ABS ACTA BIOLOGICA SLOVENICA
LJUBLJANA 2017 Vol. 60, Št. 1: 3–28

Occurrence, toxins and possibilities of control of bloom-forming cyanobacteria of European freshwaters: a review

Pojavljanje, toksičnost in kontrola cvetenja cianobakterij v evropskih celinskih vodah: pregled

Klara Jarni[a,b], Tjaša Griessler Bulc[a,b], Aleksandra Krivograd Klemenčič[a*]

[a]Faculty of Civil and Geodetic Engineering, University of Ljubljana, Hajdrihova 28, SI-1000 Ljubljana, Slovenia
[b]Faculty of Health Sciences, University of Ljubljana, Zdravstvena pot 5, SI-1000 Ljubljana, Slovenia
*correspondence: aleksandra.krivograd-klemencic@fgg.uni-lj.si

Abstract: Blooming of cyanobacteria is a common problem of eutrophic water bodies in Europe and worldwide and can cause severe problems with toxicity, taste and odour of the water. Toxins produced by cyanobacteria (cyanotoxins) are structurally diverse and their effects range from liver damage, including liver cancer, to neurotoxicity and thus they may present a serious threat for drinking water safety. Cyanobacterial blooms present major challenges for the management of rivers, lakes and reservoirs and are predicted to cause even worse problems in the future due to the climate change associated with global warming, increased availability of light to phytoplankton and rising levels of atmospheric CO_2. This paper presents the literature review of occurrence, toxins (along with their effects on human health) and possibilities of control of bloom-forming cyanobacteria.

Keywords: algal blooms, cyanobacteria, cyanobacterial control, cyanotoxins, Europe, freshwaters

Izvleček: Cvetenje cianobakterij je pogost problem v evtrofnih vodnih telesih v Evropi in po svetu. Povzroča lahko resne težave zaradi toksičnosti, spremenjenega okusa in vonja vode. Toksini, ki jih izločajo cianobakterije (cianotoksini), so po zgradbi različni, njihovi učinki pa zajemajo vse od poškodb jeter, vključno z rakom na jetrih, do nevrotoksičnosti in lahko predstavljajo resno nevarnost pri zagotavljanju varne pitne vode. Cvetenje cianobakterij predstavlja velik izziv za upravljalce rek, jezer in zbiralnikov, predvideva pa se, da bo v prihodnosti ta problematika še naraščala zaradi klimatskih sprememb in z njimi povezanih učinkov globalnega segrevanja, povečane dostopnosti svetlobe za fitoplankton in naraščajočih koncentracij atmosferskega CO_2. Članek predstavlja pregled literature o pojavljanju, toksinih (vključno z njihovimi učinki na zdravje ljudi) in kontroli cianobakterijskih vrst, ki cvetijo v evropskih celinskih vodah.

Ključne besede: cvetenje alg, cianobakterije, kontrola cianobakterij, cianotoksini, Evropa, celinske vode

Introduction

When environmental conditions such as temperature, light and nutrient status are conducive, surface waters (both freshwater and marine) may host increased growth of algae and/or cyanobacteria. If and when such proliferation is dominated by a single (or a few) species, the phenomenon is referred to as an algal or cyanobacterial bloom (CB) (Chorus and Bartram 1999). CBs are a common problem of stagnant water bodies in Europe (Eiler and Bertilson 2004, Jacquet et al. 2005) and worldwide (Paerl and Huisman 2009, Kosten et al. 2012, Michalak et al. 2013). They present major challenges for the management of rivers, lakes and reservoirs (Carey et al. 2012) and are predicted to cause even worse problems in the future due to the climate change associated with global warming, increased availability of light to phytoplankton and rising levels of atmospheric CO_2 (Jöhnk et al. 2008, Kosten et al. 2012, O'Neil et al. 2012, Paerl and Huisman 2009, Paerl and Paul 2012, Zhang et al. 2012). Some lakes, rivers and estuaries have seasonal blooms that start in summer and last into autumn, some have persistent blooms that encompass all seasons, and some have blooms that occur as extreme peaks and crashes lasting just a few days or weeks (Havens 2008). In temperate regions, CBs generally occur during the late summer and early autumn and may last two to four months (Cook et al. 2004). This is also the time when demand for recreational water is the highest (Chorus et al. 2000). In regions with Mediterranean (mild, wet winter and warm, dry summer) or subtropical climates, the bloom season may start earlier and persist longer (Cook et al. 2004).

The CBs increase the turbidity of eutrophied lakes and in turn supress growth of aquatic macrophytes affecting invertebrates and fish species in addition to oxygen depletion and odour problems (Paerl and Huisman 2009). Lastly, some cyanobacterial species produce toxic peptides and alkaloids, which are a major threat to the use of freshwater ecosystems, and reservoirs for drinking water, irrigation, fishing and recreation (Carmichael 2001). If cyanobacteria are present or even dominant for most of the year, the problems associated with high cyanobacterial biomass and the potential health threats from their toxins increase. Proliferation of toxic cyanobacteria often causes a reduction in biodiversity, leading to disruption of the trophic chain and to ecosystem imbalance (Sedmak and Eleršek 2005). Potential toxic risks, to both animal and humans, may cause problems to local fisheries and to touristic and recreational activities (Chorus and Bartram 1999, Dokulil and Teubner 2000, Briand et al. 2003).

Environmental conditions promoting bloom-forming cyanobacterial growth

The mechanism of CB occurrences is very complex as they are not caused by a single environmental driver but rather by multiple factors occurring simultaneously (Dokulil and Teubner 2000, Heisler et al. 2008). Environmental conditions promoting growth of most common potentially toxic cyanobacteria in European stagnant waters are shown in Tab. 1. Onset of development and proliferation of CBs are closely associated with eutrophication and climatic conditions. Cyanobacteria can occupy almost all kinds of aquatic habitats as they are able to use different forms of carbon (C), nitrogen (N), phosphorus (P), and sulphur (S), they grow well in shade, are resistant to grazing and release allelochemicals to out-compete other organisms (Sharma et al. 2010). Cyanobacteria possess certain unique adaptations that make them a successful competitor. These include their ability to grow in warm waters, to utilize low total N (TN) to total P (TP) ratio, to access low dissolved CO_2 concentration (in form of bicarbonate), and their ability of N fixation (Sharma et al. 2010).

Table 1: Recorded occurrencies of common potentially toxic cyanobacteria in freshwaters in Europe and environmental conditions promoting their growth.
Tabela 1: Pojavljanje najpogostejših potencialno toksičnih cianobakterij v evropskih celinskih vodah in okoljski dejavniki, ki spodbujajo njihovo rast.

Taxa	Trophic state of water body	Optimal temperature	Optimal light intensity	Occurrence	Additional info	Country	Source
Aphanizomenon flos-aquae Ralfs ex Bornet and Flahault	mesotrophic stagnant waters, reservoirs	20 °C - 28 °C	100 - 110 mmol phot. $m^{-2}s^{-1}$	Fresh and salty waters, common in plankton, sometimes creates blooms	Coexists with *M. aeruginosa*	Britain Denmark France Germany Netherlands Poland Portugal Romania Slovenia Spain Sweden Turkey (Europe)	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Aboal (1996), Kosi (1999), Dokulil and Teubner (2000), Tsujimura et al. (2001), Whitton (2002), Karlsson-Elfgren and Brunberg (2004), Aboal and Puig (2005), Dean and Sigee (2006), Ersanli and Gönülol (2006), O'Brien et al. (2006), Willame et al. (2006), Carrasco et al. (2007), Leao et al. (2009), Pérez et al. (2009), Kokocinski et al. (2010), Täuscher (2011), Caraus (2012)
Aphanizomenon gracile Lemmermann	mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C	100 - 110 mmol phot. $m^{-2}s^{-1}$	Freshwater, planktic, common in stagnant waters (ponds, reservoirs)		Belgium France Germany Luxembourg Poland Romania Spain	Caraus (2002), Whitton (2002), Willame et al. (2006), Carrasco et al. (2007), Kokocinski et al. (2010), Täuscher (2011), Caraus (2012), Mehnert et al. (2012)
Chrysosporum ovalisporum (Forti) E.Zapomelová, O.Skácelová, P.Pumann, R.Kopp and E.Janecek syn. *Aphanizomenon ovalisporum* Forti, *Anabaena ovalisporum* Forti	eutrophic and mesotrophic-eutrophic reservoirs	26 °C – 30 °C		Mostly in Mediterranean Europe, Middle East, North America and Australia		Greece Italy Poland Spain Turkey (Europe)	Alvarez-Cobelas and Gallardo (1988), Bazzichelli and Abdelahad (1994), Gkelis et al. (2005), Ersanli and Gönülol (2006), Carrasco et al. (2007), Kokocinski and Soininen (2012), Sukenik et al. (2013)
Cuspidothrix issatschenkoi (Usachev) Rajaniemi, Komárek, Willame, Hrouzek, Ka syn. *Aphanizomenon issatschenkoi* (Usacev) Proshkina-Lavrenko	mesotrophic-eutrophic stagnant waters (ponds, reservoirs)			Freshwater, planktic in lakes and ponds in Europe and Asia		Britain France Germany Hungary Poland Portugal Romania Spain	Caraus (2002), Whitton (2002), Willame et al. (2006), Carrasco et al. (2007), Leao et al. (2009), Kokocinski et al. (2010), Täuscher (2011), Caraus (2012), Horváth et al. (2013)

Taxa	**Trophic state of water body**	**Optimal temperature**	**Optimal light intensity**	**Occurrence**	**Additional info**	**Country**	**Source**
Cylindrospermopsis raciborskii (Woloszynska) Seenayya and Subba Raju	mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	29 °C - 31 °C	80 - 120 mmol phot. m-^{2}s^{-1}	Tropical and subtropical, but appears to be invading temperate regions (as far north as Vienna)		Germany Poland Portugal	Dokulil and Teubner (2000), Saker et al. (2004), Stuken et al. (2006), Wiedner et al. (2007), Carneiro et al. (2009), Leao et al. (2009), Kokocinski et al. (2010), Täuscher (2011), Mehnert et al. (2012), Kokocinski and Soininen (2012)
Dolichospermum circinale (Rabenhorst ex Bornet and Flahault) P.Wacklin, L.Hoffmann and J.Komárek syn. *Anabaena circinalis* Rabenhorst ex Bornet and Flahault	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C		Freshwater, planktic, often forming heavy water blooms; cosmopolitan distribution with exception of subpolar regions; massive populations known mainly from Central Europe, South America and Australia		Britain Czech Republic France Germany Romania Slovenia Spain Sweden Turkey (Europe)	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Caraus (2002), Whitton (2002), Karlsson-Elfgren and Brunberg (2004), Ersanli and Gönülol (2006), Täuscher (2011), Zapomelová et al. (2011), Caraus (2012), Database of Slovenian Environment Agency
Dolichospermum crassum (Lemmermann) P.Wacklin, L.Hoffmann and J.Komárek syn. *Anabaena crassa* (Lemmermann) Komark.-Legn. and Cronberg	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C		Freshwater, planktic in ponds and reservoirs, in temperate zones of both hemispheres, up to subtropical regions		Czech Republic Germany Luxembourg Slovenia Spain	Willame et al. (2006), Carrasco et al. (2007), Täuscher (2011), Zapomelová et al. (2011), Sukenik et al. (2013), Database of Slovenian Environment Agency
Dolichospermum flos-aquae (Brébisson ex Bornet and Flahault) P.Wacklin, L.Hoffmann and J.Komárek syn. *Anabaena flos-aquae* Brébisson ex Bornet and Flauhault	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C		Freshwater, common in plankton of stagnant waters, cosmopolitan species with exception of subpolar regions; tropical populations less frequent; often creates blooms		Britain Czech Republic Denmark Germany Romania Slovenia Spain Sweden	Skuja (1948), Álvarez-Cobelas (1982), Alvarez-Cobelas and Gallardo (1988), Kosi (1999), Caraus (2002), Whitton (2002), Dean and Sigee (2006), Sigee et al. (2007), Täuscher (2011), Zapomelová et al. (2011), Caraus (2012)

Taxa	Trophic state of water body	Optimal temperature	Optimal light intensity	Occurrence	Additional info	Country	Source
Dolichospermum lemmermannii (Ricter) P.Wacklin, L.Hoffmann and J.Komárek syn. *Anabaena lemmermannii* P. Richter	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C		Freshwater, common in plankton of reservoirs in whole temperate zone (distinct water blooms); never found in tropical regions	One of the dominant species in cyanobacterial mass occurrences in boreal lakes, even in relatively oligotrophic lakes	Czech Republic Denmark Finland Germany Romania	Caraus (2002), Olli et al. (2005), Täuscher (2011), Zapomelová et al. (2011), Caraus (2012)
Dolichospermum planctonicum (Brunnth.) Wacklin, L.Hoffm. and Komárek syn. *Anabaena planctonica* Brunnthaler	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C	prefers moderate light intensities	Freshwater, common in plankton of stagnant waters		Belgium Britain Czech Republic Germany Italy Luxembourg Romania Slovenia Spain	Bruno et al. (1994), Caraus (2002), Whitton (2002), Willame et al. (2006), Carrasco et al. (2007), Täuscher (2011), Zapomelová et al. (2011), Caraus (2012), Database of Slovenian Environment Agency
*Dolichospermum solitarium (*Klebahn) Wacklin, L.Hoffmann and Komárek syn. *Anabaena solitaria* Klebahn	oligotrophic stagnant waters (mountain lakes, quarries) and mesotrophic stagnant waters, reservoirs	20 °C - 28 °C		Freshwater, common in plankton of stagnant waters		Czech Republic Finland Germany Romania Slovenia	Willen and Mattsson (1997), Caraus (2002), Kastovsky et al. (2010), Täuscher (2011), Caraus (2012), Database of Slovenian Environment Agency
Dolichospermum spiroides (Kleb.) Wacklin, L.Hoffm. and Komárek syn. *Anabaena spiroides* Klebahn	hypertrophic fishponds, mesotrophic-eutrophic stagnant waters (ponds, reservoirs)	20 °C - 28 °C	prefers moderate light intensities	Freshwater, common in plankton of stagnant and slowly running waters, mainly from May to October		Belgium Britain Czech Republic France Germany Romania Slovenia Spain Sweden Turkey (Europe)	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Kosi (1999), Caraus (2002), Whitton (2002), Ersanli and Gönülol (2006), Willame et al. (2006), Täuscher (2011), Zapomelová et al. (2011), Caraus (2012)
Gloeotrichia echinulata P.Richter	mesotrophic stagnant waters, reservoirs			Freshwater, common in plankton of stagnant and slowly running waters, sometimes creates blooms		Britain Germany Romania	Whitton (2002), Täuscher (2011), Caraus (2012)

Taxa	**Trophic state of water body**	**Optimal temperature**	**Optimal light intensity**	**Occurrence**	**Additional info**	**Country**	**Source**
Limnothrix redekei (van Goor) M.-E. Meffert	mesotrophic-eutrophic and mesotrophic stagnant waters, reservoirs, also wetlands, pools, furrows, usually with water plants			Freshwater, planktic, widely distributed in temperate zone throughout the whole year (distinct populations occur in winter season); common in Northern and Central Europe	often together with *Planktothrix agardhii*	Czech Republic Germany Poland Romania Slovenia	Chorus and Bartram (1999), Kastovsky et al. (2010), Kokocinski et al. (2010), Täuscher (2011), Caraus (2012), Database of Slovenian Environment Agency
Microcystis aeruginosa (Kützing) Kützing	eutrophic water bodies (lakes, fishponds, reservoirs)	28 °C - 32 °C		Fresh and brackish waters, planktic, sometimes forming heavy water blooms, common; cosmopolitan with exception of polar and subpolar regions		Britain Germany Portugal Romania Slovenia Spain Sweden Turkey (Europe)	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Kosi (1999), Nalewajko and Murphy (2001), Caraus (2002), Carrillo et al. (2003), Whitton (2002), Martín et al. (2004), Bárbara et al. (2005), Ersanli and Gönülol (2006), Jöhnk et al. (2008), Paerl and Huisman (2008), Young et al. (2008), Leao et al. (2009), Metcalf et al. (2009), Pérez et al. (2009), Pérez et al. (2010), Täuscher (2011), Caraus (2012)
Microcystis ichtyoblabe (Kunze) Kützing	mesotrophic or slightly eutrophic, but not polluted lakes	28 °C - 32 °C		Freshwater, planktic, sometimes forming water blooms; more in northern regions of the temperate zone, probably not occurring in tropical countries		Belgium Czech Republic Germany Slovenia	Nalewajko and Murphy (2001), Willame et al. (2006), Jöhnk et al. (2008), Paerl and Huisman (2008), Kastovsky et al. (2010), Täuscher (2011), Database of Slovenian Environment Agency

Taxa	Trophic state of water body	Optimal temperature	Optimal light intensity	Occurrence	Additional info	Country	Source
Microcystis flos-aquae (Wittrock) Kirchner	mesotrophic and slightly eutrophic water bodies	28 °C - 32 °C		Freshwater, planktic, usually together with other planktic algae and cyanoprokaryotes, sometimes part of water blooms, cosmopolitan in the whole temperate zone, particularly in northern regions		Britain Germany Romania Turkey (Europe) Slovenia	Nalewajko and Murphy (2001), Caraus (2002), Whitton (2002), Ersanli and Gönülol (2006), Sigee et al. (2007), Jöhnk et al. (2008), Paerl and Huisman (2008), Täuscher (2011), Caraus (2012), Database of Slovenian Environment Agency
Microcystis viridis (A.Braun) Lemmermann	slightly eutrophic lakes and ponds	28 °C - 32 °C		Freshwater, planktic, sporadical, sometimes forming water blooms; cosmopolitan		Germany Romania Slovenia Spain Sweden	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Nalewajko and Murphy (2001), Caraus (2002), Jöhnk et al. (2008), Paerl and Huisman (2008), Eleršek (2009), Täuscher (2011), Caraus (2012), Scholz and Liebezeit (2012)
Nodularia spumigena Mertens ex Bornet and Flahault	eutrophic ponds, lakes and reservoirs	20 °C - 30 °C	high tolerance of ultraviolet radiation	Mostly in salty/brackish waters, also in fresh waters, planktonic, common, often forms blooms in lagoons and estuaries		Britain Ireland Poland Romania Spain Turkey	Guiry (1978), Alvarez-Cobelas and Gallardo (1988), Calvo and Bárbara (2002), Caraus (2002), Moisander et al. (2002), Whitton (2002), Bárbara et al. (2005), Akcaalan et al. (2009), Jodlowska and Latala (2010), Caraus (2012)
Planktothrix agardhii (Gomont) Anagnostidis and Komárek	mesotrophic-eutrophic stagnant waters (ponds, reservoirs), hypertrophic fishponds	10 °C - 25 °C	prefers low light intensities inhibited above 180 $\mu E\ m^{-2}s^{-1}$	Freshwater, planktic in lakes and ponds, often forming water blooms, widely distributed in temperate zones; less in tropical regions	Never forms scums	Belgium Germany Luxembourg Poland Romania Slovenia Spain	Chorus and Bartram (1999, Kosi (1999), Dokulil and Teubner (2000), Willame et al. (2006), Quesada et al. (2006), Willame et al. (2006), Carrasco et al. (2007), Oberhouse et al. (2007), López Rodríguez et al. (2009), Kokocinski et al. (2010), Täuscher (2011), Caraus (2012), Kokocinski and Soininen (2012)

Taxa	Trophic state of water body	Optimal temperature	Optimal light intensity	Occurrence	Additional info	Country	Source
Planktothrix rubescens (De Candolle ex Gomont) Anagnostidis and Komárek	mesotrophic and eutrophic large lakes and stagnant waters	cold water form (10 °C - 14 °C)	prefers low light intensities	Freshwater, planktic, in large lakes and stagnant waters, forming red water blooms; in several regions in northern temperate zone with obligatory distribution, outside of these areas occasionally over the whole temperate zone	Usually does not form scums during the bathing season	France Germany Italy Romania Slovenia Spain Switzerland	Kosi (1999), Dokulil and Teubner (2000), Almodóvar et al. (2004), Grach-Progrebinsky et al. (2004), Viaggiu et al. (2004), Willame et al. (2006), Carrasco et al. (2007), Holland and Walsby (2008), Täuscher (2011), Caraus (2012)
Woronichinia naegeliana (Unger) Elenkin syn. *Coelosphaerium naegelianum* Unger, *Gomphosphaeria naegeliana* (Unger) Lemmermann	eutrophic lakes and ponds			Freshwater, common in plankton of lakes and ponds, sometimes forming water blooms, in temperate zones, in Europe and North America up to northern regions		Britain Czech Republic Germany Luxembourg Romania Slovenia Spain Sweden	Skuja (1948), Alvarez-Cobelas and Gallardo (1988), Cronberg et al. (1999), Whitton (2002), Rajaniemi-Wacklin et al. (2006), Willame et al. (2006), Täuscher (2011), Caraus (2012), Database of Slovenian Environment Agency

Nitrogen and phosphorous

Because CBs often develop in eutrophic lakes, it was originally assumed that they require high P and N concentrations. However, in late summer, when CBs mostly occur, concentrations of dissolved phosphate tend to be the lowest. Experimental data showed that the affinity of many cyanobacteria for N or P is higher compared to other photosynthetic organisms meaning that they can out-compete other phytoplankton organisms under conditions of P or N limitation (Chorus and Bartram 1999). In most freshwater systems P is considered to be prime limiting nutrient (Xu et al. 2010) and small changes in P levels may influence the growth and toxin production of cyanobacteria (Sivonen 1990, Chorus and Bartram 1999). Cyanobacteria usually uptake P in orthophosphate form (PO_4^{3-}), however they are also able to uptake other phosphate forms like polyphosphates (Mukherjee et al. 2015). According to Downing et al. (2001) high concentration (30-100 µg/L) of TP promotes CB formation. Because of their high affinity for P, cyanobacteria can store substantial amount of P during P-sufficient conditions. Excess P-loading (luxury consumption) may facilitate growth of other phytoplankton groups leading to increased turbidity, which additionally favours cyanobacterial growth (Chorus and Bartram 1999). Besides P alone, P in combination with other nutrients may regulate cyanobacterial dominance in bloom environment. High TN:TP ratio is indicative for P limitation and vice-versa (Pinckney et al. 2001). However, according to Downing et al. (2001), TP is better predictor of cyanobacterial dominance than TN:TP ratios.

Light intensity

Turbid, low irradiance conditions promote growth of non-heterocystous cyanobacteria (e.g. *Oscillatoria, Lyngbia, Planktothrix rubescens*) causing their domination in the phytoplankton community, which is attributed mainly to their ability to maintain net growth at low underwater irradiance (Havens et al. 2003). However, cyanobacteria which form surface blooms (e.g. *Cylindrospermopsis raciborskii*) have a higher tolerance for high light intensities most probably due to an increase in carotenoid production, which protects the cells from photoinhibition (Paerl et al. 1983, Wiedner et al. 2007, Carneiro et al. 2009). In moderately deep, stratified eutrophic lakes typically N_2-fixing cyanobacteria such as *Anabaena* and *Aphanizomenon* (Paerl et al. 2001) are present.

Temperature

CBs in stagnant waters are correlated, to a considerable degree, with weather conditions and consequently with climate conditions in a given area (Zhang et al. 2012). Cyanobacteria usually dominate phytoplankton assemblages in temperate freshwater environments during the warmest period of the year, particularly in eutrophic systems (Paerl 2008, Paerl and Huisman 2008). Optimum temperatures for cyanobacteria are in general higher than for green algae and diatoms (e.g. 25 °C or higher for species from genera *Microcystis*), which may explain why, in addition to the lower nutrient levels in epilimnion, in temperate and boreal water bodies most CBs occur during summer (Chorus and Bartram 1999, Dokulil and Teubner 2000, Paerl and Huisman 2008, Jöhnk et al. 2008, Mehnert el at. 2010). However, some species such as *Planktothrix rubescens* and *Aphanizomenon flos-aquae* have low temperature preference or tolerance and thus bloom during late autumn and winter (Tsujimura et al. 2001). According to Lürling et al. (2013) intensification of CBs in warmer climate is not attributed to their higher growth rates compared to other phytoplankton species, but rather to their ability to migrate vertically and prevent sedimentation in warmer and more strongly stratified waters and to their resistance to grazing.

Water column stability

CBs are promoted by calm, vertically stratified conditions with adequate nutrient supplies and weak wind mixing (Paerl and Millie 1996, Kanoshina et al. 2003, Huisman et al. 2004, Sharma et al. 2010). In the case of wind- or flow induced destratification cyanobacteria may lose their competitive advantage, which together with cell and filaments damages due to increased turbulence (Moisander et al. 2002) can cause, if such conditions persist, rapid degradation of CBs. However, when intermittent weak stratification occurs during favourable growth periods (summer), blooms can quickly re-emerge. Non-disruptive, low-level turbulence can promote localized nutrient cycling, alleviate certain forms of nutrient limitation (e.g. PO_4^{3}, trace metals), and enhance cyanobacterial growth.

pH

Alkaline conditions favour CB formation (Havens 2008). Cyanobacteria capacity for photosynthesis in environments with low CO_2 concentrations (by using bicarbonate (HCO^{3-}) as their carbon source (Kaplan et al. 1991)) and high pH is an important characteristic giving cyanobacteria advantage over other phytoplankton organisms in water environments with high pH values, a general characteristic of eutrophic lakes (Dokulil and Teubner 2000, Kardinal and Visser 2005).

Salinity

Increased salination (e.g. summer droughts, rising sea levels, increased use of freshwater for agricultural irrigation) has major impacts on freshwater plankton communities with repercussions for water quality and use (Paerl and Huisman 2009). One such impact is increased vertical density stratification, which benefit buoyant cyanobacteria (Walsby et al. 1997, Huisman et al. 2004). In addition, some species of the common cyanobacterial genera *Anabaena, Anabaenopsis, Microcystis* and *Nodularia* are sometimes more salt tolerant than eukaryotic freshwater phytoplankton species (Moisander et al. 2002, Tonk et al. 2007). Thus, increased salination of freshwater and brackish waters can favour cyanobacteria over other freshwater phytoplankton species exposing other aquatic organisms and human users of these waters to elevated concentrations of cyanobacterial toxins (Paerl and Huisman 2009). The high salt tolerance of freshwater cyanobacteria is reflected by increasing numbers of CBs in brackish waters, for example, in the Baltic Sea in Scandinavia (Kanoshina et al. 2003, Suikkanen et al. 2007) and in the Küçükçekmece Lagoon in Turkey (Albay et al. 2005).

Bioactive substances

Cyanotoxins

Healthy CBs produce little extracellular toxin, while cell-bound concentrations are several orders of magnitude higher (Li et al. 2009). Very often, different strains of the same cyanobacteria species with similar growth rate produce different amounts of the same types of toxins (Watanabe and Oishi 1985, Sivonen 1990). External factors, including chemical conditions, modify not only cyanobacteria growth and toxin production but also affect cell longevity and the leakage of toxins to the environment which, in natural conditions, occurs mainly as the result of cell damage, death, lysis and decomposition of the aging cells. Thus, concentration of dissolved toxins may be much higher in ageing or declining CBs compared to healthy young CBs. However, toxin excretion from the cells can be promoted also by high temperature, high salination, high light intensities, low concentrations of P and chemical treatment for the eradication of cyanobacteria (especially use of algicides) (Sivonen 1990, van Apeldoorn et al. 2007, Rapala et al. 1997). Not all toxigenic species or toxic CBs will be toxic at all times (Carmichael 2001). Factors influencing formation and toxicity of toxic CBs include i) genetics as there are distinct toxin and non-toxin producing strains, and ii) good growth conditions together with optimum conditions for toxin production. Toxicity of CBs depends also on the ratio of toxin to non-toxin producers and the factors that lead to surface scums production (Carmichael 2001).

The freshwater cyanotoxins fall into three broad groups of chemicals: i) cyclic peptides (hepatotoxic microcystins and nodularins); ii) alkaloids (neurotoxic anatoxin-a, anatoxin-a(S), saxitoxins and hepatotoxic cylindrospermopsins); and iii) lipopolysaccharides (potentially irritant) (van Apeldoorn et al.2007). General features of the cyanotoxins occurring in freshwaters in Europe and their effects on human health are shown in Tab. 2.

Hepatotoxic cyclic peptides are the most frequently found cyanobacterial toxins in CBs from fresh and brackish waters and pose a major challenge for the production of safe drinking water from surface waters containing cyanobacteria with these toxins. In mouse bioassays, which traditionally have been used to screen toxicity of field and laboratory samples, cyanobacterial hepatotoxins (liver toxins) cause death by liver haemorrhage within a few hours of the acute doses (Chorus and Bartram 1999). The cyclic peptide microcystins and nodularins are specific liver poisons in mammals. Following acute exposure to high doses, they cause death from liver haemorrhage or from liver failure, and they may promote the growth of liver and other tumours following chronic exposures to low doses (Chorus and Bartram 1999).

Microcystins

Microcystins (MC) are the most frequently reported cyanobacterial toxins. 248 MC analogues have been reported to date (Spoof and Catherine, 2017). The amount of MC production by a cyanobacterial population in culture is directly proportional to its growth rate, no matter what environmental factor is limiting the growth (van Apeldoorn et al. 2007). While variants of MC produced by a particular strain are rather constant, the ratio of individual MC may change with time, temperature and light intensity. According to van Apeldoorn et al. (2007) at high P levels hepatotoxic cyanobacterial strains produced more toxins. Non-nitrogen fixing species such as *Microcystis* and *Oscillatoria* produce more toxins under N rich conditions (van Apeldoorn et al. 2007). MC are intracellular toxins, and whilst contained only in living cells, they are degraded slowly. MC are only released into the water by senescence or cell death or through water treatment processes such as pre-chlorination or algicide application. The study of Zastepa et al. (2014) demonstrated that MCs can persist well beyond the disappearance of the bloom. Dissolved MC-LA declined more slowly and persisted longer than particulate (cell-bound) MC-LA with *in situ* half-lives (total 1.5–8.5 days) shorter than *in vitro* (total 6.8–60.0 days).

Table 2: General features of the cyanotoxins occurring in freshwaters in Europe and their effects on human health. Adapted from Chorus and Bartram (1999), Chorus et al. (2000) and van Apeldoorn et al. (2007).

Tabela 2: Splošne značilnosti cianotoksinov, ki se pojavljajo v evropskih celinskih vodah, in njihovi učinki na zdravje ljudi. Povzeto po Chorus in Bartram (1999), Chorus in sod. (2000) in van Appeldoorn in sod. (2007).

Toxin group	**Primary target organ in mammals**	**Reported effects on human health**	**Taxa**	**LD_{50} of pure toxin (mouse bioassay)**
CYCLIC PEPTIDES				
Microcystins (MC)	Liver	Short term: gastroenteritis, liver damage, acute liver failure, birth defect, Haff disease, blistering of lips, allergic reactions (contact dermatitis, asthma, hay fever, conjunctivitis), vomiting, diarrhoea, abdominal pain, sore throat, pneumonia. Long term: hepatocellular carcinoma.	*Microcystis, Anabaena, Planktothrix (Oscillatoria), Nostoc, Hapalosiphon, Anabaenopsis Woronichinia Limnothrix Gloeotrichia Aphanizomenon*	MC in general: 45-1000 µg/kg MC-LR: 60 (25-125 µg/kg) MC-YR: 70 µg/kg MC-RR: 300-600 µg/kg
Nodularins	Liver	no human poisonings recorded, only reports of skin rashes	*Nodularia*	30-50 µg/kg
ALKALOIDS				
Anatoxin-a	Nerve synapse	no data till date	*Anabaena, Planktothrix (Oscillatoria), Aphaniziomenon Dolichospermum Microcystis aeruginosa*	250 µg/kg
Anatoxin-a(S)	Nerve synapse	no data till date	*Anabaena Dolichospermum Raphidiopsis mediterranea*	40 µg/kg
Cylindrospermopsins	Liver	hepatoenteritis, acute tender liver enlargement, constipation, vomiting and headache, diarrhoea, dehydration	*Cylindrospermopsis, Aphanizomenon, Umezakia Dolichospermum Cuspidothrix Chrysosporum*	2100 µg/kg/d 200 µg/kg/5-6 d
Saxitoxins	Nerve axons	no data till date of human poisonings	*Anabaena, Aphanizomenon, Dolichospermum Lyngbya, Cylindrospermopsis*	10-30 µg/kg
LIPOPOLYSACCHARIDES	Potentially irritant; affects any exposed tissue	can cause skin irritation	All	

Decline of MC was accelerated by higher temperature and irradiance, both of which are considered the most important environmental factors in MC degradation. MC can accumulate in aquatic organisms, such as zooplankton, phytoplankton, gastropods, mussels, clams and fish, and thus enter the food chain and pose possible threat to human health. The oral intoxication route is the most important as it involves not only the drinking of water containing cyanobacterial toxins but also the consumption of toxin-containing animal or plant tissues (Spoof 2005, van Apeldoorn et al. 2007).

Many reported worldwide cases demonstrate that MC cause both acute and chronic effects on humans (Ueno et al. 1996, WHO 1998, Zhou et al. 2002). Acute intoxication by MC coincides frequently with the lysis of the bloom-forming cells (by natural senescence or water treatment processes) and liberation of toxins to the water. The inhalation of dry cyanobacteria cells or contaminated water is more dangerous than oral ingestion of contaminated water indicating the hazardous potential of practising aquatic sports in recreational waters that suffer a microcystin producing bloom (WHO 2003). Chronic exposure to low concentrations of microcystins in drinking water can be a serious problem to public health, contributing to promotion of cancer in humans. Epidemiological studies have already related the presence of MC in drinking water to an increase in the incidence of colorectal cancer (Zhou et al. 2002) and primary liver cancer (Ueno et al. 1996). Recent studies show that toxic responses of MC may also be seen in kidney, heart, reproductive system, brain and lungs (Milutinovič et al. 2006, Wang et al. 2008, Chen et al. 2016, McLellan and Manderville 2017).

Nodularins

Nodularins are cyclic pentapeptides found in *Nodularia spumigena* (Chorus and Bartram 1999, Spoof 2005). To date, approximately 10 variants have been discovered, among which nodularin-R is the most abundant (Chen et al. 2013). The occurrence of *N. spumigena* blooms is determined by water temperature, light intensity, and nutrients concentration, among which levels of N and P are critical (Mazur et al. 2003). Nodularins tend to accumulate in mussels, clams and fish (van Apeldoorn et al. 2007) and have been implicated in the deaths of wild and domestic animals (Chen et al. 2013). No guidelines have been set for nodularins by the World Health Organization (WHO), and their toxicity can currently only be estimated from MC, which have been reported to have similar toxicity to nodularins (Paerson et al. 2010). Since nodularins generally occurs in brackish waters, accidental swallowing of water during recreational activities and seafood consumption could be the major routes with regard to human exposure.

Alkaloids

Anatoxins

Anatoxins are a group of neurotoxic alkaloids which includes anatoxin-a, homoanatoxin-a and anatoxin-a(S). Anatoxins exposure and effects on humans or aquatic biota have not been fully determined yet also no clear evidence of human poisoning from anatoxins exists (Osswald et al. 2007, van Apeldoorn et al. 2007, EPA 2015). Anatoxin-a (ANTX-a) is produced by certain species of *Anabaena* (*A. planctonica*, *A. flos-aquae*, *A. spiroides* and *A. circinalis*), *Planktothrix* (*Oscillatoria*), *Cylindrospermum, Aphanizomenon,* and in minor amounts *M. aeruginosa* (e.g. Agnihotri, 2014). ANTX-a is a potent postsynaptic depolarizing neuromuscular blocking agent and causes death in laboratory animals within minutes to a few hours (Stevens and Krieger 1991, Fitzgeorge et al. 1994, van Apeldoorn et al. 2007). According to Chorus and Bartram (1999) P levels have no effects on ANTX-a production. ANTX-a differs from other cyanotoxins (like microcystins) in that it undergoes rapid photochemical degradation in sunlight even in the absence of cell pigments. Stevens and Krieger (1991) found that the degradation of ANTX-a is dependent on the light intensity and/or pH, with higher pH favouring degradation reactions. ANTX-a has been widely identified in surface waters in North America and Europe used for recreation, and hence a risk exists for ANTX-a poisoning of recreational water users (Chorus et al. 2000). Homoanatoxin-a was reported to be produced by *Planktothrix formosa,* by Norvegian strain of *O. formosum* (*Phormidium formosum*), some unidentified *Anabaena* species from Ireland and *Raphidiopsis mediterranea* (Chorus and Bartram 1999, Furey et al. 2003, Watanabe et al.

2003). ANTX-a(S), which chemical structure is un-related to ANTX-a, is produced by *Anabaena flos-aquae, A. lemmermannii*, *A. spiroides* and *A. crassa* (Chorus and Bartram 1999, Becker et al. 2010, de Abreu et al. 2013).

Saxitoxins

Saxitoxins (STX) are a group of carbamate alkaloid neurotoxins which are either non-sulphated (saxitoxins - STX), singly sulphated (gonyautoxins - GTX) or doubly sulphated (C-toxins). In addition, decarbamoyl derivatives (dc) and several new toxins (Lyngbya-wollei toxins, LWTXs) have been identified in some cyanobacterial species (van Apeldoorn et al. 2007). STX and its analogues are produced by *Anabaena circinalis* (Chorus and Bartram 1999); very low concentrations were detected also in two other *Anabaena* species: *A pertubata* and *A. spiroides* (Velzeboer et al. 2000). In a few Danish lakes containing STX, *A. lemmermannii* was the dominant cyanobacterium (Kass and Hendriksen 2000). Also *A. flos-aquae* from Portugal and *Planktothrix* sp. FP1 from Italy were reported to produce STX (Molica et al. 2002). All saxitoxins act in the same way: they block nervous transmission causing muscle paralysis (Briand et al. 2003). Till date no reports of human poisonings due to STX presence in freshwater environments are known (Chorus and Bartram 1999).

Cylindrospermopsin

Cylindrospermopsin (CYN) is a tricyclic alkaloid, possessing a tricyclic guanidine moiety combined with hydroxymethyluracil produced by *Cylindrospermopsis raciborskii*, *Umezakia natans* and *Aphanizomenon ovalisporum* (van Apeldoorn et al. 2007). CYN like microcystins, primarily affects the liver, although causes considerable damage also to other major organs e.g. kidneys, spleen, thymus and heart. CBs which caused both liver and kidney damage due to the CYN (and possibly related cyanotoxins) have been reported in Australia, Japan, Israel and Hungary (Chorus and Bartram 1999). Chorus and Bartram (1999) and Falconer (2001) reported health problems associated with presence of CYN in drinking water supplies in Australia. Patients suffered from an unusual hepatoenteritis, acute tender liver enlargement, constipation, vomiting and headache, followed by diarrhoea and dehydration. Chonudomkul et al. (2004) pointed out that *C. raciborskii* is not only an ongoing invasive species but also a species with different physiological strains or ecotypes and temperature tolerance.

Volatile organic compounds and other bioactive substances

Cyanobacteria can produce various compounds causing off-flavour, also known as volatile organic compounds (VOC). 2-Methylisoborneol (2-MIB) and geosmin are among the most important odorous compounds in cyanobacteria and are often cited as sources of unpleasant earth-like and musty odour, especially in various aquatic environments (Fujise et. al. 2010). VOC are primarily produced by different prokaryotic and eukaryotic benthic and pelagic aquatic microorganisms (e.g. Streptomyces, fungi). Many of the known cyanobacterial producers of VOC are nonplanktic (approx. 30%), while the remainder are benthic or epiphytic. According to Jüttner and Watson (2007) geosmin and 2-MIB production is limited to filamentous cyanobacteria and is unknown among chorococcalean taxa. According to Milovanović et al. (2015) growing conditions have significant impact on production of VOC in cyanobacteria, and altering these conditions may be useful in obtaining cyanobacterial biomass with favourable sensory properties for potential use in formulation of food and feed products.

Beside toxins and VOC, cyanobacteria produce also other very heterogeneous biologically active substances, such as peptides, retinoids, alkaloids, lactones, phospholipids (Sychrova et al. 2012, Wu et al. 2012a). Some of these metabolites are also potentially toxic to mammals, as they can cause inhibition of enzymes in key metabolic pathways, skin irritation, signalling and hormonal disruption, cytotoxicity, reproductive disorders, and neurological damage, or act as a tumour promotors. Also, they can influence CB physiology and their blooming capacity (Sukenik et al. 2002, Schatz et al. 2007). Bioactive substances produced by cyanobacteria can be divided in following groups a) aeruginosins and spumigins (Ersmark et al. 2008, Fewer et al. 2009); b) anabaenopeptins (Harada et al. 1993, Bubik et al. 2008); c) biogenic amines (MLA 2001, EFSA 2011); d) depsipeptides (Blom et al. 2006, Bubik et al. 2008); e) endocrine disruptors and novel tumour promoters (Bláha et al. 2010, Nováková et al. 2013); f) microginins (Neumann et al. 1997); and g) microviridins (Murakami et al. 1995).

Most common bloom-forming cyanobacterial taxa of European freshwaters

Occurrence and reported observations of the most common potentially toxic bloom-forming cyanobacteria in European freshwaters are shown in Tab. 1. Ecology of the most common cyanobacterial taxa occurring in European freshwaters is shown in Tab. 3.

Control of cyanobacterial blooms

Several approaches are available to control CBs in water bodies such as minimizing nutrient load, using chemical, biological, and/or physical treatment. Nutrient removal can have positive long-term effects leading to the reduction in the trophic state of the water body and thus to the reduction of CBs, but is almost impossible for most areas across the world due to economical limitations (Jančula and Maršálek 2011).

CBs can be efficiently reduced by addition of chemicals to water such as copper-based algaecides, herbicides, photosensitizers, and chemical flocculants (e.g. Surosz and Palinska, 2004; Jančula and Maršálek 2011). However, chemical treatment has several disadvantages: (1) toxicity against non-target organisms; (2) generation of secondary pollutants; (3) introduction of heavy metals to the water and their accumulation in the environment (Jančula et al. 2014). Chemical treatment of CBs especially using potassium permanganate or chlorine may indirectly effect other organisms due to the sudden release of cyanotoxins from cyanobacteria cells as a consequence of cell lysis (Mahvi and Dehgani 2005). Dissolved cyanotoxins can enter water supplies and pose potential risk for human health (van Apeldoorn 2007, Rajasekhar et al. 2012). In such cases, additional treatment of water by activated carbon, powerful oxidants such as ozone and/or intense ultraviolet light are needed to inactivate or degrade dissolved toxins (Chorus and Bartram 1999; Jančula and Maršálek 2011). Copper-based algaecides and chemical flocculants are commonly used to control CBs, but may be harmful to aquatic life by generating secondary pollutants (Mahvi and Dehgani 2005, McNeary and Erickson 2013, Jančula et al. 2014) and large amount of algae sludge (Xu et al. 2006). More sustainable treatment method is using clay minerals as flocculation agents, where dense clay particles attach to the cyanobacteria cells and promote conglomeration and sinking of the cells, despite their buoyancy (McNeary and Erickson 2013). Also, low concentrations of hydrogen peroxide (HP) have shown promising potential to act as specific cyanocide for *Planktothrix agardhii*, *Anabaena*, *Aphanizomenon* and *Microcystis*, both in the laboratory and in whole-lake treatments. HP acts very fast and there are no lasting chemical traces of the added HP (sustainability), nor toxic substances including released cyanotoxins or particulate organic matter from dead cyanobacteria retained in the water body (Matthijs et al. 2016).

Biological removal of CBs such as natural grazing by phytoplanktivorous fish (Jančula et al. 2008) or biomanipulation by introduction of new cyanobacteria eating species to the water body (Lacerot et al. 2013) is gaining importance due to its environmental friendliness compared to chemical treatment. Biomanipulation is faster than natural establishment of cyanobacteria eating communities and can selectively affect only target organisms (Guo et al. 2015).

Hydrodynamic and acoustic cavitation are the main physical methods for CBs control. Although the effects of acoustic cavitation on CBs removal have been studied more extensively compared with hydrodynamic cavitation (Dular et al. 2016), both techniques are still in the research phase. According to Xu et al. (2006) hydrodynamic cavitation is causing the collapse of gas vesicles and the destruction of thylakoid together with the changes in the structures of phycocyanins and chlorophyll *a* in *M. aeruginosa* cells, eventually resulting in the death of the cells. Wu et al. (2012b) studied combined effects of hydrodynamic cavitation and ozone treatment on growth of *M. aeruginosa* assuming that mechanical forces affect the cyanobacteria by damaging the cell wall and make them more sensitive to ozone treatment. 99% reduction of cyanobacteria was achieved

Table 3: Ecology of the most common cyanobacterial taxa occurring in European freshwaters. Chl *a* = chlorophyll *a*, N = nitrogen, P = phosphorus, PAR = photosynthetically active radiation, CB = cyanobacteria.
Tabela 3: Ekologija najpogostejših cianobakterijskih taksonov, ki se pojavljajo v evropskih celinskih vodah. Chl *a* = klorofil *a*, N = dušik, P = fosfor, PAR = fotosintetsko aktivno sevanje, CB = cianobakterije.

Species	Blooms typically found in	Advantages	Importance	Sources
***Microcystis* spp.**	• Warm, turbid, slow-moving waters, high in nutrients • Waters deeper than 3 m, but also in shallower lakes (temperate regions) • Bodies with chl *a* concentrations of 20-50 µg/L and Secchi transparency of 1-2 m • Spring and summer	• Less sensitive to high light intensities (capable of buoyancy regulation)	• *M. aeruginosa* one of the most damaging species. Prevalence in bodies with varying nutrient loading. High toxicity to aquatic and terrestrial organisms. • Rapid reproduction triggered the most by P runoff. • High nutrient levels favour the growth of toxic over nontoxic strains.	Prasath et al. 2014, Chorus and Bartram 1999, Lehman et al. 2005, Vezie et al. 2002
Planktothrix agardhii	• Turbulent, low radiance waters • First few meters of the water column in shallow waters • Greatly dependent on high-frequency phosphate availability • Summer (temperate regions)	• Ability to absorb sufficient energy from the entire PAR spectrum • Resistance to photoinhibition • Tolerant to continuous mixing of water column • High P storage capacity • Buoyancy regulation • Tolerant to shade and temperature variation	• One of the most common toxic bloom-forming species.	Budzyńska et al. 2009, Scheffer et al. 1997, Oberhaus et al. 2007, Dokulil and Teubner 2000, Padisak and Reynolds 1998, Bonilla et al. 2012, Catherine et al. 2008, Crossetti and Bicudo 2008, Kokocinski et al. 2010, Aubriot et al. 2011
Aphanizome-non flos-aquae	• Higher latitudes (less frequent at lower latitudes) • Grows independently of dissolved N resources and also under P limitation • Late autumn and winter	• Low temperature preference • Ability of autonomous fixation of atmospheric N • Able to grow in unfavourable conditions (forms akinetes) • Substantial storage capacity for P	• May appear as plankton in eutrophic waters where other CB are almost undetectable. • Its dynamic affected by co-occurring CB like *Microcystis* spp.	Tsujimura et al. 2001, Yamamoto 2009, Preussel et al. 2006, Takano and Hino 2000
***Anabaena* spp.**	• Lake environment	• N fixing abilities • Toxin production	• Widely diversified group with around 80 morphospecies. • Dominant long term populations • *A. flos-aquae* usually appears during summer (max N starvation and PAR inputs).	Zapomelova et al. 2010, Dean et al. 2008, Agnihotri 2014, Paerl 1979

compared to less than 15% removal of cyanobacteria by hydrodynamic cavitation and 35% by ozone treatment alone. According to Jančula et al. (2014) and Dular et al. (2016) hydrodynamic cavitation is more effective on removal of buoyant cyanobacteria by disintergrating their gas vesicles than other planktonic algae without gas vesicles (e.g. green microalgae), which indicates good potential of hydrodynamic cavitation for selective cyanobacterial removal from water bodies.

Acoustic cavitation has similar effects on cyanobacteria as hydrodynamic cavitation (Jančula et al. 2014, Li et al. 2014), namely reducing the growth rate of cyanobacteria by collapsing the gas vesicles, inhibiting cell division, and/or inflicting immediate damage on photosynthetic activities (Nakano et al. 2001, Ahn et al. 2003, Mahvi and Dehgani 2005, Zhang et al. 2006a). Acoustic cavitation is known to cause cell lysis and thus releasing the intracellular materials in water column (Zhang et al. 2006b, Rajasekhar et al. 2012). On the other side it is also effective in degrading the cyanotoxins (Song et al. 2005). Acoustic cavitation has potential to reduce algal capacity to float and thus reducing their concentration near the surface of water bodies, which is consequently inhibiting their growth and survival (Mahvi and Dehgani 2005). Effects of acoustic cavitation on cyanobacteria removal depends on frequency, intensity and time of sonication (Rajasekhar et al. 2012). Beside acoustic cavitation, a low intensity ultrasound without cavitation can be used for CBs control; in fact several such technologies are already available on the market. Low intensity ultrasound is appropriate solution for aquaculture systems, natural ponds or drinking water reservoirs, since it is not damaging the cyanobacteria cells and the toxins are not released from the cells (Krivograd Klemenčič and Griessler Bulc 2010). Furthermore, it is affecting cyanobacteria selectively by collapsing gas vacuoles causing cyanobacteria cells to sink at the bottom of the water body, where cells in deep water bodies die due to lack of light necessary for photosynthesis (Krivograd Klemenčič and Griessler Bulc 2010). The disadvantage of low intensity ultrasound technology is relatively long contact time with cyanobacteria to affect their buoyancy (Williams 2014).

In 2014 the European Commission funded the research project (7FP Dronic, http://dronicproject.com) developing the monitoring and ultrasonic treatment robotic system that can localize and treat hotpots of CBs in large water bodies. Because of the direct and localized treatment, the Dronic system is environmentally friendly, with a minimal impact on the ecology of the water body. The Dronic system is equipped with ultrasound acoustic system that uses two different types of ultrasound. The first type precipitates the cyanobacteria by directly affecting their buoyancy, while the second type is neutralizing the cyanotoxins by cavitation. The Dronic system is still in the research phase. However, if it proves successful it will be the first system that can autonomously locate and localized treat CBs only at the part of the water body, which is experiencing CB.

Povzetek

Ob ugodni temperaturi, svetlobnih pogojih in zadostni količini hranil v površinskih vodah lahko pride do cvetenja cianobakterij, ki je pogost problem evtrofnih vodnih teles v Evropi in po svetu. Pričakovano je, da se bo s klimatskimi spremembami problem še poglobil, kar prestavlja nove izzive za upravljalce voda.

Cianobakterije v splošnem cvetijo pozno poleti in zgodaj jeseni, ko so rekreacijske aktivnosti na vodnih telesih v porastu. Cvetenje cianobakterij poveča motnost vode, zavira rast makrofitov in vpliva na nevretenčarje in ribe v vodnem okolju. Poleg tega nekatere cianobakterijske vrste proizvajajo toksine, škodljive ljudem in živalim. Cvetenje toksičnih vrst cianobakterij pogosto povzroči zmanjšanje biodiverzitete, porušenje trofičnih verig in ravnotežja v ekosistemih.

Mehanizem pojavljanja cianobakterijskega cvetenja je kompleksen, ker do tega pride ob hkratnem delovanju več dejavnikov. Posamezne cianobakterijske vrste posedujejo vrsto prilagoditev na različne okoljske dejavnike, kar jim omogoča prednost pred tekmeci in naselitev večine vodnih habitatov. Med najpogostejšimi cianobakterijskimi vrstami, ki se pojavljajo v evropskih celinskih vodah, so *Microcystis* spp., *Planktothrix agardhii*, *Aphanizomenon flos-aquae* in *Anabaena* spp.

Acknowledgement

The research was performed in the frame of 7FP Dronic project "Application of an unmanned surface vessel with ultrasonic, environmentally friendly system to (map and) control blue-green algae (Cyanobacteria)". Authors are grateful for all the support.

References

Aboal, M., 1996. Epipelic algal communities in irrigation channels of Southeastern Spain. Arch. Hydrobiol. Algological Studies, 82, 117-131.

Aboal, M., Puig, M.A., 2005. Intracellular and dissolved microcystin in reservoirs of the river Segura basin, Murcia, SE Spain. Toxicon, 45, 509-518.

Agnihotri, V.K., 2014. *Anabaena flos-aquae*. Crit. Rev. Env. Sci. Tec., 44, 1995-2037.

Ahn, C.Y., Park, M.H., Joung, S.H., Kim, H.S., Jang K.Y., Oh H.M., 2003. Growth inhibition of cyanobacteria by ultrasonic radiation: laboratory and enclosure studies. Environ. Sci. Technol., 37, 3031-3037.

Akcaalan, R., Mazur-Marzec, H., Zalewska, A., Albay M., 2009. Phenotypic and toxicological characterization of toxic *Nodularia spumigena* from a freshwater lake in Turkey. Harmful Algae, 8, 273–278.

Albay, M., Matthiensen, A. and Codd, G., 2005. Occurrence of toxic blue-green algae in the Kucukcekmece Lagoon (Istanbul, Turkey). Environ Toxicol., 20, 277-84.

Almodóvar, A., Incola, G.G., Nuevo, M., 2004. Effects of a bloom of *Planktothrix rubescens* on the fish community of a Spanish reservoir. Limnetica, 23, 167-178.

Álvarez Cobelas, M., 1982. Las algas de una charca ganadera temporal: su sucesión en relación con los factores ambientales. [Algae from a cattle temporary pond: Their succession in relation to environmental factors]. Collectanea Botanica, 13, 709-722.

Alvarez-Cobelas, M., Gallardo, T., 1988. Catálogo de las algas continentales españolas V. *Cyanophyceae* Schaffner 1909. [Catalogue of Spanish continental algae, 5: Cyanophyceae Schaffner 1909]. Acta Botanica Malacitana, 13, 53-76.

Aubriot, L., Bonilla, S., Falkner, G., 2011. Adaptive phosphate uptake behaviour of phytoplankton to environmental phosphate fluctuations. FEMS Microbiol. Ecol., 77, 1-16.

Bárbara, I., Cremades, J., Calvo, S., López-Rodríguez, M.C., Dosil, J., 2005. Checklist of the benthic marine and brackish Galician algae (NW Spain). Anales Jard. Bot. Madrid., 62, 69-100.

Bazzichelli, G., Abdelahad, N., 1994. Morphometric and statistic characterization of two *Aphanizomenon* populations of the group *Aphanizomenon ovalisporum* Forti from the lakes of Nemi and Albano. Archiv Fuer Hydrobiologie Supplement-band., 103(0), 1-21.

Becker, V., Ihara, P., Yunes, J.S., Huszar, V.L.M., 2010. Occurrence of anatoxin-a(s) during a bloom of *Anabaena crassa* in a water-supply reservoir in southern Brazil. J. Appl. Phycol., 22, 235–241.

Bláha, L., Babica, P., Hilscherová, K., Upham, B., 2010. Inhibition of gap-junctional intercellular communication and activation of mitogen-activated protein kinases by cyanobacterial extracts - indications of novel tumor promoting cyanotoxins? Toxicon., 55(1), 126-134.

Blom, J.F., Baumann, H. I., Codd, G.A., Jüttner, F., 2006. Sensitivity and adaptation of aquatic organisms to oscillapeptin J and [D-Asp^3, (E)-Dhb^7]microcystin-RR. Arch. Hydrobiol., 167(1-4), 547-559.

Bonilla, S., Aubriot, L., Soares, M.C.S., González-Piana, M., Fabre, A., Huszar, V.L.M., Lürling, M., Antoniades, D., Padisák, J., Kruk C., 2012. What drives the distribution of the bloom-forming cyanobacteria *Planktothrix agardhii* and *Cylindrospermopsis raciborskii*? FEMS Microbiol. Ecol., 79, 594-607.

Briand, J.F., Jacquet, S., Bernard, C., Humbert, J.C., 2003. Health hazards for terrestrial vertebrates from toxic cyanobacteria in surface water ecosystems. Vet. Res., 34, 361-377.

Bruno, M., Barbini, D.A., Pierdominici, E., Serse, A.P., Ioppolo, A., 1994. Anatoxin-A and a previously unknown toxin in *Anabaena planctonica* from blooms found in Lake Mulargia (Italy). Toxicon, 32(3), 369-373.

Bubik, A., Sedmak, B., Novinec, M., Lenarčič, B., Lah, T.T., 2008. Cytotoxic and peptidase inhibitory activities of selected non-hepatotoxic cyclic peptides from cyanobacteria. Biol. Chem., 389, 1339-1346.

Budzyńska, A., Gołdyn, R., Zagajewski, P., Dondajewska, R., Kowalczewska-Madura, K. 2009. The dynamics of a *Planktothrix agardhii* population in a shallow dimictic lake. Int. J. Oceanogr. Hydrobiol., 38(2), 7-12.

Calvo, S., Bárbara I., 2002. Algas bentónicas de las marismas de Ortigueira, Betanzos, Baldaio y Corrubedo (Galicia, España). [Benthic algae from Ortigueira, Betanzos, Baldaio and Corrubedo salt-marshes (Galicia, Spain)]. Nova Acta Cient. Compostel. Biol., 12, 5-34.

Caraus, I., 2002. The algae of Romania. Studii si Cercetari, Universitatea Bacau. Biologie, 7, 1-694.

Caraus, I., 2012. Algae of Romania. A distributional checklist of actual algae. Version 2.3 third revision. Bacau: Univ. Bacau.

Carey, C.C., Ibelings, B.W., Hoffman, E.P., Hamilton, D.P., Brookes, J.D., 2012. Ecp-physiological adaptations that favour freshwater cyanobacteria in a changing climate. Wat. Res., 46, 1394-1407.

Carmichael, W.W., 2001. Health effects of toxin-producing cyanobacteria: "The cyanoHABs". Hum. Ecol. Risk Assess., 7(5), 1393-1407.

Carneiro, R.L., Venâncio dos Santos, M.E.V., Furlanetto Pacheco, A.B., Feliciano de Oliveira e Azevedo, A.S.M., 2009. Effects of light intensity and light quality on growth and circadian rhytm of saxitoxins production in *Cylindrospermopsis raciborskii* (Cyanobacteria). J. Plankton Res., 1(1), 1-8.

Carrasco, D., Moreno, E., Paniagua, T., de Hoyos, C., Wormer, L., Sanchis, D., Cirés, S., Martín-del-Pozo, D., Codd, G.A., Quesada, A. 2007. Anatoxin-a occurrence and potential cyanobacterial anatoxin-a producers in Spanish reservoirs. J. Phycol., 43, 1120-1125.

Carrillo, E., Ferrero, L.M., Alonso-Andicoberry, C., Basanta, A., Martin, A., López-Rodas, V., Costas E., 2003. Interstrain variability in toxin production in populations of the cyanobacterium *Microcystis aeruginosa* from water-supply reservoirs of Andalusia and lagoons of Doñana National Park (southern Spain). Phycologia, 42, 269-274.

Catherine, A., Quiblier, C., Yéprémian, C., Got, P., Groleau, A., Vinçon-Leite, B., Bernard, C., Troussellier, M., 2008. Collapse of a *Planktothrix agardhii* perennial bloom and microcystin dynamics in response to reduced phosphate concentrations in a temperate lake. FEMS Microbiol. Ecol., 65, 61-73.

Chen, Y., Shen, D., Fang, D., 2013. Nodularins in poisoning. Clin. Chim. Acta. 425: 18-29.

Chen, L., Chen, J., Zhang, X., Xie, P., 2016. A review of reproductive toxicity of microcystins. J. Hazard. Mater., 301, 381-399.

Chonudomkul D., Yongmanitchai W., Theeragool G., Kawachi M., Kasai F., Kaya K. and Watanabe M.M. 2004. Morphology, genetic diversity, temperature tolerance and toxicity of *Cylindrospermopsis raciborskii* (Nostocales, Cyanobacteria) strains from Thailand and Japan. FEMS Microb. Ecol., 48, 345-355.

Chorus, I., Bartram, J. 1999. Toxic Cyanobacteria in Water: A Guide to their Public Health Consequences, Monitoring and Management. EandFN Spon, London, 416 pp.

Chorus, I., Falconer, I.R., Salas, H.J., Bartram, J., 2000. Health risks caused by freshwater cyanobacteria in recreational waters. J. Toxicol. Environ. Health, part B, 3, 323-347.

Cook, C.M., Vardaka, E., Lanaras, T., 2004. Toxic cyanobacteria in Greek freshwaters, 1987-2000: Occurrence, toxicity, and impacts in the Mediterranean region. Acta Hydrochim. Hydrobiol., 32(2), 107-124.

Cronberg, G., Annadotter, H., Lawton, L.A., 1999. The occurrence of toxic blue-green algae in Lake Ringsjön, southern Sweden, despite nutrient reduction and fish biomanipulation. Hydrobiologia, 404, 123–129.

Crossetti, L.O., de M. Bicudo, C.E., 2008. Adaptations in phytoplankton life strategies to imposed change in a shallow urban tropical eutrophic reservoir, Garças Reservoir, over 8 years. Hydrobiologia, 614, 91-105.

de Abreu, F.Q., Ferrão-Filho, A.d.S., 2013. Effects of an Anatoxin-a(s)-Producing Strain of *Anabaena spiroides* (Cyanobacteria) on the Survivorship and Somatic Growth of Two *Daphnia similis* Clones. J. Environ. Prot., 4, 12-18.

Dean, A.P., Estrada, B., Nicholson, J.M., Sigee, D.C., 2008. Molecular response of *Anabaena flos-aquae* to differing concentrations of phosphorus: a combined Fourier transform infrared and X-ray microanalytical study. Phycol. Res., 56, 193-201.

Dean, A.P., Sigee D.C., 2006. Molecular heterogeneity in *Aphanizomenon flos-aquae* and *Anabaena flos-aquae* (Cyanophyta): a synchrotron-based Fourier-transform infrared study of lake micropopulations. European J. Phycol., 41, 201-212.

Dokulil, M.T., Teubner, K., 2000. Cyanobacterial dominance in lakes. Hydrobiologia, 438, 1-12.

Downing, J.A., Watson, S.A., McCauley, E., 2001. Predicting cyanobacteria dominance in lakes. Can. J. Fish. Aquat. Sci., 58, 1905-1908.

Dular, M., Griessler-Bulc, T., Gutierrez-Aguirre, I., Heath, E., Kosjek, T., Krivograd Klemenčič, A., Oder, M., Petkovšek, M., Rački, N., Ravnikar, M., Šarc, A., Širok, B., Zupanc, M., Žitnik, M., Kompare, B., 2016. Use of hydrodynamic cavitation in (waste)water treatment. Ultrasonics Sonochemistry, 29, 577–588.

EFSA, 2011. European Food Safety Authority: Scientific Opinion on risk based control of biogenic amine formation in fermented foods. EFSA Panel on Biological Hazards (BIOHAZ), EFSA Journal, 2393, 9(10), 93 pp.

Eiler, A., Bertilsson, S., 2004. Composition of freshwater bacterial communities associated with cyanobacterial blooms in four Swedish lakes. Environ. Microbiol., 6(12), 1228-1243.

Eleršek, T., 2009. First report of cyanobacterial bloom of *Microcystis viridis* (A. Braun) Lemmermann in Slovenia. Acta Biol. Slov., 52(1), 37–47.

EPA. United States Environmental Protection Agency, 2015. Health Effects Support Document for the Cyanobacterial Toxin Anatoxin-A. Health and Ecological Criteria Division Washington, DC 20460, 47 pp.

Ersanli, E., Gönülol, A., 2006. A study on the phytoplankton of Lake Simenit, Turkey. Cryptogamie Algol., 27, 289-305.

Ersmark, K., Del Valle, J.R., Hanessian, S., 2008. Chemistry and biology of the aeruginosin family of serine protease inhibitors. Angew. Chem. Int. Ed., 47, 1202-1223.

Falconer, I.R., 2001. Toxic cyanobacterial bloom problems in Australian waters: risks and impacts on human health. Phycologia, 40(3), 228-233.

Fewer, D.P., Jokela, J., Rouhiainen, L., Wahlsten, M., Koskenniemi, K., Stal, L.J., Sivonen, K., 2009. The non-ribosomal assembly and frequent occurrence of the protease inhibitors spumigins in the bloom-forming cyanobacterium *Nodularia spumigena.* Mol. Microbiol, 73, 924-937.

Fitzgeorge, N.L.M., Clark, S.A., Kelvin, C.W., 1994. Routes of intoxication. In: Codd, G.A., Jeffreies, T.M., Kelvin, C.W., Potter, E. (eds.): Detection Methods for Cyanobacterial (Blue-Green Algal) Toxins and First International Symposium on Detection Methods for Cyanobacterial (Blue-Green Algal) Toxins, Royal Society of Chemistry, Cambridge, U.K., pp. 69-74.

Fujise, D., Tsuji, K., Fukushima, N., Kawai, K., Harada, K.-I., 2010. Analytical aspects of cyanobacterial volatile organic compounds for investigation of their production behaviour. J. Chromatogr. A, 1217, 6122-6125.

Furey, A., Crowley, J., Shuilleabhain, A.N., Skulberg, O.M., James, K.J., 2003. The first identification of the rare cyanobacterial toxin, homoanatoxin-a, in Ireland. Toxicon, 41, 297-303.

Gkelis, S., Moustaka-Gouni, M., Sivonen, K., Lanaras, T., 2005. First report of the cyanobacterium *Aphanizomenon ovalisporum* Forti in two Greek lakes and cyanotoxin occurrence. J. Plankton Res., 27(12), 1295-1300.

Grach-Pogrebinsky, O., Sedmak, B., Carmeli, S., 2004. *Seco*[D-Asp3]microcystin-RR and [D-Asp3,D-Glu(OMe)6]microcystin-RR, two new microcystins from a toxic water bloom of the Cyanobacterium *Planktothrix rubescens.* J. Nat. Products, 67, 337-342.

Guiry, M.D., 1978. A consensus and bibliography of Irish Seaweeds, Cramer. Vaduz 287 pp.

Guo, L., Wang, Q., Xie, P., Tao, M., Zhang, J., Niu, Y., Ma, Z., 2015. A non-classical biomanipulation experiment in Gonghu Bay of Lake Taihu: control of Microcystis blooms using silver and bighead carp. Aquaculture Research, 46, 2211-2224.

Harada, K.-I., Mayumi, T., Shimada, T., Suzuki, M., Kondo, F., Watanabe, M. F., 1993. Occurrence of four depsipeptides, aeruginopeptins, together with microcystins from toxic cyanobacteria. Tetrahedron Lett., 34, 6091–6094.

Havens, K.E., 2008. Cyanobacteria blooms: effects on aquatic ecosystems. Adv Exp Med Biol., 619, 733-47.

Havens, K.E., James, R.T., East, T.L., Smith, V.H., 2003. N:P ratios, light limitation, and cyanobacterial dominance in a subtropical lake impacted by non-point source nutrient pollution. Environ. Pollut., 122, 379-390.

Heisler, J., Glibert, P.M., Burkholder, J.M., Anderson, D.M., Cochlan, W., Dennison, W.C., Dortch, Q., Gobler, C.J., Heil, C.A., Humphries, E., Lewitus, A., Magnien, R., Marshall, H.G., Sellner, K., Stockwell, D.A., Stoecker, D.K., Suddleson, M., 2008. Eutrophication and harmful algal blooms: a scientific consensus. Harmful algae, 8, 3-13.

Holland, D.P., Walsby, A.E., 2008. Viability of the cyanobacterium *Plankothrix rubescens*, in the cold and dark, related to over-winter survival and summer recruitment in Lake Zürich. European J. Phycol., 43(2), 179-184.

Horváth, H., Kovács, A.W., Riddick, C., Présing, M., 2013. Extraction methods for phycocyanin determination in freshwater filamentous cyanobateria and their application in a shallow lake. European J. Phycol., 48(3), 278-286.

Huisman, J., Sharples, J., Stroom, J.M., Visser, P.M., Kardinaal, W.E.A., Verspagen, J.M.H., Sommeijer, B., 2004. Changes in turbulent mixing shift competition for light between phytoplankton species. Ecology, 85(11), 2960-2970.

Jacquet, S., Briand, J.-F., Laboulanger, C., Avois-Jacquet, C., Oberhaus, L., Tassin, B., Vinçon-Leite, B., Paolini, G., Druart, J.-C., Anneville, O., Humbert, J.-F., 2005. The proliferation of the toxic cyanobacterium *Planktothrix rubescens* following restoration of the largest natural French lake (Lac du Bourget). Harmful algae, 4, 651-672.

Jančula, D., Maršálek, B., 2011. Critical review of actually available chemical compounds for prevention and management of cyanobacterial blooms. Chemosphere, 85, 1415-1422.

Jančula, D., Míkovcová, M., Adámek, Z., Maršálek, B., 2008. Changes in the photosynthetic activity of *Microcystis* colonies after gut passage through Nile tilapia (*Oreochromis niloticus*) and silver carp (*Hypophthalmichthys molitrix*). Aquac. Res., 39, 311-314.

Jančula, D., Mikula, P., Maršálek, B., Rudolf, P., Pochylý, F., 2014. Selective method for cyanobacterial bloom removal: hydraulic jet cavitation experience. Aquacult. Int., 22, 509-521.

Jodlowska, S., Latala, A., 2010. Photoacclimation strategies in the toxic cyanobacterium *Nodularia spumigena* (Nostocales, Cyanobateria). Phycologia, 49(3), 203-211.

Jöhnk, K.D., Huisman, J., Sharples, J., Sommeijer, B., Visser, P.M., Stroom, J.M., 2008. Summer heatwaves promote blooms of harmful cyanobacteria. Glob. Chang. Biol., 14, 495-512.

Jüttner, F., Watson, S.B., 2007. Biochemical and Ecological Control of Geosmin and 2-Methylisoborneol in Source Waters. Appl. Environ. Microbiol., 73(14), 4395–4406.

Kanoshina, I., Lips, U., Leppänen, J.-M., 2003. The influence of weather conditions (temperature and wind) on cyanobacterial bloom development in the Gulf of Finland (Baltic Sea). Harmful algae, 2, 29-41.

Kaplan, A., Schwarz, R., Lieman-Hurwitz, J., Reinhold, L., 1991. Physiological and molecular aspects of the inorganic carbon-concentrating mechanism in cyanobacteria. Plant. Physiol., 97, 851-855.

Kardinal, W.E.A., Visser, P.M., 2005. Dynamics of Cyanobacterial Toxins. In: Huisman, J., Matthijs, H.C.P., Visser, P.M. (eds.): Harmful Cyanobacteria, Aquatic Ecology Series, Springer, Dordrecht, The Netherlands, pp. 41-64.

Karlsson-Elfgren, I., Brunberg, A.K., 2004. The importance of shallow sediments in the recruitment of *Anabaena* and *Aphanizomenon* (Cyanophyceae). J. Phycol. 40: 831-836.

Kass H. and Henriksen P. 2000. Saxitoxins (PSP toxins) in Danish lakes. Wat. Res., 34(7), 2089-2097.

Kaštovsky, J., Hauer, T., Komárek, J., Skácelová, O., 2010. The list of cyanobacterial species of the Czech Republic to the end of 2009. Fottea, 10(2), 245-249.

Kokocinski, M., Soininen, J., 2012. Environmental factors related to the occurrence of *Cylindrospermopsis raciborskii* (Nostocales, Cyanophyta) at the north-eastern limit of its geographical range. European J. Phycol., 47(1), 12-21.

Kokocinski, M., Stefaniak, K., Mankiewicz-Boczek, J., Izydorczyk, K., Soininen, J., 2010. The ecology of the invasive cyanobacterium *Cylindrospermopsis raciborskii* (Nostocales, Cyanophyta) in two hypereutrophic lakes dominated by *Planktothrix agardhii* (Oscillatoriales, Cyanophyta). European J. Phycol., 45(4), 365-374.

Kosi, G., 1999. The occurence of toxic cyanobacteria in the Slovenian fresh-water bodies, Dissertation Thesis, Biotehnical faculty, Department of Biology, Ljubljana (in Slovene).

Kosten, S., Huszar, V.L.M., Bécares, E., Costa, L.S., van Donk, E., Hansson, L.-A., Jeppesen, E., Kruk, C., Lacerot, G., Mazzeo, N., de Meester, L., Moss, B., Lürling, M., Nöges, T., Romo, S., Scheffer, M., 2012. Warmer climates boost cyanobacterial dominance in shallow lakes. Glob. Chang. Biol., 18, 118-126.

Krivograd Klemenčič, A., Griessler Bulc, T., 2010. The efficiency of ultrasound on algal control in a closed-loop water treatment system for cyprinid fish farms. Fresenius Environmental Bulletin, 19, 919-931.

Lacerot, G., Kruk, C., Lürling, M., Scheffer, M., 2013. The role of subtropical zooplankton as grazers of phytoplankton under different predation levels. Freshwater Biol., 58, 494-503.

Leao, P.N., Vasconcelos, M.T.S.D., Vasconcelos, V.M., 2009. Allopathic activity of cyanobacteria on green microalgae at low cell densities. European J. Phycol., 44(3), 347-355.

Lehman, P.W., Boyer, G., Hall, C., Waller, S., Gehrts, K., 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia, 541, 87-99.

Li, H., Murphy, T., Guo, J., Parr, T., Nalewajko, C., 2009. Iron-stimulated growth and microcystin production of Microcystis novacekii UAM 250. Limnologica, 39, 255-259.

Li, P., Song, Y., Yu, S., 2014. Removal of Microcystis aeruginosa using hydrodynamic cavitation: performance and mechanisms. Water Research, 62, 241-248.

López Rodríguez, M.C., Leira, M., Toural, C., Penalta, M., 2009. Flora dulceacuícola del Parque Natural de la Sierra de la Encina de Lastra. Algas, Bol. Soc. Esp. Ficología, 42, 18-19.

Lürling, M., Eshetu, F., Faassen, E.J., Kosten, S., Huszar, V.L.M., 2013. Comparison of cyanobacterial and green algal growth rates at different temperatures. Freshwater Biol., 58, 552-559.

Mahvi, A.H., Dehghani, M.H., 2005. Evaluation of ultrasonic technology in removal of algae bloom from surface waters. Pak. J. Biol. Sci., 8(10), 1457-1459.

Martín, A., Carrillo, E., Costas, E., 2004. Variabilidad genética para la producción de toxina en poblaciones de *Microcystis aeruginosa* en dos embalses de abastecimiento de Andalucía. Limnetica, 23, 153-158.

Matthijs, H.C.P., Jančula, D., Visser, P.M., Maršálek, B., 2016. Existing and emerging cyanocidal compounds: new perspectives for cyanobacterial bloom mitigation. Aquat. Ecol., 50, 443–460.

Mazur, H., Pliński, M., 2003. *Nodularia spumigena* blooms and the occurrence of hepatotoxin in the Gulf of Gdańsk. Oceanologia, 45(1), 305-316.

McLellan, N.L., Manderville, R.A., 2017. Toxic mechanisms of microcystins in mammals. Toxicol. Res., 2017.

Meat and Livestock Australia (MLA), 2001. Biogenic amines in meat meal, ISBN: 1 74036 702 2.

Mehnert, G., Leunert, F., Cirés, S., Jöhnk, K.D., Rücker, J., Nixdorf, B., Wiedner, C., 2010. Competitiveness of invasive and native cyanobacteria from temperate freshwaters under various light and temperature conditions. J. Plankton Res., 32(7), 1009-1021.

Mehnert, G., Rücker, J., Nicklisch, A., Leunert, F., Wiedner, C., 2012. Effects of thermal acclimation and photoacclimation on lipophilic pigments in an invasive and a native cyanobacterium of temperate regions. European J. Phycol., 47(2), 182-192.

Metcalf, J.S., Reilly, M., Young, F.M., Codd, G.A., 2009. Localization of microcystin synthetase genes in colonies of the cyanobacterium *Microcystis* using fluorescence in situ hybridization. J. Phycol., 45(6), 1400-1404.

Michalak, A.M., Anderson, E.J., Beletsky, D., Boland, S., Bosch, N.S., Bridgeman, T.B., Chaffin, J.D., Cho, K., Confesor, R., Daloğlu, I., DePinto, J.V., Evans, M.A., Fahnenstiel, G.L., He, L., Ho, J.C., Jenkins, L., Johengen, T.H., Kuo, K.C., LaPorte, E., Liu, X., McWilliams, M.R., Moore, M.R., Posselt, D.J., Richards, R.P., Scavia, D., Steiner, A.L., Verhamme, E., Wright, D.M., Zagorski, M.A., 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. PNAS, 110(16), 6448-6452.

McNeary, W.W., Erickson, L.E., 2013. Sustainable management of algae in eutrophic ecosystems. J. Environ. Prot., 4, 9-19.

Milovanović, I., Mišan, A., Simeunović, J., Kovač, D., Jambrec, D., Mandić, A. 2015. Determination of Volatile Organic Compounds in Selected Strains of Cyanobacteria. J. Chem., 2015, 1-6.

Milutinović, A., Zorc-Pleskovic, R., Petrovic, D., Zorc, M., Suput, D., 2006. Microcystin-LR induces alterations in heart muscle. Folia Biol (Praha), 52, 116-118.

Moisander, P.H., McClinton III, E., Paerl, H.W., 2002. Salinity effects on growth, photosynthetic parameters, and nitrogenase activity in estuarine planktonic cyanobacteria. Microb. Ecol., 43, 432-442.

Molica, R., Onodera, H., García, C., Rivas, M., Andrinolo, D., Nascimento, S., Meguro, H., Oshima, Y., Azevedo, S., Lagos, N., 2002. Toxins in the freshwater cyanobacterium *Cylindrospermopsis raciborskii* (Cyanophyceae) isolated from Tabocas reservoir in Caruaru, Brazil, including demonstration of a new saxitoxin analogue. Phycologia, 41(6), 606-611.

Mukherjee, C., Chowdhury, R., Ray, K., 2015. Phosphorus Recycling from an Unexplored Source by Polyphosphate Accumulating Microalgae and Cyanobacteria-A Step to Phosphorus Security in Agriculture. Front. Microbiol. 6: 1421.

Murakami, M., Suzuki, S., Itou, Y., Kodani, S., Ishida, K., 2000. New anabaenopeptins, potent carboxypeptidase-A inhibitors from the cyanobacterium *Aphanizomenon flos-aquae.* J. Nat. Prod., 83, 1280-1282.

Nakano, K., Lee, T.J., Matsumura, M., 2001. In situ algal bloom control by the integration of ultrasonic radiation and jet circulation to flushing. Environ. Sci. Technol., 35, 4941-4946.

Nalewajko, C., Murphy, T.P., 2001. Effects of temperature, and availability of nitrogen and phosphorus on the abundance of *Anabaena* and *Microcystis* in Lake Biwa, Japan: an experimental approach. Limnology, 2, 45-48.

Neumann, U., Forchert, A., Flury, T., Weckesser, J., 1997. Microginin FR1, a linear peptide from a water bloom of *Microcystis* species. FEMS Microbiol. Lett., 153(2), 475–478.

Nováková, K., Kohoutek, J., Adamovský, O., Brack, W., Krauss, M., Bláha, L., 2013. Novel metabolites in cyanobacterium *Cylindrospermopsis raciborskii* with potencies to inhibit gap junctional intercellular communication. J. Hazard. Mate., 262(15), 571-579.

Oberhaus, L., Briand, J.F., Leboulanger, C., Jacquet, S., Humbert, J.F., 2007. Comparative effects of the quality and quantity of light and temperature on the growth of *Planktothrix agardhii* and *P. rubescens*. J. Phycol., 43, 1191-1199.

O'Brien, H.E., Miadlikowska, J., Lutzoni, F., 2006. Assessing host specialization in symbiotic cyanobacteria associated with four closely related species of the lichen fungus *Peltigera*. European J. Phycol., 40, 363-378.

Olli, K., Kangro, K., Kabel, M., 2005. Akinete production of *Anabaena lemmermannii A. cylindrica* (Cyanophyceae) in natural populations of N- and P-limited coastal mesocosms (Note). J. Phycol., 41, 1094-1098.

O'Neil, J.M., Davis, T.W., Burford, M.A., Gobler, C.J., 2012. The rise of harmful cyanobacteria blooms: The potential roles of eutrophication and climate change. Harmful algae, 14, 313-334.

Osswald, J., Rellán, S., Gago, A., Vasconcelos, V., 2007. Toxicology and detection methods of the alkaloid neurotoxin produced by cyanobacteria, anatoxin-a. Environ. Int., 33, 1070-1089.

Padisák, J., Reynolds, C.S., 1998. Selection of phytoplankton associations in Lake Balaton, Hungary, in response to eutrophication and restoration measures, with special reference to the cyanoprokaryotes. Hydrobiologia, 384, 41-53.

Paerl, H.W., 1979. Optimization of carbon dioxide and nitrogen fixation by the blue-green alga *Anabaena* in freshwater bloom. Oecologia, 38(3), 275-290.

Paerl, H.W., 2008. Nutrient and other environmental controls of harmful cyanobacterial blooms along the freshwater-marine continuum. In: Hudnell, H.K. (ed.): Cyanobacterial Harmful Algal Blooms: State of the Science and Research Needs, Advances in Experimental Medicine and Biology, 619, Springer New York, New York, pp. 217-237.

Paerl, H.W., Fulton III, R.S., Moisander, P.H., Dyble, J., 2001. Harmful freshwater algal blooms, with an emphasis on cyanobacteria. Sci. World J., 1, 76-113.

Paerl, H.W., Huisman, J., 2008. Blooms like it hot. Science, 320, 57-58.

Paerl, H.W., Huisman, J., 2009. Climate change: a catalyst for global expansion of harmful cyanobacterial blooms. Environ. Microbiol. Reports, 1(1), 27-37.

Paerl, H.W., Millie, D.F., 1996. Physiological ecology of toxic aquatic cyanobacteria. Phycologia, 35(6), 160-167.

Paerl, H.W., Paul, V.J., 2012. Climate change: links to global expansion of harmful cyanobacteria. Wat. Res., 46, 1349-1363.

Paerl, H.W., Tucker, J., Bland, P.T., 1983. Carotenoid enhancement and its role in maintaining blue-green algal (Microcystis aeruginosa) surface blooms. Limnol. Oceanogr., 28(5), 847-857.

Pearson, L., Mihali, T., Moffitt, M., Kellmann, R., Neilan, B., 2010. On the chemistry, toxicology and genetics of the cyanobacterial toxins, microcystin, nodularin, saxitoxin and cylindrospermopsin. Mar. Drugs, 8, 1650-1680.

Pérez, M.C, Comas, A., Maidana, N., 2010. Estudio taxonómico del fitoplancton del tramo inferior del río Júcar con especial énfasis en las algas verdes cocales (Valencia - España). ALGAS. Boletín de la Sociedad Española de Ficología, 44, 13-19.

Pérez, M.C., Maidana, N.I., Comas, A., 2009. Phytoplancton composition of the Ebro River estuary, Spain. Acta Bot. Croat., 68, 11-27.

Pinckney, J.L., Paerl, H.W., Tester, P., Richardson, T.L., 2001. The role of nutrient loading and eutrophication in estuarine ecology. Environ. Health Persp., 109(5), 699-706.

Prasath, B., Nandakumar, R., Jayalakshmi, T., Santhanam, P., 2014. First report on the intense cyanobacteria *Microcystis aeruginosa* Kützing, 1846 bloom at Muttukkadu Backwater, outheast coast of India. Indian J. Geomarine Sci., 43(2), 258-262.

Preußel, K., Stüken, A., Wiedner, C., Chorus, I., Fastner, J., 2006. First report on cylindrospermopsin producing *Aphanizomenon flos-aquae* (Cyanobacteria) isolated from two German lakes. Toxicon, 47, 156-162.

Quesada, A., Moreno, E., Carrasco, D., Paniagua, T., Wormer, L., de Hoyos, C., Sukenik, A. 2006. Toxicity of *Alphanizomenon ovalisporum* (Cyanobacteria) in a Spanish water reservoir. European J. Phycol., 41, 39-45.

Rajaniemi-Wacklin, P., Rantala, A. Mugnai, M.A., Turicchia, S., Ventura, S., Komárková, J., Lepisto, L., Sivonen, K., 2006. Correspondence between phylogeny and morphology of *Snowella* spp. and *Woronichinia naegeliana*, cyanobacteria commonly occurring in lakes. J. Phycol., 42, 226-232.

Rajasekhar, P., Fan, L., Nguyen, T., Roddick, F.A., 2012. Impact of sonication at 20 kHz on *Microcystis aeruginosa*, *Anabaena circinalis* and *Chlorella* sp. Wat. Res., 46, 1473-1481.

Rapala, J., Sivonen, K., Lyra, C., Niemelä, S.L., 1997. Variation of microcystins, cyanobacterial hepatotoxins, in *Anabaena* spp. as a function of growth stimuli. Applied and Environ. Microbiol., 63(6), 2206-2212.

Saker, M.L., Nogueira, I.C.G., Vasconcelos, V.M., 2004. Distribution and toxicity of *Cylindrospermopsis raciborskii* (Cyanobacteria) in Portuguese freshwaters. Limnetica, 23, 145-152.

Schatz, D., Keren, Y., Vardi, A., Sukenik, A., Carmeli, S., Borner, T., 2007. Towards clarification of the biological role of microcystins, a family of cyanobacterial toxins. Environ. Microbiol., 9, 965-70.

Scheffer, M., Rinaldi, S., Gragnani, A., Mur, L.R., van Nes, E.H., 1997. On the dominance of filamentous cyanobacteria in shallow, turbid lakes. Ecology, 78(1), 272-282.

Scholz, B., Liebezeit, G., 2012. Microphytobenthic dynamics in a Wadden sea intertidal flat - Part II: Seasonal and spatial variability of non-diatom community components in relation to abiotic parameters. European J. Phycol., 47(2), 120-137.

Sedmak, B., Eleršek, T., 2005. Microcystins induce morphological and physiological changes in selected representative phytoplanktons. Microb. Ecol., 50, 298–305.

Sharma, N.K., Choudhary, K.K., Bajpai, R., Rai, A.K., 2010. Freshwater cyanobacterial (blue-green algae) blooms: causes, consequances and control. In: Nemr, A.E. (ed.): Impact, Monitoring and Management of Environmental Pollution, Pollution Science, Technology and Abatement, Nova Science Publishers, New York, pp. 73-95.

Sigee, D.C., Selwyn, A., Gallois, P., Dean, A.P., 2007. Patterns of cell death in freshwater colonial cyanobacteria during the late summer bloom. Phycologia, 46(3), 284-292.

Sivonen, K., 1990. Effects of light, temperature, nitrate, orthophosphate, and bacteria on growth of and hepatoxin production by *Oscillatoria agardhii* strains. Applied and Environ. Microbiol., 56(9), 2658-2666.

Skuja, A., 1948. Taxonomie des Phytoplanktons einiger Seen in Uppland, Schweden*.* Symb. Bot. Upsal*.*, 9(3), 1-399.

Song, W., Teshiba, T., Rein, K., O'Shea, K.E., 2005. Ultrasonically Induced Degradation and Detoxification of Microcystin-LR (Cyanobacterial Toxin). Environ. Sci. Technol., 39, 6300-6305.

Spoof, L., 2005. Microcystins and nodularins. In: Meriluoto, J., Codd, G.A. (eds.): TOXIC Cyanobacterial Monitoring and Cyanotoxin Analyses, Åbo, Åbo Akademi University Press, pp. 15-40.

Spoof, L., Catherine, A., 2017. Appendix 3: Tables of Microcystins and Nodularins. In: Meriluoto, J., Spoof, L., Codd, G.A. (eds.): Handbook of Cyanobacterial Monitoring and Cyanotoxin Analysis, First Edition, John Wiley & Sons, Ltd., United Kingdom, pp. 526-537.

Stevens, D.K., Krieger, R.I., 1991. Stability studies on the cyanobacterial nicotinic alkaloid anatoxin-a. Toxicon, 29, 167–179.

Stuken, A., Rucker, J., Endrulat, T., Preussel, K., Hemm, M., Nixdorf, B., Karsten, U., Wiedner, C., 2006. Distribution of three alien cyanobacterial species (Nostocales) in northeast Germany: *Cylindrospermopsis raciborskii, Anabaena bergii* and *Aphanizomenon aphanizomenoides*. Phycologia, 45(6), 696-703.

Suikkanen, S., Laamanen, M., Huttunen, M., 2007. Long-term changes in summer phytoplankton communities of the open northern Baltic Sea. Estuar. Coast. Shelf Sci., 71, 580-592.

Sukenik, A., Eshkol, R., Livne, A., Hadas, O., Rom, M., Tchernov, D., 2002. Inhibition of growth and photosynthesis of the dinoflagellate *Peridinium gatunense* by *Microcystis* sp. (cyanobacteria): a novel allelopathic mechanism. Limnol. Oceanogr., 47, 1656-63.

Sukenik, A., Kaplan-Levy, R.N., Viner-Mozzini, Y., Quesada, A., Hadas, O., 2013. Potassium deficiency triggers the development of dormant cells (akinetes) in *Aphanizomenon ovalisporum* (Nostocales, Cyanoprokaryota). J. Phycol., 49(3), 580-587.

Sychrova, E., Stepankova, T., Novakova, K., Blaha, L., Giesy, J.P., Hilscherova, K., 2012. Estrogenic activity in extracts and exudates of cyanobacteria and green algae. Environ. Int., 39, 134-140.

Surosz, W., Palinska, K.A., 2004. Effects of heavy-metal stress on cyanobacterium Anabaena flos-aquae. Arch. Environ. Contam. Toxicol., 48, 40-48.

Takano, K., Hino, S., 2000. Effect of temperature and soluble reactive phosphorus on abundance of *Aphanizomenon flos-aquae* (Cyanophyceae). Phycol. Res., 48, 9-13.

Täuscher, L., 2011. Checklisten und Gefährdungsgrade der Algen des Landes Brandenburg I. Einleitender Überblick, Checklisten und Gefährdungsgrade der Cyanobacteria/Cyanophyta, Rhodophyta und Phaeophyceae/Fucophyceae. Verh. Bot. Vereins Berlin Brandenburg, 144, 177-192.

Tonk, L., Bosch, K., Visser, P.M., Huisman, J., 2007. Salt tolerance of the harmful cyanobacterium Microcystis aeruginosa. Aquat. Microb. Ecol., 46, 117-123.

Tsujimura, S., Ishikawa, K., Tsukada, H., 2001. Effect of temperature on growth of the cyanobacterium *Aphanizomenon flos-aquae* in Lake Biwa and Lake Yogo. Phycol. Res., 49, 275-280.

Ueno, Y., Nagata, S., Tsutsumi, T., Hasegawa, A., Watanabe, M.F., Park, H.-D., Chen, G.-C., Chen, G., Yu S.-Z., 1996. Detection of microcystins, a blue-green algal hepatotoxin, in drinking water sampled in Haimen and Fusui, endemic areas of primary liver cancer in China, by highly sensitive immunoassay. Carcinogenesis, 17(6), 1317-1321.

van Apeldoorn, M.E., van Egmond, H.P., Speijers, G.J.A., Bakker, G.J.I., 2007. Toxins of cyanobacteria. Review. Mol. Nutr. Food Res., 51, 7-60.

Velzeboer, R.M.A., Baker, P.D., Rositano, J., Heresztyn, T., Codd, G.A., Raggett, S.L., 2000. Geographical patterns of occurrence and composition of saxitoxins in the cyanobacterial genus *Anabaena* (Nostocales, Cyanophyta) in Australia. Phycologia, 39(5), 395-407.

Vézie, C., Rapala, J., Vaitomaa, J., Seitsonen, J., Sivonen, K., 2002. Effect of nitrogen and phosphorus on growth of toxic and nontoxic *Microcystis* strains and on intracellular microcystin concentrations. Microb. Ecol., 43, 443-454.

Viaggiu, E., Melchiorre, S., Volpi, F., Di Corcia, A., Mancini, R., Garibaldi, L., Crichigno, G., Bruno, M., 2004. Anatoxin-a toxin in the cyanobacterium *Planktothrix rubescens* from a fishing pond in northern Italy. Environ. Toxicol., 19(3), 191-7.

Walsby, A.E., Hayes, P.K., Boje, R., Stal, L.J., 1997. The selective advantage of buoyancy provided by gas vesicles for planktonic cyanobacteria in the Baltic Sea. New Phytol., 136, 407-417.

Wang, Q., Xie, P., Chen J., Liang, G. 2008. Distribution of microcystins in various organs (heart, liver, intestine, gonad, brain, kidney and lung) of Wistar rat via intravenous injection. Toxicon., 52, 721-727.

Watanabe, M.F., Oishi, S., 1985. Effects of environmental factors on toxicity of a cyanobacterium (*Microcystis aeruginosa*) under culture conditions. Applied and Environ. Microbiol., 49(5), 1342-1344.

Watanabe, M.F., Tsujimura, S., Oishi, S., Niki, T., Namikoshi, M., 2003. Isolation and identification of homoanatoxin-a from a toxic strain of the cyanobacterium *Raphidiopsis mediterranea* Skuja isolated from Lake Biwa, Japan. Phycologia, 42(4), 362-369.

Whitton, B.A., 2002. Phylum Cyanophyta (Cyanobacteria). In: John, D.M., Whitton, B.A., Brook, A.J. (eds.): The Freshwater Algal Flora of the British Isles. An identification guide to freshwater and terrestrial algae, Cambridge University Press, Cambridge, pp. 25-122.

WHO, 1998. Guidelines for drinking-water quality, Second edition, Volume 2, Health criteria and other supporting information – Addendum, Geneva, 127 pp.

WHO, 2003. Guidelines for safe recreational water environments, Volume 1, Coastal and fresh waters, Geneva, 219 pp.

Wiedner, C., Rücker, J., Brüggemann, R., Nixdorf, B., 2007. Climate change affect timing and size of populations of an invasive cyanobacterium in temperate regions. Oecologia, 152(3), 473-484.

Willame, R., Boutte, C., Grubisic, S., Wilmotte, A., Komarek, J., Hoffmann, L., 2006. Morphological and molecular characterization of planktonic cyanobacteria from Belgium and Luxembourg. J. Phycol., 42, 1312-1332.

Willén, T., Mattsson, R., 1997. Water-blooming and toxin-producing cyanobacteria in Swedish fresh and brackish waters, 1981–1995. Hydrobiologia, 353, 181–192.

Williams, A., 2014. Seek and Destroy: Algal Blooms. Combating Algae Blooms with Unmanned Ultrasonic Technology, Water and Wastewater International, June-July 2014.

Wu, X., Jiang, J., Wan, Y., Giesy, J.P., Hu, J., 2012a. Cyanobacteria blooms produce teratogenic retinoic acids. Proc. Natl. Acad. Sci. USA, 109(24), 9477–9482.

Wu, Z., Shen, H., Ondruschka, B., Zhang, Y., Wang, W., Bremner, D.H., 2012b. Removal of blue-green algae using the hybrid method of hydrodynamic cavitation and ozonation. J. Hazard Mate., 235-236, 152-158.

Xu, H., Paerl, H.W., Qin, B., Zhu, G., Gao, G., 2010. Nitrogen and phosphorus inputs control phytoplankton growth in eutrophic Lake Taihu, China. Limnol. Oceanogr., 55(1), 420-432.

Xu, Y., Yang, J., Wang, Y., Liu, F., Jia, J., 2006. The effects of jet cavitation on the growth of *Microcystis aeruginosa*. J. Environ. Sci. Health A., 41, 2345-2358.

Yamamoto, Y., 2009. Environmental factors that determine the occurrence and seasonal dynamics of *Aphanizomenon* flos-aquae. J. Limnol., 68(1), 122-132.

Young, F.M., Morrisom, L.F., James, J., Codd G.A., 2008. Quantification and localization of microcystins in colonies of a laboratory strain of *Microcystis* (Cyanobacteria) using immunological methods. European J. Phycol., 43(2), 217-225.

Zapomelová, E. Reháková, K., Jezberová, J., Komárková, J., 2010. Polyphasic characterization of eight planktonic *Anabaena* strains (Cyanobacteria) with reference to the variability of 61 *Anabaena* populations observed in the field. Hydrobiologia, 639, 99-113.

Zapomelová, E., Hrouzek, P., Rezanka, T., Jezberová, J., Reháková, K., Hisem, D., Komárková, J., 2011. Polyphasic characterization of *Dolichospermum* spp. and *Sphaerospermopsis* spp. (Nostocales, Cyanobacteria): morphology, 16S rRNA gene sequences and fatty acid and secondary metabolites profiles. J. Phycol., 47(5), 1152-1163.

Zastepa, A., Pick, F.R., Blais, J.M., 2014. Fate and Persistence of Particulate and Dissolved Microcystin-LA from Microcystis Blooms. Human and Ecological Risk Assessment: An
International Journal, 20(6), 1670-1686.

Zhang, G., Zhang, P., Liu, H., Wang, B., 2006a. Ultrasonic damages on cyanobacterial photosynthesis. Ultrason. Sonochem., 13, 501-505.

Zhang, G., Zhang, P., Wang, B., Liu, H., 2006b. Ultrasonic frequency effects on the removal of *Microcystis aeruginosa*. Ultrason. Sonochem., 13, 446-450.

Zhang, M., Duan, H., Shi, X., Yu, Y., Kong, F., 2012. Contributions of meteorology to the phenology of cyanobacterial blooms: implications for future climate change. Wat. Res., 46, 442-452.

Zhou, L., Yu, H., Chen, K., 2002. Relationship between microcystin in drinking water and colorectal cancer. Biomedical and environmental sciences, 15, 166-171.