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PHYCOFLORA COMPOSITION IN AN ARTIFICIAL POND SUBJECT TO ECOLOGICAL SUCCESSION

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Summary. The stimulating influence of sugar plant liquid wastes on the development of phytoplankton was observed when drying an artificial „Hot-water Pond 1". Changes in biomass, species richness, biodiversity, percentage similarity and dominance within phytoplankton communities were related to the level of water temperature and to the water depth. With gradual lowering of the water level in the pond, a dominance shift occurred in green algae common in ponds and puddles, from *Coelastrum microporum* to *Pandorina morum* and *Pteromonas angulosa*. Euglenoids and cryptomonads dominated during the replacement of green algae species.

Key words: hot-water pond, industrial pond, green algae, succession, *Coelastrum microporum*, *Pandorina morum*

INTRODUCTION

Reservoirs used in the sugar industry have the character of artificial ponds built for specific industrial purposes. They are performing the role of settling vats, in which hot industrial waters get cooled down before being directed onwards to the sewage treatment plant. So far no research on the biotic aspect of accumulation ponds collecting heated water, rich in organic compounds, constituting an element of systems of cooling industrial water, have been carried out. In the territory of our country the number of containers of this type is very big and undoubtedly, apart from their purely industrial function, they are also exceptional aqueous ecosystems with unique habitat conditions for living organisms.

Stimulating influence of sugar plant sewage on the development of phytoplankton was found in fish ponds in Gołysz. Over years, after the supply of sewage ceased, a rise of the number of algae and their early maxima at the beginning of the season were noted as a consequence of industrial waters (rich in nutrients) [Kyselowa 1973, Krzeczkowska-Wołoszyn 1977]. There is a large body of literature about temperature, light and nutrient supply as important factors limiting algal production [e.g. Reynolds 1984, 1996, Lampert and Sommer 1997, Wetzel 2001]. All these elements were assured in that artificial pond. However, together with lowering surface of water, light is becoming the important factor limiting the development of algae [Fong and Zedler 1993, Kawecka and Eloranta 1994, Reynolds 1995, Kingston 2002]. The purpose of this study was to examine the phycoflora structure of a hot water pond, in the summer period after the finish of the last sugar-beet harvest campaign till the moment of its total drying.

STUDY AREA, MATERIALS AND METHODS

An accumulation reservoir belonging to the complex of ponds of Sugar Factory Kościan S.A., located in the area of Kościan (Wielkopolska), was the object of examinations. Intense filling of the ponds with industrial waste waters took place during the sugar-beet campaign, in the period from October to January. „Hot-water Pond 1" was the place where the first stage of industrial waste waters cooling. The pond was 22 m wide and had a length of 102 m (surface area of 2244 m^2). The bottom of the pond was flat and it was covered with a layer of clay to prevent the waste water infiltration through to the ground. Water filling the pond was waste utilized earlier in the process of thickening the beet juice on so-called vaporizers. During the sugar campaign, the water flowing out from the water supply system had a temperature of about 60ºC. Phytoplankton samples of the pond water were taken every two weeks from July till September, 2004, when the pond was left to dry. Total covering with herbaceous plants occurred in July, 2005.

Phytoplankton samples were counted using the Utermöhl [1958] sedimentation method. Cells were the main counting units. The determination of the phytoplankton community biomass was based on the estimation of the biovolume of each species, using appropriate geometric formulae and counted cell numbers of each [Edler 1979]. The Jaccard index (variation from 0 to 1) was used to analyse the percentage similarity o phytoplankton communities. The evenness index was calculated based on the Shannon-Weaver diversity index [Pielou 1975].

RESULTS AND DISCUSSION

In July and August 2004, after the finish of the last campaign, the temperature of water in the examined pond fluctuated in the range of 21.0-25.0ºC. It was an appropriate temperature for the summer period. Hot summer days, high solar exposure, and gradual lowering of the water level became the cause of mass development of phytoplankton. It can appear when the amount of nutrients is big enough for the coming into existence of big phytoplankton biomass, especially when fast growing algae are appearing in the environment, at insufficient activity of consumers [Yusof *et al*. 2002]. The high nutrient concentration in the examined pond was connected with a huge amount of sewage inflow from earlier years and gradual lowering of the surface of water. Such disorders, resulting from a pond being almost dry, cause more intense oxygen decomposition of organic matter, which leads to faster freeing of nutrient elements than in ponds still having water [Wetzel 2001, Zimmo *et al*. 2004]. The process of freeing nutrient elements to water was observed in this study, when concentration of both nitrate and ammonium nitrogen as well as dissolved phosphorus achieved maximum value above 2.60 mg l^{-1} and it kept at a steady level all the way till total drying.

Small water bodies which are exploited in the sugar industry are more productive than natural ponds on account of the huge nutrient load arriving from the drainage area. It leads to increased eutrophication of such an ecosystem, with the development of a mix of phytoplankton species causing water blooms. In the conducted examinations, 59 taxa of algae including *Chlorophyta* (25), *Bacillariophyceae* (15) and *Cyanoprokaryota* (8) were recognized as dominant taxonomical algae groups. Species richness oscillated from

23 (11.09.2004) to 30 species (28.08.2004) in particular samples. The Jaccard similarity between the studied periods was from 0.47 up to 0.68. Such an arrangement resulted from similar composition of species sporadically noted in samples. Furthermore, the Shannon biodiversity index (1.85-0.64) as well as the evenness index (0.40-0.15) demonstrated a downward trend with the drying of the pond. It involved changes in the phytoplankton biomass as a result of the dominance of particular species of algae.

Characteristic phytoplankton communities for individual examination periods were observed (Tab. 1). In the pond a gradual increase of the total biomass, from 37.4 mg l^{-1} in July to 155.9 mg l^{-1} in the end of August 2004, was observed. This resulted from the big number of green algae *Coelastrum microporum*, the percentage share of which in the total biomass, noted in the pond in August, achieved the value of 69%. Big numbers of this species continued for a period of six weeks, but the maximum biomass was built by the species on 28th August (Fig. 1). It is a planktonic species which is active in eutrophic waters, particularly at high concentrations of nitrates [Bucka and Wilk-Woźniak 2002, Koreiviene and Kasperoviciene 2003]. At the same time, diatom *Aulacoseira granulata*, known as a summer species in temperate waters, was also very abundant (Tab. 1). The peak of dense development of phytoplankton in the „Hot-water Pond 1" took place in the beginning of September, 2004, when the total biomass attained the value of 742.4 mg l^{-1}. *Pandorina morum* and *Pteromonas angulosa* were dominant in the water (Fig. 1, Tab. 1). They are green algae common in ponds and puddles. Moreover, *Pandorina morum* prefers waters that are well irradiated and rich in nutrients [Bucka and Wilk-Woźniak 2002]. This is a species rated among the group of organisms presenting the strategy of the K type [Reynolds 1984, 1996], that is being characterised by a largeness of colony and a low reproductive rate in cells. Monad green alga *Pteromonas angulosa* is characteristic for strongly eutrophicated water in which it can create monocultures. Its mass appears to be related with the drying of the pond and the increasing concentration of the suspension of nutrients in the shallower water.

Euglenoids dominance, mainly *Euglena proxima* together with cosmopolitic *Euglena acus* and *Euglena pisciformis*, appeared in the middle of August (Tab. 1). Results obtained by Kingston [1999, 2002] indicate that *E. proxima* population is significantly greater in dissolved inorganic nutrient enrichment and, as a benthic, highly motile species, can respond to changes in light through vertical migration. The abundant *E. proxima* population observed in this study might have resulted from greater upward migration from the sediment to the surface of shallower water in the pond. During the bloom *Phacus mirabilis* and *Phacus pyrum* were also noted. Both the species are characteristic of small, rich in nutrients water bodies [Wołowski 1998, Hitchman and Jones 2000]. Furthermore, dense cryptomonads accompanying euglenoids indicated huge availability of organic matter in the pond at that time.

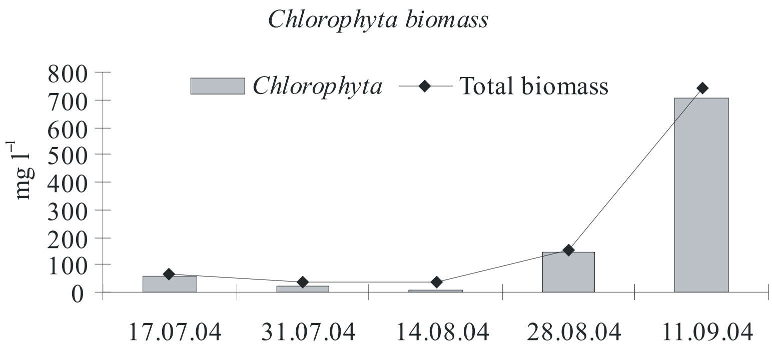
Research on the influence of light and temperature on algae suggest that phytoplankton and benthic algae have a threshold (> 22°C) response to temperature [Fong and Zedler 1993]. Hanagata *et al*. [1992] state that some species, like *Scenedesmus obliquus,* can tolerate 45°C with an optimum growth temperature of 31-32°C, and *Desmodesmus communis* 39°C with its growth optimum around 32°C. Both species were noted in the pond, but only *D. communis* remained for the entire period of examinations, demonstrating a downward trend of biomass. A similar trend was observed for *Scenedesmus acuminatus* which reached its highest biomass in July. In this study, limitation by light could explain the low levels of *Scenedesmus*/*Desmodesmus* biomass, although optimal conditions of water temperature and nutrients availability appeared.

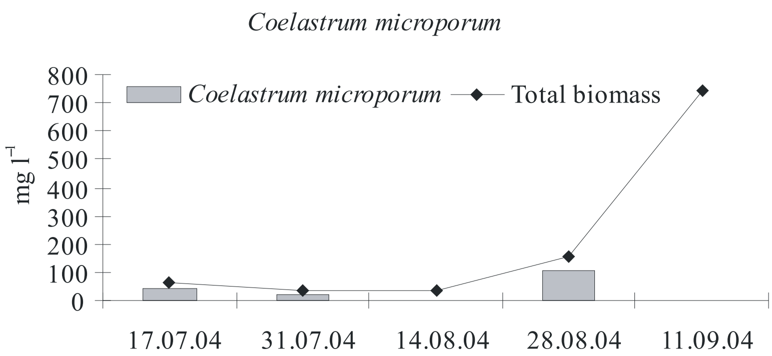
Table 1. Biomass (mg l^{-1}) structure of phytoplankton community in the pond in 2004
Tabela 1. Struktura biomasy (mg·l^{-1}) zbiorowiska fitoplanktonu w stawie w roku 2004

Taxa / Takson	17.07	31.07	14.08	28.08	11.09
Cyanoprokaryota					
Oscillatoria limnetica Lemm.	0.01	+	0.01	0.01	+
Planktothrix agardhii (Gom.)An.et Kom.	–	–	–	1.07	2.67
Pannus microcystiformis Hindák	–	–	–	3.22	–
Chlorophyta					
Scenedesmus acuminatus (Lag.) Chod.	5.31	1.89	0.03	0.33	0.46
Coelastrum microporum Nag. in A. Br.	**45.14**	**19.90**	**0.27**	**107.5**	+
Monoraphidium arcuatum (Korš.) Hind.	1.30	0.70	+	1.35	3.26
Monoraphidium griffithii (Ber.) K.-Legn.	1.39	0.15	+	0.29	0.87
Desmodesmus communis (Heg.) Hegew.	1.12	0.29	+	0.10	0.36
Pandorina morum (O.F. Mül.) Bory	+	+	**5.02**	**33.06**	**679.2**
Pteromonas angulosa (Carter) Lemm.	0.12	+	+	+	**22.59**
Oocystis lacustris Chod.	2.61	1.06	+	–	–
Closteriopsis acicularis (G.M. Sm.) Bel.	0.82	–	–	–	–
Kirchneriella aperta Teil.	0.10	–	–	–	–
Scenedesmus obliquus (Turp.) Kütz.	0.08	–	–	–	+
Monoraphidium contortum (Th.)K.-Leg.	0.03	+	–	–	–
Monoraphidium pussilum (Prin.)K.-Leg.	–	0.07	–	–	–
Tetraedron minimum (A.Br.) Hansg.	–	–	0.01	+	–
Kirchneriella irregularis Korš.	–	–	0.01	+	0.11
Chlamydomonas reinhardti Dang.	–	–	0.57	0.63	–
Gonium sociale (Dujardin) Warm.	–	–	1.01	+	0.95
Chlamydomonas quiescens Skuja	–	–	–	0.02	–
Tetraedron caudatum (Corda) Hansg.	+	–	–	0.01	–
Planktosphaeria gelatinosa G.M. Smith	–	–	–	0.09	0.09
Tetraedron triangulare Korš.	+	–	+	+	0.01
Didymocystis planctonica Korš.	–	–	–	–	0.08
Bacillariophyceae					
Nitzschia recta Hantzsch	2.76	0.59	1.15	2.30	4.60
Nitzschia palea (Kütz.) W.Sm.	0.27	0.05	0.13	0.20	1.42
Aulacoseira granulata (Ehr.) Simon.	+	**11.84**	**0.54**	**4.61**	**10.85**
Cyclotella radiosa (Grun.) Lemm.	0.42	0.03	+	0.13	0.13
Cyclotella ocellata Pantocsek	0.04	0.01	–	–	–
Cocconeis placentula Ehr.	3.97	+	–	–	–
Cyclotella bodanica Grunow	–	0.06	–	–	–
Nitzschia hungarica Grunow	–	0.06	–	+	–
Navicula hungarica Grun.	–	–	0.08	–	–
Fragillaria capucina (Desm.) Raben.	–	–	–	0.15	–
Achnanthes minutissima Kütz.	–	–	–	–	0.03
Phacus mirabilis Pochman	0.10	–	–	–	–
Euglenophyta					
Euglena acus Ehr.	–	0.34	–	–	–
Euglena proxima Dangeard	–	–	**25.48**	–	–
Euglena pisciformis Klebs	–	–	0.41	–	–
Trachelomonas hispida (Petry) Stein	–	+	–	–	**14.75**
Cryptophyta					
Cryptomonas erosa Ehr.	–	–	0.34	–	–
Cryptomonas ovata Ehr.	–	–	0.48	–	–
Rhodomonas minuta Skuja	–	–	0.22	–	
Chrysophyceae					
Chrysococcus rufescens Klebs	–	0.05	0.60	–	–
Dinophyta					
Peridinium sp. – cysts	–	–	–	0.85	–

+ noted sporadically; – absent; maximum values – bold

+ notowany sporadycznie; – brak; wartości maksymalne – pogrubienie





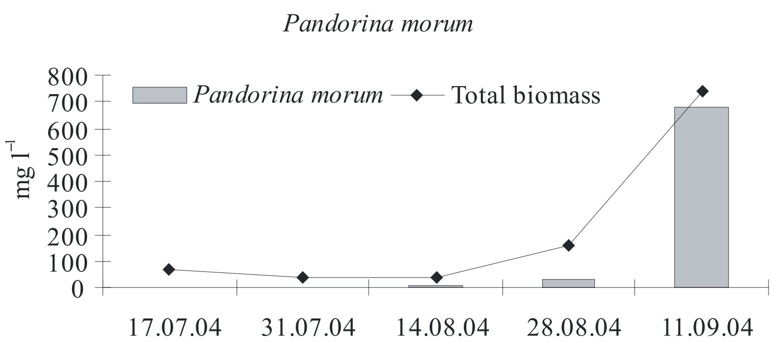


Fig. 1. Distribution of dominant green algae biomass in the pond in 2004
Ryc. 1. Rozkład biomasy dominujących zielenic w stawie w 2004 roku

Together with gradual lowering of the water surface, a very strong succession of the bank flora of the pond occurred. Very fast it captured the dry bottom of the pond, picking the aqueous space up at the same time. The weir surrounding the pond was dominated by the *Chenopodio rubri-Atriplicetum patulae* community. The layer of herbaceous plants on the dry pond, for which covering took as much as 95%, created a dense canopy of *Atriplex prostrata ssp prostrata*. Individual plants developed particularly luxuriantly and achieved the height of 2 m in some places. *Chenopodium album* and *Artemisia vulgaris* were the most abundant species. They created outstandingly nitrophilic and ruderal community similar to vegetation developing on city landfill sites and on garbage dumps at smaller centres of the countryside.

CONCLUSION

The taxonomic groups predominantly represented were chlorophytes, euglenoids, and diatoms. Green algae can grow in severe environments and was the dominant group in the pond where the most favourable temperature occurred for it. Together with drying of the pond, the algae biomass grew, which resulted from the development of single species monocultures. Replacement of the phytoplankton dominants from chlorococcal green algae by euglenoids to monad green algae was noted. In spite of lowering of the water level, no frequent appearance was observed of diatoms which should make the phytoplankton community rich in benthic species from the sediment. In general, this study showed that in the pond, chlorophytes dominance was not replaced by cyanobacteria as nutrient concentrations increased with the drying period. More studies on phytoplankton communities in small artificial ponds are needed.

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STRUKTURA FYKOFLORY SZTUCZNEGO STAWU PODLEGAJĄCEGO SUKCESJI EKOLOGICZNEJ

Streszczenie. Stymulujący wpływ ścieków cukrowniczych na rozwój fitoplanktonu stwierdzono w sztucznym, wysychającym „Stawie wody gorącej 1". Zmiany w biomasie, liczbie taksonów, bioróżnorodności, podobieństwie i dominacji gatunków w obrębie zbiorowisk fitoplanktonu były uzależnione od temperatury wody i jej głębokości. Wraz ze stopniowym obniżaniem się poziomu wody w stawie nastąpiła przebudowa dominantów w obrębie pospolitych w stawach i kałużach zielenic z *Coelastrum microporum* na *Pandorina morum* i *Pteromonas angulosa*. W okresie wymiany tych gatunków dominowały eugleniny i kryptofity.

Słowa kluczowe: staw wody gorącej, staw przemysłowy, zielenice, sukcesja, *Coelastrum microporum*, *Pandorina morum*