			•		•		
- sulcata Kahl	•							Oxytricha sp.	•		•		•	•	
- turrita Ehrb.							•	Paramecium caudatum Ehrb.	•	•	•	•	•	•	•
Caenomorpha universalis Levander						•		- trichium Stokes							•
Chilodonella cucullulus O.P.M.					•			Paruroleptus lacteus Kahl				•	•		
- turdigula Penard					•			- sp.						•	
- uncinata Ehrb	•	•	•		•	•	•	Plagiopyla nasuta Stein			•			•	
- sp			•	•	•	•		- sp.		•					
Cinetochilum margaritaceum Perty	•	•	•	•	•	•	•	Pleuronema sp	•	•	•	•			•
Codonella cratera Leidy			•		•			Prorodon ovum Stein		•					
Coleps amphacanthus Ehrb						•		- teres Ehrb						•	
- hirtus Nitzsch	•	•	•	•		•	•	- sp.	•	•	•			•	
- incurvus Ehrb						•	•	Saprodinium dentatum Lauterborn					•		
Colpidium sp			•					Spatnidium spathula O.P.M.							•
Cyclidium sp		•		•	•	•		- sp						•	
Didinium sp.							•	Spirostomum filum (Ehrb.) Penard			•				
Dileptus cygnus Clap. et L.		•	•					- minus Roux	•	•	•		•	•	
- monilatus Stokes			•				•	- teres Clap. et L.						•	
- sp.						•		Stentor coeruleus Ehrb						•	
Euplotes patella Kahl	•						•	- polymorphus Müller						•	•
- sp.						•		- sp			•				
Prontonia acuminata Ehrb	•		•			•	•	Strobilidium gyrans Stokes		•	•	•			
- leucas Ehrb.	•						•	Stylonychia mytilus Ehrb			•				
Glaucoma scintillans (Ehrb.) Schew.							•	- sp.						•	
- sp.	•		•	•	•			Trachelophyllum pusillum Perty-Clap. et L.	•	•					
Halteria grandinella O.F.M.	•	•	•	•		•	•	- sp.			•			•	
Heniophrys sp					•			Urocentrum turbo O.F.M.							
Lembadion lucens Maskell		•						Uroleptus sp	•		•			•	
Litonotus fasciola Ehrb.-Wrześ			•					Urostyla sp	•	•				•	•
- sp.	•	•		•		•	•	Vorticella citrina O.F.M.	•						
Loxocephallus sp.			•		•			- limnearis Stokes							•
Loxodes magnus Stokes						•		- similis Stokes			•	•			•
- striatus Engelmann		•			•	•	•	- sp.	•	•			•	•	
- sp.						•		Holotrichs non. det	•	•	•	•	•	•	
Loxophyllum helus Stokes							•	Hypotrichs non det.		•	•		•	•	
Metacystis sp.		•				•									
Mesodinium acarus Stein	•		•	•											
- sp.				•			•								
Metopus acuminatus Stokes						•		Total number in %	30	36	37		27	51	21
- es O.F.M.		•													
- pulcher		•													

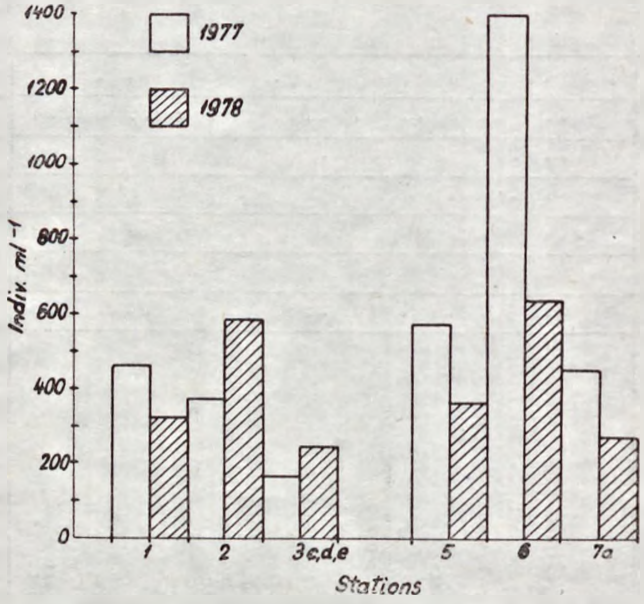

Fig. 2. Annual average numbers of *Ciliata* at investigated stations in the period 1977—1978

polluted environment (polisaprobic ones) appeared only occasionally and in small numbers, thus they played hardly any role in the community.

Before it enters the dam reservoir at Kozłowa Góra (station 2) the River Brynica already constitutes a backwater with respect to it. In the *Ciliata* community there species characteristic of both pure and polluted waters appeared again, the presence of *Ciliata* belonging to all saprobic zones being recorded there. The species from the β, β-α, and α-β-mesosaprobic zones, however, prevailed, though only species typical of the α-mesosaprobic zone (*Aspidisca lynceus* and *Coleps hirtus*) showed distinct continuous occurrence. Species from the oligo- and polysaprobic zones were also encountered here, though very sporadically and in small numbers. The numbers of *Ciliata* at this station were slightly higher than in the upper section of the river (station 1).

The reservoir at Kozłowa Góra (stations 3c, 3d, 3e). In the mud from this reservoir a microfauna moderately differentiated but with small numbers was found, mainly composed of *Ciliata* and *Rhizopoda*. A relatively large proportion of *Rhizopoda*, which often amounted to as much as 50% of the number of specimens found in the mud, is here worth noting. These were undoubtedly forms derived from the great numbers of plankton falling to the bottom. Live specimens accounted for a small percentage only. The community included *Ciliata* from the oligo- to the polysaprobic zones, species characteristic for relatively pure waters occurring in the greatest numbers. However, species characteristic for

strongly polluted waters appeared only once when *Ciliata* from the family *Metopidae* appeared in winter 1979 when the reservoir was covered with ice. The annual numerical averages were lower than at station 1 on the River Brynica (fig. 2).

The section of the River Brynica below the dam reservoir at Kozłowa Góra (station 5) was characterized throughout the investigated period by greater numbers of the *Protozoa* microfauna than in the upper section of this river. The greatest number over the last years was recorded in 1976 (1000 specimens in 1 cm^3), whereas in the following years a gradual decrease in the number of *Ciliata* was observed. The *Ciliata* community included species from oligo- to the polysaprobic, with a distinct predominance of those belonging to the β- and α-mesosaprobic zones. They accounted for over 50% of the total number of species. The most frequently encountered were *Aspidisca costata, A. lynceus,* and *Colpidium colpoda*. The constant components of the microfauna here were the *Rotatoria* and *Nematoda*, always occurring, however, in small numbers.

The Świerklaniec park pond (station 6) was distinguished in the whole material from the examined territory by the greatest abundance of the *Ciliata* fauna. At the same time the *Ciliata* were here the most abundant in comparison with the other water bodies. This station also had the greatest number of *Ciliata* species from all the investigated points, the maximum number being recorded in 1977, with an annual average over 1400 specimens in 1 cm^3, i.e. three times greater than in the relatively fertile lower section of the River Brynica. In the *Ciliata* community there occurred species from β to polysaprobic zones and it defined waters from the β- to α-mesosaprobic zones. Typical polysaprobic species, such as *Caenomorpha* and *Metopus*, appeared in very small numbers only in the summer and autumn. In character the Świerklaniec park pond most resembles an eutrophicated fishpond.

Unlike the Świerklaniec park pond, Lake Chechło-Nakło (station 7a) had a very poor bottom microfauna with very few species, this state being maintained throughout the investigated period.

The River Brynica just below the dam reservoir (station 4) was only marginally dealt because of its different character. Along this section the river flows in a narrow bed lined with concrete, whose bottom is covered with periphyton; hence the typical bottom mud does not develop. For this reason material was taken only in 1976.

3.2. Qualitative changes in the microfauna with respect to seasons

With reference to the seasonal changes in the microfauna of the *Ciliata*, it was found that in the investigation period there occurred great differences in species composition. In addition to species which were recorded continuously throughout, or with only small breaks, there also

appeared species occurring only periodically or altogether sporadically. The group of species which might be described as constant components of the bottom microfauna is small but those ascribed to it were found at all stations. Only seven species were classified as belonging to this group: *Aspidisca costata, A. lynceus, Chilodonella uncinata, Cinetochilum margaritaceum, Coleps hirtus, Halteria grandinella,* and *Paramecium caudatum*. Their presence at all the investigated stations, however, does not mean their uninterrupted occurrence in the investigated period. Generally speaking, these species were present in most samples (over 50%), hence they were regarded as the leading forms in the *Ciliata* microfauna.

The next most numerous group of *Ciliata* (76 species) included those which were described as "frequent". They appeared periodically and were found in less than 50% of the samples. The last group was formed by "sporadic" species, found only a few times in the investigated period, or even once only. Here belong the species *Caenomorpha,* 4 species from the family *Metopidae* (Table II), and plankton species such as *Codonella, Didinium,* or *Strobilidium gyrans*. The plankton *Ciliata* found at the bottom were undoubtedly an incidental element.

The particular stations were characterized by different numbers of *Ciliata* species. The Świerklaniec park pond had as regards quality, the most varied microfauna. Of the total number of 86 *Ciliata* species 51% of them were found there. Also relatively rich in this respect were the Kozłowa Góra reservoir and the River Brynica. However, Lake Chechło-Nakło was the poorest with respect to the number of species (21%). The percentage participation of species at the particular stations is given in Table II.

3.3. Saprobiological characteristics of the water basing on the microfauna

The *Ciliata* community in the River Brynica and in the three water bodies was composed of species representing all saprobic zones, starting with the oligo species, through β-meso- and α-meso- to polysaprobic ones. However, in all cases the indicatory species for the oligo- and the polysaprobic zones were here only accessory elements. In the first place, they occurred sporadically, mostly in very small numbers, frequently only one specimen of the given species being found. Thus, considering their small numbers these species played hardly any role in the community.

The prevailing number of species of the examined community of *Ciliata* were the indicatory animals for the β- or α-mesosaprobic zones. This group dominated not only on account of the number of species but also because of their quantities. In determining the degree of water purity expressed by the saprobity index after P a n t l e - B u c k it was established that the investigated waters are within the water range from β- to

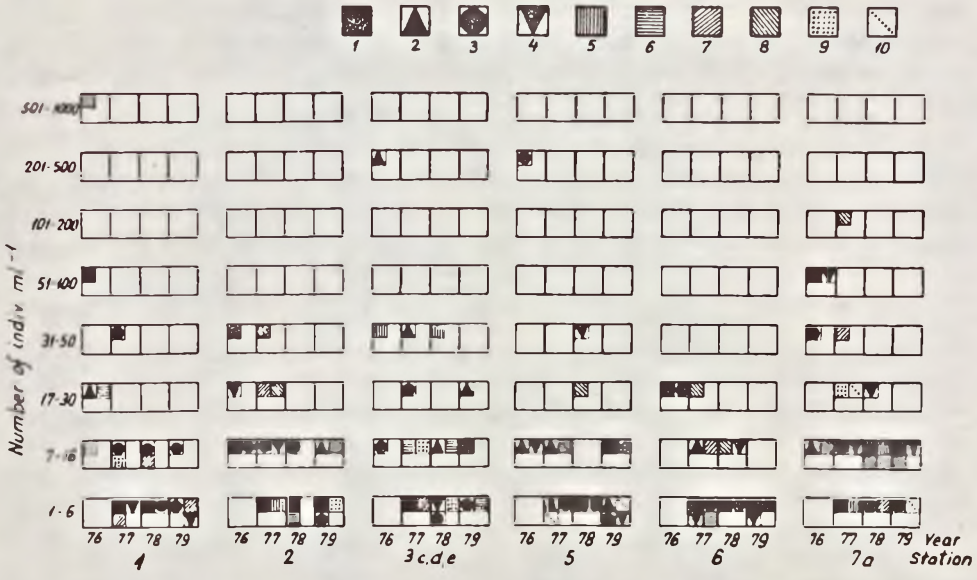

Fig. 3. Occurrence of some more important bioindicators of *Ciliata* at investigated stations. 1 — *Aspidisca costata*; 2 — *A. lynceus*; 3 — *Cinetochilum margaritaceum*; 4 — *Coleps hirtus*; 5 — *Colpidium colpoda*; 6 — *Cyclidium citrullus*; 7 — *Frontonia acuminata*; 8 — *Halteria grandinella*; 9 — *Paramecium caudatum*; 10 — *Spirostomum minus*

α-mesosaprobic. The range of variation of the saprobity index for the particular stations is given in Table III. Comparatively most polluted the water was that of the River Brynica below the dam reservoir at station 5. Over the whole investigated period water from this river section showed an α-mesosaprobic character, due to the inflow of various liquid wastes from the nearby villages and agricultural areas. The Świerklaniec park pond is also numbered among the polluted waters and, to a smaller degree, Lake Chechło-Nakło. Their waters belonged in principle to the β-mesosaprobic type, only at times assuming an α-mesosaprobic character. However, the pollution of these waters had an entirely different back-

Table III Range of variations in the saprobic index at the particular stations in the period 1976-1979

Station No		Saprobic index
River Brynica 1	1	1.6 - 2.4
River Brynica 2	2	2.0 - 2.9
Reservoir at Kozłowa Góra	3 a,b,c,d,e	1.9 - 2.6
River Brynica	5	2.5 - 3.1
Świerklaniec park pond	6	1.6 - 2.7
Lake Chechło-Nakło	7a	1.0 - 2.6

ground. In the park pond it was manifested by the considerable eutrophication of the environment, indicated by the qualitatively rich microfauna of the *Ciliata*, whereas Lake Chechło-Nakło was the poorest with respect to the species occurring there. The water at the remaining stations was slightly polluted, of β-mesosaprobic character. Deterioration of the water quality towards the α-mesosaprobic type was observed only in certain periods, e.g., in the backwaters of the Kozłowa Góra reservoir (station 2) collecting run -off and municipal liquid wastes from the nearest village in the summer, at low water levels, and — in its lower sections — from the dam reservoir (station 3e), silted up in winter when it was covered with ice. The deterioration of the environmental conditions in the water was most frequently manifested by the appearance of certain species from the family *Metopidae*, which are a sensitive index of the progress of oxygen-free processes of the decay of organic matter in the bottom.

4. Discussion

On account of the close vicinity of the Upper Silesian Industrial Region, the investigated territory is subject to the influence of considerable industrial pollution, mostly atmospheric through the deposition of industrial dusts (Skawina 1967, Skawina, Wąchalewska 1965, Pasternak 1974). Similar information for the reservoir at Kozłowa Góra with respect to the sediments was given by Reczyńska-Dutka (1985b). Heavy metals form a considerable percentage of the pollution from the zinc plant in Miasteczko Śląskie (Pasternak 1974). The occurrence in these waters of increased amounts of zinc and lead in particular, as well as of cadmium was observed by Reczyńska-Dutka (1985a). In assessing water purity on the basis of examination of bottom mud, the *Ciliata* community were accepted as criteria, since these organisms are fairly sensitive to the biological properties of the environment, this also having been utilized as the basis for developing the saprobic system by Kolkwitz and Marsson (1909), modified later by Liebmann (1962). Moreover, the *Ciliata* are the dominating group in the microfauna. The authors of the saprobic system established that in waters of various degrees of pollution different groups of organisms develop. The list of species of indicatory animals prepared by various authors for the particular saprobic zones differ considerably from each other. The results of the present study are a confirmation of the fact that cases of close adherence of a given species to a definite saprobic zone are somewhat rare. Among Polish researchers Turoboyski (1970) drew attention to this fact.

As has been indicated in the present study, at stations with α- or β-me-

sosaprobic purity degrees, usually found were the *Ciliata* species which are indicators for all zones, from the oligo- to polysaprobic ones. However, those species characteristic for oligo- and polysaprobic conditions did not play here any great role because of their small numbers. This is a confirmation of the generally acknowledged opinion that *Ciliata* reveal a considerable tolerance to various environmental factors (Noland 1925, Bick 1966, Bick, Kuntze 1974, Czapik 1982). Hence, if we wish to classify this species as indicatory we may do so only if it appears in the material in great numbers. On the other hand, it may be that the opinion of Madoni and Ghetti (1981) is justified. In analysing the application of *Ciliata* for saprobiological analysis, they suggested that different saprobic values of these indicatory organisms should be carefully examined in different geographic zones. In Poland this research was started by Turoboyski (1970), who prepared a list of the indicatory organisms occurring most frequently in surface waters in Poland.

In the course of the present study it was established that the assessment of water purity on the basis of *Ciliata* yielded results similar to the evaluation carried out on the basis of the communities of phytoplankton and periphyton (Bucka 1985). On the other hand, comparison with evaluation on the basis of the zooplankton (Krzeczkowska-Wołoszyn 1985) reveals greater divergencies, especially with reference to the River Brynica and the reservoir at Kozłowa Góra.

In the biological analysis, water purity was evaluated mainly on the basis of the dominating species, i.e. those which showed considerable persistence in addition to greater numbers. The surface waters of the areas of the catchment basin adjoining the heavily industrialized territories were subject above all to atmospheric pollution and showed a weak or medium degree of water pollution. This corresponded to the zones from the β-meso- to α-mesosaprobic, and in the microfauna of the bottom sediments of the investigated waters a community of organisms typical for such waters developed.

5. Polish summary

Ekologia niektórych wód w leśno-rolniczej zlewni rzeki Brynicy w pobliżu Górnośląskiego Okręgu Przemysłowego

8. Orzęski w osadach dennych

Badano orzęski w mikrobentosie kilku powierzchniowych zbiorników wodnych, a to: zbiornik wodociągowy w Kozłowej Górze, dwa zbiorniki rekreacyjne (jezioro Chechło-Nakło i staw parkowy w Świerklańcu) oraz środkowy odcinek rzeki Brynicy powyżej i poniżej zbiornika. Praca stanowi część kompleksowego opracowania podję-

tego przez Zakład Biologii Wód PAN w Krakowie nad zbadaniem stanu czystości wód powierzchniowych na leśno-rolniczych terenach Górnego Śląska. Zlewnia Brynicy wraz z wymienionymi zbiornikami znajduje się na terenie o charakterze leśno-rolniczym, przylegającym do silnie uprzemysłowionego i zanieczyszczonego, głównie na drodze atmosferycznej, regionu GOP.

Celem pracy było jakościowe i ilościowe przebadanie zespołów orzęsków w osadach dennych badanych wód powierzchniowych (ryc. 1) oraz ocena stanu czystości wód na ich podstawie. W badanym materiale znaleziono łącznie 86 gatunków orzęsków (tabela II). Stwierdzono, że badane wody należą do stosunkowo mało bogatych jakościowo (tabela II). Najbogatszy w gatunki był zeutrofizowany staw parkowy w Świerklańcu, a najuboższe pod tym względem było jezioro Chechło-Nakło. Liczebność orzęsków scharakteryzowana za pomocą średnich rocznych (ryc. 2) wskazuje, że najbogatszy pod tym względem był również staw parkowy. Najuboższa liczebnie mikrofauna orzęsków rozwijała się w zbiorniku zaporowym w Kozłowej Górze oraz w jeziorze Chechło-Nakło (ryc. 2). Przy określeniu stopnia czystości wody wyrażonego za pomocą indeksu saprobowości według P a n t l e - B u c k a ustalono, że badane wody mieszczą się w zakresie wód od beta- do alfa-mezo-saprobowych (ryc. 3, tabela III). Stosunkowo najbardziej zanieczyszczoną wodę posiadała rzeka Brynica na odcinku poniżej zbiornika zaporowego (stanowisko 5). Do wód zanieczyszczonych należy też staw parkowy w Świerklańcu (stanowisko 6) i jezioro Chechło-Nakło (stanowisko 7). Wpływa na to dopływ ścieków z powyżej leżących Zakładów Wapienniczych. Jednak na ogólny stan zanieczyszczenia badanych wód wpływa niewątpliwie sąsiedztwo zanieczyszczonego i uprzemysłowionego regionu GOP.

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