Ecotoxicology and Environmental Safety 145 (2017) 420–430

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

The biodegradation of microcystins in temperate freshwater bodies with previous cyanobacterial history

Dariusz Dziga[a,*], Anna Maksylewicz[a], Magdalena Maroszek[a], Agnieszka Budzyńska[b], Agnieszka Napiorkowska-Krzebietke[c], Magdalena Toporowska[d], Magdalena Grabowska[e], Anna Kozak[b], Joanna Rosińska[b], Jussi Meriluoto[f]

[a] Faculty of Biochemistry, Biophysics and Biotechnology, Jagiellonian University, Gronostajowa 7, 30387 Krakow, Poland
[b] Department of Water Protection, Faculty of Biology, Adam Mickiewicz University, Umultowska 89, 61614 Poznań, Poland
[c] Department of Ichthyology, Hydrobiology and Aquatic Ecology, Inland Fisheries Institute, Oczapowskiego 10, 10719 Olsztyn, Poland
[d] Department of Hydrobiology, University of Life Sciences in Lublin, Dobrzańskiego 37, 20262 Lublin, Poland
[e] Department of Hydrobiology, University of Białystok, Ciołkowskiego 1J, 15245 Białystok, Poland
[f] Biochemistry, Faculty of Science and Engineering, Åbo Akademi University, Tykistökatu 6A, 20520 Turku, Finland

ARTICLE INFO

Keywords:
Cyanobacteria
Microcystins
Biodegradation
Freshwater bodies
Degradation products

ABSTRACT

Cyanobacterial blooms and cyanotoxins occur in freshwater lakes and reservoirs all over the world. Bacterial degradation of microcystins (MC), hepatotoxins produced by several cyanobacterial species, has also been broadly documented. However, information regarding MC biodegradation in European water bodies is very limited. In this paper, the occurrence and identification of MC biodegradation products was documented for 21 European lakes and reservoirs, many of which have well-documented cyanobacterial bloom histories. Varying cyanobacterial abundance and taxonomical composition were documented and MC producers were found in all the analysed samples. *Planktothrix agardhii* was the most common cyanobacterial species and it formed mass occurrences in four lakes. MC biodegradation was observed in 86% of the samples (18 out of 21), and four products of dmMC-LR decomposition were detected by HPLC and LC-MS methods. The two main products were cyclic dmMC-LR with modifications in the Arg-Asp-Leu region; additionally one product was recognized as the tetrapeptide Adda-Glu-Mdha-Ala. The composition of the detected products suggested a new biochemical pathway of MC degradation. The results confirmed the hypothesis that microcystin biodegradation is a common phenomenon in central European waters and that it may occur by a mechanism which is different from the one previously reported. Such a finding implies the necessity to develop a more accurate methodology for screening bacteria with MC biodegradation ability. Furthermore, it warrants new basic and applied studies on the characterization and utilization of new MC-degrading strains and biodegradation pathways.

1. Introduction

Cyanobacterial blooms and production of cyanotoxins are a growing global problem (Paerl, 2014). Microcystins (MCs) are the most commonly occurring toxins produced by cyanobacteria (Sivonen and Börner, 2008). These toxins are monocyclic heptapeptides which induce harmful effects in plant, animal and human cells (Rastogi et al., 2014). The main risks for people are liver damage and tumor promotion, but cardiotoxic and neurotoxic effects have been reported as well (Rastogi et al., 2014). There were also incidents of hemodialysis centre patients deaths, which most probably resulted from using MC-contaminated water in the process of hemodialysis (Jochimsen et al., 1998; Azevedo et al., 2002). MCs were identified in serum and post-mortem liver tissue samples of the patients, as well as in water-treatment devices in the hemodialysis centre and in the reservoir serving as the water source (Jochimsen et al., 1998). However, later studies revealed also the presence of saxitoxin in water treatment devices of the hemodialysis centre (Azevedo et al., 2002). Due to the use of many surface waters as a source of drinking water or for recreation, the health problems related to MC toxicity are well documented. Among the MC producers, there are cyanobacterial genera which form water blooms in fresh and brackish water, such as *Microcystis*, *Anabaena* (both benthic and planktonic species, the latter recently grouped in the new genus *Dolichospermum*) and *Planktothrix* (Sivonen and Jones, 1999; Dittmann et al., 2013; Grabowska et al., 2014). The occurrence of these potential toxin producers is common in eutrophic waters in Europe (Gkelis and

* Corresponding author.
E-mail address: dariusz.dziga@uj.edu.pl (D. Dziga).

http://dx.doi.org/10.1016/j.ecoenv.2017.07.046
Received 23 February 2017; Received in revised form 17 July 2017; Accepted 18 July 2017
Available online 31 July 2017

Table 1
Characteristics of investigated freshwater bodies.

Nr	lake / reservoir	Location and morphometric data						Water parameters in 2015				Trophic state parameters according to literature **			
		latitude	longitude	type of reservoir*	lake surface (ha)	max depth (m)	mean depth (m)	SD (m)	water temp. (°C) at 0.5 m	pH at 0.5 m	conduct. (μS*mm^{-1}) at 0.5 m	TP (μgP L^{-1})	TN (mgN L^{-1})	chl a (μg L^{-1})	References
1.	Siemianówka	52°56'23"N	23°45'39"E	A	3250.0	10.0	2.5	0.4	21.8	8.0	31.8	290	2.65	34.8	Zieliński et al. (2016)
2.	Białe Sosnowickie	51°31'57"N	23°02'33"E	mL	134.0	2.7	1.3	0.2	24.0	7.5	18.7	260	n.a.	64.5	Pawlik-Skowrońska and Toporowska (2016)
3.	Czarne Sosnowickie	51°30'55"N	23°01'37″E	mL	39.0	15.6	5.1	1.4	22.0	8.4	31.7	70	n.a.	17.8	Toporowska et al., in preparation
4.	Tomaszne	51°27'59"N	23°00'08"E	mL	95.0	3.1	2.3	0.4	23.5	7.5	31.5	230	n.a.	63.3	Pawlik-Skowrońska and Toporowska (2016)
5.	Zemborzycki	51°11'18"N	22°31'47"E	A	230.0	4.5	2.3	0.3	22.5	8.5	27.9	40	n.a.	84.0	Pawlik-Skowrońska et al. (2013)
6.	Klimkówka	49°33′08″N	21°05′16″E	A	306	31.0	13.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
7.	Czchowskie	49°48′22″ N	20°39′37″E	A	345	9.5	3.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
8.	Rożnowskie	49°43′56″N	20°42′52″E	A	1600	35.0	12.1	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
9.	Nowińczyk	50°00′41″N	19°24′07″E	A	–	–		n.a	n.a	n.a	n.a	n.a	n.a	n.a	
10.	Goczałkowicki	49°55′51″N	18°52′29″E	A	3200	12.0	5.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
11.	Łąka	49°58′16″N	18°52′16″E	A	320	–	4.0	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
12.	Paprocańskie	50°05′13″N	18°59′01″E	A	132	3.5	1.5	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
13.	Dziećkowice	50°08′20″N	19°13′18 E	A	780	11.0	–	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
14.	Sosina	50°14′25″N	19°20′07″E	A	50	3.0	2.0	n.a	n.a	n.a	n.a	n.a	n.a	n.a	
15.	Uzarzewskie	52°26'52"N	17°08'03"E	L	10.6	7.3	3.4	0.4	20.7	8.8	43.6	140	5.6	45.9	Kozak and Goldyn (2014)
16.	Swarzędzkie	52°24′49″N	17°03′54″E	L	93.7	7.2	2.6	1.0	22.9	8.3	58.1	80	2.61	50.7	Goldyn (2014)
17.	Rusałka	52°25'36"N	16°52'39"E	A	36.7	9.0	1.9	0.7	17.1	8.8	71.0	60	5.8	33.0	Goldyn et al. (2014)
18.	Konin	52°23'04"N	15°52'30"E	L	87.7	4.2	3.1	0.3	25.2	9.5	24.5	150	4.7	243.0	Dondajewska et al. (2015a)
19.	Wielgie	52°58'52"N	15°46'34"E	L	136.9	6.8	2.2	0.5	22.0	9.0	33.0	130	2.9	118.5	Dondajewska et al. (2015b)
20.	Ukiel	53°46'45"N	20°25'51″E	L	412.0	43.0	10.6	3.7	21.3	8.3	25.3	120	0.86	11.9	Kapusta et al. (2016)
21.	Redykajny	53°48'55″N	20 °25′04″E	L	29.9	20.6	8.0	2.3	21.1	8.2	24.4	60	1.31	8.7	Lossow et al. (2005)

L- natural lake, mL – hydrologically modified lake, A – artificial; [2] mean value for summer period (June-September) in the surface water layer; n.a.- not analysed.