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Experience, reviews, discussions

Water Quality Evaluation: Toxic Cyanobacteria in Surface Water

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Task of this article is to discuss the risk of blue green algal bloom to public health and to compare water quality assessment standards of surface waters among the EU Member States: France, Germany and Lithuania, drawing attention to the EU Water Framework Directive and its aims. Influence of toxic cyanobacteria on human health and the need of more detailed measures of concentration of cyanobacteria in surface waters are pointed out.

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Key words: *EU Water Framework Directive, cyanobacteria, surface water, WHO guidelines.*

1. Introduction

Water is mentioned as a source of life and its pollution can destroy biosphere. For the purpose of protecting a good status of ecosystem, its biota and human beings, the European Community has recognized environmental issues. EU politicians have defined the most significant achievements that help protect, preserve and improve natural recourses and their rational use (Water Framework Directive 2000/60/EC). One of the important EU documents on a water body issue is the Water Framework Directive (further – WFD) 2000/60/EC.

The WFD is an example of the most progressive law of Environmental Protection that is functioning today. The aim of the Directive is to overcome the water resources consumption crisis. The purpose of this EU Directive that was legally approved in 2000 (2000/60/EC) is to reach *good* surface water quality in the period of fifteen years since the Directive has been established. Among significant aspects of the Directive elimination of certain harmful substances and appearance of specific organic compounds in the concentrations similar to natural background values are of special interest.

The status of *good* water quality includes chemical and ecological water properties. According to the WFD surface water bodies are distinguished by different kinds of types. The quality is assessed by chemical and ecological aspects by means of the methods described in the annexes of WFD. The Environment Quality Standards (EQS) established by the Directive 2008/105/EC after some WFD corrections are defined there. These standards are used for assessment of chemical water pollution. Ecological conditions are assessed according to the population of phytoplankton, fishes and benthos organisms. There are no values for these parameters. Researchers all over the world have provided a lot of information about a negative impact of cyanobacteria on ecosystem and the existence of humans and animals.

This study reviews WFD implementation policies in some EU Member States, how these countries achieve *good* ecological condition in surface water bodies, how much attention is dedicated by them to protection of water against blue-green algae. The study provides some recommendations concerning secure operation and usage of surface water resources.

2. Legal basis of surface water quality regulation

In 2008 the WFD was corrected by Directive 2008/105/EC. This correction presents the allowed values of chemical substances having the priority status in surface water. According to these values chemical pollution should be measured in a polluted water outlet with a view of reaching its *good* chemical condition. The Member States collect and manage the information about the types of anthropogenic impact and values which could affect all water bodies in the river basins and thus ensure their chemical condition. One of first tasks of this Directive is to diffuse information on management and evaluation of pollution to various sources: cities, industry, agriculture and other facilities.

Ecological condition can be assessed when the types of water bodies are determined. According to this typology the parameters and values are set to each type of water body. The most important ecological parameters are:

– structure, biomass and abundance of phytoplankton;
– structure and abundance of other water fauna;
– structure and abundance of spineless fauna;
– structure, abundance and life structure of fish fauna.

Directive 2000/60/EC seems to confirm results of the comparison of biologic monitoring as the background of ecological status classification among the Members States. The latter are required to compare the results of the monitoring and classification status, using the inter-calibration network in the monitoring place: in each Member State and each community eco-district (Directive 2005/646/EC). The inter-calibration network was applied to surface waters by the Member States in 2005. They had to prescribe two parameters of national ecological assessment policy for the surface water body that belong to *very good* and *middling good* water quality classes.

Values of ecological quality proportion set to identify the ecological status after inter-calibration should be equally used to show the ecological status. Differences between the values of the same biological quality parameter depend on application of different national methods. Furthermore, because of different measurement methods it is impossible to compare the values of different ecological quality proportion. Such parameters as concentration of chlorophyll-a, biomass of phytoplankton, the percentage sum of cyanobacteria or algae depth limit do not include all the elements of biological quality. However, there are some data and some management methods based on the parameters and there is one of the background indicators used in the inter-calibration work in lakes and estuaries. The values of these parameters should be verified equally in each Member State according to different methods of taking samples and analyses (Directive 2008/915/EC).

Blue – green algae can destroy the whole other phytoplankton in the blooming period. It could be the main factor of biological variation decline and, after splitting in surface water, the source of deadly disease for humans. Cyanbacteria do not need long life-cycles, they split quickly in low debit waters bodies such as lakes, estuaries, seas.

3. Cyanobacteria found in surface waters

Most of the algae (cyanobacteria) are autotrophic. Their vital needs are very modest: water, carbon dioxide, inorganic materials and daylight. Cyanobacteria receive necessary energy during the photosynthesis process. However, it is known that some of species can survive for long periods of time, total darkness being their natural surrounding (Chorus I. 2005). Cyanobacteria's 'bloom' is detected in a lot of eutrophic and hypertrophic lakes, swamps and rivers all over the world. In tropic countries, strongly polluted reservoirs are affected by high temperatures and intensive sun beams which provide optimum conditions for the growth of cyanobacteria. While growing cyanobacteria change water reservoir colour to impressive green: water looks like pea soup (Directive 2008/915/EC).

One more cyanobacteria's feature is ability to survive at extremely high or extremely low temperatures. Cyanobacteria algae locations are found in fresh waters as well as in sea waters; this fact proves that all the species can survive in the water of varied salinity. The ability to develop the colonies on various benthic surfaces, like volcanic pellets, desert sand or stones, enables cyanobacteria to exist either on the bottom or on the surface of lakes and seas.

On the seaside and estuaries cyanobacteria exist in various forms: from a single, individual cell to floating algae colonies. Cyanobacteria appeared in the seas a long time ago and it strongly started spreading in the last decades. In some areas as the Baltic and North Seas, the Adriatic Sea, Japan Seaside or Mexican bay waters, cyanogens of bacteria have become repetitive phenomena. Fast and visible growth of bacteria colonies refers to their access to nutrients in the seaside waters. It can be seen by the changed colour of surface water and by emergence of eutrophication. Cyanobacteria's toxicity is determined differently. What is more, it depends on assigning to hepatoxic, neurotoxic or dermatoxic influence of general proteins synthesis inhibition. According to the chemical structure, it could be assigned to one of three groups (Table 1):

– cyclic peptide – hepatoxicity;
– alkaloid – neurotoxin;
– lipopolysaccharide;

Table 1. Classification of cyanobacterial toxins

Group of Toxins	Organ of mammal that is primarily damaged	Type of cyanobacteria
Cyclic peptides		
Microcystins	Liver	*Microcystis, Anabaena, Planktothrix (Oscillatoria), Nostoc, Hapalosiphon, Anabaenopsis*
Nodularins	Liver	*Nadularia*
Alkaloids		
Anatoxin-a	Nerves Synapses	*Anabaena, Planktothrix (Oscillatoria), Aphanizomenon*
Anatoxin-a (S)	Nerves Synapses	*Anabaena*
Aplysiatoxins	Skin	*Lyngbya, Schizothrlix, Planktothrix (Oscillatoria)*
Cylindrospermopsins	Liver	*Cylindrospermopsis,Aphanizomenon, Umezakia*
Lingbiatoxin-a	Skin, Gastrointestinal	*Lyngbya*
Saxitoxins	Nerves Axons	*Anabaena, Aphanizomenon, Lyngbya, Cylindrospermopsis*
Lipopolysaccharides	Affects any damaged place	All

Cyclic peptides hema-toxins (*Anabaena, Microcystis, Oscillatoria (planktothrix), Nostoc, Anabaenopsis* and *Nodularia spumigena*) are the most common cyanobacteria toxins in 'blooming' fresh and lightly salty water clusters. They are making the biggest changes in cyanobacteria in the surface drinking water. The influence on human being health can be made not only through human gut, but, also by the contact with the human skin.

4. Toxic cyanobacteria. Methods of identifying cyanobacterial toxicity

Cyanobacteria could be one dominant species in the population. There could be also the combination of a few species and not all of them necessarily toxic. Even in the EU Member States among the same kind of cyanogen bacteria there could be toxic and non-toxic varieties of algae. Variety is determined as a genetic subgroup between particular species. What is more, each of the species can include ten or thousand varieties that may only slightly differ. Some of the varieties can be more toxic than the others; toxicity might be higher even up to three times. Thus, one small but very toxic element occurring in an immensely big non-toxic cyanobacteria colony may turn it into a very toxic one (Burch D. M. 2008).

There are a lot of different methods of performing qualitative and quantitative evaluation of cyanobacterial toxins, most popular of them being a high-pressure chromatographic method (HPLC). A number of studies on this subject can be found in science literature (Codd, G. A 1983). To determine the existence of cyanobacteria in water, as well as cyanobacterial toxins and their concentration the methodology is needed. The health of bathing people is to be ensured from harmful cyanobacteria (Saker, M.L. 2007). To identify the latter, the microscope methods and *in vivo* florimetric methodology are applied. Recently, cyanobacteria have been experimentally detected by a satellite and this method has been put into practice.

Determination of cyanobacterial toxins is mostly computer-assisted. It is not so easy to do taking into account the time of preparing the sample. It takes at least about 24 hours. For this reason toxins cannot be determined in this way in situ.

5. Implementation of WFD aims in different EU Member States

Internationally the main focus has been put on microcystin toxins produced by *Microcystis aeruginosa* and *Planktothrix agardhii*. This is because microcystins are on a world wide scale considered to be the most significant potential source of human injury from cyanobacteria. Many international guidelines have taken their lead from the World Health Organization (WHO) provisional guideline of 1 µg L-1 for microcystin-LR in drinking-water (Chorus I. 2005). In some European countries WHO guidelines and the management of cyanobacteria is perceived as falling within the scope of the EU WFD, which calls for a '*good ecological status*' of the water resources by the year 2015. According to it the management of cyanobacteria is integrated into the national water protection law.

For further analysis we have taken three EU Member States (Table 2). All these countries are included in the same Central/Baltic inter-calibration group, according to the 2005/646/EC. Analysis has dealt with the following subject: how three different Member States manage national surface water and how cyanobacteria in surface water are assessed.

In Lithuania the WFD is integrated into the water protection legislation. At the moment, water quality is evaluated by the biggest allowable concentrations (BAC) indicated in the following legal documents:

- 'Regarding approval of wasted water conduction regulation confirmed by the Minister of the Environment on 17 of May, 2006 (Zin., 2006, No. 59-2103);
- 'Regarding approval of protection requirements for surface water clusters where could live and breed fresh water fishes', approved by the Minister of the Environment on 21 of December, 2005 (Command D1-633) (Zin., 2006, No. 5-159).

BAC is determined with reference to the environmental quality standards (2008/105/EC) and with reference to the water body inter-calibration (2008/915/EC). For inter-calibration the surface water bodies under benchmark conditions have been chosen. The benchmark condition of phytoplankton is estimated according to the historical parameters and its values which were measured in lakes under the lowest chemical load. Collection of phytobenthos data has just its start in Lithuania while cyanobacteria assessment is not yet included in the monitoring programs because of lack of the study and information on them. The following parameters of Lithuanian surface water bodies in benchmark conditions have been measured (Tables 2-3):

- Lithuanian fish index (LFI) and Denmark rivers fauna index (DRFI) in rivers;
- Concentration of chlorophyll-a in lakes and other closed water bodies. Chlorophyll-a is a substance found in blue – green algae and used in measuring the concentration of cyanobacteria and algae (Chorus I. 2000).

Table 2. Biological parameters in rivers

Parameter	Description
Biological	
Lithuanian fishes index (LFI)	1
Denmark rivers fauna index (DRFI)	7
Physical-chemical	
General indicators for water quality	General oxygen uptake per 7 days (GOU_7) ≤1.8 mg/l; O_2 ≥8.5 mg/l; $N_{general}$ ≤ 1.4 mg/l; NH_4N≤0.06 mg/l; NO_3N≤0,9 mg/l; PO_4P≤0.03 mg/l; $P_{general}$≤0.06 mg/l.

Table 3. Biological parameters in lakes

Parameter	Description
Biological	
Chlorophyll-a (annual average)	1st and 2nd type lakes ≤ 2.5 µg/l 3rd type lakes ≤2 µg/l
Chlorophyll-a (max value)	1st and 2nd type lakes ≤ 5 µg/l 3rd type lakes ≤4 µg/l
Physical-chemical	
General indicators for water quality	1st and 2nd type lakes: $N_{general}$ ≤ 1 mg/l; $P_{general}$ ≤ 0.02 mg/l 3rd type lakes: $N_{general}$ ≤ 0.75 mg/l; $P_{general}$ ≤ 0.015 mg/l.

In Germany, about 1/3 of drinking water resources are the surface water. Many efforts have been made to enforce the water control sector to operate effectively. Nowadays the European WFD 2000/60/EC is a fundamental element of the national water control system there. A lot of various technologies and experiences are engaged into the goals of this Directive.

Germany is one of the two countries in which the WHO guidelines indicating microcystin-LR values very important for implementation of the Directive have been prepared. WHO value for microcystin-LR provides an important definition of its concentrations (Directive 2005/646/EB). The ecological status of the surface water bodies is being ranked on the basis of the assessments of quality elements classified as relevant, starting from the worst-case approach and giving special weight to the biological elements (Nion G., 2009).

In France, the WHO recommendations for the surface water quality were included into the national legal system in 1999. Referring to these recommendations, since 2001 the French drinking water law has indicated the maximum allowed value as 1 µg L-1 microcystin-LR in raw water. In that country the surface water quality control is organized in accordance with the European WFD 2000/60/EC. In France, the management of cyanobacteria is perceived to fall within the scope of the EU WFD which calls for a '*good ecological status*' of the water resources by the year 2015.

6. Conclusions

Standards for the surface water quality indicated in the EU General WFD are not sufficient enough to secure the public health against possible cyanobacteria and their toxic negative influence.

After reviewing the water quality control standards of the EU Member States it may be seen that the pursuit of *good ecological condition* is differently interpreted by them. Monitored chlorophyll-a is not available to indicate the risk degree of toxic cyanobacteria.

At present inadequate attention is drawn to the danger for public health that is caused by cyanobacteria because of the lack of research and information. In a number of developing countries there are no cyanobacteria monitoring and assessment of their potential hazards to public health. Referring to scientific researches and the experience of other countries, the EU WFD and other related documents recommend both to legislate for monitoring of cyanobacteria and their toxins and to indicate their marginal concentration values.

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2008/915/EB, kuriuo pagal Europos Parlamento ir Tarybos direktyvą 2000/60/EB nustatomos atlikus interkalibraciją gautos valstybių narių monitoringo sistemų klasių vertės;

2008/105/EB, dėl aplinkos kokybės standartų vandens politikos srityje, iš dalies keičianti ir panaikinanti Tarybos direktyvas 82/176/EEB, 83/513/EEB, 84/156/EEB, 84/491/EEB, 86/280/EEB ir iš dalies keičianti Europos Parlamento ir Tarybos direktyvą 2000/60/EB

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Patirtis, apžvalgos, diskusijos

Vandens kokybės vertinimas: toksiškos melsvabakterės paviršiniuose vandenyse

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Bendrosios vandens politikos direktyvos - 2000/60/EB (BVPD) tikslas – pasiekti "*gerą būklę*" paviršiniuose vandens telkiniuose. Pakoregavus BVPD, 2008/105/EB direktyvoje, nustatytos aplinkos kokybės standartai (AKS), kurių vertėmis remiantis siekama "*geros cheminės būklės*". Pagal BVPD, ekologinė vandens kokybė vertinama atsižvelgiant į fitoplanktono populiaciją, žuvų ir bentoso organizmų koncentracijas, tačiau šiems parametrams nėra nustatytų konkrečių verčių

Pagrindinis tarptautinis dėmesys krypsta į toksiškus mikrocistinus, gaminamus melsvabakterių *Microcystis aeruginosa* ir *Planktothrix agardhii*., kadangi būtent jie įvardijami kaip pavojingiausi visuomenės sveikatai pasauliniu mastu. Kai kuriose Europos sąjungos valstybės narės vandens valdymo politikoje remiasi Pasaulio Sveikatos Organizacijos (PSO) pateiktomis rekomendacijomis dėl leistino melsvabakterių koncentrasijos kiekio paviršiuniuose vandenyse. Tokiu būdu PSO rekomendacijos dėl cianobakterijų kiekio vandenyse kai kuriose valstybėse narėse priimamos kaip priemonė BVPD tikslui "gera ekologinė būklė" iki 2015 m. pasiekti. Remiantis tuo, melsvabakterių monitoringas įtraukiamas į nacionalinius teisės aktus, reglamentuojančius vandens valdymą.

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