| ACTA HYDROBIOL. | 15 | 1 | 51—88 | KRAKÓW 1973 |
| --- | --- | --- | --- | --- |

**KRYSTYNA KYSELOWA**

# Plankton stawów zasilanych ściekami cukrowniczymi

# The plankton of ponds enriched with wastes from beet sugar factories

Mémoire présenté le 6 mars 1972 dans la séance de la Commission Biologique de l'Académie Polonaise des Sciences, Cracovie

Abstract The feeding of ponds with wastes from sugar factories generally stimulated the growth of phyto- and zooplankton. A high concentration prolonged the period of self-purification. The development of the algae considerably outpaced that of zooplankton. The succession of individual groups of plankton followed in four stages whose length was affected by the concentration of wastes. Stage I — of heterotrophy, showed the beginning of development of *Volvocales* (mainly genus *Chlamydomonas*) and *Euglenophyceae* (genera *Euglena, Phacus*) and an almost total lack of zooplankton. It was a period of high $BOD_5$ and COD, and of oxygen deficit. Stage II — of hyperautotrophy, was characterized by the appearance of *Chlorococcales* and *Cryptophyceae* with growing numbers of zooplankton (mainly rotifers). It was correlated with a further decrease in $BOD_5$ and COD and with a high content of oxygen. In this stage the mineralization processes of organic substances from the wastes were almost at an end and the content of oxygen was often very high. In the III, transition, stage a decrease in the number of algae and an increase in *Cladocera* were observed. Stage IV was characterized by stabilization of the chemical conditions and by the formation of phyto- and zooplankton communities characteristic for normally utilized ponds.

The aim of the present work was to characterize the phyto- and zooplankton of ponds filled in the years 1967 and 1968 with wastes of different concentration. The ponds are situated in the Mnich complex (district Cieszyn) of the Experimental Fishery Farms of the Laboratory of Water Biology of the Polish Academy of Sciences at Gołysz. The wastes used in the experiments came from the beet sugar factory in Chybie.

The Polish beet sugar industry, whose production occupies the tenth place in the world, uses enormous quantities of water. It was calculated that about 60 m³ of water is needed for the production of 1 ton of sugar



http://rcin.org.pl

(Zaręba 1969); at the same time this industry drains away about 110 mil. $m^3$ of wastes in a year, and these insufficiently purified wastes unfavourably influence the receivers, though they could be utilized in agriculture as well as in carp ponds (Wierzbicki 1959, 1963, Tomczyńska 1969). The load of pollution released in sewage is very large. It is estimated that, on the average, the wastes obtained in the processing of 1000 tons of beets, treated in Nolt ponds, possess a large content of organic substances, corresponding to $BOD_5$ of about 4440 kg $O_2$ (Kołaczkowski, Bierwagen 1960). According to Wierzbicki (1963), 1 $m^3$ of mixed wastes contain on the average 30 kg N (total nitrogen), 10 kg $P_2O_5$, 50 kg $K_2O$, and 170 kg CaO, hence fed into a fish pond in suitable concentration they can replace fertilization. This kind of wastes only partially purified, introduced in great amounts into receivers, which are mainly small rivers, effect damages in natural biocenosis, producing a mass development of bacteria and aquatic fungi. More than once such action has been observed in biological studies on small rivers polluted by wastes in the period of the beet sugar campaign in Poland. Several authors also drew attention to the indirect threat to ponds and lakes (Gabański et al., 1934, 1937, 1938, Kulmatycki et al., 1931). The above-mentioned works had a fishery approach. After the war the problem was taken up and widened by Michalski (1948), Cabejszek et al. (1961), and Dojlido et al. (1964). The cited works approached the problem from the point of view of the negative influence of sugar factory wastes on the biocenosis and pointed out the unfavourable changes in the chemism of water.

As no efficient methods of treatment are known, for a long time the beet sugar industry wastes have been purified in accumulation lagoons in the grounds of the factories. A separate problem is presented by the utilization of wastes in pond management as has already been done with municipal sewage. The first experimental trout farm which utilized diluted municipal sewage from a sewage treatment plant was established near Berlin in 1887 (Demoll 1937). After a time, a method of biological ponds, called the Hofer method after its author, was developed in Germany. It was based on the utilization of municipal sewage in carp ponds and resulted in good growth of fish (Walter 1922, Demoll 1937). Similar experiments were carried out in the Soviet Union in the thirties (Mejen 1932). The arrangements installed by Stroganov (quoted according to Pytlik 1954) in Moscow for the treatment of municipal sewage were based on a different principle from Hofer's biological ponds. Their principle was continuous flow, no dilution, and fishery utilization. The self-purification was effected by anaerobic and aerobic processes. This principle is still employed in many localities in the Soviet Union, where municipal sewage is treated in ponds (Winberg, Lachnowicz 1968).

http://rcin.org.pl

It has also been known for a long time that not only municipal but also industrial wastes can be treated in ponds, fertilizing effects being obtained as well. If fish-culture is carried out, ponds play a double part: to their old function in fish-culture another not less important is added: that of purification of sewage and hence of protection of rivers against pollution. Already the experiments carried out in Germany before the war indicated the possibility of utilization of wastes from cellulose factories, properly diluted with clean water, in fish ponds (Graf 1926, Winberg, Lachnowicz 1968). The wastes of different branches of the food industry, such as spirit distilleries, starchworks, breweries (Graf 1926), dairies (Pytlik, Svec̆ 1954 a), and slaughter houses (Pytlik, Dus̆ek 1956), were also successfully used in pond management. Graf pointed out the utilization of wastes of sugar factories as early as 1926. After the war the problem was taken up in Czechoslovakia, where an original method was proposed and developed by Pytlik et al. (1954, 1954 b). This is a method of accumulation and assimilation lagoons. The author recommended the liming of ponds in order to adjust the reaction of the water after the inflow of acid beet sugar factory wastes, and hence to create better conditions for the processes of biological self-purification. The principle of this method is the unflowability of ponds and the culture of fish in them.

With regard to the problem of formation of biocenosis in the ponds used in biological treatment of municipal sewage, investigations of phyto- and zooplankton have been repeatedly undertaken. The works of Loedolff (1964), Arora (1966), Kalisz et al. (1966), Bożek et al. (1966), Uhlmann (1966a, 1966b, 1967), and Klimowicz (1968) can be mentioned here. In the ponds supplied with municipal sewage high yields of fish can be obtained in consequence of good development of the trophic basis, which forms the natural food of fish (Wolny 1962).

The first hydrobiological investigations concerning the phyto- and zoocommunities of plankton in an experimental pond fertilized with wastes from a beet sugar factory were carried out by Sládec̆ek et al. (1958). The authors presented comprehensive data on the forming of phyto- and zooplankton and on the chemism of a reservoir where the wastes were treated using Pytlik's method with full fishery exploitation. Prosjanyj et al. (1965) were interested in the utilization of such wastes in accumulation lagoons for fish-culture in the Ukraine; they also presented the dynamics of the development of plankton. Other Soviet authors were engaged in a similar problem, carrying out complex chemical and biological observations of ponds on the filtration fields at Minsk (Sivko, Lachnovic̆ 1967), while Ilchenko et al. (1969) investigated the algae in sludge tanks and technological ponds of a sugar factory in the Ukraine, to which chlorella was introduced to activate the processes of self-purification.

In spite of a large number of works on the treatment of sugar factory

http://rcin.org.pl

wastes in ponds, the succession of phyto- and zoocommunities in this kind of reservoir has not yet been investigated in detail. Among other things, it resulted from the fact that the processes of self-purification of stagnant waters were less know than those of the flowing waters.

## General characteristic of ponds and methods of investigation

For the investigations on the effect of fertilization with sugar factory wastes the following ponds were selected: Polny III, Łąkowy, Zimowy Wielki, and Żabiniec. Table I presents some data concerning these ponds.

In 1967, parallelly with chemical (Lewkowicz 1973) and other biological (Grabacka 1973, Huk 1973, Zięba 1973) investigations, the samples of plankton were taken at two points of the ponds Polny III and Łąkowy. One point was situated at the outflow and the other at the inflow; Polny III was kept continuously filled for two years, hence more samples were taken from it than from Łąkowy, which was drained in autumn 1967. At the beginning of the season and in winter the samples were taken every month, and from June at intervals of a few to several days. In 1968 the experiments were repeated on the ponds Zimowy Wielki and Żabiniec, using different concentrations of wastes. In that year the samples were taken from the last named ponds and from the ponds Polny III and Łąkowy.

Plankton was collected with a 5-litre Patalas bathometer. After twofold scooping, the water was poured into a pail, stirred and 9 litres were strained through a plankton net of No 25 bolting cloth. It was immediately fixed with 4 per cent formalin. From a sample usually condensed to 100 ml, 0.5 ml was taken to a Kolkwitz chamber for counting of the animal organisms and larger algae. The biomass was also calculated using the table for standard weights (Starmach 1955). The numbers and biomass of zooplankton were calculated for 1 l of water. The remaining 1 l of unfiltered water was used for the examination of phytoplankton. If was treated with Lugol solution, sedimented for 10 days, carefully syphoned, centrifuged to lesser volumes (usually to 100 ml), and treated with 4 per cent formalin. The qualitative composition of algae were determined on examination of 3 specimens. The quantitative composition was determined by counting the individuals with a net micrometer eyepiece, taking as units individual cells as well as colonies and filamentous algae. From each sample of 100 ml volume, condensed usually to 5 ml, two specimens were always prepared using a drop of 0.05 ml for each. In each specimen all algae were counted within 20 fields of view limited by a square of the micrometer net. Each time the surfaces of the encountered algae were also measured, relating them to the known surface of the

http://rcin.org.pl

Tabela I. Niektóre dane dotyczące badanych stawów

Table I. Some data concerning the investigated ponds

| Staw / Pond | Powierzchnia w ha / Area in ha | Rok badań / Year of investigation | Okres dopływu ścieków / Period of wastes supply | Rozcieńczenie ścieków / Wastes dilution | Wapno Data / Lime Date | Ilość / Amount t/ha | Początek masowego rozwoju fitoplanktonu / Beginning of mass phytoplankton development |
|---|---|---|---|---|---|---|---|
| Polny III | 9.0 | 1967 | XII 1966 - - II 1967 | 1 : 0 | XI 1966<br>III 1967 | 2.5<br>2.0 | 25.IV.1967 |
| | | 1968 | Bez ścieków Without wastes | Bez ścieków Without wastes | IV 1967 | 3.0 | |
| Łąkowy | 8.1 | 1967 | I - II 1967 | 4 : 1 | XI 1966 | 1.5 | 29.III.1967 |
| | | 1968 | Bez ścieków Without wastes | Bez ścieków Without wastes | | | |
| Zimowy Wielki | 8.0 | 1968 | XI 1967 - - I 1968 | 1 : 3 | V 1968 | 2.8 | 26.III.1968 |
| Żabiniec | 10.0 | 1968 | XI 1967 - - I 1968 | 1 : 4 | ------ | | 26.III.1968 |

http://rcin.org.pl

squares of the micrometer net. The method proposed by Starmach (1969 a, 1969 b, 1969 c, 1969 d) and afterwards used by Bucka and Krzeczkowska-Wołoszyn (1969) was applied here. Thus, not only the number of algae was recorded but it was also attempted to determine their size in order to obtain an index corresponding in some measure to the idea of agreement or quantitativity, employed in the sociology of higher plants. A 40× lens and 12× eyepiece were used, in which assembly one small square of the net micrometer had a surface of 128 $\mu^2$. In consideration of the fact that the cells of algae assimilate with their whole surface while only one plane was measured, it was conventionally multiplied by 2. In this way approximate assimilation surfaces, active in the process of photosynthesis and forming the place of mutual contact with the environment (Starmach 1969 a), were obtained. The surfaces of algae calculated in $\mu^2$, $mm^2$, or $cm^2$ do not express correct sizes but only proportional surfaces, which indicate the ratio of one individual to another. The numbers and surfaces of algae were calculated for 1 l of water.

## The composition of phytoplankton

In the phytoplankton of ponds filled with beet sugar factory wastes 293 systematic units were determined, among them 241 species with varieties and forms. Figures 1—3 illustrate quantitative occurrence of certain taxons at different periods (above all of the dominants) determined from the following groups: *Cyanophyceae, Euglenophyceae, Cryptophyceae, Flagellata apochromatica, Volvocales, Chlorococcales,* and *Conjugales.*

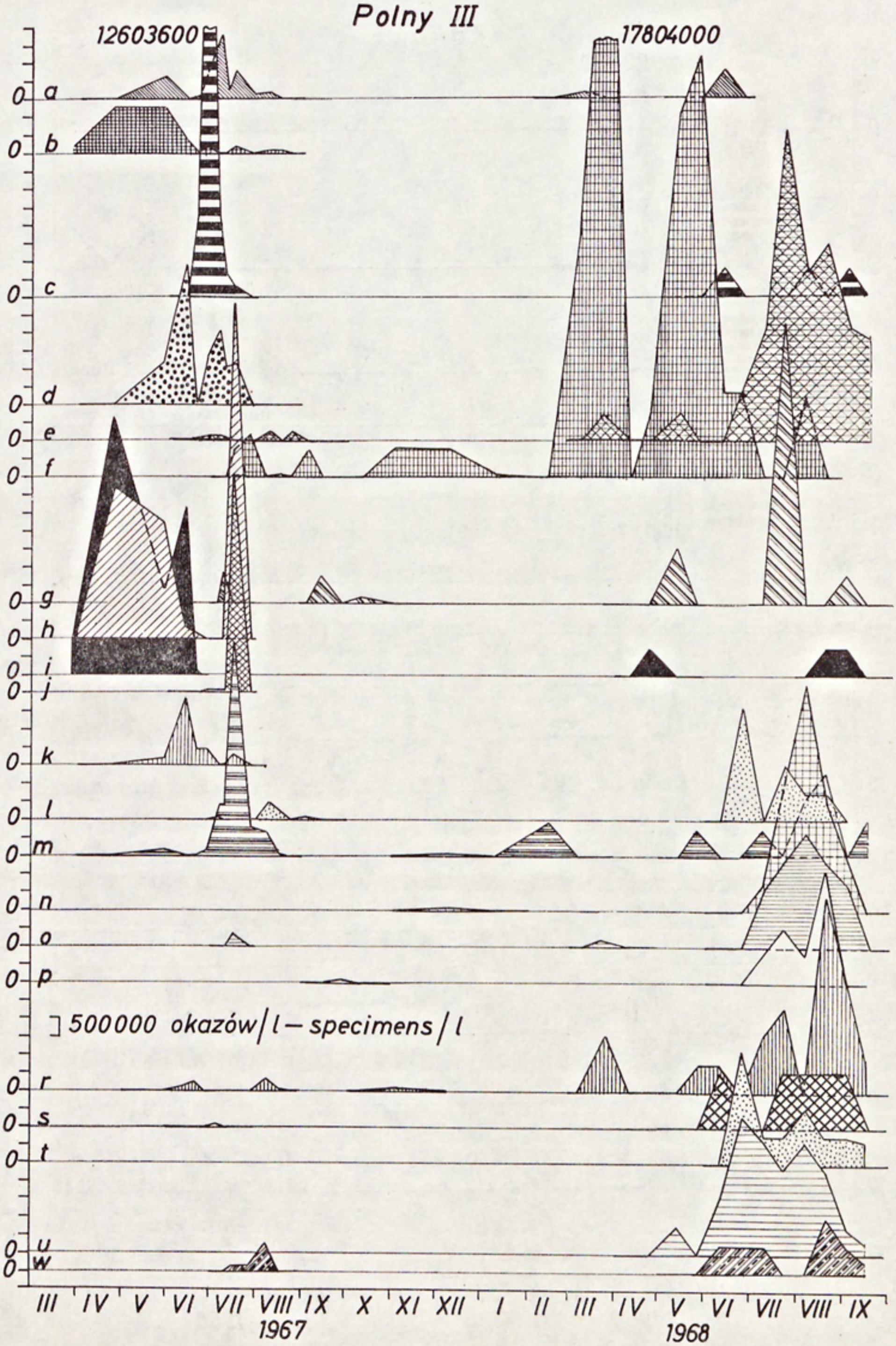
*Cyanophyceae* — the blue-green algae — occurred often in fairly large numbers. Among the most frequently recorded were species of the genera *Merismopedia* (*M. tenuissima* Lemm., *M. glauca* (Ehr.) Näg.), *Gomphosphaeria,* and *Oscillatoria.* It is characteristic that in the investigated ponds usually no water-blooms of blue-green algae took place, and no abundant development of species commonly found in fertilized carp ponds, such

→

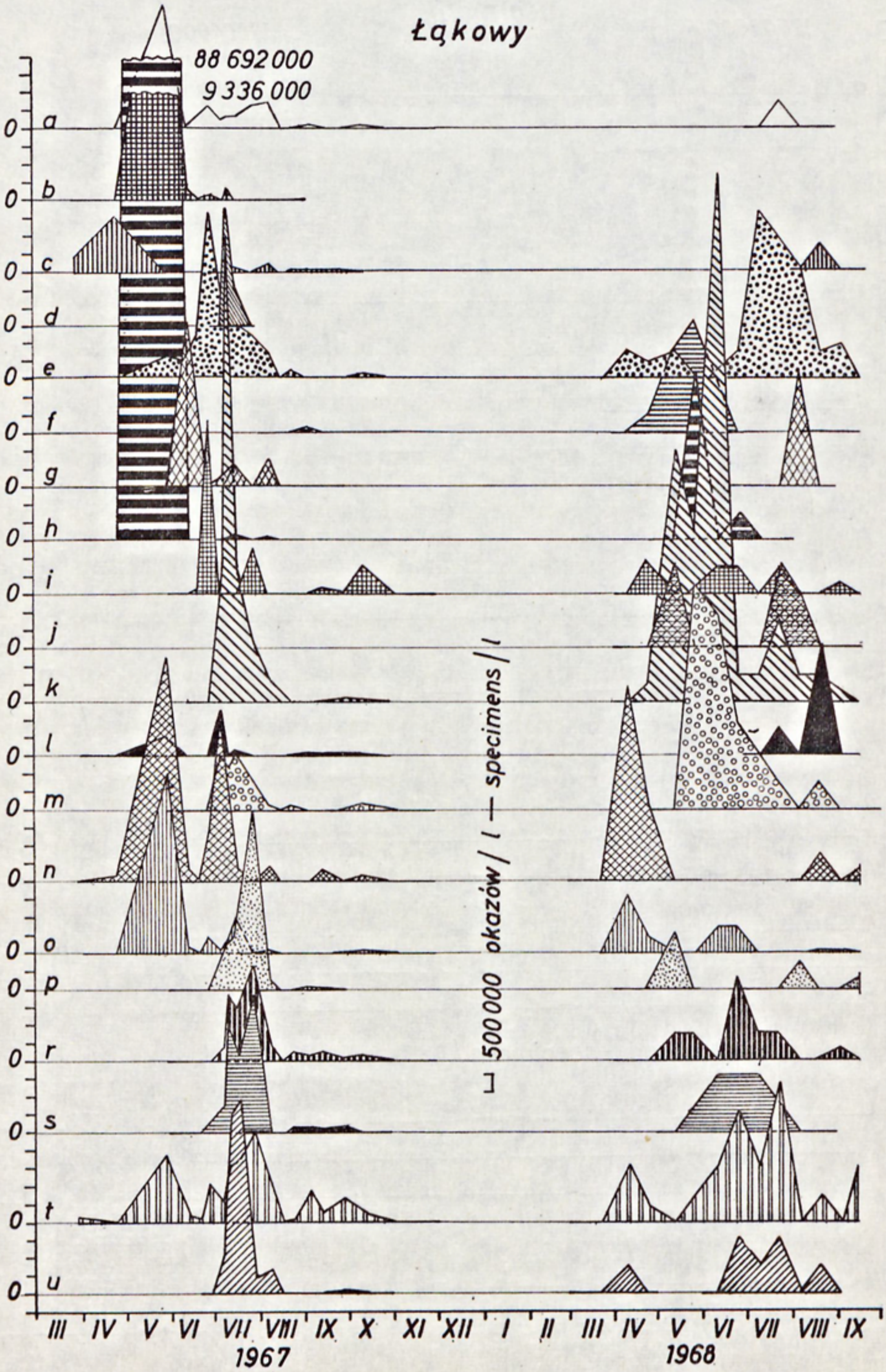
Ryc. 1. Występowanie liczniejszych glonów w litrze wody w latach 1967—1968 w stawie Polny III

Fig. 1. Occurrence of more numerous algae per litre of water in 1967—1968 in the pond Polny III: a — *Euglena proxima,* b — *E. viridis,* c — *Phacus Wettsteinii,* d — *Ph. caudatus* var. *minor,* e — *Trachelomonas volvocina,* f — *Cryptomonas Marssonii,* g — *Cryptomonas* sp. div., h — *Flagellata apochromatica,* i — *Chlamydomonas* sp., j — *Brachiomonas crux,* k — *Uva* sp. div., l — *Coelastrum microporum,* m — *Ankistrodesmus* sp. div., n — *Teträedron minimum,* o — *Scenedesmus acuminatus,* p — *S. ecornis,* r — *S. quadricauda,* s — *Crucigenia apiculata,* t — *C. quadrata,* u — *C. tetrapedia,* w — *Closterium gracile*

http://rcin.org.pl




http://rcin.org.pl




http://rcin.org.pl

as *Microcystis aeruginosa* Kütz., *Anabaena flos aquae* Brèb., or *Aphanizomenon flos aquae* (L.) Ralfs was observed. They occurred occasionally, chiefly *Microcystis delicatissima* (W. G. S.) Starm., *Gloeocapsa* sp. (?), small blue-green algae of the family *Cyanochloridacae* (*Pediochloris paralella* (Szaf.) Geitl.), *Romeria elegans* (Wołosz.), *Pseudoanabaena catenata* Lauterb., and others of the family *Pelonemataceae*, which were not precisely determined. In spring *Spirulina laxissima* G. S. and *Phormidium arcuatum* Skuja were 7 times more numerous in the pond Żabiniec (dilution of wastes 1 : 4) than blue-green algae in summer and autumn (fig. 3).

*Euglenophyceae* — euglenins — played an important role in the plankton in some periods, species of the genera *Trachelomonas, Phacus, Euglena,* and *Lepocinclis* being dominant.

Of the genus *Trachelomonas* the most numerous was *T. volvocina* Ehr., a ubiquist species, found also by Sládeček et al. (1958) in a similar environment and by Haughey (1968) in oxidation ponds. *T. hispida* Playf., and the varieties *T. hispida crenulatocollis* Lemm., f. *minor* Bourr., and *T. hispida* var. *coronata* Lemm. were less numerous. *T. rugulosa* Stein, *T. Stokesiana Palmer* (described by Krzeczkowska-Wołoszyn et al. 1971), *T. oblonga* Lemm., *T. intermedia* Dang., *T. Dybowskii* Dreż, *T. pseudofelix* Delf., *T. cribrum* Conrad, *T. caudata* (E.) Stein, and *T. bernardinensis* W. Fischer were found occasionally. In the plankton species of the genus *Strombomonas: S verrucosa* (Daday) Delf., *S urceolata* (Stokes) Delf., and *S. fluviatilis* (Lemm.) Defl. were also encountered.

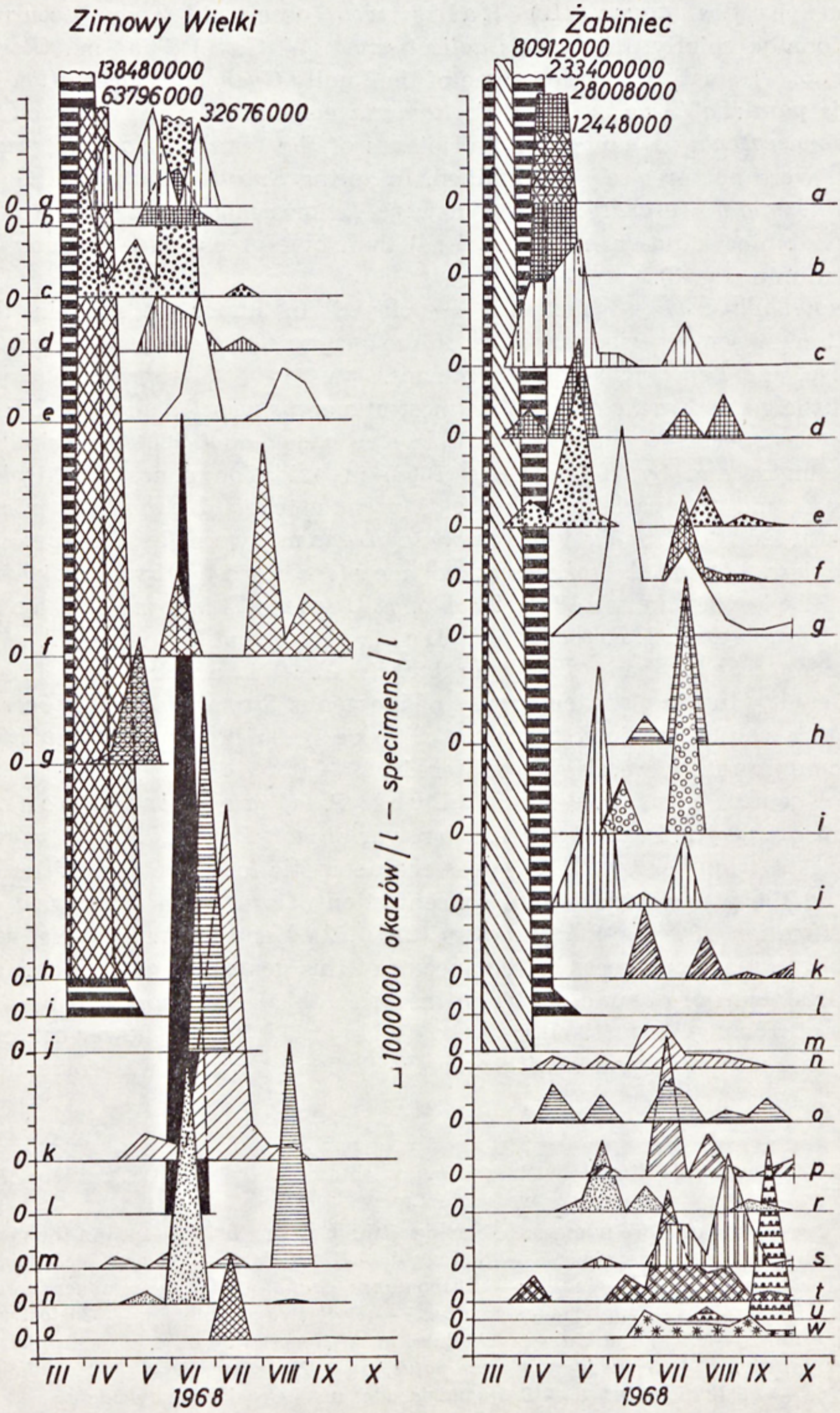
The genus *Phacus (P. Wettsteini* Dreż., *P. inflexus* (Kiss.) Pochm., *P. agilis Skuja, P. caudatus* Hübn. var. *minor* Dreż., *P. curvicauda* Swir., *P. triqueter* (E). Duj.) was characteristic for the communities of algae in the ponds with a high concentration of wastes in the period of intensification of reduction processes (fig. 1, 2). Hence it may be claimed that numerous occurrences of the species of this genus are conditioned by greater amount of organic matter in the pond, this being supported by the works of Haughey (1969) and Godzik et al. (1963). A lower content of organic matter in ponds with greater dilution of wastes was correlated

←

Ryc. 2. Występowanie liczniejszych glonów w litrze wody w latach 1967—1968 w stawie Łąkowy

Fig. 2. Occurrence of more numerous algae per litre of water in 1967—1968 in the pond Łąkowy: a — *Euglena proxima,* b — *E. acus,* c — *E. viridis, d — Phacus Wettsteinii,* e — *Trachelomonas volvocina,* f — *Chroomonas acuta,* g — *Cryptomonas erosa,* h — *C. Marssonii,* i — *Cryptomonas* sp. div., j — *Pediastrum duplex,* k — *Coelastrum microporum,* l — *Dictyospaerium pulchellum,* m — *Oocystis* sp. div., n — *Ankistrodesmus* sp. div., o — *Scenedesmus acuminatus,* p — *S. armatus,* r — *S. bicaudatus,* s — *S. denticulatus,* t — *S. quandricauda,* u — *Crucigenia apiculata*

http://rcin.org.pl




http://rcin.org.pl

with smaller numbers of these species. Other species were also found, such as *P. longicauda* (E.) Duj., *P. tortus* (Lemm.) Skv., *P. helicoides* Pochm., and *P. pyrum* (E.) Stein.

The genus Euglena was mainly represented by 3 species (*E. proxima* Dang., *E. acus* Ehr., *E. viridis* Ehr.) whose occurrence was mainly noted in the spring — summer period. The mass occurrence of these species, similarly as that of species of the genus *Phacus,* was conditioned by the abundance of organic matter (figs 1—3), this being supported by the results of Sládeček et al. (1958) and Ilchenko et al. (1969). The above-mentioned species were often accompanied by *E. tripteris* (Duj.) Klebs, *E. spathirhyncha* Skuja, *E. spirogyra* Ehr., and *E. limnophila* Lemm., while *E. subehrenbergii* Skuja and *E. Ehrenbergii* Klebs were only occasionally found.

Species of the genus *Lepocinclis* accompanied other euglenins and though they sometimes occurred in greater numbers, the period of their occurrence was shorter. They were noted either in all ponds (*L. texta* (Duj.) Lemm. — considered beta-alpha-mesosaprob (according to Slâdeček et al. 1958 and Slâdeček 1963, and *L. ovum* (Ehr.) Lemm. — or in some of them only (*L. Marssonii* Lemm., *L. Steinii* Lemm., *L. constricta* Matv., varieties *L. ovum:* var. *ovata* Swir., var. *punctato-striata* Lemm., and var. *palatina* Lemm.).

The epiphytic alga *Colacium vesiculcsum* Ehr., which is a euglenin, occurred on crustaceans mainly in ponds with undiluted wastes, this being also given by Ilchenko et al. (1969). It may by stated that the euglenins occurred in all ponds, but particularly intensive growth was developed under conditions of higher concentrations of wastes.

Algae of the group *Dinophyceae* (*Ceratium hirundinella* Duj., *Peridinium* sp.) were found in small numbers.

*Cryptophyceae,* represented by *Cryptomonas erosa* Utermöhl, *C. rostratiformis* Skuja, *C. Marssonii* Skuja, and *Chroomonas acuta* Utermöhl, occurred in very great numbers, giving a specific character to the

Ryc. 3. Występowanie liczniejszych glonów w litrze wody w 1968 r.

Fig. 3. Occurrence of more numerous algae per litre of water in 1968 Staw — pond Zimowy Wielki: a — *Euglena proxima,* b — *E. acus,* c — *E. viridis,* d — *Lepocinclis* sp. div., e — *Trachelomonas volvocina,* f — *Cryptomonas Marssonii,* g — *Trigonomonas intermittens,* h — *Chlamydomonas Ehrenbergii,* i — *Chlamydomonas* sp., j — *Pandorina morum,* k — *Coelastrum microporum,* l — *Dictyosphaerium pulchellum,* m — *Ankistrodesmus* sp. div., n — *Scenedesmus acutus,* o — *S. ecornis*
Staw — pond Żabiniec: a — *Phormidium arcuatum,* b — *Spirulina laxissima,* c — *Euglena proxima,* d — *E. acus,* e — *E. viridis,* f — *Lepocinclis constricta,* g — *Trachelomonas volvocina,* h — *Chroomonas acuta,* i — *Cryptomonas erosa,* j — *Cr. Marssonii,* k — *Cryptomonas* sp., l — *Chlamydomonas* sp., m — *Polytoma* sp., n — *Coelastrum microporum,* o — *Ankistrodesmus* sp. div., p — *Scenedesmus acuminatus,* r — *S. acutus,* s — *S. bicaudatus,* t — *S. quadricauda,* u — *S. opoliensis,* w — *Crucigenia apiculata*

http://rcin.org.pl

communities in certain periods (figs. 1—3). In all ponds species belonging to this genus, preferring strongly eutrophic waters, were always encountered slightly later than the euglenins. It seems that this type of algae adopts itself rather in periods of more advanced destruction, hence at higher or even total mineralization of the environment.

*Xanthophyceae,* forming an inconsiderable part of the determined taxons, occurred sporadically. The encountered species were among those common in other types of ponds (*Ophiocythium capitatum* Wolle with the var. *longispinum* (Moeb.) Lemm., *Dichotomococcus curvatus* Korsch., *Centritractus belonophorus* Lemm.) or those rarely noted, such as *Centritractus dubius* Printz.

*Chrysophyceae* also formed an inconsiderable part of the phytoplankton composition, occurring rather occasionally and usually in small numbers (*Pseudokephyrion hiemale* Hilliard, *P. Schilleri* (Schiller) Conrad, *Kephyriopsis globosa* Hilliard, *Chrysococcus minutus* (Fritsch) Nygaard, *Mallomonas* sp., and *Dinobryon divergens* Imhof). Notes on some of them were given in an earlier communication (Krzeczkowska-Wołoszyn et al. 1971).

Of this group only *Ochromonas* sp. were recorded in mass quantities in one of the ponds.

*Flagellata apochromatica* — colourless flagellates — occurred in all ponds. However, *Anthophysa vegetans* Bory, reckoned among alpha-mesosaprobs or polisaprobs, occurred in ponds with a higher concentration of wastes, while *Trigonomonas intermittens* Skuja and *Trepomonas rotans* Klebs. (fig. 3) — assessed as polisaprobs — were found in the more diluted pond Zimowy Wielki. The colourless flagellates fedding osmotically participate directly in the liquidation of wastes (Starmach 1969 e).

*Bacillariophyceae* — diatoms — formed about 10 per cent of the list of species but they occupied further places in the communities of algae. In all ponds they occurred either continuously during a certain period or at intervals, but always in smaller numbers than other algae. Among the most frequently encountered were: *Cyclotella* sp., *Navicula* sp. div., *Gomphonema* sp., *Nitzschia* sp., *Melosira granulata* (Ehr.) Ralfs, *M. granulata* var. *angustissima* (O. F. M.) Hust., *Asterionella formosa* Hass., *Achnantes* sp., *Pinnularia* sp. div., *Synedra acus* Kütz., *S. ulna* (Nitzsch) Ehr., *Cymbella* sp., *Cymatopleura* sp. Only some of them are euplankters, others come from the bottom or from epiphytes, and hence were only accidentally found in the plankton.

In the group *Chlorophyceae* the algae determined belonged to the orders: *Volvocales, Chlorococcales, Conjugales,* and *Ulotrichales.*

Of the *Volvocales* the genus *Chlamydomonas* (figs. 1—3) was most often found in all ponds (especially in spring). According to Huber-Pestalozzi (1961) the species of this genus (only *Ch. Ehrenbergii* Gor. was

http://rcin.org.pl

determined) occupy different biotopes, including strongly eutrophized waters. Other authors (Sládeček et al. 1958, Haughey 1969, Godzik et al. 1963) observed very large numbers of these algae in different waters even with a high degree of pollution. The genera *Tetrachloridium* sp., *Chlorogonium* sp., and *Polytoma* sp. belonging to the same order — characteristic for strongly eutrophized or polluted waters — occurred occasionally, though sometimes in great numbers, along with the species *Brachiomonas crux* Ettl and *Furcilla lobosa* Stokes, characteristic for waters with rotting plant wastes (Huber-Pestalozzi 1961).

Of that order also algae of the genus *Uva* (*U. elongata* (Korschik.) Fott, *U. casinoënsis* Playfair, described by Bucka et al. 1968) occurred in great numbers in the pond with condensed wastes in spring and summer (fig. 1). It is worthy of note that species of the genera *Volvox, Eudorina,* or *Pandorina,* usually common in other ponds, were not among the more frequent or more numerous, and were noted later (Krzeczkowska-Wołoszyn 1966, Bucka et al. 1967).

The species of the order *Chlorococcales* formed almost half the list of the recorded alga. 110 species with varieties and forms and 9 higher systematic units were determined.

In the investigated ponds the greatest variability was demonstrated by the genus *Scenedesmus* (*S. aculeatus* Reinsch., *S. acuminatus* (Lagerh.) Chod., *S. acuminatus* var. *biseriatus* Reinsch., *S. acuminatus* var. *elongatus* G. M. Smith, *S. acuminatus* f. *tortuosus* (Skuja) Uherkov., *S. acutus* (Meyen) Chod. and its form *alternans* Reinsch.,*S. arcuatus* Lemm. var. *platydisca* G. M. Smith, and the form *Uherkovich* Uherkov., *S. armatus* (Chod.) G. M. Smith, *S. bicaudatus* (Hansg.), *S. circumfusus* Hortob., *S. denticulatus* Lagerh. with a variety *linearis* Hansg., *S. ecornis* (Ralfs) Chod., with a variety *disciformis* Chod., *S. granulatus* G. S. West, *S. intermedius* Chod., *S. opoliensis* P. Richt., *S. quadricauda* Chod., *S. rostrato-spinosus* Chod., *S. spinosus* Chod,) and other only occasionally noted.

The genus *Ankistrodesmus (A. acicularis* Korschik., *A. arcuatus* Korschik., *A. convolutus* Corda, *A. falcatus* (Corda) Ralfs, and a variety *acicularis* (Corda) Ralfs, G. S. West, A. *longissimus* (Lemm.), *A. minutissimus* Korschik., *A. pseudomirabilis* Korschik.) often occurred in the investigated ponds. The occurrence of these algae in the plankton of the reservoirs in the grounds of the beet sugar factories was reported by Ilchenko et al. (1969).

The algae of the genus *Tetraëdron* (*T. caudatum* (Corda) Hansg., with the variety *longispinum* Lemm., *T. incus* (Ted) G. M. Smith., *T. limneticum* Borge, *T. minimum* (A. Br.) Hansg., *T. proteiforme* var. *granulatum* Hortob,) and *Pediastrum (P. biradiatum* Meyen, *P. boryanum* (Turp.) Menegh., *P. duplex* Meyen with the variety *reticula-*

http://rcin.org.pl

*tum* Lagerh., *P. simplex* (Meyen) Lemm., *P. tetras* (Ehr.) Ralfs and var. *tetraodon* (Corda) Rbh.) occurred rather in the ponds with lower concentration of wastes, or a year after the treatment, but at any rate in the period of more advanced mineralization.

Of the genus *Coelastrum* the most numerous was *C. microporum* Näg., *C. cambricum* Archer, *C. cubicum* Näg., *C. proboscideum* Bohl., *C. reticulatum* (Dang.) Senn, and *C. sphaericum* Näg. being noted more rarely and in smaller numbers (figs. 1—3).

Small nannoplankton species of the genus *Lagerheimia* (most often *L. wratislaviensis* Schroed.), generally rare in the investigated ponds, preferred rather conditions of advanced mineralization. Similar lower adaptability to the environment of too strong organic pollution was shown by the usually common algae *Crucigenia apiculata* Schmidle, *C. quadrata* Schmidle, and *C. tetrapedia* (Kirch.) West.

Also *Westella botryoides* (W. West) Wild, *Dictyosphaerium pulchellum* Wood, species of the genus *Oocystis* (*O. Borgei* Snow, *O. solitaria* Wittr.), *Siderocoelis ornata* Fott, *Nephrochlamys Willeana* (Printz) Korschik, *Kirchneriella* sp. div., *Franceia ovalis* (Francé) Lemm., *Tetrastrum glabrum* (Roll), *T. heteracanthum* (Nordst.) Chod., *T. staurogeniaeforme* (Schröd.) Lemm., *Actinastrum Hantzschii* Lagerh., *Micractinium pusillum* Fres. (recorded by Šivek et al. 1967 in the ponds with sugar factory wastes) and *M. quadrisetum* (Lemm.) entered into the plankton composition of individual ponds. Among rarely noted species *Juranyiella Javorkae* Hortob., *Quadrigula lacustris* (Chod.) Smith, and *Lauterborniella appendiculata* Korschik. should be mentioned. *Characium limneticum* Lemm. occurred on *Copepoda* and cladocerans with a certain continuity, while *Hyaloraphidium moine* Korschik. occurred rather occasionally in connection with the presence of the cladoceran *Moina rectirostris*.

The order *Ulotrichales* was only represented by occasionally occurring individuals of the genera *Ulothrix* and *Stigeoclonium*.

From the order *Conjugales* not many taxons were determined; these were: *Closterium acerosum* (Schrank) Ehr., *Cl. exiguum* W. G. West., *Cl. gracile* Brèb., *Cl. littorale* Gay, *Cl. moniliferum* (Bory) Ehr., *Euastrum verrucosum* Ehr. var. *alatum* Wolle, *Cosmarium granatum* Brèb., *C. phaseolus* Brèb., and *Staurastrum tetracerum* Ralfs. The desmids usually occurred rather in small numbers and sporadically.

### The effect of dilution of wastes on the number and assimilation surface of the algae

The quantity and surface of individual algae depended on the concentration of wastes in individual ponds. In comparing the ponds Polny III, filled with undiluted wastes, and Łąkowy, filled with wastes diluted

http://rcin.org.pl

in the ratio of 4 : 1, a great difference in the numbers of algae is noted. In the pond Łąkowy the numbers as well as the surfaces of the algae were larger and in the first period of the investigations the algae were even 7 times more numerous than in the pond Polny III; e.g. in May 1967 in Polny III 8.24 million individuals/1 l with an assimilation surface of 46.7 cm², containing 42.1 cm² of euglenins, were found, while at the same time in Łąkowy 134.6 million individuals/1 l with an assimilation surface of 638.8 cm², containing 320 cm² of euglenins, were counted.

In the following year the dependence became reversed in these ponds. Łąkowy, drained in the autumn of the previous year, and not refilled with wastes but with river water from the feeding channel, had continuously less phytoplankton than Polny III, which had not been drained. In August 1968 in this pond the maximum was 78 million individuals/1 l with an assimilation surface of 168.4 cm² (among them *Chlorococcales* 107.2 cm²), while at the same time in Łąkowy there were 28 million individuals/1 l with an assimilation surface of 101.8 cm² (among them 55.0 cm² of *Chlorococcales*).

Then in the pond Polny III, especially in early spring the number of algae was smaller than in the ponds Zimowy Wielki and Żabiniec, filled with wastes diluted in the ratios of 1 : 3 and 1 : 4 respectively. While on March 26, 1968 in the pond Polny III 22.8 million individuals/1 l covering a surface of 100.26 cm², with the dominance of *Cryptophyceae* (90.2 cm²), in Zimowy Wielki 146.3 million individuals/1 l with a surface of 589.5 cm² (domination of *Volvocales* — 565.6 cm² of the covered surface), and in Żabiniec 215.5 million individuals/1 l with a surface of 734.9 cm², with the domination of *Volvocales* (711 cm²), were recorded.

This suggests, on the one hand that after one year's utilization of a pond filled with water containing wastes (if it was drained in autumn) no consequential influence of wastes occurs and on the other that a higher content of nutritive substances persists if the pond is kept filled till the next year. Probably, to obtain a strong development of phytoplankton the concentration of wastes can be reduced only to a certain limit beyond which a reduction in numbers of individuals and in the surface covered by them follows.

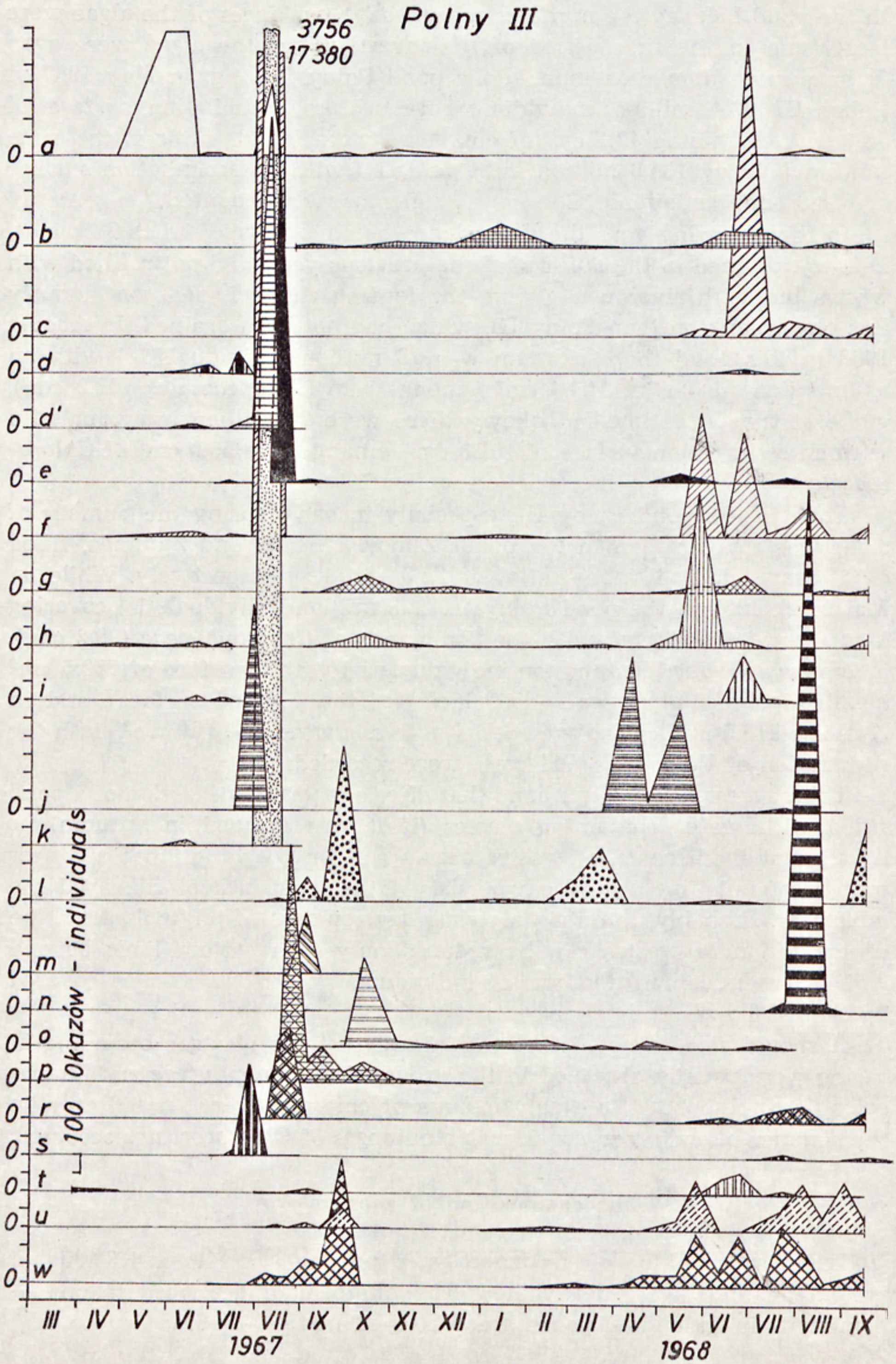
It should also be noted that the largest surfaces of algae occurring in spring were usually observed in the group of *Euglenophyceae* and *Volvocales*. It corresponded to great amounts of chlorophyll, not noted even in the summer period when considerable numbers of *Chlorococcales* occurred.

## The composition of zooplankton

In the zooplankton of the investigated ponds 63 species and 33 higher systematic units were determined. The numbers of described taxons — dominants in individual ponds are presented in figs. 4—6.



http://rcin.org.pl




http://rcin.org.pl

*Protozoa* formed an inconsiderable part of the list of genera: 8 were determined as to species, 5 as to genus or higher systematic unit. This group was described in detail by G r a b a c k a (1973).

In the investigated ponds most frequent and numerous were *Arcella vulgaris* E h r., *Difflugia limnetica* E h r., and *Codonella cratera* L e i d y. The number of protozoans was variable and their occurrence in the majority of ponds was not limited to any determined season.

*Rotatoria,* represented by the greatest numbers of individuals and species, constituted half of the determined taxons. Great variability of species was observed in the genera *Brachionus* (*B. quadridentatus* H e r m a n, *B. calyciflorus* P a l l a s with the form *amphiceros* (E h r.) and varieties var. *pala* (E h r.) and var. *dorcas* G o s s e), *B. urceolaris* O. F. M ü l l., *B. rubens* E h r., *B. budapestinensis* D a d a y, *B. diversicornis* (D a d a y), *B. angularis* G o s s e) and *Polyarthra* (*P. euryptera* W i e r z., *P. vulgaris* C a r l i n, *P. dolichoptera* I d e l s o n, *P. longiremis* C a r l i n). *Anureopsis fissa* (G o s s e), *Keratella cochlearis* (G o s s e), *K. quadrata* (O. F. M ü l l.), and *Filinia longiseta* (E h r.) were among species occurring often and everywhere. In some ponds the species *Trichocerca cylindrica* (I m h o f), *T. pusilla* (J e n n i n g s), *Pompholyx sulcata* H u d s o n, *Pedalia mira* (H u d s o n), *Filinia brachiata* (R o u s s e l e t), as well as species of the genera *Asplanchna* and *Synchaeta* were sometimes encountered in great numbers. *Lepadella sp., Colurella sp., Lecane bulla* (G o s s e), *L. lunaris* (E h r.) *Cephalodella* sp., and species of the family *Conochilidae* were sometimes observed.

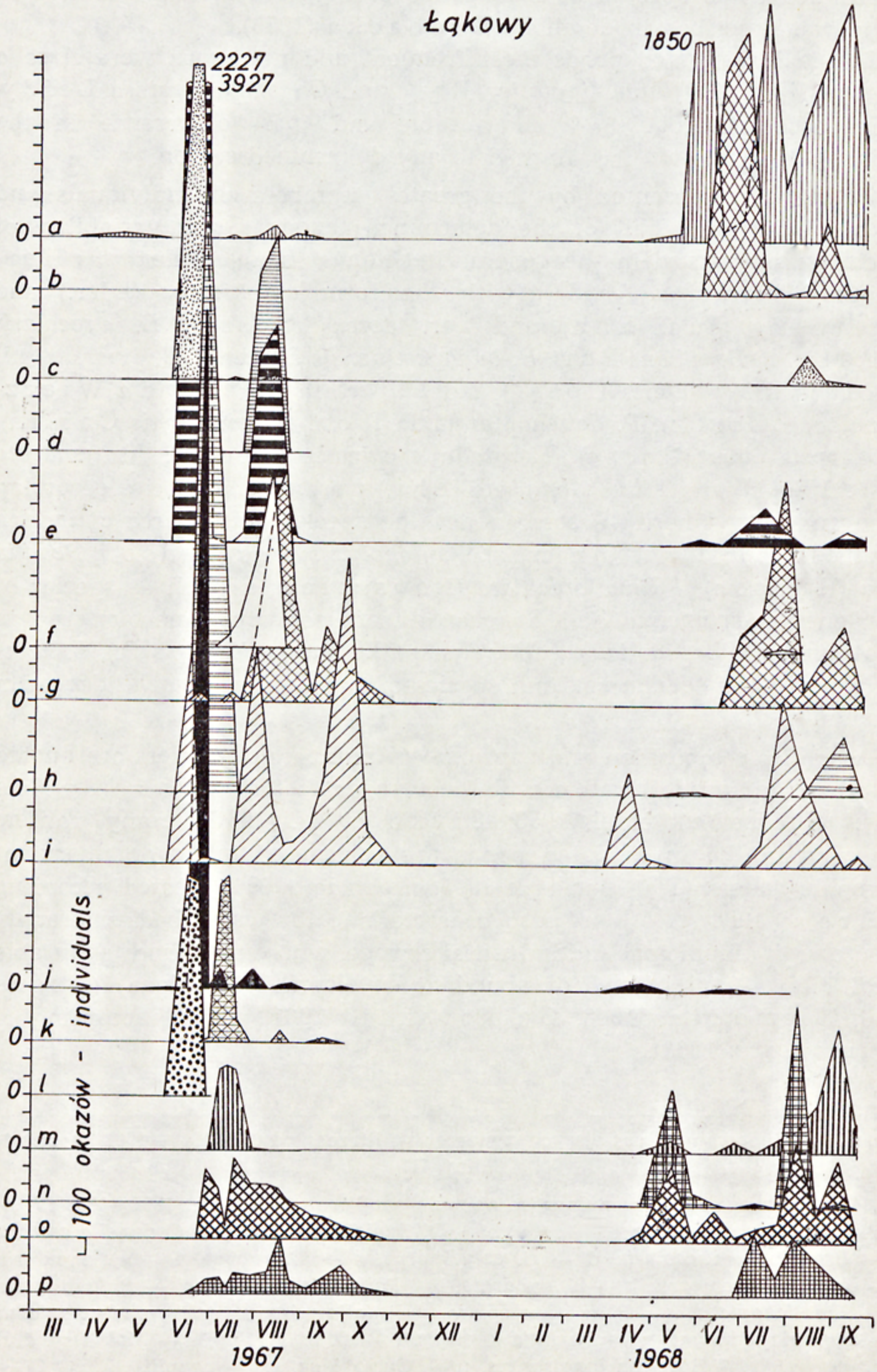
A similar composition and approximate numbers of rotifers are quoted by other authors for waters with beet sugar factory wastes (P y t l i k 1954, S l á d e č e k et al. 1958, Š i v k o et al. 1967). Many rotifers occurring in the investigated ponds are considered index organisms of eutrophic waters (T h u n m a r k 1945, B e r z i n s 1949 quoted according to A r o r a 1966). They are also characteristic for water bodies strongly polluted with municipal and industrial sewage, where they find favourable conditions in consequence of abundant development of algae (A r o r a 1966, K l i m o w i c z 1968, G a l k o v s k a j a 1961, quoted according to K l i m o w i c z 1968).

Ryc. 4. Występowanie liczniejszych zwierząt w litrze wody w 1967—1968 w stawie Polny III

Fig. 4. Occurrence of more numerous animals per litre of water in 1967—1968 in the pond Polny III: a — *Arcella vulgaris,* b — *Difflugia limnetica,* c — *Codonella cratera,* d — *Brachionus urceolaris,* d — *B. calyciflorus,* e — *B. rubens,* f — *B. angularis,* g — *Keratella cochlearis,* h — *K. quadrata,* i — *Polyarthra vulgaris,* j — *P. longiremis,* k — *P. dolichoptera,* l — *Polyarthra* sp., m — *Pedalia mira,* n — *Pompholyx sulcata,* o — *Daphnia* s. *magna,* p — *Daphnia* s. *pulex,* r — *D. longispina,* s — *Moina* sp. div., t — *Bosmina longirostris,* u — *Cyclopidae,* w — *nauplii*



http://rcin.org.pl




http://rcin.org.pl

In regard to the number of determined taxons, *Cladocera* occupied the second position in the composition of zooplankton. In all ponds smaller or greater numbers of such species as *Daphnia longispina* O. F. Müll., *Ceriodaphnia quadrangula* O. F. Müll., *Moina rectirostis* Leydig, and *Bosmina longirostris* O. F. Müll. were encountered. In some of them only *Daphnia* of section *magna* (pond Polny III), *Daphnia* of section *pulex, Scapholeberis mucronata* O. F. Müll., and *Moina macropa* Jurine, *M. brachiata* Jurine, *Ceriodaphnia reticulata* var. *serrata* G. O., and *Polyphemus pediculus* Linné occurred. Species of the family *Chydoridae* were occasionally noted. It is worthy of attention that cladocerans, usually occurring in considerable quantities in ponds with a high content of organic matter brought in with wastes from a sugar factory (Pytlik 1954, Slàdeček et al. 1958, Prosjanyj et al. 1967) had the greatest individual biomass in comparison with other groups of zooplankton, hence they played an important part in the processes of self-purification of ponds. In the course of two years of investigation certain differences in the frequency of occurrence of the representatives of this order in individual ponds were observed. In a pond with condensed wastes they appeared with a certain delay in relation to the ponds where wastes of considerable dilution were used.

In the order *Copepoda* the families *Diaptomidae* and *Cyclopidae*, and a larval stage (*nauplius*) were distinguished. While *Cyclopidae* and *naupli* were a frequent and numerous constituent of the communities of zooplankton, *Diaptomidae* occurred in smaller quantities and not everywhere. Species of this order appeared in greater numbers in a less eutrophized environment. Greater numbers and biomass of organisms belonging to this order were noted in the second year after treatment with wastes and in the pond where the concentration of wastes was the lowest.

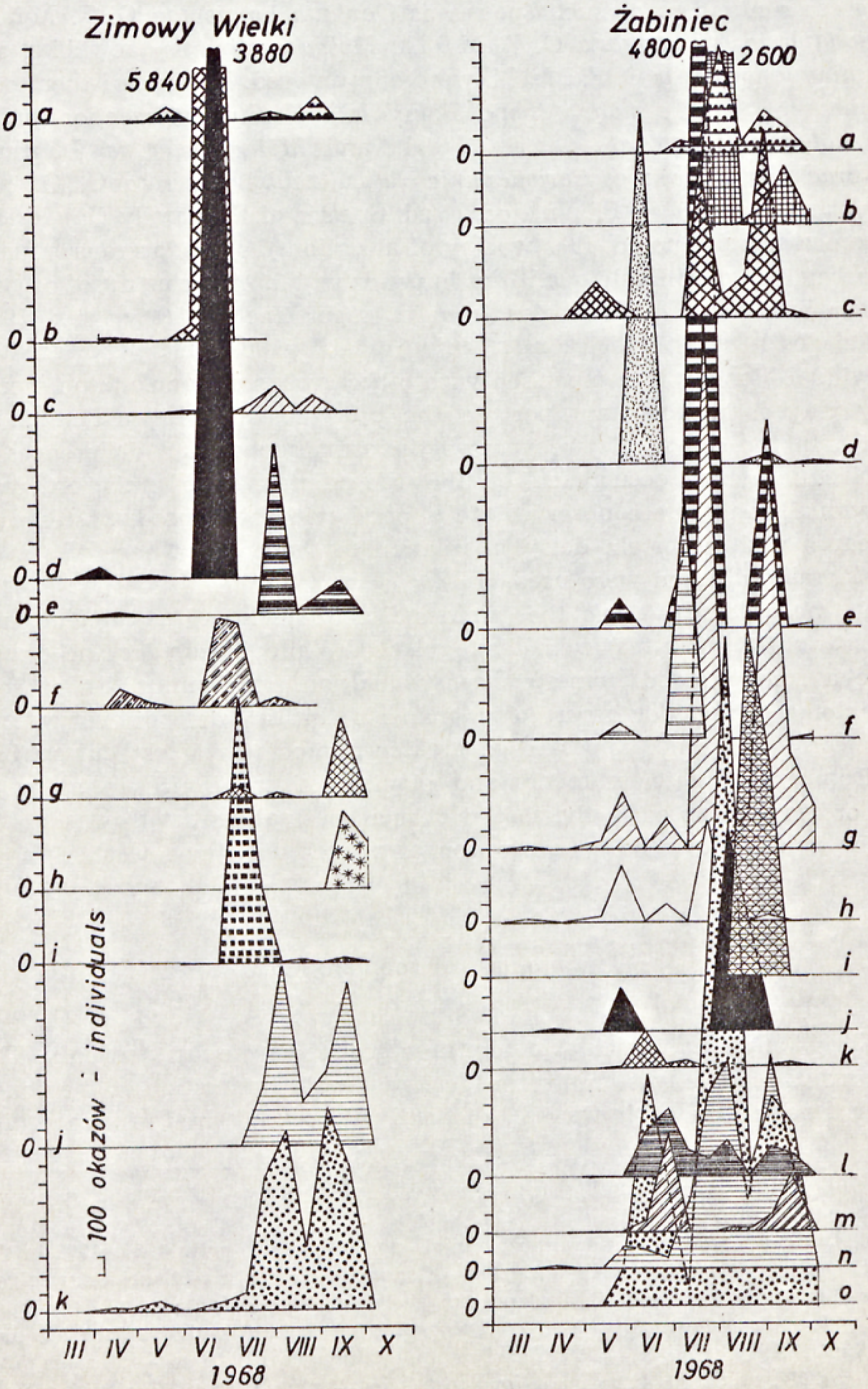
**The biomass of zooplankton**

The biomass was calculated for three groups of zooplankton only. The biomass of rotifers was greater in the first year of utilization of the ponds (after fertilization with wastes), distinctly decreasing in the second. No

Ryc. 5. Występowanie liczniejszych zwierząt w litrze wody w 1967—1968 r. w stawie Łąkowy

Fig. 5. Occurrence of more numerous animals per litre of water in 1967—1968 in the pond Łąkowy: a — *Difflugia limnetica*, b — *Codonella cratera*, c — *Brachionus calyciflorus* f. *amphiceros*, d — *B. budapestinensis*, e — *B. angularis*, f — *Anureopsis fissa*, g — *Keratella cochlearis*, h — *Polyarthra vulgaris*, i — *Polyarthra* sp. div., j — *Synchaeta* sp. div., k — *Pedalia mira*, l — *Filinia brachiata*, m — *Ceriodaphnia quandrangula*, n — *Bosmina longirostris*, o — *nauplii*, p — *Cyclopidae*

http://rcin.org.pl




http://rcin.org.pl

correlation between the maximum biomass of rotifers and the initial concentration of wastes in the pond was found (on the average it amounted to 36.6 mg/l in Polny III, 78.8 mg/l in Łąkowy, in Zimowy Wielki to 40.5 mg/l, and in Żabiniec to 9.2 mg/l).

It is obvious that the size of individual species decided the amount of biomass. Hence, in August 1967 in the pond Polny III with 28 690 individuals of rotifers/l of 36.6 mg/l biomass the following composition was found:

*Brachionus angularis* — 60 per cent of the number of individuals and 19 per cent of biomass of rotifers,

*B. calyciflorus* var. *dorcas* — 5.9 per cent of individuals, 30.5 per cent of biomass of rotifers,

*Polyarthra dolichoptera* — 30 per cent of individuals, 6.9 per cent of biomass of rotifers,

*Asplanchna* sp. — 1.7 per cent of individuals, 40.6 per cent of biomass of rotifers.

The biomass of cladocerans was the greatest. Though they appeared much later than rotifers, when the content of oxygen increased, the greatest biomass was found in the pond with the highest concentration of wastes, but in the period of considerably advanced self-purification. Thus in this pond 2332 individuals/l of 1486.5 mg biomass, with the dominance of *Daphnia* of the section *pulex* were found in September 1967, 2860 individuals/l of 1870.4 mg biomass (*Daphnia* of the section *pulex*, in November of that year), and 639 individuals/l with the dominance of *Daphnia* of the section *magna* in October.

The biomass of *Copepoda* was inconsiderable in comparison with cladocerans Contrary to *Cladocera,* a greater biomass of *Copopoda* was found in the ponds with lower concentration of wastes or in the second year of their filling, when the wastes were already mineralized.

Thus in the pond Polny III the maximum of the first year amounted to only 792 individuals/l of 4.59 mg biomass but in the second to 680 individuals/l of 9.06 mg biomass. In the pond Łąkowy with the

Ryc. 6. Występowanie liczniejszych zwierząt w litrze wody w 1968 r.

Fig. 6. Occurrence of more numerous animals per litre of water in 1968. Staw — pond Zimowy Wielki: a — *Difflugia limnetica,* b — *Brachionus calyciflorus,* c — *Keratella cochlearis,* d — *Polyarthra longiremis,* e — *Polyarthra* sp., f — *Filinia longiseta,* g — *Daphnia longispina,* h — *Ceriodaphnia quadrangula,* i — *Moina rectirostris,* j — *Cyclopidae,* k — nauplii

Staw — pond Żabieniec: a — *Difflugia limnetica,* b — *Codonella cratera,* c — *Brachionus calyciflorus,* d — *B. rubens,* e — *B. angularis,* f — *Anureopsis fissa,* g — *Keratella cochlearis,* h — *K. quadrata,* i — *Polyarthra dolichoptera,* j — *P. longiremis,* k — *Daphna longispina,* l — *Ceriodaphnia* sp. div., m — *Bosmina longirostris,* n — *Cyclopidae,* o — nauplii

http://rcin.org.pl

concentration of 4 : 1 of wastes the maximum biomass was 8.62 mg, in the pond Zimowy Wielki with the concentration of 1 : 3 it was 20.58 mg, and in the pond Żabiniec with the concentration of 1 : 4 — 33.94 mg.

## Succesion of phyto- and zooplankton

In the ponds with beet sugar factory wastes a distinct succession of groups of phyto- and zooplankton resulting from biochemical changes in the environment were observed during the vegetation period. It should be stressed that it was not a one-sided action; the abiotic environment was also transformed by the action of bacteria, fungi, algae, and zooplankton (Odum 1963).

Beside the author's own data some results of physico-chemical investigations carried out by Lewkowicz (1973) in these same ponds were taken as a criterion for the delimitation of the stages of succession. Different levels of concentrations of wastes used in each pond and different meteorological conditions in the two years in which the investigations were carried out may have influenced the variability of time of the stages of succession.

The first stage of succession, which concerned a later period of heterotrophy, determined on the basis of chemical investigations carried out earlier was characterized by fairly intensive processes of decomposition, by the absence of dissolved oxygen, and a high biochemical oxygen demand ($BOD_5$ within the range 640—32 mg $O_2$/l). Besides great numbers of bacteria this stage was mainly characterized by the occurrence of green algae of the order *Volvocales,* chiefly *Chlamydomonas* sp., then *Euglenophyceae,* zooplankton being almost absent. Sládeček et al. (1958) postulated that the action of *Chlamydomonas* in a similar environment changed the anaerobic conditions to aerobic ones. It seems that the different conditions under which the investigations of these authors (an inflow of clean water form a stream in consequence of a breakdown), as well as those of Russian authors (Prosjanyj et al. 1965, Šivko et al. 1967, Ilchenko et al. 1969 — ponds in the grounds of a sugar factory, additions of chlorella mass) were carried out, might have effected the decrease in the share of euglenins and favoured chlorococcous algae in this stage of self-purification of water in the reservoirs. In the investigations carried out in the ponds of the Mnich complex, chlorococcous algae did not in the initial stage play any great part in the plankton, though beside *Volvocales* and euglenins they are facultative autotrophs (Starmach 1969 e), and hence are capable of utilizing the organic matter dissolved in water. In spite of the fact that free $CO_2$ strongly affects the occurrence of *Chlamydomonas* (King 1970), a number of species of this group of algae (e.g. *Uva* sp.) show

http://rcin.org.pl

optimum development in the presence of greater amounts of organic compounds (F o g g 1969). Thus euglenins and *Volvocales* are better adapted to development in an environment strongly polluted with organic compounds. They occurred in great numbers when the chlorococcous algae barely began to appear. In the presence of large amounts of dissolved organic matter algae decrease the intensity of photosynthesis, as was described by D a n f o r t h (1962) on the example of *Chrysophyceae,* whose assimilation in the presence of sugar in the medium did not even meet the demand for oxygen for the purpose of transpiration. It is possible that in the case of a mass occurrence of green algae (euglenins and chlamydomonades) the phenomenon of photoassimilation of organic compounds occurred and the oxygen being less intensively produced could be bound immediately in oxidizing processes; therefore it was not detected in this period, since in this stage the decrease in the content of organic matter, in COD, oxygen consumption, and $BOD_5$ were observed. In a further phase of this stage the dominance of destruction processes was maintained with the absence of oxygen, high oxygen consumption, and $BOD_5$ still above 50 mg $O_2$/l. *Euglenophyceae* and *Volvocales* already present in the former phase of the first stage of succession, appeared more and more numerously in the further phase of this stage. At the same time, *Chlorococcales, Cyanophyceae,* and, rarely, *Cryptophyceae* as well as small amounts of zooplankton, mainly *Protozoa* and *Rotatoria,* were observed.

At the beginning of the second stage of succesion in the period of hyperautotrophy (L e w k o w i c z 1973), when the processes of destruction of organic matter were already coming to an end (with already constant, though changing content of oxygen, and $BOD_5$ not exceeding 29.4 mg $O_2$/l), the organisms characteristic for the former stage were still present, though at the same time a strong development of *Cryptophyceae* had already begun in the majority of ponds. Among the representatives of this group the presence of the frequently encountered species *Cryptomonas erosa, C. Marssonii,* and *Chroomonas acuta* was conspicuous. According to U t e r-m ö h l, the occurrence of *Chroomonas acuta* depends on the presence of great amounts of organic matter, while according to N y g a a r d it is connected with strongly eutrophized waters with a considerable content of calcium, nitrogen, and phosphorus (quoted after H u b e r-P e s t a l o z z i 1955). The simultaneity of occurrence of *Cryptophyceae* and of the increase of amounts of zooplankton, mainly of the rotifers *Brachionus angularis, B. calyciflorus, Polyarthra dolichoptera,* was determined. A similar dependence was described by S l á d e č e k et al. (1958). At this stage of succession a considerable dominance of production over destruction of organic substance was observed, this being chiefly manifested by a large content of dissolved oxygen, rarely found in other ponds (L e w k o w i c z 1973).

At the third, transition stage the number of algae decreased and in

http://rcin.org.pl

the zooplankton rotifers generally receded in favour of cladocerans. In the water of the ponds a low oxygen content and little turbidity were found.

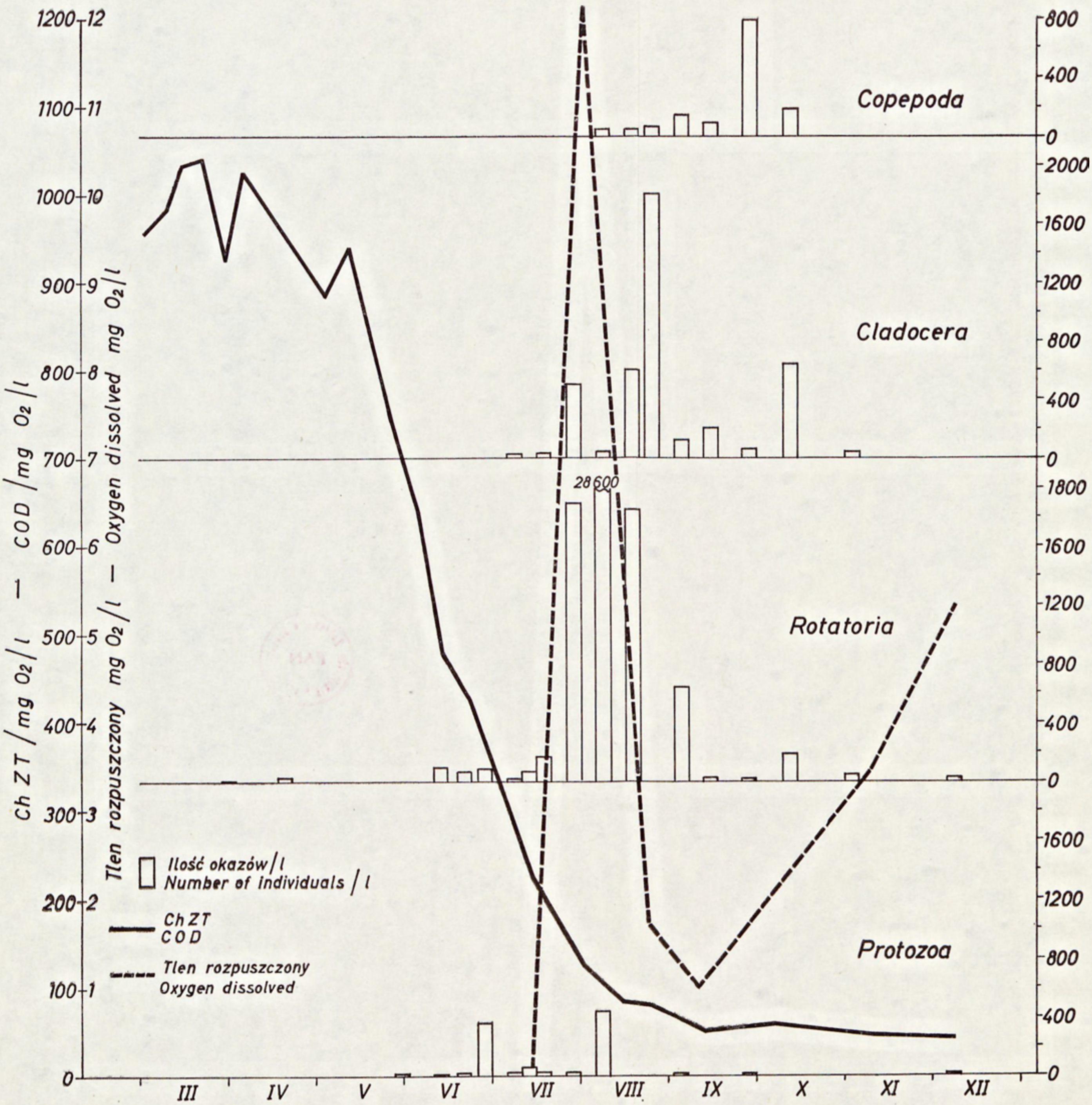
After this stage a complete stability of primary and secondary production (stage IV) prevailed, so that the investigated ponds resembled the normally utilized ones. A dominance of chlorococcous algae was observed and in the zooplankton rather cladocerans and *Copepoda* dominated because of their greater biomass, in spite of greater numbers of rotifers.

The individual stages of self-purification of wastes in the ponds had various duration which was manifested in the earlier or later appearance of different groups of algae and of animals in plankton communities (Tables II, III, IV, V, fig. 7).

In the pond Polny III, which had been filled with undiluted wastes (Tables I and II), the first stage of succession took place from March 1967 to almost the middle of July 1967. In the plankton the genera *Chlamydomonas* and *Euglena* were mainly found. In the second part of this stage euglenins reached their maximum number. New species, especially of the genus *Euglena* (*E. proxima, E. acus*) and *Phacus (P. Wettsteini, P. caudatus* var. *minor*), appeared among them. Besides the earlier encountered genus *Chlamydomonas,* the order *Volvocales* was also represented by genera *Uva, Furcilla,* and *Brachiomonas.* At the end of June the first more numerous appearance of *Chlorococcales (Ankistrodemus sp., Scenedesmus quadricauda*), some few species of *Bacillariophyceae,* and in the first decade of July *Cryptophyceae,* were observed. In this period great numbers of various diatoms and chlorococcous green algae developed on an artificial medium (H u k 1973). Rotifers were also recorded, especially in the littoral region (*Brachionus urceolaris, B. angularis,* and *Polyarthra* sp. div.)

At the second stage, which began in the middle of July 1967, plankton communities more characteristic for normally utilized carp ponds of this region gradually began to form (B u c k a, K y s e l o w a 1967). This stage lasted to the middle of August. The share of *Euglenophyceae* decreased, no algae of the order *Volvocales* appeared; the presence of the species *Cryptophyceae (Cryptomonas erosa, C. Marssonii, Chroomonas acuta)* and not numerous *Conjugales* and *Bacillariophyceae* was maintained, species of the order *Chlorococcales (Ankistrodesmus* and *Scenedesmus*) prevailing. Only after the mineralization of the main part of organic matter in the ponds did species of the genus *Scenedesmus* prevail this being supported by the data of S l á d e č e k (1958) and Š i v k o, L j a c h n o v i č (1967) for beet sugar factory ponds. Great numbers of zooplankton developed, in July and August mainly rotifers of the genus *Brachionus* (*B. rubens, B. angularis, B. calyciflorus*). The role of these animals in the processes of self-purification of wastes in ponds is variously estimated. K r y u t c h k o v a (1968) stresses their share in the destruction of organic matter and in reducing the biochemical oxygen demand, while K l i m o w i c z (1968) postulates

http://rcin.org.pl




Ryc. 7. Sukcesja grup zooplanktonu na tle niektórych parametrów chemicznych (za Lewkowiczem 1973) w stawie Polny III w 1967 r.

Fig. 7. Succesion of zooplankton groups on the background of some chemical parameters (after Lewkowicz 1973) in the pond Polny III in 1967

http://rcin.org.pl

Tabela II. Zmiana zbiorowisk w stawie Polny III
ChZT początkowe - 1380 mg $O_2$/l

Table II. Change of communities in the pond Polny III
Initial COD - 1380 mg $O_2$/l

| Etapy - Stages / Nazwa - Name | I<br>Heterotrofia - Hetrotrophy | II<br>Hiperautotrofia-Hyperautotrophy | III<br>Przejściowy - Transition | IV<br>Stabilizacja - Stabilization |
|---|---|---|---|---|
| Data - Date | Marzec do połowy lipca 1967<br>March to mid-July 1967 | Od połowy lipca do połowy sierpnia 1967<br>From mid-July to mid-August 1967 | Od połowy sierpnia 1967 do końca lutego 1968<br>From mid-August 1967 to the end of February 1968 | Od marca 1968 do jesieni<br>From March 1968 to autumn |
| ChZT<br>COD mg $O_2$/l | 1040 - 224 | 125 - 84.2 | 69.8 | 47.3 - 28.1 |
| $BZT_5$<br>$BOD_5$ mg $O_2$/l | 640 - 83.2 | 27.8 - 9.6 | 6.4 | 2.8 - 5.8 |
| $O_2$ rozpuszcz.<br>dissolved mg/l | 0 - 0.1 | 0.8 - 12.1 | 2.72 | 5.2 - 12.5 |
| Glony typowe dla etapów<br>Algae typical for stages | Chlamydomonas sp.<br>Phacus Wettsteini<br>- caudatus v. minor<br>- inflexus<br>Euglena viridis<br>- proxima<br>- acus<br>Uva casinoensis<br>- elongata<br>Chroomonas acuta<br>Brachiomonas crux<br>Furcilla lobosa | Cryptomonas erosa<br>- Marssonii<br>Chroomonas acuta<br>Ankistrodesmus sp. div.<br>Scenedesmus sp. div. | Colacium vesiculosum<br>Cryptomonas Marssonii<br>Characium limneticum<br>Chroomonas acuta<br>Navicula sp.<br>Gomphonema sp.<br>Nitzschia sp. div. | Cryptomonas Marssonii<br>- erosa<br>- rostratiformis<br>Chroomonas acuta<br>Trachelomonas volvocina<br>Trachelomonas sp. div.<br>Pediastrum tetras<br>- duplex<br>Scenedesmus quadricauda<br>- acuminatus<br>- bicaudatus<br>Scenedesmus sp. div.<br>Crucigenia tetrapedia<br>- apiculata<br>- quadrata<br>Tetraedron minimum<br>Coelastrum microporum<br>- sphaericum<br>Closterium gracile |
| Razem glony-okaz./l<br>Total algae-specimens/l | 1 400 000 - 24 500 000 | 2 200 000 - 13 600 000 | 140 000 - 3 700 000 | 4 000 000 - 78 500 000 |
| Zwierzęta typowe dla etapów<br>Animals typical for stages | | Brachionus angularis<br>- calyciflorus v. dorcas<br>- rubens | Daphnia s. pulex<br>- s. magna<br>- longispina<br>Nauplii<br>Cyclopidae | Brachionus angularis<br>Polyarthra longiremis<br>Keratella quadrata<br>Bosmina longirostris<br>Cyclopidae<br>Nauplii |
| Razem zwierzęta - osob./l<br>Total animals - individuals/l | 2 - 187 | 2 400 - 28 700 | 22 - 1 900 | 154 - 3 700 |

http://rcin.org.pl

their negative influence on the oxygen balance during the warm part of the year from eating up the algae and consuming oxygen in the respiration process.

In the next, third stage (from the middle of August 1967 till February 1968) a distinct decrease in numbers of all groups of algae was observed, while in the zooplankton rather cladocerans (*Daphnia* of section *pulex,* of section *magna,* and *D. longispina*) and *Copepoda* prevailed.

Cladocerans are a very important constituent of ponds with organic wastes as well as of country ponds, or of ponds where municipal sewage is treated. On account of a great individual biomass they play a considerable part in the processes of self-purification. Being continually in motion they contribute to the translocation of oxygen in the reservoirs, while their filtration activity causes the disappearance of organic and inorganic suspended matter, diminishing the turbidity of water (Loedolff 1964, Uhlmann 1967). On the example of *Daphnia magna* the former author proved the usefulness of heterotrophic organisms which, together with mixotrophs, ensure the progressing decrease in pollution of aquatic environment. Similarly Kryutchkova (1968) proved the direct role of zooplankton, including also cladocerans, in the reduction of biochemical oxygen demand.

In the pond where the purified water had not been drained the fourth stage began in spring 1968. After the winter decrease in the number of algae the first spring maximum of alga development, chiefly of *Crytophyceae* (*C. Marssonii*), characteristic for stages I and II of the previous year (fig. 1), occurred in March in a much stronger degree than in the previous year. A second maximum maintained during summer and autumn resulted from great numbers of various species of the order *Chlorococcales.* These algae occurred in greater numbers than in summer 1967. On the other hand, *Chlamydomonadaceae,* so characteristic for the first stage in 1967, lost their importance, appearing only occasionally and in small numbers. In comparison with the first year of investigations the occurrence of euglenins, particularly of the genus *Trachelomonas,* less numerous in the previous year, was shifted to the period from the middle of summer to autumn 1968. Considerable numbers of zooplankton were encountered from winter 1967/68 to autumn, but they were lower than in the previous year. This applies to all determined groups.

The pond Łąkowy was filled with less concentrated wastes diluted with water in the ratio 4 : 1 (the initial COD 913 mg $O_2$/1). It was drained for winter and in spring 1968 refilled without any addition of wastes (Table III).

In this pond the author did not manage to differentiate the initial phase of the first stage on the basis of the collected samples. The first two samples (29. III, 25. IV. 1967) characterized the pond in the course of the final phase of this stage. A considerable shortening of this period in comparison with the pond Polny III was observed. It was characterized

http://rcin.org.pl

Tabela III. Zmiana zbiorowisk w stawie Łąkowy
ChZT początkowe - 913 mg $O_2$/l

Table III. Change of communities in the pond Łąkowy
Initial COD - 913 mg $O_2$/l

| Etapy - Stages / Nazwa - Name | I<br>Heterotrofia - Heterotrophy | II<br>Hiperautotrofia-Hyperautotrophy | III<br>Przejściowy - Transition | IV<br>Stabilizacja - Stabilization |
|---|---|---|---|---|
| Data - Date | Marzec do końca kwietnia 1967<br>March to the end of April 1967 | Maj do I dekady czerwca 1967<br>May to the first decade of June 1967 | Od II dekady czerwca do połowy sierpnia 1967<br>From second decade of June to mid-August 1967 | Od połowy sierpnia do I dekady października 1967<br>From mid-August to the first decade of October 1967 |
| ChZT COD mg $O_2$/l | 412.2 | 103.7 | 97.3 - 51.1 | 44.3 - 32.3 |
| $BZT_5$ $BOD_5$ mg $O_2$/l | 143.6 | 12.8 | 16.0 - 6.4 | 4.0 - 0.9 |
| $O_2$ rozpuszcz. dissolved mg/l | 0 | 21.4 | 2.02 - 17.9 | 4.1 - 7.2 |
| Glony typowe dla etapów<br>Algae typical for stages | Chlamydomonas sp.<br>Euglena viridis | Cryptomonas Marssonii<br>- erosa<br>Euglena acus<br>- proxima<br>Ankistrodesmus acicularis<br>- pseudomirabilis<br>Scenedesmus acuminatus<br>- quadricauda | Coelastrum microporum<br>Coelastrum sp. div.<br>Ankistrodesmus falcatus var. acicularis<br>Ankistrodesmus convolutus<br>Scenedesmus arcuatus<br>- bicaudatus<br>- quadricauda<br>- denticulatus<br>Crucigenia apiculata<br>Tetraëdron minimum | Scenedesmus quadricauda<br>Crucigenia sp. div. |
| Razem glony - okaz./l<br>Total algae - specimens/l | 3 100 000 - 10 700 000. | 134 600 000 | 2 100 000 - 48 200 000 | 1 700 000 - 4 000 000 |
| Zwierzęta typowe dla etapów<br>Animals typical for stages | | | Brachionus angularis<br>- rubens<br>- budapestinensis<br>Polyarthra vulgaris<br>Keratella cochlearis<br>Anureopsis fissa<br>Pedalia mira<br>Filinia brachiata<br>Ceriodaphnia quadrangula<br>Moina sp. div. | Keratella cochlearis<br>Polyarthra sp. div.<br>Keratella quadrata<br>Pedalia mira<br>Nauplii<br>Cyclopidae<br>Daphnia longispina |
| Razem zwierzęta - osob./l<br>Total animals - individuals/l | 12 | 6 | 682 - 12 300 | 429 - 2 700 |

http://rcin.org.pl

by the occurrence (limited to this stage only) and domination of *Chlamydomonadaceae,* by a so far small share of euglenins and chlorococcous algae, and by the almost complete absence of zooplankton.

The course of the stage of hyperautotrophy (stage II) could be inferred from a sample collected in May 1967. Though the maximum occurrence of *Euglenophyceae (Euglena acus* and *E. proxima*), characteristic rather for the final phase of the first stage, was found, nevertheless a mass development of *Cryptophyceae* had begun and the share of *Chlorococcales* (*Ankistrodesmus* sp. div., *Scenedesmus acuminatus, S. quadricauda*) increased. In this period no great development of zooplankton was yet observed.

The third stage was maintained till the end of August. In its course a decrease in the numbers of algae in relation to the previous period was observed, though these numbers were nevertheless great. The chlorococcous algae prevailed. Zooplankton developed just at this time, 6 weeks earlier than in the pond Polny III, with a considerable prevalence of rotifers whose greatest numbers were found in June (*Brachionus angularis, Polyarthra vulgaris*). The less numerous cladocerans constituted the greatest biomass in the middle of July (*Ceriodaphnia quadrangula, Moina* sp. div.).

The fourth stage, i.e. the period of stabilization, lasted from the middle of August to the draining of the pond in autumn. It was characterized by a decrease in the numbers of algae among which chloroccocous algae prevailed (*Scenedesmus* sp. div., *Crucigenia* sp. div.): In this period in the zooplankton, besides the above-mentioned species of the genus *Brachionus, Anureopsis fissa, Keratella cochlearis,* as well as cladocerans (*Daphnia longispina*) and *Copepoda* were observed.

In 1968 in the pond Łąkowy already at the beginning of April a considerable development of phytoplankton was observed, which was maintained till the end of the vegetation period. The algae of the order *Chlorococcales* prevailed here, but they did not attain the numbers of the summer of the previous year. The maximum occurred in June and July. Species of the genera *Pediastrum, Coelastrum, Oocystis,* and *Scenedesmus* were numerous. Among other algae greater numbers of *Cryptophyceae* were encountered in spring and blue-green algae in summer. Among those more rarely found were *Conjugales, Xanthophyceae, Chrysophyceae,* and *Volvocales,* while *Bacillariophyceae* were noted in greater numbers than in 1967. They usually developed after the filling of the pond. The share of certain *Euglenophyceae* (various species of the genus *Euglena* and *Phacus*) was smaller than in the previous year. Only *Trachelomonas volvocina* occurred in great numbers in both the years of investigation, but *Lepocinclis texta* only in 1968. Numbers of zooplankton were also smaller in 1968, smaller numbers of *Rotatoria* being decisive.

The pond Zimowy Wielki was filled with wastes diluted with water in the ratio 1 : 3 (the initial COD 931 mg $O_2$/l). The occurrence of phyto- and

http://rcin.org.pl

zooplankton here was formed in a characteristic pattern, determined by the stages of progressing self-purification (Table IV, fig. 6).

The samples collected in the period from the last decade of March to the end of May 1968 indicated the phase of heterotrophy in the pond. In April a mass appearance of algae of the order *Volvocales* (up to 158.7 million individuals/l) of the genera *Chlamydomonas, Chlorogonium,* and *Polytoma* was recorded. They were accompanied by less numerous *Euglenophyceae.* It was a late period of their increasing share (mainly *Euglena viridis, E. proxima, E. acus*), decreasing numbers of algae of the order *Volvocales* as well as the entering of *Chlorococcales (Coelastrum microporum, Quadringula lacustris, Scenedesmus quadricauda*) into communities. The zooplankton was limited to inconsiderable numbers, mainly of rotifers (*Filinia longiseta, Polyarthra longiremis*).

In this pond the second period lasted to the middle of July. After an increased occurrence at the beginning of this period, *Euglenophyceae* ceased to prevail in the communities of algae. *Volvocales* (*Pandorina morum, Uva elongata),* still sometimes numerous, gradually disappeared. The share of *Cryptophyceae* and *Chlorococcales* (*Coelastrum microporum, Dictyosphaerium pulchellum, Scenedesmus* sp. div.) considerably increased. Maximum numbers of zooplankton connected with the increase in rotifers (*Brachionus calycilforus, Polyarthra longiremis, Filinia longiseta)* were noted at the end of June. In the first decade of July *Moina rectirostris* began to appear.

In the third period (from the middle of July to the first decade of August) the number of algae, mainly of *Chlorococcales* and *Euglenophyceae* with the dominance of *Cryptophyceae (Cryptomonas erosa* and *C. Marssonii*), decreased in the waters of this pond. In animal communities, in spite of the presence of rotifers, the share of cladocerans as well as quantitative and gravimetric prevalence of *Copepoda* was observed.

The next, fourth stage lasted to the end of the season with a further though variable occurrence of euglenins, *Cryptophyceae*, and chlorococcous algae. In the zooplankton the share of *Copepoda* (*Cyclopidae* and nauplii) and cladocerans *(Ceriodaphnia quandrangula, Daphnia longispina*) considerably increased, influencing the amount of biomass (35.23 mg/l).

In the pond Żabiniec (Table V, fig. 6) where the dilution of wastes was 1 : 4 (the initial COD 823 mg $O_2$/l) the differentiation of separate stages was more difficult, with the exception of the distinct first stage.

The first stage of heterotrophy began in March and lasted to the third decade of April. In this time a characteristic almost exclusive dominance of algae of the order *Volvocales (Chlamydomonas* sp., *Polytoma* sp., *Chlorogonium* sp.), besides smaller numbers of *Euglenophyceae* (*Euglena viridis*), was observed in the pond. In April in a further course of this stage increased numbers of *Euglenophyceae* (*Euglena proxima, E. viridis*) were observed. At one time a great number of blue-green algae (*Spirulina*

http://rcin.org.pl

Tabela IV. Zmiana zbiorowisk w stawie Zimowy Wielki
ChZT początkowe - 931 mg $O_2$/l

Table IV. Change of communities in the pond Zimowy Wielki
Initial COD - 931 mg $O_2$/l

| Etapy - Stages / Nazwa - Name | I<br>Heterotrofia - Heterotrophy | II<br>Hiperautotrofia-Hyperautotrophy | III<br>Przejściowy - Transition | IV<br>Stabilizacja - Stabilization |
|---|---|---|---|---|
| Data - Date | Marzec do końca maja 1968<br>March to the end of May 1968 | Od czerwca do połowy lipca 1968<br>From June to mid-July 1968 | Od połowy lipca do I dekady sierpnia 1968<br>From mid-July to the first decade of August 1968 | Od II dekady sierpnia do I dekady października 1968<br>From the second decade of August to the first decade of October |
| ChZT / COD mg $O_2$/l | 628.7 - 290.5 | 187.2 - 88.5 | 61.7 - 53.8 | 66.1 - 40.3 |
| BZT$_5$ / BOD$_5$ mg $O_2$/l | 384 - 53 | 29.4 - 11.2 | 11.2 - 5.1 | 5.7 - 10.5 |
| $O_2$ rozpuszcz. / dissolved mg/l | 0 | 2.5 - 4.4 | 1.1 - 6.5 | 5.7 - 10.5 |
| Glony typowe dla etapów<br>Algae typical for stages | Chlamydomonas Ehrenbergii<br>Chlamydomonas sp.<br>Chlorogonium sp.<br>Polytoma sp.<br>Tetrachloridium sp.<br>Euglena viridis<br>- proxima<br>- acus<br>Lepocincilis texta<br>- ovum<br>Quadrigula lacustris<br>Coelastrum microporum<br>Ankistrodesmus acicularis | Euglena acus<br>- proxima<br>Euglena sp. div.<br>Lepocinclis Steinii<br>Phacus inflexus<br>- triqueter<br>Trachelomonas volvocina<br>Cryptomonas Marssonii<br>Cryptomonas sp.<br>Chroomonas acuta<br>Ankistrodesmus sp.<br>Coelastrum microporum<br>Dictyosphaerium pulchellum<br>Scenedesmus acutus<br>- ecornis<br>Tetraëdron minimum<br>Actinastrum Hantzschii | Cryptomonas Marssonii<br>Coelastrum microporum<br>Scenedesmus acuminatus<br>- quadricauda | Cryptomonas Marssonii<br>Ankistrodesmus sp. div.<br>Trachelomonas volvocina<br>Kirchneriella sp.<br>Tetraëdron minimum<br>Scenedesmus sp. div. |
| Razem glony - okaz./l<br>Total algae - specimens/l | 14 000 000 - 164 000 000 | 29 000 000 - 136 100 000 | 10 800 000 - 22 200 000 | 1 500 000 - 22 100 000 |
| Zwierzęta typowe dla etapów<br>Animals typical for stages | Filinia longiseta<br>Polyarthra longiremis | Brachionus calyciflorus<br>- - var pala<br>Polyarthra longiremis<br>Moina rectirostris<br>Filinia longiseta<br>Brachionus angularis | Nauplii<br>Cyclopidae<br>Polyarthra sp. div<br>Moina rectirostris<br>Trichocerca cylindrica<br>Keratella cochlearis | Nauplii<br>Cyclopidae<br>Ceriodaphnia quadrangula<br>Daphnia longispina |
| Razem zwierzęta - osob./l<br>Total animals-individ./l | 60 - 180 | 140 - 10 800 | 3 200 - 4 700 | 187 - 2 700 |

http://rcin.org.pl

*laxissima, Phormidium arcuatum), Chrysophyceae (Ochromonas* sp.), and a decrease in *Volvocales* were observed. The qualitative composition was broadened by various algae of *Chlorococcales.*

Moreover, in the plankton of this pond a continued share of euglenins with a distinct maximum occurrence in the middle of May (species of the genera *Euglena, Trachelomonas,* and *Phacus*), and the beginning of occurrence of *Cryptophyceae* (stage II?) were observed. The maximum development of *Cryptophyceae* occurred beside another peak of increase in euglenins in July (stage III—IV). Increased numbers of chlorococcous algae (*Scenedesmus* sp. div., *Ankistrodesmus* sp. div., *Nephrochlamys Willeana*) with considerable amplitude of variance was also recorded. After a distinct period of heterotrophy, an abundant appearance of zooplankton was observed, first of rotifers (middle of May), *Copepoda* (the end of May), and cladocerans (the beginning of June). Their maximum development occurred at the end of July (*Brachionus calyciflorus, B. angularis, Keratella cochlearis,* and *K. quadrata*), at the beginning of August (nauplii and *Cyclopidea*), and at the end of June *(Ceriodaphnia* sp., *Bosmina longirostris*), respectively. A considerable share of protozoans in the summer months was characteristic for this pond (*Difflugia limnetica, Codonella cratera*) (fig 6).

The comparison of all 4 ponds in the aspect of succession of plankton organisms points to a difference in the length of the stages. In the pond Polny III with undiluted wastes, kept filled for 2 years, the first three stages lasted the longest: to the end of February of the next year. In 1968 a strong development of algae, especially of chlorococcous algae, occurred, this not having been recorded in the pond Łąkowy, which had been drained for winter and refilled without the use of wastes. This indicated the inconsiderable sequent effect of wastes on the fertility of ponds with this system of their filling.

## Conclusions

1) The feeding of properly condensed wastes from a beet sugar factory to a pond increased the numbers of phyto- and zooplankton.

2) The development of algae considerably preceded the development of zooplankton. The succession of individual groups corresponded to the changes in chemical composition of the water, resulting mainly from the mineralization of organic substance.

3) The zooplankton developed abundantly in the presence of a considerable content of oxygen, when the mineralization of organic matter was already far advanced.


http://rcin.org.pl

Tabela V. Zmiany zbiorowisk w stawie Żabiniec
ChZT początkowe - 823 mg $O_2$/l

Table V. Change of communities in the pond Żabiniec
Initial COD - 823 mg $O_2$/l

| Etapy - Stages / Nazwa - Name | I | II | III - IV |
|---|---|---|---|
| | Heterotrofia - Heterotrophy | Hiperautotrofia-Hyperautotrophy | Przejściowy - Stabilizacja<br>Transition - Stabilization |
| Data - Date | Od końca marca do końca kwietnia 1968<br>From the end of March to the end of April 1968 | Maj 1968<br>May 1968 | Czerwiec do końca września 1968<br>June to the end of September 1968 |
| ChZT COD mg $O_2$/l | 471.6 - 224.8 | 150.8 - 94.9 | 73.2 - 49.2 |
| $BZT_5$ $BOD_5$ mg $O_2$/l | 224 - 32 | 24 | 23.5 - 8.2 |
| $O_2$ rozpuszcz. dissolved mg/l | 0 - 0.25 | 2.0 - 6.4 | 1.7 - 10.0 |
| Glony typowe dla etapów<br>Algae typical for stages | Chlamydomonas sp.<br>Polytoma sp.<br>Ochromonas sp.<br>Spirulina laxissima<br>Phormidium arcuatum<br>Euglena viridis<br>- proxima<br>Lepocinclis sp.<br>Chlorogonium sp. | Cryptomonas Marssonii<br>Euglena proxima<br>- viridis<br>- acus<br>Cryptomonas rostratiformis<br>Trachelomonas volvocina<br>Phacus pyrum<br>- Wettsteini<br>- agilis<br>Trachelomonas hispida | Trachelomonas volvocina<br>Cryptomonas sp. div.<br>Chroomonas acuta<br>Lepocinclis constricta<br>Euglena sp. div.<br>Scenedesmus quadricauda<br>- bicaudatus<br>- acuminatus<br>- ecornis<br>Coelastrum microporum<br>Crucigenia apiculata<br>Nephrochlamys Willeana<br>Dictyosphaerium pulchellum<br>Pediastrum tetras |
| Razem glony - okaz./l<br>Total algae - specimens/l | 90 200 000 - 245 800 000 | 38 100 000 - 38 900 000 | 12 700 000 - 67 600 000 |
| Zwierzęta typowe dla etapów<br>Animals typical for stages | | Karatella quadrata<br>- cochlearis<br>Brachionus angularis<br>- urceolaris<br>- calyciflorus v. pala<br>Asplanchna sp.<br>Conochilus sp.<br>Polyarthra longiremis<br>Cyclopidae<br>Nauplii<br>Brachionus diversicornis | Nauplii<br>Cyclopidae<br>Keratella cochlearis<br>- quadrata<br>Brachionus angularis<br>Codonella cratera<br>Difflugia limnetica<br>Brachionus calyciflorus<br>Bosmina longirostris<br>Ceriodaphnia sp. div.<br>Daphnia longispina |
| Razem zwierzęta - osob./l<br>Total animals - individuals/l | 10 - 30 | 640 - 1 700 | 1 100 - 12 500 |

http://rcin.org.pl

4) The appearance of various groups of plankton organisms occurred in a characteristic order. The succession of individual groups of phyto- and zooplankton depended on the concentration of wastes and on the course of processes of self- purification.

5) Succession can be divided into 4 stages:
stage I — of heterotrophy, was always represented by the development of *Euglenophyceae* and *Volvocales* (*Cryptophyceae* from the middle of the period in the pond of concentrated wastes only), with the almost complete absence of zooplankton. Chemical analysis of the water indicated high COD and $BOD_5$, as well as an oxygen deficit.
stage II — of hyperautotrophy, was still characterized by a considerable share of formerly occurring groups and by the appearance of *Chlorococcales* and *Cryptophyceae*, with growing numbers of zooplankton, mainly of rotifers and protozoans. It was correlated with the decrease in COD and $BOD_5$, and constantly increasing content of oxygen, especially at the end of this stage. The organic substance from the wastes was mineralized in this period, the oxygen content being sometimes very high.
stage III — transition stage, was characterized by a decrease in the numbers of algae and by an increased share of *Cladocera* in plankton communities.
stage IV was characterized by stability of the chemical conditions and by the occurrence of phyto- and zooplankton characteristic for normally utilized ponds. In alga communities chlorococcous algae prevailed, while in animal communities rather cladocerans and *Copepoda*.

6) High concentration of wastes influenced unfavourably the number of algae and the size of the total assimilation surface, this resulting in prolongation of the period of self-purification of the pond.

7) *Cladocera* decided the greatest biomass of zooplankton, showing the best development in the pond with the highest concentration of wastes, but already after their complete mineralization.

8) *Rotatoria* occurred in the greatest numbers in the second stage of succession and their number increased in ponds with higher concentration of wastes, but *Copepoda* occurred more numerously at lower concentration.

## STRESZCZENIE

W ramach kompleksowego doświadczenia przeprowadzono w latach 1967—1968 badania nad kształtowaniem się fito- i zooplanktonu 4 stawów, do których doprowadzono ścieki cukrownicze w różnym stężeniu (tabela I).

Podstawą badań fitoplanktonu był 1 l wody nie filtrowanej, a zooplanktonu 9 l cedzone przez siatkę planktonową nr 25. Glony liczono w obrębie 20 pól widzenia ograniczonych kwadratem siatki mikrometru okularowego, przy pomocy której mierzono również powierzchnie glonów, uzyskując przybliżone powierzchnie asymila-



http://rcin.org.pl

cyjne, czynne w procesie fotosyntezy (Starmach 1969 c). Zooplankton liczono w 0,5 ml komorze Kolkwitza, podając biomasę dla wrotków, wioślarek i widłonogów.

Wśród glonów wyróżniono 293 taksony. Występowanie niektórych z nich przedstawiono na rys. 1—3. W zooplanktonie oznaczono 96 jednostki systematyczne. Stosunki ilościowe dotyczące ważniejszych gatunków lub rodzajów zestawiono na ryc. 4—6.

Rozwój różnych grup fito- i zooplanktonu w stawach wykazywał pewną sukcesję w ciągu okresu badań. Objawiała się ona kolejnością i nasileniem pojawiania się poszczególnych grup w wyniku przemian biochemicznych zachodzących w środowisku. Sukcesję tę można było podzielić na 4 etapy, przy których rozgraniczaniu przyjęto za kryterium oprócz własnych danych niektórych parametry chemiczne (Lewkowicz 1973). Czas trwania poszczególnych etapów kształtował się w poszczególnych stawach zależnie od stężenia doprowadzonych ścieków (tabele II—V).

I etap sukcesji, nazwany etapem heterotrofii, odznaczał się bardzo silnymi procesami rozkładu materii organicznej, a stąd dużą utlenialnością, brakiem rozpuszczonego tlenu w wodzie, bardzo dużym ChZT i $BZT_5$. Tego rodzaju środowisko sprzyjało rozwojowi pierwszych glonów, głównie zielenic rzędu *Volvocales* i z gromady *Euglenophyceae*. Z tym okresem wiązały się największe ilości glonów wymienionych grup systematycznych (w stawie Żabiniec nawet ponad 240 mln okazów/l). W tym czasie nie stwierdzono większych ilości zooplanktonu.

Na początkach II etapu sukcesji w okresie hiperautotrofii, w którym dobiegały już końca procesy rozkładu materii organicznej (przy stałej już, chociaż zmieniającej się ilości tlenu i dużo mniejszym $BZT_5$), były jeszcze obecne organizmy charakterystyczne dla poprzedniego etapu, lecz równocześnie w większości stawów rozpoczął się silny rozwój glonów *Cryptophyceae* i zwiększał się udział chlorokokków. Z wyjątkiem stawu Łąkowego wszędzie nastąpiło zwiększenie ilości zooplanktonu (ryc. 5). głównie wrotków (*Brachionus angularis, B. calyciflorus, Keratella quadrata, K. cochlearis, Polyarthra* sp. div.).

W etapie III — przejściowym następowało zmniejszenie ilości glonów, a w zooplanktonie zaczęły na ogół ustępować wrotki na rzecz wioślarek. W wodzie stwierdzano niską zawartość tlenu oraz małą mętność. Etap ten w stawie Polnym III trwał do końca lutego 1968 r.

W IV etapie następowała już pełna stabilizacja produkcji pierwotnej i wtórnej. W zbiorowiskach glonów zaznaczała się przewaga glonów chlorokokkowych, a w biomasie zooplanktonu raczej wioślarek i widłonogów mimo większej czasem liczebności wrotków.

Zauważono niekorzystne oddziaływanie dużego stężenia ścieków na ilość glonów i wielkość ich łącznej powierzchni asymilacyjnej czynnej w procesie fotosyntezy, czego wynikiem było znaczne przedłużenie okresu samooczyszczenia się stawu Polnego III w porównaniu do stawów o mniejszym stężeniu ścieków.

*Rotatoria* stanowiły najliczniejszą grupę zooplanktonu. Występowały na ogół przed *Cladocera* i *Copepoda*. Przy większym stężeniu ścieków występowały później, ale liczniej. Tak np. w stawie Polnym III w 1967 r. maksimum rzędu 28 tys. okaz./l notowano w lipcu i sierpniu, gdy w Łąkowym (roz. 4 : 1) już w czerwcu 1967 r.

Na ogół we wszystkich stawach spotykano podobny skład wrotków. Powtarzały się gatunki rodzajów *Brachionus, Polyartha, Filinia, Asplanchna* i *Keratella*. Wioślarki występowały nieco później, były to najczęściej *Daphnia* z sekcji *pulex, D.* z sekcji *magma, D. longispina, Ceriodaphnia quandrangula, Moina* sp. div. i *Bosmina longirostris*. O największej biomasie zooplanktonu decydowały wioślarki, rozwijające się w stawach o większym stężeniu ścieków, lecz już w czasie zaawansowanej mineralizacji materii organicznej.

http://rcin.org.pl

## REFERENCES

Arora H., C., 1966. Rotifers as indicators of trophic nature of environments. Hydrobiol., 27, 146—159.

Bożko L., L. Kalisz, T. Suchecka, 1966. Stawy biologiczne jako trzeci stopień oczyszczania ścieków. Gaz, Woda, Techn. Sanit. 40, 201—202.

Bucka H., K. Kyselowa, 1967. Plankton wybranych stawów karpiowych w Gołyszu i Landeku — The plankton of selected carp ponds at Gołysz and Landek. Acta Hydrobiol., 9, 339—380.

Bucka H., Ł. Krzeczkowska-Wołoszyn, K. Kyselowa, 1968. Niektóre glony w planktonie stawów Gołysza i Landeka — Some planktonic algae in the ponds of Gołysz and Landek. Acta Hydrobiol., 10, 415—425.

Bucka H., Ł. Krzeczkowska-Wołoszyn, K. Kyselowa, 1968. O kilku gatunkach zielenic z rodzaju *Uva* Playfair 1914. Acta Hydrobiol., 10, 433—437.

Cabejszek I., J. Łuczak, I. Rybak, J. Stanisławska, M. Stasiak, 1961. Kształtowanie się biocenozy rzeki pod wpływem ścieków cukrowni. Gaz, Woda, Techn. Sanit., 35, 48—53.

Danforth W., F., 1962. Substrate assimilation and heterotrophy. w — in Physiology and biochemistry of algae. New York, London. R. A. Lewin (ed.). 99—123.

Demoll R., 1937. Die Reinigung von Abwässern in Fischteichen. Handbuch d. Binnenfisch. Mitteleuropas. 6, 223—262.

Dojlido J., J. Moraczewski, K. Czyż, 1964. Wpływ ścieków cukrowni na stopień zanieczyszczenia Cetyni. Gaz, Woda, Techn. Sanit., 38, 192—195.

Fogg G. E., 1968. Photosynthesis. London, English Univ. Press LTD.

Gabański J., W. Pęska-Kieniewiczowa, W. Kulmatycki, 1934. Materiały do poznania zanieczyszczenia jeziora Jelonek pod Gnieznem. Zdrowie Publ., 4, 253—269.

Gabański J., K. Michalski, W. Pęska-Kieniewiczowa, W. Kulmatycki, 1937. O zanieczyszczeniu rzeczki Dąbroczni w okolicy Miejskiej Górki. Zdrowie Publ., 52, 87—110.

Gabański J., K. Michalski, W. Kulmatycki, 1938. Materiały do znajomości zanieczyszczenia rzeczki Średzianki w woj. poznańskim. Pam. Państw. Inst. Nauk Gosp. Wiejsk. w Puławach, 17, 2B, 278—302.

Godzik S., B. Kotulski, P. Szczygieł, 1963. Badania nad oczyszczaniem ścieków Zakładów Chemicznych „Oświęcim" metodą stawów ściekowych. Gaz, Woda, Techn. Sanit., 37, 19—29.

Grabacka E., 1973. Pierwotniaki w stawach napełnionych ściekami cukrowniczymi — Protozoans in ponds filled with sugar factory wastes. Acta Hydrobiol., 15. 97—111.

Graf F., 1926. Abwasserbeseitigung und Gewässerverunreinigung. Handbuch d. Binnenfisch. Mitteleuropas, 6, 263—287.

Haughey A., 1968. The planktonic algae of Auckland sewage treatment ponds. New Zeeland J. Marine a. Freshwater Res., 2, 721—766.

Huber-Pestalozzi G., 1955. Das Phytoplankton des Süsswassers. Die Binnengewässer. Stuttgart, Schweitzerbart., 16, 4.

Huber-Pestalozzi G., 1961. Das Phytoplankton des Süsswassers. Die Binnengewässer. Stuttgart, Schweizerbart, 16, 5.

Huk W., 1973. Mikrofity porośłowe w stawie zanieczyszczonym ściekami cukrowniczymi — Epiphytic microphytes in a pond polluted with beet sugar factory wastes. Acta Hydrobiol., 15. 89—95.

Ilchenko N., A. M. Matvenko, 1969. K izuceniju algoflory stočnych vod sacharnych zavodov — On studying algoflora of sugar plant waste. Gidrobiol. Ž. 5/55.

http://rcin.org.pl

Kalisz L., T. Suchecka, 1966. Znaczenie pewnych organizmów w procesie oczyszczania ścieków w stawach biologicznych. Gaz, Woda, Techn. Sanit., 40, 236—237.

King D., L., 1970. The role of carbon in eutrophication. Jour. Water Poll. Control Fed., 42, 2035—2051.

Klimowicz H., 1968. Occurrence of rotifers (*Rotatoria*) in sewage ponds. Pol. Arch. Hydrobiol., 15, (28), 3, 225—235.

Kołaczkowski S., H. Bierwagen, 1960. Gospodarka wodno-ściekowa cukrowni. Gaz. Cukr., 5, 131—141.

Kryutchkova N., M., 1968. The role of zooplankton on the self-purification in water bodies. Hydrobiol., 31, 585—596.

Krzeczkowska-Wołoszyn Ł., 1966. Plankton nowych stawów przesadkowych gospodarstwa Gołysz — Das Plankton der neuen Streckteiche der Teichwirtschaft Gołysz. Acta Hydrobiol., 8, suppl. 1, 47—109.

Krzeczkowska-Wołoszyn Ł., H. Bucka, 1969. Glony rzeki Soły na odcinku Rajcza—Porąbka — Algae from river Soła in the sector Rajcza—Porąbka. Acta Hydrobiol., 11, 245—260.

Krzeczkowska-Wołoszyn Ł., H. Bucka, K. Kyselowa, 1971. Wybrane glony zbiorników zaporowych, rzeki Soły i stawów karpiowych — Selected algae of dam reservoirs, the River Soła and carp ponds. Acta Hydrobiol., 13, 107—116.

Kulmatycki W., J. Gabański, 1931. O zanieczyszczeniu rzeczki Jankowej przez ścieki cukrowni. Inż. Rolna, 6, 119—137.

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

Loedolff C., J., 1964. Die Role der Cladoceren in Oxydationsteichen Vort. II Internat. Abw. Konf. Tokio, 24—28.

Mejen V., A., 1932. Očistka stočnoj zidkosti v prudach i vyrasčivanie v nich ryby. Moskva, Izd. Vses. nauč. inž.-tech. ob. vodos. i sanit. techn.

Michalski K., 1948. Zmiany biocenozy rzeki Zgłowiączki w wyniku zanieczyszczeń ściekami cukrowni — Changes in the biocenosis of the Zgłowiączka river as a result of its contamination by the sewage of a sugar-factory. Kosmos, A, I, III, 162—208.

Odum E., P., 1963. Podstawy ekologii. Warszawa, PWRL.

Prosjanyj V., S., Z., A. Makina, E., M. Francuzova, 1965. Ispolzovanie vodoemov stočnych vod sacharnych zavodow dja wyraščivanija ryby. Rybn. Chozjaj., 2, 21—25.

Pytlik R., 1954. Oczyszczanie ścieków domowych oraz organicznych ścieków przemysłowych metodą stawów akumulacyjnych i asymilacyjnych. Biul. Zakł. Biol. Stawów, PAN, 5, 119—132.

Pytlík R., Z. Švec, 1954 a. Čištěni a využitkovani odpadnich vod mlekárenesých v asimilacnich rybnicích. Sb. Českosl. Akad. zeměd. věd., 177—198.

Pytlík R., J. Votava, V. Beněs, 1954 b. Čištěni a využitkováni rizkových odpadnich vod cukrovarských v akumulačnych rybnicích. Sb. Českol. Akad. zeměd. ved., 337—344.

Pytlík R., K. Dušek, 1956. Čištěni a využtkowáni odpadnich vod jatek a zavodu masneho prumyslu v asimilačnich rybnicich. Sb. Českosl., Akad. zeměd. věd. Živoč. vyroba. 239—254.

Sivko T. N., V. P. Ljachnovič, 1967. Nabljudenija na prudach biologiceskoj očistki stočnych vod sacharnogo zavoda. Gidrobiol. Ž. 3, 54—61.

Sládeček V., Z. Cyrus, A. Borovičková, 1958. Hydrobiological investigations

http://rcin.org.pl

of a treatment of beet sugar factory's wastes in an experimental lagoon. Sb. Vys. Š. Chem.-Techn. 2, 7—120.

Sládeček V., 1963. A guide to limnosaprobical organisms. Sb. Vys. Š. Chem.-Techn. 7, 543—612.

Starmach K., 1955. Metody badania planktonu. Warszawa. PWRiL.

Starmach K., 1969 a. *Hildebrandia rivularis* i glony towarzyszące w potoku Cedronka koło Wejherowa (województwo Gdańsk) — *Hildebrandia rivularis* and associating algae in the stream Cedronka near Wejherowo (Gdańsk voivode). Fragm. Flor. et Geobot. 15, 387—398.

Starmach K., 1969 b. Glony źródeł na wybrzeżu morskim w Chłapowie — Algae of springs on the sea coast at Chłapowo (Northern Poland) Fragm. Flor. et Geobot. 15, 503—511.

Starmach K., 1969 c. *Hildebrandia rivularis* (Liebm.) y Ag., *Chamaesiphon fuscoviolaceus* n. sp. i glony towarzyszące w potoku Lubogoszcz w Beskidzie Wyspowym — *Hildebrandia rivularis* (Liebm.) J. Ag. and *Chamaesiphon fuscoviolaceus* n. sp., and accompanying algae in the stream Lubogoszcz in the Beskid Wyspowy (Polish Western Carpathians). Fragm. Flor. et Geobot. 15, 487—501.

Starmach K., 1969 d. Glony kałuż nadmorskich przy ujściu rzeki Batova w Bułgarii — Algae of sea side pools near the mouth of the river Batova in Bulgaria. Fragm. Flor. et Geobot., 15, 513—521.

Starmach K., 1969 e. Wody śródlądowe — Zarys hydrobiologii. Kraków Wyd. UJ.

Tomczyńska J., 1969. Stawy biologiczne. w — in Woda i ścieki w przemyśle spożywczym (praca zbiorowa — collective work), 135—140. Wyd. Nauk.-Techn.

Uhlmann D., 1966 a. Beitrag zur Limnologie extrem nährstoffreicher Flachgewässer. II Plankton-Massenwechsel. Wissensch. Ztsch. d. Karl Marx Univ. 2, Leipzig, 373—423.

Uhlmann D., R. Wegelin, 1966 b. Oxydationsteiche, Theorie, Betriebserfahrungen, Hinweise für Bau und Betrieb. WZT-Mitt. VVB Wassersorgung u. Abwasserbehandl. Postdam.

Uhlmann D., 1967. Beitrag zur Limnologie saprothropher Flachgewässer, Arch. Hydrobiol., 63, 1—85.

Walter E., 1922. Kleiner Leitfaden der Teichdüngung. Neudam.

Wierzbicki J., 1959. Możliwości wykorzystania ścieków w stawach rybnych na terenie GOP. Biul. 30.

Wierzbicki J., 1963. Wykorzystanie ścieków w rolnictwie i leśnictwie. Warszawa. PWRL.

Winberg G., W. Lachnowicz, 1968. Nawożenie stawów. Warszawa. PWRL.

Wolny P., 1962. Przydatność oczyszczonych ścieków miejskich do hodowli ryb. Roczn. Nauk Roln., 81, B, 231—250.

Zaręba Z., 1969. Przemysł cukrowniczy. w — in Woda i ścieki w przemyśle spożywczym (praca zbiorowa — collective work), 184—206.

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

Adres autorki — Author's address

mgr Krystyna Kyselowa

Zakład Biologii Wód — Polska Akademia Nauk, Kraków, Sławkowska 17.

http://rcin.org.pl

## ERRATA

| Strona — Page | Wiersz — Line: od góry from above | Wiersz — Line: od dołu from below | Zamiast — Instead of | Winno być — Ought to be |
|---|---|---|---|---|
| 7 | 3 | | turbicity | turbidity |
| 7 | | 8 | relased | released |
| 23 | 3 | | auded | added |
| 45 | 20 | | hiperautotropii | hiperautotrofii |
| 47 | | 23 | G l o u e k e | G o l u e k e |
| 54 | | 12 | If | It |
| 74 | 22 | | *Ankistrodemus* | *Ankistrodesmus* |
| 79 | 11 | | *Quadringula* | *Quadrigula* |
| 81 | 17 | | *Cyclopidea* | *Cyclopidae* |
| 84 | 11 | | niektórych | niektóre |
| 84 | | 6 | *Polyartha* | *Polyarthra* |
| 84 | | 4 | *magma* | *magna* |
| 87 | 13 | | y | I. |
| 90 | | 5 | H a l u š k a | H a n u š k a |
| 108 | | 17 | of investigation in 1968 the third association of *Ciliata* occurred, the | of May. Large numbers of *Ciliata* were also found at the beginning of |
| 108 | | 9 | asseociation | association |
| 111 | 1 | | Macrbenthos | Macrobenthos |
| 115 | 11 | | *Glycoria* | *Glyceria* |
| 119 | | 6 | afuna | fauna |
| 121 | 11 | | *conjungens* | *conjugens* |
| 125 | 4 | | *Psescrocladius* | *Psectrocladius* |
| 127 | 19 | | indicatesthe | indicates the |
| 128 | 9 | | *Chyptochironomus* | *Cryptochironomus* |
| wkładka — insert (Lewkowicz) | 7 | | автофильтрации | самоочищения |
| wkładka — insert (Kyselowa) | 8 | | автофильтрации | самоочищения |
| insert (Huk) | 12, 13 | | фильтрации | очищения |
| insert (Grabacka) | 6,9,10 | | автофильтрации | самоочищения |



http://rcin.org.pl