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Organizmy wskaźnikowe i ich zmienność ekologiczna

The indicator organisms and their ecological variability

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Abstract — A number of indicator species of plant and animal organisms of the micro- and macrobenthos from various rivers were selected, their zonal association and resistance to different kinds of factory wastes and municipal sewage being determined. The zones of pollution were determined according to the communities of indicator organisms and on the basis of chemical investigations. A number of species of organisms were classified as individual ecological groups: 1. of saprophobous organisms, 2. of saproxenous organisms, 3. of saprophilous organisms, and 4. of saprobiontic organisms. The work was carried out for the purpose of biological analysis of polluted waters.

In the protection of waters against pollution biological analysis of the water is carried out for the purpose of:

1. determination of the composition and the state of the biocoenosis of a given water body,
2. determination of its pollution.

Besides other values this is the only method of investigation which makes it possible to find out whether a given water body is in the natural undisturbed state or if any unfavourable changes have occurred there.

The system of indicator organisms, being in a sense the instrument of this method, is gradually changed and completed. It must be regarded as quite natural, since in connection with the constant development of industry and of its technologies the composition of wastes and their influence on the receivers and organisms are changing and becoming more and more complicated.

In the last ten years the following systems of biological evaluation of wastes have been reported: Starmach (1960), Liebmann (1962), and Fjerdingstad (1964), who also published a work which is a kind of collection of environment charts of various species of organisms (1965).

The author of the present work (1970) gave a list of indicator organisms and their descriptions for the waters of this country, and he is convinced that regional evaluations are indispensable because of ecological differences and often different indicator values of water organisms living in various geographical regions.

Method

1800 hydrobiological analyses of the micro- and macrobenthos have been selected. The microbenthos was investigated as follows: samples of the bottom mud were taken in the littoral part using a pipette with a rubber bulb. The organisms were determined under a microscopic slide (with sides of 24 mm). The number of organisms found under the slide indicated the degrees of frequency: 1st degree — < 3 specimens, 2nd degree — 3-10 specimens, 3rd degree — 11-25 specimens, 4th degree — 25-50 specimens, 5th degree — $>$ 50 specimens.

The bottom macrofauna was taken from 1 square metre of the bottom using a hand net, and determined with the degrees of a corresponding scale, the numbers between 20 and 50 (in relation to 1 square metre) being taken as fairly numerous, and those higher than 50 — as numerous.

The larvae of mayflies and caddis-flies from the stones were collected with tweezers from an area of 1 to 5 square decimetres (using a 1 dcm frame) and calculated for 1 square metre. The scale was similar to that used for the bottom macrofauna.

In Table I the numbers of microbenthos organisms amounting to from 3 to 10 specimens were determined as fairly numerous (the mark „—" by the figure), and those above 10 as numerous (the mark „+" by the figure). The numbers from 20 to 50 specimens per 1 square metre of the bottom macrofauna and the organisms from the stones were indicated with figures marked „—", and those greater than 50 with figures with „+".

The frequency of occurrence of organisms was determined according to the degrees mentioned above, in various zones of pollution of the receivers of industrial and municipal wastes as well as in their pure sections.

Table I presents the frequency of occurrence of individual systematic indicator units and characterizes the environmental „background" in the form of the given kinds of wastes. Typical „cases" were considered when a given organism developed as a dominant or occurred as fairly numerous in a certain zone of pollution evaluated on the basis of saprobity and of the general chemical character of the investigated environment. Moreover, the Table also presents the frequency of occurrence of the selected indicator taxons (figures) in relation to the kind of pollution (wastes).

The discussion of the results

Bacteriophyta were determined microscopically according to their morphological features. As resulted from Table I, the ecological „value" of two taxons was most distinctly determined: *Beggiatoa* sp., as a saprobiontic organism, and *Sphaerotilus natans* as a saprophilous organism. The filamentous bacteria, not exactly determined, which are often encountered in the biological analyses, had a wide ecological distribution and were found in the whole zone of saprobity, as well as in the zone of extermination and in the antisaprobic one. They were found to be dominant as far as the β-mesosaprobic zone, while the zone of pure water, the oligosaprobic, and the transition zone between the β-meso and oligo- had these bacteria in small numbers only. Altogether the filamentous bacteria showed a tendency to saprophilia. Similarly *Sphaerotilus natans* has its representatives in all zones, but dominated only up to the β-meso zone inclusive. This bacteria was most frequently found in waters polluted with municipal wastes mixed with those from cellulose works, and it may be inferred that it was typical for this environment.

In the quite pure water *Sphaerotilus* could not dominate. For the bacteria *Beggiatoa* the range of its less numerous occurrence was also wider than for its dominance, but it did not pass the α-zone and hence may be taken for a saprobiontic organism. The phenomenon recorded for the bacteria, that of a wider zonal distribution with less numerous occurrence than with dominance, is wholly natural and understandable because the zones of purer water were not a suitable environment for them and their development could not be so intensive as in the zones of polluted waters.

Ferruginous bacteria — *Leptothrix ochracea* did not reveal any indicator „value" as far as the pollution of the water with organic, easily decomposed, compounds was concerned. They only indicated the content of iron in the water.

The sulphuric bacteria of the genus *Thiothrix* and the putrid *Zoogloea* were so rarely found in the benthos that it was impossible to draw any conclusions about them. Though the polysaprobic waters were often investigated, *Zoogloea* was among the more rarely found organisms, as the investigations concerned flowing waters where the disappearance of oxygen rarely occurred. Hence this organism, which was a very good indicator in the biological treatment of sewage or in the polysabrobic water bodies, probably did not have favourable conditions for its development in the environment of the surface waters which were investigated by the author. The communities of *Zoogloea ramigera* were similarly rarely recorded.

Tabela I. Częstotliwość występowania wyróżnionych taksonów wskaźnikowych w zależności od rodzaju ścieku i strefy zanieczyszczenia.
Litery podkreślone oznaczają rodzaj ścieku, w którym dany takson często występował; rodzaj ścieków: bg - bytowo-gospodarcze (komunalne); br - browarniane; c - z fabryk celulozy; cuk - z cukrowni; ch - z fabryk chemicznych; dr z drożdżowni; f - fenolowe; g - z garbarni; h - hutnicze; k - z kopalni; kok - z koksowni; m - mieszane przemysłowe z bytowo-gospodarczymi (komunalnymi); nf - z rafinerii nafty; prz - przemysłowe (różne); sł - słone; zf - z zakładów filcowych; cz - woda czysta. Przy oznaczeniach złożonych pierwszy symbol oznacza przewagę danego ścieku. Liczby oznaczają ile razy znaleziono dany takson. Znak + przy liczbie oznacza dominację, znak - dość liczne występowanie. Strefy: w - wyniszczenia; an - antysaprobowa; p - polisaprobowa; pα - poli-alfa-mezosaprobowa; α - alfa-mezosaprobowa; αβ - alfa-beta-mezosaprobowa; β - beta-mezosaprobowa; βo - beta-oligosaprobowa; o - oligosaprobowa

Table I. The frequency of occurrence of selected indicator taxons in relation to the kind of wastes and the zone of pollution.
The underlined letters indicate the kind of wastes where a given taxon frequently occurred; Kind of wastes: bg - domestic sewage (municipal); br - from breweries; c - from cellulose plants; cuk - from sugar factories; ch - from chemical factories; dr - from yeast factories; f - phenol wastes; g - from tanneries; h - from steel plants; k - from mines; kok - from cokeries; m - mixed industrial wastes and domestic sewage (municipal); nf - from petroleum refineries; prz - industrial (various); sł - salty; zf - from felt plants; cz - pure water. With mixed symbols the first one indicates the prevailing sewage. The mark + (plus) beside a figure indicates the dominance; the mark - (minus) denotes a fairly numerous occurrence. Zones: w - extermination zone; an - antisaprobic zone; p - polisaprobic zone; pα - poli-alpha-mesosaprobic zone; α - alpha-mesosaprobic zone; αβ - alpha-beta-mesosaprobic zone; β - beta-mesosaprobic zone; βo - beta-oligosaprobic zone; o - oligosaprobic zone.

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
<u>Bacteriophyta</u>	1-	3-	5- 10+	5- 5+	5 4+				
Beggiatoa sp.	bg c c+h+m c+m c+ch cuk c+prz dr+m dr+sł+f g m m+f k+bg								
Leptothrix ochracea Kütz.					3+	1- 2+	1- 6+	3+	5+
	bg cz m								
Sphaerotilus natans Kütz.	2- 2+	12- 2+	5- 48+	12- 36+	18- 54+	24- 28+	23- 19+	5-	3-
	<u>bg</u> bg+m+f br <u>c</u> c+m c+h+m c+ch c+prz c+h+prz cuk dr+sł dr+sł+f g g+br+c h h+m h+bg k k+m k+bg+f k+bg <u>m</u> m+f nf nf+m sł+bg								
Thiothrix sp.				2- 6+					
	dr+sł dr+sł+f								

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
Zoogloea			2-		1-		1+		
	bg								
Zoogloea ramigera Itzig.			1-		2+				
	c c+prz								
<u>Fungi</u>					3-	1-	1-	1-	
Fusarium aquaeductum Lag.			1+				1+		
	bg c cz g+br+c m								
Apodya lactea (Leptomitus lacteus) Ag.			2- 3+	1- 1+	1- 3+	3-			
	bg c cuk m								
<u>Cyanophyta</u>					1-	1-			
Dactylococcopsis rhaphidioides Hansg.	c								
Oscillatoria guttulata v. Goor			1- 1+	2+	3- 2+		2-		
	h <u>m</u>								

Oscillatoria limosa Ag.					3- 2+	1- 2+	14- 1+		1-
	bg k	c m	o+h+prz k+bg		c+h+m	cuk	cz	g	
- tenuis Ag.		2- 1+	1+	7- 4+	2- 5+	3- 1+	6- 2+	1- 2+	1-
	bg m	c sł+bg	cz	dr+sł	dr+sł+f		h	h+m	
Euglenophyta			1-	1- 3+	2- 1+	4-	1-		
Euglena viridis Ehrb.	c+ch k+bg	cz sł+bg	dr+sł		dr+sł+f		n+f	m	
Trachelomonas hispida Stein		1-		3-	6- 1+	2- 1+	1- 1+		1-
	bg sł+bg	c	c+ch	c+prz	c+h+prz		cz	m	
- volvocina Ehrb.		1-					1+		
	c+prz	m							
Bacillariophyceae									
Amphora ovalis Kütz.							1+		
	m								
Asterionella formosa Hassal		1-		2-	1-	3-	1- 1+		1-
	cz	m	nf						
Caloneis amphisbaena (Bory) Clévè					1-	1+	1+		
	cz	m							
Ceratoneis arcus (Ehrb.) Kütz.						3-	3- 10+	1- 1+	1- 7+
	bg	br	oz	g	g+br+c	m	nf		
Cocconeis placentula Ehrb.								1-	
	cz								
Cyclotella Meneghiniana Kütz.					1-	1-	1- 3+		
	k	k+bg	m						

Cymatopleura solea W. Sm.					1+	1-	2-		
	cz	g	m	m+f					
Cymbella lanceolata (Ehrb.) v.H.						1-	1-		
	g+br+c								
Cymbella sp.d.				1-	4-	4- 6+	12- 7+	2- 3+	2- 8+
	bg dr+sł	br g	c g+br+c	c+prz	cuk	oz	c+m k+bg	m	sł+bg
- ventricosa Kütz.		1-		1-	1-	1- 1+	4- 2+	1- 1+	4- 2+
	bg m	c m+ch	c+m nf	c+prz	cz	g	g+br+c		
Diatoma hiemale Heiberg.						1- 1+		1- 3+	1- 1+
	bg	cz							
- elongatum Ag.				1-	2-	1- 1+	2-		
	cz	m	m+ch						
- vulgare Bory		1-		1-	1- 2+	2- 2+	4- 8+	4+	1+
	bg m	br nf	c	c+m	c+prz	cz	g	g+br+c	
Fragilaria capucina Desm.						2-	2- 7+	1+	1- 3+
	bg	m	oz						
- crotonensis Kitton						3- 1+	3- 2+	1-	1- 3+
	bg	c	cuk	cz	g	sł+bg			
Gomphonema angustatum Rabh.							1+		
	k+bg								
- olivaceum Kütz.					1-		1-	1- 2+	
	br	cz	g+br+c	m					

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
Gomphonema parvulum Kütz.							2-		1+
	bg		oz						
Melosira italica Kütz.						1-	1- 2+		
	m		h+m						
- varians Ag.					1-	7- 2+	15- 8+	2- 4+	5- 3+
	bg	c	cuk	cz	g	m	m+ch	nf	
Meridion circulare Ag.		1-		4-	3- 1+	5- 1+	7- 2+	3- 3+	5- 4+
	bg	c	c+m	c+p+z	cuk	cz	dr+sł	dr+sł+f	g
	g+br+c	m	nf						
Navicula cryptocephala Kütz.	1-	1-	1-		9- 7+	1- 9+	30- 31+	4- 3+	7-
	bg	c	c+m	c+prz	cz	h+m	k	k+bg	m
	m+f	m+k+f							
- cuspidata Kütz.		1-		12- 4+	4- 1+	6- 5+	3- 1+	1+	1+
	bg	br	br+bg+c	c	c+m	c+prz	cz	dr+sł	g
	m	m+f	sł+bg						
- - v. ambigua Clévè				2- 14+		1- 3+			
	dr+sł	dr+sł+f	m+f	sż+bg					
- gracilis Ehrb.					1-		1+	1+	1+
	c	cz							
- hungarica Grun. v. capitata (Ehrb.) Clévè						1-	6-		
	cz	h+m	k	k+bg	m				
- radiosa Kütz.							1-	1+	
	cz								

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
Navicula sp. d.		1- 2+		5-	2- 3+	12- 4+	13- 9+	3- 1+	4- 3+
	bg	c	c+m	c+prz	cz	dr+sł	g	k+bg	m
	m+f	nf							
- viridula Kütz.	1-	5- 2+		1-	12- 5+	10- 3+	10- 15+	3- 1+	3- 2+
	bg	c	c+m	c+prz	o+h+prz	cz	g	g+br+c	h
	k	m	m+f	m+ch					
Nitzschia acicularis W. Sm.		1-	2-	8-	18- 7+	12- 10+	18- 12+	4-	1- 1+
	bg	br	c	c+m	c+prz	c+ch	c+h+prz	cz	dr+sł
	b	g+br+c	h+m	k	k+bg	m	nf	sł+bg	
- dissipata Grun.		1-		1-		1-	1-		
	br	c+m	c+prz	m					
- linearis W. Sm.				1-	5-	1-	5- 5+	3- 2+	2-
	bg	c	cuk	cz	h+m	m	m+k+f		
- palea W. Sm.		1- 1+	4-	9- 6+	9- 11+	7- 12+	8- 11+	3-	1-
	bg	c	c+m	c+ch	cz	c+h+prz	dr+sł	dr+sł+f	g
	g+br+c	h+m	h	k+bg	m	m+f	m+k+f	nf	prz
	sł	bg							
- sigmoidea A. Sm.				1- 2+		2- 2+	6- 2+		1-
	cz	dr+sł	dr+sł+f	k	m	sł+k			
Nitzschia sp. d.	1-	7-	8-	18- 3+	31- 8+	20- 15+	28- 35+	10- 4+	15- 9+
	bg	c	c+h+prz	cuk	c+prz	cz	c+m	dr+sł	g
	h	h+m	m	m+f	m+k+f	k+bg	sł+bg		
- vermicularis Gr.				6-		2- 4+	2-		
	dr+sł	dr+sł+f	m	m+f	sł+bg				

Pinnularia viridis Ehrb.				1-	1-	2-	3- 2+		2-
	c	cz	dr+sł+f		h	m			
Surirella ovata Kütz.				7- 4+		3- 2+	1- 3+	1- 1+	2-
	dr+sł	dr+sł+f	g	k	m	sł+bg			
Synedra ulna Ehrb.	2-		1-	14- 1+	19- 6+	21- 21+	25- 29+	2- 7+	5- 22+
	bg	br	c	c+m	cuk	c+prz	ck	cz	
	dr+sł	dr+sł+f	g	g+br+c	h	k			
	m	m+f	m+ch	nf	nf+m	sł+bg			
- acus Kütz.					1-	5- 1+	6-		
	bg	c	cz	m	m+ch	sł+bg			
Tabellaria fenestrata Kütz.									3-
	cz								
- flocculosa Kütz.							1-		2-
	cz								
Chlorococcales									
Scenedesmus acuminatus (Lager.) Chod.							3+		
	bg	cz							
- quadricauda Bréb.				1-		1-	5- 2+		1- 1+
	bg	c	cz	m	sł+bg				
Cladophorales									
Cladophora glomerata Kütz.							4+		3+
	bg	cz	k+bg	m					
Ulotrichales							1- 2+		1- 1+
Ulothrix zonata Kütz.	cz								
Conjugales					2-		1-		
Closterium acerosum Ehrb.	m								

Closterium moniliferum Ehrb.									1-
	cz								
Cosmarium botrytis Menegh.						1-	1- 1+		3- 2+
	bg	br	cz						
Chaetophorales					2+	1+			1+
Stigeoclonium tenue Kütz.	bg	cz	m						
Flagellata apochromatica			1-		1-		2- 1+		
Anthophysa vegetans (O.F.M.) Stein	cz	m							
Flagellata apochr. n. d. sp. div.		12- 4+	21- 12+	4- 19+	14- 17+	11- 4+	23- 20+	5- 2+	9- 2+
	bg	br	c	ch	cuk	c+prz	cz		
	dr+sł+f	g	h	h+m	k	k+m	k+kok		
	k+bg	m	m+f	nf	sł+bg				
Ciliata		2- 1+	4- 6+	3- 3+	11- 4+	11- 2+	2- 1+		
Chilodonella cucullulus O.F. Müll.	bg	cuk	h	h+m	k+bg	m			
Ciliata n. d. sp. div.	3-	7- 1+	17- 18+	10- 16+	34- 19+	23- 18+	19- 3+	2-	6-
	bg	br	c	cuk	c+prz	dr+sł			
	dr+sł+f	g	g+br+c	h	h+m	k+bg	m		
	m+f	sł+bg	zf						
Colpidium campylum Breslau		1-			2-	2- 1+			
	bg	dr+sł	h	m					
- colpoda Stein		2- 1+	6- 18+	6+	4- 12+	4- 1+	5- 3+		2-
	bg	cuk	cz	g	g+br+c	h+m	k+bg		
	m+f	nf	m						
Colpoda cucullulus O.F.M.				1+					
	dr+sł								

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
Euplotes patella Ehrb.				2-	4- 5+	4- 4+	1-		
	bg		cz	g	m	sł+k			
Glaucoma scintillans Ehr.			2-	 1+	4- 6+	2-			2- .
	bg		g	g+br+c	m				
Lionotus lamella Schew.		2-	 1+	1-	1-	2-			
	h+m		k+bg	m	m+f	sł+bg	cz		
Metopus es O.F.M.			 1+	2-	3-				
	bg		m						
Paramecium aurelia Ehrb.				3- 7+	1-	3+			
	bg		dr+sł	dr+sł+f		m	sł+bg		
- caudatum Ehrb.		3-	10- 5+	2- 5+	6- 22+	13- 5+	3-		
	bg		br	cuk	dr+sł	g	h+bg	h+m	
	k+bg		m	m+f	nf				
- putrinum Cl. et. L.			5- 1+	1- 1+	4- 4+				
	bg		cuk	dr+sł	m				
Plagiopyla nasuta Stein			1-	5- 3+	1-				
	dr+sł		g	m					
Prorodon teres Ehrb.			1-	2- 1+	10- 1+	5- 2+			
	bg		dr+sł	k+bg	m	sł+bg			
Spirostomum ambiguum Ehrb.			 2+	 1+	8- 7+	8- 1+			
	bg		c	g	m	sł+bg			

Takson - Taxon	Strefy - Zones								
	w	an	p	pα	α	αβ	β	βo	o
Stentor coeruleus Ehrb.					11-	5-			
	bg		m						
- roeseli Ehrb.				1-	7- 5+	4-			
	bg		m						
Turbellaria								1-	1-
Planaria gonocephala Duges	cz								4+
Oligochaeta							1-		
Limnodrilus hoffmeisteri Clap.		2+		1+	2+	1+	5+		
	h+m		m						
- udekemianus Clap.			2+		1+	1+			
	m								
Tubifex tubifex Müll.		2-	 2+	 9+	 5+	 4+	4- 4+		
	bg+f		dr+sł	dr+sł+bg		dr+sł+f			
	h+m		m	sł+bg					
Tubificidae n. d. sp. div.		1- 2+		1- 5+	4- 8+	14- 31+	6- 13+	1-	2-
	c		cz	m	h+bg	h+m			
Hirudinea					2- 1+	5- 3+	10- 4+	1+	1+
Herpobdella octooculata Carena	br		cz	h	g+m	h+m	m		
Mollusca							1- 1+	2+	3-
Ancylus fluviatilis Müll.	cz		g+br	g+m	m				
Limnaea ovata Drap.									2+
	cz								
- stagnalis L.						1-			
	c								

Physa fontinalis Drap.					2+	3+				h h+bg m+h
<u>Ephemeroptera</u> Baëtis bioculatus Linnè					1+	1-	3- 1+	1-	3+	h+m m cz
- carpatica Mort.									1- 1+	cz
- rhodani Pictet					1- 1+		4+	6+	14- 12+	bg br <u>cz</u> c+tekt g g+m m
Cloëon dipterum L.				1-						c
Ecdyonurus fluminum Pict.						2- 1+	1- 2+	2-	14- 14+	br <u>cz</u> g g+m g+c+br
- helveticus Etn.									3- 10+	<u>cz</u>
- venosus Fab.							2+		2- 6+	bg cz
Epeorus assimilis Etn.							1-		4- 7+	<u>cz</u>
Ephemeroptera n. d. sp. div.						5- 1+	4- 6+	6+	26- 19+	bg br <u>cz</u> o g g+m g+c+br m
Habroleptoides modesta Hag.							- 2+		3- 2+	bg cz
Heptagenia lateralis Curt.								1+	3+	cz

Heptagenia sulfurea M.								1+	7+	cz
Oligoneuria rhenana Imhof									2- 2+	o+tekt cz
Potamanthus luteus L.							2+		1- 1+	cz m g+m
Rhithrogena semicolorata Curt.							3- 1+		1+	bg cz
<u>Plecoptera</u> Plecoptera n. d. sp. div.							2- 2+		19- 11+	bg <u>cz</u> c+tekt m
<u>Trichoptera</u> Hydropsyche lepida Pictet									1+	cz
Rhyacophila vulgaris Pictet									1+	cz
Trichoptera n. d. sp. div.						3-	2-	6-	26-	br <u>cz</u> g h+bg h+m g+br+c
<u>Tendipedidae</u> Tendipes plumosus				1- 3+	6+	1- 4+	1-			c dr+sł dr+sł+f m m+f
Tendipedidae (larwy żółte - yellow larvae)						1- 2+	1-	1-		bg c cz m
Tendipedidae (larwy czerwone - red larvae)				1- 3+	3+	7- 2+		1-	1-	<u>o</u> cz
Orthocladinae (larwy zielone - green larvae)		1-		4- 3+	7- 6+	13- 24+	7-	4-	2- 3+	br o <u>cz</u> dr+sł+bg dr+sł+ h / h+bg <u>h+m</u> <u>m</u> m+f m+h sł+bg
<u>Crustacea</u> Asellus aquaticus L.					2-	2- 1+	1- 1+		1-	br o cz m
Gammarus pulex De G.						1- 1+	1+	8+	9- 9+	c cz

From fungi the occurrence of two common species, *Apodya lactea* and *Fusarium aquaeductum*, was determined, while the tendency of the former to be saprophilous was noted.

Among the species presented in Table I the next type, the blue-green algae- **Cyanophyta,** did not reveal any organisms which could have any exact indicator value. *Oscillatoria tenuis* and *Oscillatoria* sp. div. dominated, beginning from the poly- to the β-oligo and from the p-α to the oligo zone. Since *Oscillatoria guttulata* occurred rather rarely in the investigations, the available material was to scanty for the determination of its ecological character.

Among pigmented euglenoids (**Euglenophyta** type) *Euglena viridis* occurred as a dominant only in strongly polluted waters in agreement with its well- known saprophilous character. However, the scanty records do not present it distinctly, there being a similar problem with *Trachelomonas hispida.*

The class of diatoms — *Bacillariophyceae* was the most numerously represented — of all the algae of the investigated waters, hence the greatest number of different species was elaborated. Various *Achnanthes* species not exactly determined occurred as saproxenous organisms and were dominants only in the β-mezo and oligosaprobic zones. The species *Ceratoneis arcus* did not occur in the zones of strong pollution beginning from the „intermediate" α-β zone. It may be included with saproxenous organisms and qualified as typical for pure waters in the natural state without any artificial sewage pollution. The species *Cymbella* sp. div. might be qualified as most frequently occurring in the waters not polluted with wastes but they could also occur in great numbers in the α-β — mesosaprobic zone, in not great numbers in the α-zone, and could even appear in the poly- α — mesosaprobic zone. It is worthy of note that they occurred in waters polluted with various wastes.

The diatom *Cymbella ventricosa* was found in the receivers of various wastes but it had some saproxenous characters. *Diatoma vulgare* occurs as a dominant in the zone of purer waters but also in the α-meso-saprobic zone, i. e. in the zones of strong pollution, while in the zones of the strongest pollution its development was neither numerous nor strong. The ecological category of this diatom does not as yet seem very certain. *Fragilaria capucina* occurred as a saproxenous organism and a dominant only in the zones from β-meso to oligo, and *F. crotonensis* in those from α-β- mesosaprobic to oligo. In the more polluted zone it was not noted in numbers of any practical significance. It may be classified as a saproxenous organism. The diatom *Melosira varians* may be classified as a saproxenous organism typical for water without artificial pollution and also for waters slightly polluted with domestic sewage.

Meridion circulare should rather have a saproxenous character and was found in the waters with various wastes. *Navicula cryptocephala* could dominate in the zones from α to β, and even but more rarely in the β-oligo one. But this diatom was not numerous in the oligozone, while it dominated in the zone of strong pollution and was found frequently in the municipal and mixed wastes and also in waters without wastes. *N. cuspidata* most frequently dominated in the zones of very strong pollution but it could also appear as a dominant in pure water. It is difficult to determine it as an indicator. Its variety var. *ambigua* occurred as a saprophilous organism. *N. viridula* resisted a very strong and also a toxic pollution. It often dominated in the environment with municipal or mixed wastes, though it could as well be a dominant in pure waters. The dominance was found most frequently from the β-meso to α-zone and this diatom revealed saprophilous as well as saproxenous features. As might be expected, *Nitzschia acicularis* was saprophilous and often occurred in water bodies with wastes from cellulose works together with mixed ones, but it also appeared in waters without wastes. *N. linearis* was not dominant in zones more polluted than the β-mesosaprobic zone and is a saproxenous organism occurring most often in waters without wastes. *N. palea,* a very common diatom in polluted waters, is resistant to many wastes; it was most often found in an environment polluted with municipal sewage or with mixed wastes. It was encountered as a dominant in the zones of the strongest pollution, but also in the β-meso zone, it was never dominant in the quite pure oligosaprobic water. It could also appear in the water which was to a high degree antisaprobic. It can be classifield as a saprophilous organism. *N. sigmoidea* revealed saprophilous tendencies. *Nitzschia* sp. div., not exactly determined and presented jointly, had a very wide zonal distribution, especially when found in not very great numbers. They often occurred in waters with domestic sewage, with wastes from cellulose plants, with mixed wastes, in pure waters, and also but not so often in media polluted with other wastes. *Synedra ulna* also had a very wide range of occurrence but its disappearance in the zones of strong pollution, beginning from the α-zone, may be distinctly seen in Table I, thus it had rather saproxenous tendencies.

The order *Chlorococcales* was presented only in a small range in the Table because these organisms are generally not numerous in the microbenthos of polluted flowing waters. A common species, *Scenedesmus quadricauda,* dominated in only three cases in zone of purer waters.

In the present work green algae of the *Cladophorales, Ulotrichales,* and *Chaetophorales* are elaborated only on a limited scale. It may only be concluded that the alga *Stigeoclonium tenue* was found dominating in zones of strong pollution and in α—β, and oligo zones, while other species dominated in less polluted or pure waters. The species from the

Conjugales dominated only in the β-meso and oligosaprobic zones of purer waters.

The organisms of the physiological group of consumers will be discussed below.

Flagellata apochromatica are given in Table I without specification of individual species. It was found that the range of their occurrence might be very wide, including all zones from the oligo- to poly-, together with the zone of so called poisoned water. The frequency of their dominance distinctly decreases in the zones of purer water, so it may be inferred that in the main they are largely saprophilous organism. They were especially often found in waters with mixed wastes and domestic sewage. Moreover, these organisms occurred in waters with very varied wastes, and even fairly often in the microbenthos of pure waters, but only in small numbers. Among *Flagellata apochromatica* the species *Anthophysa vegetans,* the indicator of iron in the water, was very rarely found in the microbenthos either in fairly small numbers or as a dominant.

Ciliata such as *Chilodonella cucullulus, Glaucoma scintillans, Colpidium colpoda, Paramecium aurelia, P. caudatum, Spirostomum ambiguum,* and *Prorodon teres* revealed their saprophilous character as they dominated in very strongly and strongly polluted waters, their numbers decreasing in the purer zones. The species *Paramecium putrinum* behaved as a distinctly saprobiontic organism.

In the occurrence of *Ciliata* in the waters polluted with different wastes the following dependences may by observed: the characteristic indicators for waters with domestic (municipal) sewage were *Chilodonella cucullulus, Colipidium colpoda, Paramecium caudatum, Stenor roeseli,* and *S. coeruleus,* as well as the species not exactly determined and presented globally; in waters with mixed municipal sewage and industrial wastes *Chilodonella cucullulus, Colpidium colpoda, Paramecium caudatum,* and other *Ciliata* presented globally. Thus it may be seen that this group was typical of strongly and very strongly polluted waters.

Turbellaria were only found in very pure water.

Oligochaeta such as *Tubificidae* sp. div. *Tubifex tubifex,* and *Limnodrilus hoffmeisteri* may be considered as saprophilous organisms resistant to toxic compounds, though in the zones of weakly polluted water they were also found in dominance. However, it must be considered that these organisms occur in those zones of water bodies where, especially under the influence of wastes, the bottom reveals stronger organic pollution than the water.

The evaluation of the water was mainly based on the communities of organisms from the littoral parts of the receivers of wastes and also on the chemical analyses. The most frequent occurrence of the species *Tubifex tubifex* in water with mixed wastes, and of various other species

of *Tubificidae* in water with municipal sewage, with wastes from cellulose works, and with mixed wastes was also recorded.

Hirudinea, species *Herpobdella octooculata*, may be characterized as saprophilous, but the frequent occurrence of this species also in the zones of pure water arouses certain doubts. It was most often found in waters with mixed wastes.

Mollusca dominated in strongly polluted waters and in those of transition character between the α and β zones, or in the β zone of relatively pure water, and also in the β-oligo and oligosaprobic zones.

Mayflies — **Ephemeroptera**: the larvae of the species *Baëtis rhodani, Ecdyonurus fluminum, Heptagenia sulfurea,* and various species not exactly determined showed fairly distinctly their saproxenous character, as they dominated in purer waters. The species *Ecdyonurus helveticus* and *Epeorus assimilis* (especially the former) revealed their saprophobic character. It was difficult to classify other species definitely as they were too rarely found in sufficient amounts, but it was striking that they principally occur in purer waters and only exceptionally in strongly polluted ones. On the whole two such cases occurred with mayflies. No species if mayfly was found to occur frequently in waters polluted with a particular kind of wastes. This group of organisms was characteristic for quite pure waters or for those slightly polluted (β-mesosaprobic ones).

Plecoptera — various not exactly determined species of caddis-fly dominated in purer waters or in weakly polluted ones. One may consider them to be saproxenous organisms.

The larvae of stoneflies — **Trichoptera** — different species presented globally, also showed their saproxenous character.

The larvae of **Tendipedidae** such as *Tendipes plumosus* and other red larvae of this group were characterized as saprophilous organisms. *Orthocladiinae* (larvae of green colour) dominated most often in the transition α—β mesosaprobic zone; their appearance in great numbers in the zone of pure water aroused doubts as to the saprophilous character of these organisms, especially as they might occur in smaller numbers in pure waters. *Orthocladiinae* were often encountered in water polluted with mixed wastes and with wastes from cellulose works.

Among **Crustacea**, *Gammarus pulex* appeared as a saproxenous organism and principally dominated in purer waters.

Discussion

The present work suggests that the so-called „valency" or „value" or, as it is popularly called, „ecological variability" of organisms in polluted waters is often wider when they occur in small numbers than when they

dominate. There exist certain groups of organism which possess a general distinct tendency to be saprophilous, e. g. *Ciliata,* while others, such as diatoms, have a mainly saproxenous character. No species revealed complete indifference in relation to the zones of pollution and to the character of the water in general. In principle it may be supposed that every species of aquatic organism has its own lesser or greater indicator value. On the basis of the domination of species it was found that one can always find some zones where a given species will not find suitable conditions for strong development. It must be mentioned that pollution with municipal sewage, with industrial wastes mixed with municipal sewage, with wastes from breweries, cellulose and yeast works, is often the „medium" for certain indicator species. The difference of the indicator value of different organisms consists in the fact that the more zones are unsuitable for the abundant development of a given organism the more sensitive it is as an indicator of the zone where it finds the necessary conditions for its dominance. The evaluation of the water should be principally based on all the organisms found in the samples, hence on whole communities of aquatic organisms found in a given station. From the results discussed in the work it appears that at the present state of science the so-called mathematical or statistical methods cannot yet be properly applied for evaluation of the water on the basis of indicator species. It was found in the present work that different organisms have a wide range of occurrence, e. g. the known indicator of pollution *Sphaerotilus natans* could occur in great numbers as a dominant in the zones from polysabrobic to β-mesosaprobic ones, and also in the antisaprobic zone. Hence how is it possible to consider such species as absolute indicators of only one zone and to use these values as allegedly mathematically exact, e. g. in the formula of P a n t l e and B u c k (1955) or in the so-called vector method, as is done by the advocates of these methods? Another formula, that of Z e l i n k a and M a r v a n (1961), does not resolve this problem. According to these last authors *Sphaerotilus natans* is noted with 5 points in the α and polysaprobic zones, while the author's own findings indicate that in our rivers it is often numerous in the β-mesosaprobic zone as well. According to Z e l i n k a and M a r v a n, of the *Ciliata Colpidium colpoda* is noted in the poly and α-zones with 7 and 3 points respectively, while in the present author's investigations it occurred in great numbers in the poly α and β-meso zones. Similar statements may be made as to other organisms. Hence it must be concluded that only the method of evaluation of the water given by S t a r m a c h (1960) (on the basis of communities), by L i e b m a n n (1962), or by K o l k w i t z (1950) may be reliable under the present conditions.

The evaluation of the pollution of water on the basis of the communities of organisms is indispensable in the biological analysis.

Hence the synecological evaluation may be reckoned as the most justified, while the dominance of one of the four main ecological groups of aquatic organisms may characterize the water: with the dominance 1) of the saprobiontic organisms — as very strongly polluted, 2) of the saprophilous organisms — as strongly polluted, 3) of saproxenous organisms — as slightly polluted (organic compounds almost mineralized), 4) of the saprophobous organisms — as very slightly polluted or pure. Such a suggestion for the evaluation system was earlier presented by the author (T u r o b o y s k i 1970).

STRESZCZENIE

Z analiz wykonanych przez autora wybrano szereg najbardziej pospolitych mikro- i makroorganizmów bentosu różnych rzek i określono ich reagowanie oraz częstotliwość występowania w odbiornikach różnych ścieków w poszczególnych strefach zanieczyszczenia. Na tej podstawie określano dane gatunki jako saprobionty, saprofile, saprokseny i saprofoby, zaznaczając ich odporność na różne rodzaje zanieczyszczeń. Stosunki te przedstawiono w tabeli I. W określaniu stref zanieczyszczenia kierowano się synekologiczną oceną środowiska, biorąc za podstawę poszczególne zbiorowiska organizmów jak również wyniki analiz chemicznych. Synekologiczne badania wymagają oczywiście autekologicznej znajomości poszczególnych jednostek systematycznych, co właśnie podkreślono w niniejszej pracy. Omówiono wiele przypadków występowania organizmów wskaźnikowych w różnych warunkach. Spośród najbardziej typowych bakteria *Sphaerotilus natans* była charakterystyczna dla stref w zakresie od poli do β-mezosoprobowej, z tym, że największe nasilenie jej rozwoju występowało w zakresie stref poli- i α-mezosaprobowej, a w zupełnie czystej wodzie bakteria ta mogła wegetować nielicznie. W strefie antysaprobowej, toksycznej, *S. natans* częściej występował w małych ilościach niż w dużych. Można go określić jako saprofilny, charakterystyczny i odporny specjalnie na ścieki bytowo-gospodarcze, mieszane z bytowo-gospodarczymi i przemysłowymi oraz z fabryk celulozy.

Okrzemka *Navicula cryptocephala* występowała najczęściej w strefie β-mezosaprobowej, również była charakterystyczna dla strefy α i pośredniej α—β. Zakres strefowy jej występowania mniej licznego był dużo szerszy niż przy dużej ilości, gdyż obejmował wszystkie strefy. Liczne występowanie notowano w strefach od α do β mezo-oligosaprobowej, przy tym w (tej ostatniej) strefie oligosaprobowej *N. cryptocephala* nie była liczna. Można sądzić, że gatunek ten raczej jest saprofilny i odporny zwłaszcza na ścieki mieszane bytowo-gospodarcze z przemysłowymi i same bytowo-gospodarcze.

Orzęsek *Colpidium colpoda* przy średnio licznym występowaniu miał szeroki zakres strefowy, od strefy anty- do oligosaprobowej, przy silnym rozwoju zakres ten był mniejszy gdyż dosięgał strefy β-mezosaprobowej, charakterystyczne dla niego były strefy poli i α. Można by go określić jako organizm saprofilny, najbardziej odporny na ścieki bytowo-gospodarcze i mieszane przemysłowe z bytowo-gospodarczymi.

Larwy jętki reofilnej *Ecdyonurus fluminum* najczęściej występowały w silnym rozwoju w strefie wody czystej oligosaprobowej, mogły pojawić się licznie nawet w strefie przejściowej pomiędzy α i β, lecz w warunkach szybkiego nurtu, turbu-

lencji i intensywnego natleniania. Gatunek ten, jak wynika z badań, nie jest odporny na ścieki i wykazuje cechy saproksemiczne.

Przedstawicielami organizmów saprobiontycznych, mogących bytować normalnie tylko w strefach bardzo i silnie zanieczyszczonych, mogą być np. bakterie *Beggiatoa, Spirillum* lub inne typowe dla środowiska gnilnego (dające się określić przy pomocy mikroskopu), dalej orzęski tzw. „siarkowodorowe", bytujące w takim środowisku lub różne wiciowce bezbarwne.

Wyżej wymienione formy bakterii i pierwotniaków są odporne na ścieki bytowo-gospodarcze i wiele innych przemysłowych. Największe trudności związane są z opracowaniem saprofobów — typowych organizmów wód czystych. Gatunki, które mogą rozwijać się silnie tylko w strefie olisaprobowej lub katarobowej, należą raczej do wyjątków w naszych rzekach.

Odnośnie do organizmów wskaźnikowych należy ogólnie stwierdzić, że wytypowanie gatunków specyficznych dla jakiegoś określonego pojedynczego rodzaju ścieków fabrycznych jest rzeczą bardzo wątpliwą, gdyż takie określenie jest praktycznie możliwe tylko dla ścieków organicznych w szerokim pojęciu i w mniejszym stopniu dla nieorganicznych np. ścieków słonych. Można natomiast łatwiej określić gatunki charakterystyczne jako odporne na dane ścieki, jak to obszerniej omówiono w pracy.

REFERENCES

Fjerdingstad E., 1964. Pollution of Streams Estimated by Benthal Phytomicro-Organisms. I. A. Saprobic System Based on Communities of Organisms and Ecological Factors. Int. Rev. ges. Hydrobiol., 49, 63-131.

Fjerdingstad E., 1965. Taxonomy and Saprobic Valency of Benthic Phytomicro-Organisms. Inst. Rev. ges. Hydrobiol., 50, 1-604.

Kolkwitz R., 1950. Ökologie der Saprobien. Über die Beziehungen der Wasserorganismen zur Umwelt. Schriftenreihe Ver. Wasser-, Boden — u. Lufthygiene 4, 1-64.

Liebmann H., 1962. Handbuch der Frischwasser und Abwasserbiologie. 1, Jena, G. Fischer Verl.

Pantle R., H. Buck, 1955. Die biologische Überwachung der Gewässer und die Darstellung der Ergebnisse. Besondere Mitt. Deutsch. Gewässerk. Jahrb., 12.

Starmach K., 1960. Biologia Sanitarna. Kraków, PWN.

Turoboyski L., 1970. Listy organizmów wskaźnikowych najczęściej spotykanych w wodach powierzchniowych Polski. Mat. Bad. IGW, 5, 2, 1-78.

Zelinka M., P. Marvan, 1961. Zur Präzisierung der biologischen Klassifikation der Reinheit fliessender Gewässer. Arch. Hydrobiol., 57, 389-407.

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