Oceanological and Hydrobiological Studies
International Journal of Oceanography and Hydrobiology

Volume 40, Issue 4

ISSN 1730-413X
eISSN 1897-3191

(30–37)
2011

VERSITA

DOI: 10.2478/s13545-011-0038-z
Original research paper

Received: *February 10, 2011*
Accepted: *September 22, 2011*

Blooms of toxin-producing Cyanobacteria – a real threat in small dam reservoirs at the beginning of their operation

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Key words: anatoxin-*a*, microcystins, dam reservoir, *Microcystis, Planktothrix, Anabaena*

Abstract

Large and harmful cyanobacterial blooms appeared in two newly-built artificial reservoirs shortly after being filled with water. Taxonomic composition of cyanobacterial communities was highly variable in both water bodies and fast species replacement was observed. In the first year of the operation of the smaller Konstantynów Reservoir, the mass development of *Anabaena flos-aquae* and *Planktolyngbya limnetica* (48.7 and 53.6% of the cyanobacterial abundance) occurred in summer, while in autumn the dominance of *Planktothrix agardhii* (99.9%, 14.95×10^{6} ind. dm^{-3}) was noted. The surface scum developed in summer consisted of *An. flos-aquae* that contained high amounts of anatoxin-*a* (1412.4 μg AN-a dm^{-3} of scum) and smaller amounts of microcystins (10 μg eq. MC-LR dm^{-3} of scum). In the larger Kraśnik Reservoir, *Aphanizomenon flos-aquae* occurred in high abundance in spring and summer, however, it was replaced by different species of *Microcystis* (1.3×10^{7} ind. dm^{-3}) which created thick surface scum. Simultaneously, a hazardous increase in the total concentration of microcystins (from 13.6 to 788.5 μg eq. MC-LR dm^{-3} of water with scum) and anatoxin-*a* (from 0.03 to 43.6 μg dm^{-3}) was observed.

INTRODUCTION

In shallow eutrophic lakes and dam reservoirs, toxin-producing species of cyanobacteria often create water blooms and become an increasing problem in many countries (Sivonen et al. 1990, Dokulil and Teubner 2000, Pawlik-Skowrońska et al. 2004, Tonk et al. 2005, Kurmayer and Christiansen 2009, Toporowska et al. 2010). Mass development of toxigenic Cyanobacteria may be a real hazard in water bodies used as drinking water supplies and for recreational or fishery purposes (Malbrouck and Kestemont 2006, Palus et al. 2007, Grabowska and Pawlik-Skowrońska 2008). Hepatotoxins, neurotoxins and other secondary metabolites produced by cyanobacteria, are dangerous for humans, domestic animals and wildlife (Carmichael 1992, Mazur-Marzec 2006, Welker and von Dohren 2006). Hepatotoxic microcystins (MC), which occur in about 80 different isoforms, inhibit the eukaryotic enzyme protein phosphatase 1 and 2A. Among the former, microcystin-LR (MC-LR) is the most common and toxic one. Neurotoxic anatoxin-*a* (AN-a) is a potent post-synaptic depolarizing neuromuscular blocking agent (Carmichael 1992, Van Apeldoorn et al. 2007). Although there are several potential exposure routes for cyanotoxins (oral consumption, inhalation, or skin absorption), the most common is the ingestion of water by drinking and/or by an accidental recreational intake (Kabziński and Kabziński 2006). The World Health Organization established a provisional guideline limiting MC-LR to 1 μg dm^{-3} in drinking water (Chorus and Bartram 1999) and to 10 μg dm^{-3} in

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recreational waters (WHO, 2008). The anatoxin-*a* database is limited in quantitative and qualitative studies on effects following the oral exposure to sublethal levels, however, neurotoxicity and death were observed in acute, short-term and sub-chronic oral animal studies (USEPA, 2006). Anatoxin-*a* half-life in natural blooms in eutrophic lakes was estimated at about 24 hours while under laboratory conditions – at about five days, therefore 450 μg AN-a dm^{-3} was recommended by the Washington State Department of Health (USA) as a provisional short-term recreational guideline value and 75 μg dm^{-3} as a sub-chronic one (Hardy 2008). According to the Directive of UE 2006/7/WE, assessment of recreational water quality should be based on the abundance of bloom-forming cyanobacteria capable of toxin production. Recently, a tendency for construction of small, water retention reservoirs on rivers has been increasing in Poland.

The aim of this paper was to study the structure and development dynamics of cyanobacteria communities, as well as threats posed by their toxins in newly-built, multipurpose dam reservoirs.

MATERIALS AND METHODS

Study area

Samples of surface water (0 – 0.5 m) were collected (August – October, 2007) near the shore (3 – 4 m) of the small, lowland Reservoir Konstantynów (2 ha, mean depth 1.9 m, max. depth 2.9 m) located (N 52º 12', E 23º 5') on the Czyżówka River, and in May – September, 2008, 4-5 m far from the shore of the larger, upland Reservoir Kraśnik (39.1 ha; mean depth 2.5 m, max. depth 6 m) located (N 50º 56', E 22º 11') on the Wyżnica River (both in the Lublin province, Eastern Poland). The Konstantynów Reservoir was built in countryside and it was filled with water in May, 2007. The reservoir is mainly used for retention and fishing purposes. Its agricultural catchment area has no sewage system on most of the area. The Kraśnik Reservoir, located at the border of Kraśnik city, was filled with water in 2006 and since then it has been affected by mass development of cyanobacteria. It is used for retention and recreational (swimming, angling) purposes. The reservoir is enriched with nutrients contained in water of the Wyżnica River and its catchment area.

Physicochemical and biological analyses

Physicochemical and biological characteristics of water from both reservoirs are presented in Table 1. Biogenic nutrients were determined according to Golterman (1971) and chlorophyll-*a* − according to PN-ISO 10260 (2000). The Carlson Trophic Status Index (TSI) based on chlorophyll-*a* and SD values was also calculated (Carlson 1977). The samples of water (VIII b) with thick scum (Kraśnik R.) were not taken into account for the TSI calculation. The qualitative and quantitative structure of phytoplankton communities was analyzed by means of an inverted microscope (Utermöhl 1958), and

Table 1

Physicochemical and biological parameters of water in the studied reservoirs.

Parameters	Physic-chemical parameters						
	Konstantynów R.				Kraśnik R.		
	Months						
	VIII^{a}	VIII^{b}	IX	X	V	VII	IX
Temperature (°C)	19.8	21.5	17.0	10.0	nd.	20.7	15.9
pH	7.6	7.6	7.4	6.7	7.7	8.1	8.1
Conductivity (μS cm^{-1})	398	372	479	562	421	nd.	344
Transparency - SD (m)	0.33	0.30	0.41	0.55	1.73	0.65	0.40
Oxygen conc. (mg dm^{-3})	9.9	nd.	8.6	9.0	nd.	5.7	6.9
$P-PO_4$ (mg dm^{-3})	nd.	nd.	0.073	0.133	0.059	0.085	0.090
$N-NH_4$ (mg dm^{-3})	nd.	nd.	0.106	0.053	0.301	0.339	0.043
$N-NO_3$ (mg dm^{-3})	nd.	nd.	nd.	nd.	0.076	0.069	0.786

	Biological parameters								
	Konstantynów R.				Kraśnik R.				
	Months								
	VIII^{a}	VIII^{b}	IX	X	V	VII	VIII^{a}	VIII^{b,c}	IX
Chlorophyll-*a* (μg dm^{-3})	140.4	212.6	122.8	69.9	9.7	63.2	132.8	1600.0	29.9
Trophic status	TSI = 78				TSI = 68				
Phytoplankt. biomass (mg dm^{-3})	35.6	66.8	37.4	26.1	4.9	16.3	21.1	273.0	10.5
Total MCs (μg equiv. MC-LR dm^{-3})	10.0^{c}	nd.	nd.	nd.	nd.	nd.	13.6	788.5	nd.
AN-a (μg dm^{-3})	1412^{c}	nd.	nd.	nd.	nd.	nd.	0.03	43.6	nd.

^{a} – beginning of August, ^{b} – middle of August, nd. – not determined, ^{c} – per dm^{3} of water with cyanobacterial scum taxonomical identification was based on Van den Hoek et al. (1995) and Komárek and Anagnostidis (1999/2000, 2005). For all Oscillatoriales and Nostocales with straight filaments 100 μm was set as one individual. One curve of curved *Anabaena* spp. and one colony of *Microcystis* spp. were recognized as individuals. Phytoplankton biomass was estimated by cell volume measurement (Kawecka and Eloranta 1994).

Analyses of cyanotoxins

For determination of cyanotoxin concentrations, surface water (0.5 - 1.0 dm^{-3}) containing cyanobacterial biomass was concentrated on Whatman GF/C filters to 1 - 1.5 cm^{-3} and extracts of the biomass were prepared in 75% (v/v) methanol (Merck, pure p.a.) using ultrasonication (3 times for 5 min., 50W, ultrasonic homogenizer Sonoplus, Bandelin).

Total concentration of microcystins (MC) in extracts was determined using gas chromatography/mass spectrometry (GC/MS, Varian) according to Kaya and Sano (1999) and the modified procedure described by Pawlik-Skowrońska et al. (2008). The method is based on oxidation of Adda (a specific amino acid present in MCs) to MMPB (2-methyl-3-methoxy-4-phenylbutyric acid) and determination of MMPB as a methyl ester. The oxidation was carried out for 4 hours with 99.8% NaIO$_4$ and 0.024 M KMNO$_4$. For derivatization, 14% BF$_3$ –methanol was used. As a modification, phenylbutyric acid (PB) was used as an internal standard step after oxidation. Derivatized samples were dissolved in n-hexane and subjected to GC/MS analysis (Saturn 2000, Varian). In EI-MS mode, the identification and quantification of MMPB methyl ester was based on ions at m/z 91, 131 and 190; for PB methyl ester 91, 104 and 146 m/z were used. The identification of MMPB and PB was confirmed by CI-MS at m/z 191 and 147, respectively. Total microcystin concentrations were expressed as equivalents of MC-LR, which was used as a standard (MC-LR, Alexis)

Anatoxin-*a* (AN-*a*) in extracts was determined using liquid chromatography (HPLC, Beckman) with fluorescence detection (Shimadzu) according to James et al. (1998) and Furey et al. (2005). For AN-*a* derivatization 10% NBD-F (4-fluoro-7-nitrobenzofuran; Fluka) was used. The detector parameters were as follows: excitation wavelength 470 nm, emission wavelength 530 nm. For identification and quantitative determinations, the standard AN-*a* (Tocris, Bioscence) was used.

RESULTS

The mass development of cyanobacteria in both reservoirs was observed shortly after being filled with water. Hydro-morphological and chemical parameters (Table 1) supported this negative phenomenon. Low water transparency in summer (0.30 – 0.55 m and 0.40 – 0.65 m in Konstantynów and Kraśnik, respectively) and high chlorophyll-*a* concentrations were a consequence of mass development of phytoplankton. Also the total phytoplankton biomass was very high (>20 mg dm^{-3}) in the surface water of both reservoirs (Table 1). In terms of species richness, cyanobacteria (after Chlorophyceae and Bacillariophyceae) were the third most important components of phytoplankton (Fig. 1). Both the number of cyanobacteria taxa and their

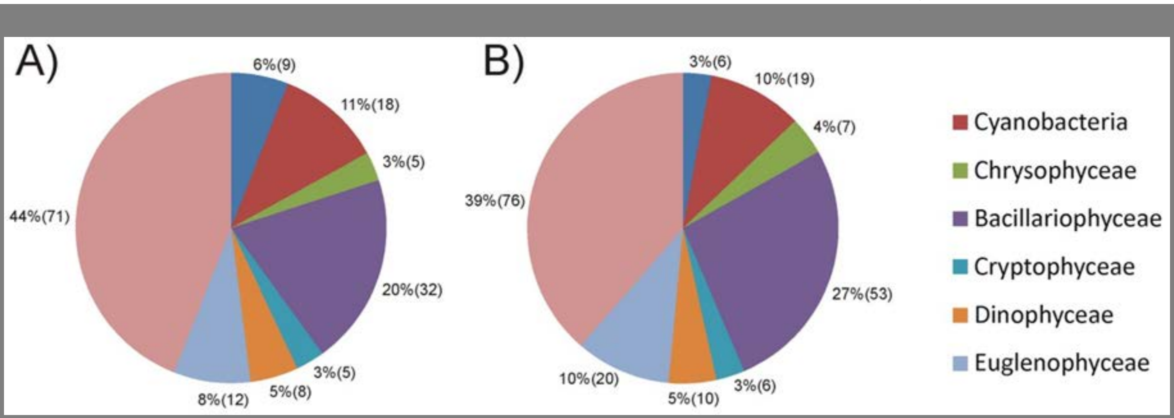

Fig. 1. The contribution of the number of taxa (%) from particular taxonomic groups in phytoplankton recorded in the reservoirs of Konstantynów (A) and Kraśnik (B). The total number of phytoplankton taxa was set as 100%. Parentheses shows number of taxa from particular taxonomic groups.

percentage contribution in the total number of phytoplankton taxa were similar (Fig. 1), however, different cyanobacteria taxa dominated quantitatively in different study periods (Table 2). In total, 18 taxa of cyanobacteria from 11 genera were found in the Konstantynów Reservoir. Fourteen of them (Table 2) were potential toxin producers and 11 were bloom-forming species. In the Kraśnik Reservoir 19 taxa of cyanobacteria from 11 genera were identified. Twelve of them were potential toxin producers (Table 2) and 10 were able to create water blooms. In the Konstantynów Reservoir the total abundance of particular taxonomic groups of cyanobacteria ranged within 6.59 – 19.7 ind. × 10^6 dm^{-3} (Fig. 2A), and their biomass ranged within 22.0 – 29.9 mg dm^{-3} (Fig. 3A) accounting for 45 – 62% of the total phytoplankton biomass. In both reservoirs, the species composition of bloom-forming cyanobacteria communities varied significantly during the study periods (Table 2). At the beginning of August (Figs 2A, 3A) mass development of Nostocales (52.4% of the cyanobacteria abundance and 94.5% of the cyanobacteria biomass) with the dominant filamentous *Anabaena flos-aquae* Bréb. ex Born. et Flah. (48.7% of the cyanobacteria abundance and 89.9% of the cyanobacterial biomass) was observed in Konstantynów R. Two weeks later Oscillatoriales (*Planktolyngbya limnetica* (Lemm.) Kom.-Legn. et Cronberg) dominated quantitatively (10.6 ind. × 10^6 dm^{-3}; 54.0%), though the abundance of *An. flos-aquae* was still high (2.6 ind. × 10^6 dm^{-3}; 7.3%) and this species dominated in the biomass of blue-green algae (20.3 mg dm^{-3} and 67% of cyanobacteria biomass; Fig. 3A, Table 3). In early autumn, a strong increase in the density of *Planktothrix agardhii* (Gom.) Anagn. et Kom. (Oscillatoriales) occurred (Fig. 2A, 3A,

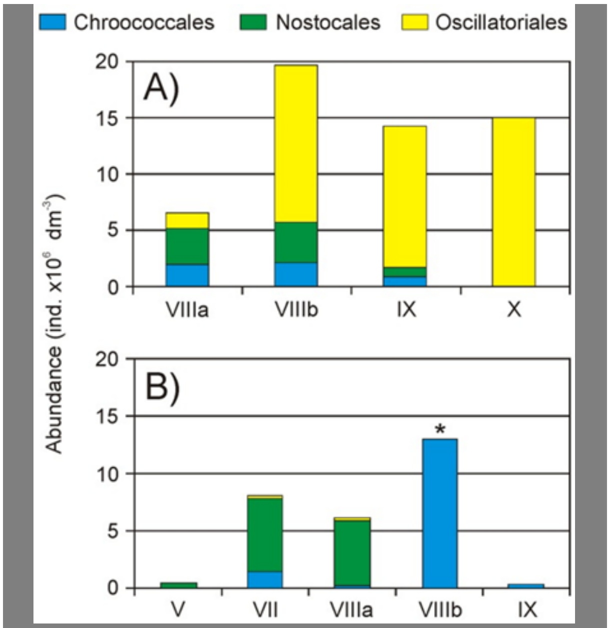

Fig. 2. Comparison of the total abundance of Chroococcales, Nostocales and Oscillatoriales in the studied reservoirs: A – Konstantynów (a – the beginning of August, b – the middle of August), B – Kraśnik. * - abundance in water with *Microcystis* scum.

Table 2

The list of bloom-forming (▼) and potential toxin-producing (*) taxa of Cyanobacteria in the phytoplankton of the reservoirs and their contribution (%) in the total abundance of phytoplankton.

Taxa	Konstantynów R.				Kraśnik R.				
	Month								
	VIII^{a}	VIII^{b}	IX	X	V	VII	VIII^{a}	VIII^{b}	IX
Anabaena flos-aquae (Lyngb.) Bréb. ex Born. et Flah. * ▼	++++	++	+		+				
An. lemmermannii Richt. * ▼	+		+						
An. planctonica Brunnth.*		+	+						
An. solitaria Kleb.* ▼	++	++				+			
An. spiroides Kleb. * ▼	+	+	+		+				
Aphanizomenon flos-aquae (L.) Ralfs ex Born. et Flah. * ▼					+++	+++++	++++	+	
Aph. gracile (Lemm.) Lemm. * ▼			+						
Aph. Issatschenkoi (Usač.) Prošk.-Lavr.*	+	+	+						
Limnothrix redekei Van Goor ▼			+						
Lyngbya sp. *			+						
Microcystis aeruginosa (Kütz.) Kütz. * ▼		+	+			+	++++	+++++	+
M. flos-aquae (Wittr.) Kirch. * ▼		+				+	+++	++++	+
M. wesenbergii (Kom.) Kom.in Kondr.* ▼						+	+	++	+
M. viridis (A. Br. in Rabenh.) Lemm. * ▼						+	+		+
Oscillatoria sp. *			+						
Planktolyngbya sp.*					+				
P. limnetica (Lemm.) Kom.-Legn. et Cronb. * ▼	++	++++	+++	+	+	+			+
Planktothrix agardhii (Gom.) Anagn. et Kom. * ▼		++	++	+++++		+	+		+
Snowella lacustris (Chod.) Kom. et Hind.*	+	+							+
Woronichinia sp. * ▼	++		+						

+ - (< 1%); ++ - (1 – 10%); +++ - (10 – 25%); ++++ - (25 – 50%); +++++ - (>50%)

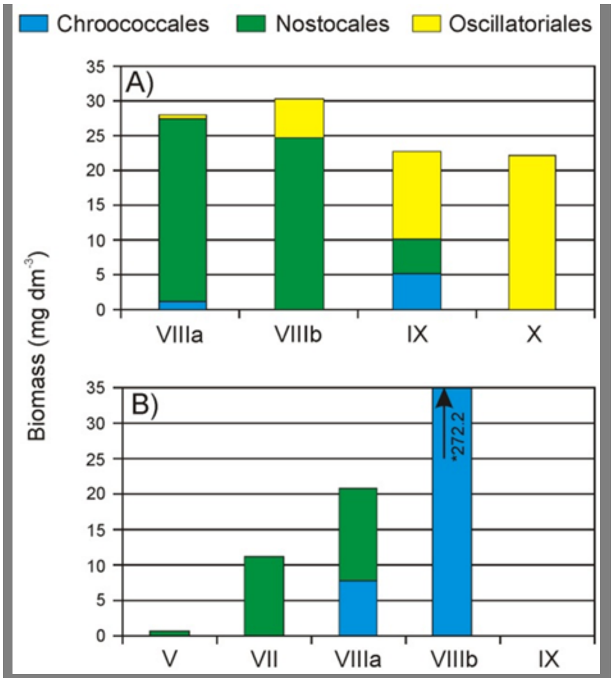

Fig. 3. Comparison of the total biomass of Chroococcales, Nostocales and Oscillatoriales in the studied reservoirs: A – Konstantynów (a – the beginning of August, b – the middle of August), B – Kraśnik. In September the biomass <0.08 mg dm^{-3}; * - biomass in water with *Microcystis* scum.

Table 3

Abundance and biomass of the dominant, bloom-forming species of Cyanobacteria.

Taxa	Konstantynów R.				Kraśnik R.		
	Months						
	VIII[a]	VIII[b]	IX	X	VII	VIII[a]	VIII[b,c]
Abundance (×10^6 ind. dm^{-3})							
An. flos-aquae	3.21	2.60	1.02	—	—	—	—
Aph. flos-aquae	—	—	—	—	9.66	6.00	0.03
Microcystis spp.	—	—	—	—	0.01	0.20	13.00
Pl. limnetica	0.91	10.58	5.22	0.92	—	—	—
P. agardhii	0.27	3.32	3.43	14.95	—	—	—
Biomass (mg dm^{-3})							
Taxa	Konstantynów R.				Kraśnik R.		
	Months						
	VIII[a]	VIII[b]	IX	X	VII	VIII[a]	VIII[b,c]
An. flos-aquae	25.05	20.33	7.94	—	—	—	—
Aph. flos-aquae	—	—	—	—	11.19	12.91	0.72
Microcystis spp.	—	—	—	—	0.01	7.80	272.80
Pl. limnetica	0.03	1.08	0.78	0.12	—	—	—
P. agardhii	0.28	4.45	4.51	19.63	—	—	—

[a] – beginning of August, [b] – middle of August, [c] – per dm^3 of water with cyanobacterial scum

Table 3), and its dominance (14.95 × 10^6 ind. dm^{-3}; 99.9% of the cyanobacterial abundance and 19.6 mg dm^{-3}; 99.99% of the cyanobacterial biomass) was observed even at low water temperature. Cyanobacterial scum, which appeared on the water surface at the beginning of August, consisted mainly of *An. flos-aquae* and contained high amounts of cyanotoxins i.e. 1412.4 µg of anatoxin-*a* dm^{-3} and 10.0 µg eq. MC-LR dm^{-3} of water with scum (Table 1). In the Kraśnik Reservoir other species of cyanobacteria (Nostocales and Chroococcales) created a large water bloom (Table 2). In summer months, the total abundance of particular taxonomic groups of Cyanobacteria in the surface water ranged within 6.2 – 13.0 × 10^6 ind. dm^{-3} (Fig. 2B), while the biomass – within 11.2 - 272.2 mg dm^{-3} (Fig. 3B) due to a big change in the species composition. In spring and the beginning of summer (Fig. 2B, 3B) the bundle-forming cyanobacterium *Aphanizomenon flos-aquae* (L.) Ralfs ex Born. et Flah. (Nostocales) dominated. Heavy water blooming of this species (9.67 × 10^6 ind. dm^{-3}; 82% of the cyanobacterial abundance, 99% of the biomass) occurred in July and also at the beginning of August (Tables 2, 3), whereas about 3 weeks later, Chroococcales comprising different species of *Microcystis* (*Microcystis aeruginosa*, *M. flos-aquae*, *M. wesenbergii* and *M. viridis*) replaced *Aph. flos-aquae* and other cyanobacteria. Only during 19 days of August, a strong increase in the total abundance of *Microcystis* spp. occurred − from 0.2. × 10^6 to 13 × 10^6 colonies per dm^{-3} (Tables 2, 3). The biomass of *Microcystis* spp. in the surface water layer covered with scum increased within this period about 35 times. At the same time, an increase in the total concentration of microcystins (from 13.6 to 788.5 µg eq. MC-LR dm^{-3}) and anatoxin-*a* (from 0.03 to 43.6 µg dm^{-3}) was recorded in the water containing the scum (Table 1). The heavy water blooming, formed by *Microcystis* spp., disappeared already in the early autumn when the water temperature decreased to about 15°C.

DISCUSSION

Intense toxic cyanobacterial blooms and their consequences are the most detrimental effects of eutrophication in various water bodies (Paerl 1988, Smith 2003, Burchardt and Pawlik-Skowrońska 2005). In the two newly-built, water reservoirs located on small rivers, water blooms caused by different species of cyanobacteria appeared shortly after filling with water (also in Kraśnik R. already in summer 2006, Pawlik-Skowrońska, personal communication). The values of the trophic status index (TSI = 68 and 78), estimated according to Carlson (1977), showed that both dam reservoirs are highly eutrophicated. Their shallowness enabled a rapid increase in the water temperature in spring/summer, thus supporting the mass development of different cyanobacteria species, which seriously reduced the water quality by lowering the water transparency and formation of toxin-containing cyanobacterial scum on the water surface. Interestingly, in spite of the similar reservoir depth and high trophic status, the qualitative and quantitative structures of cyanobacteria communities in the studied reservoirs were completely different. Similar, high species variability of bloom-forming communities and species succession were also stated in other artificial eutrophic water reservoirs in Poland (Pawlik-Skowrońska et al. 2004, Grabowska and Pawlik-Skowrońska 2008). In both studied reservoirs, N_2-fixing filamentous Nostocales *Anabaena flos-aquae* and *Aphanizomenon flos-aquae* created water blooms first, being competitive with both Oscillatoriales and Chroococcales, which are dependent on other nitrogen sources (Dokulil and Teubner 2000, Wilk-Woźniak and Mazurkiewicz-Boroń 2003). The observed replacement of Nostocales by Chrooococcales (in the larger Kraśnik Reservoir) or by Oscillatorialles (in the smaller Konstantynów Reservoir) might be caused by an increase in supplies of other forms of nutrients and/or a change in temperature, as well as light and water mixing conditions during mass proliferation of Cyanobacteria (Paerl 1996). Interestingly, no mass development of *Limnothrix redekei* (Van Goor) Meffert, typical of other hypertrophic, polymictic reservoirs (Rücker et al. 1997, Wiśniewska et al. 2007) was observed. In the Konstantynów Reservoir, the abundance of the cold-adapted *P. agardhii* (Oscillatoriales) was similar to that found in the eutrophic dam reservoir Zemborzycki near Lublin (Pawlik-Skowrońska et al. 2004). However, at the same water temperature (10°C), it was four times lower than in a small hypertrophic lake (Wiśniewska et al. 2007). The dominance of *P. agardhii* observed in autumn, could result from a higher nutrient level in the studied reservoir. Probably, also the lower water temperature, the declining intensity of photosynthetically active radiation and stronger water mixing in the very shallow reservoir enhanced its development (Scheffer et al. 1997, Pawlik-Skowrońska et al. 2004, Toporowska et al. 2010). *P. agardhii* may develop even under the ice cover and create perennial blooms (Seip and Reynolds 1995, Polučkowa et al. 2004, Wiśniewska et al. 2007, Burchardt et al. 2009) dangerous for aquatic ecosystems due to its capability of microcystin production (Tonk et al. 2005, Akcaalan et al. 2006, Pawlik-Skowrońska et al. 2008). For example, the replacement of Chroococcales and Nostocales by *P. agardhii* in water of a large dam reservoir in Eastern Poland resulted in an essential increase in microcystin concentrations (Grabowska and Pawlik-Skowrońska 2008). In the case of the Kraśnik Reservoir, an extremely high increase in the total levels of microcystins and anatoxin-a in the surface water layer was a consequence of strong development of *Microcystis* spp. and/or their sub-populations with higher capability of MC production. In large water bodies with poor vertical mixing (Jöhnk et al. 2008) and high temperatures (>20°C), the abundance of *Microcystis* can increase rapidly within a few days. Such a phenomenon was also observed earlier , in several large dam reservoirs in Poland (Wilk-Woźniak 1996, Grabowska 2005, Mankiewicz-Boczek et al. 2006). The upward floating of *Microcystis* supports the formation of dense cyanobacterial blooms at the water surface (Visser et al. 1996). It seems that in both reservoirs apart from high nutrient concentrations, also their size, water retention time and water mixing intensity could be essential factors determining the differences in species dominance of cyanobacteria.

In the Konstantynów Reservoir the bloom-forming *An. flos-aquae* produced considerable amounts of AN-*a*, however, MCs were also detected. Apart from *Anabaena* spp, other species i.e. *M. aeruginosa*, *M. flos-aquae* , *P.aghardii* are known as MC-producers (Carmichael 1992, Kurmayer and Christiansen 2009). Also anatoxin-*a* producing *Microcystis* sp. was previously reported (Van Apeldoorn et al. 2007). It must be emphasized that within the same species of cyanobacteria their sub-populations of diverse capability of producing different isoforms and amounts of cyanotoxins develop under natural conditions (Kurmayer et al. 2004, Kardinaal et al. 2007). Coccoid *Microcystis* spp, filamentous *Anabaena* spp, *Aph. flos-aquae*, *P. agardhii*, and *Pl. limnetica*, which created water blooms in the reservoirs we studied, are the most common bloom-forming cyanobacteria in freshwaters (Bucka and Wilk-Woźniak 2007, Pawlik-Skowrońska et al. 2004). The nineteen taxa of cyanobacteria found in both reservoirs during the study period make up almost half of about 40 species of freshwater blue-green algae, which are so far known as potential toxin producers (Burchardt and Pawlik-Skowrońska 2005). Their successive mass development may cause a serious human and animal health risk (Dawson 1998, Orr et al. 2001, Osswald et al. 2007). Consumption of fish living in water reservoirs affected by cyanobacterial blooms is hazardous due to accumulation of cyanotoxins in edible fish muscles (Malbrouck and Kestemont 2006, Toporowska and Pawlik-Skowrońska 2009) and possible transfer to human bodies (Chen et al. 2009). The collapse of a cyanobacterial bloom causes a release of cyanotoxins directly to water and sediment, where some of them, especially microcystins, can persist for a long time (Pawlik-Skowrońska et al. 2010) and affect aquatic biocenoses and reservoir users.

Prevention of the excessive development of cyanobacteria in small dam reservoirs is extremely desirable, although difficult or even impossible in cases when they are filled with waters from nutrient-polluted rivers or when their catchment areas are not properly managed. In eu/hypertrophic water reservoirs, where nutrient limitation does not play any role, the population dynamics of different cyanobacteria species are driven by light availability, temperature and water mixing processes.

CONCLUSIONS

Our studies showed that the mass development of toxin-producing Cyanobacteria in the newly-built dam reservoirs may appear shortly after the commencement of their operation and become a serious ecological and social problem. The species richness and composition of cyanobacterial communities in two small nutrient-rich water bodies were significantly different and highly variable within one season, with successive quantitative dominance of species producing both hepatotoxins and neurotoxins. The obtained results suggest that there is a strong need for environmental expertise concerning both the water quality in rivers and the management of their catchment areas before each decision has been taken on the construction of small dam reservoirs.

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