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Establishment of an Alert Level Framework for cyanobacteria in drinking water resources by using the Algae Online Analyser for monitoring cyanobacterial chlorophyll *a*

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ABSTRACT

The Algae Online Analyser (AOA) fluorometer simultaneously distinguishes four different phytoplankton groups by their specific fluorescence spectra and thus allows for real-time *in-situ* chlorophyll *a* measurements per algal group. This AOA was used for monitoring cyanobacterial chlorophyll *a* in the drinking water at the Bronisławow Bay abstraction point in Sulejow Reservoir (Poland). The main goal of this research was to develop an early warning method for the detection of cyanobacterial biovolume in the source water, in order to establish an Alert Level Framework for the drinking water abstraction point in Sulejow Reservoir. A positive correlation between cyanobacterial biovolume, as determined by conventional methods, and cyanobacterial chlorophyll *a*, as measured by the AOA, was found ($p < 0.05$). The results of this study were used to determine threshold values for the Alert Level Framework, based on cyanobacterial chlorophyll *a* concentrations in the source water of Sulejow Reservoir. The presented threshold values are determined specifically for this abstraction point, but the principles can be applied to other locations.

1. Introduction

Appearance of toxic cyanobacterial blooms is an adverse effect of eutrophication. Microcystins (toxins produced by *Microcystis* and other cyanobacterial genera) are possibly carcinogenic, have tumour-promoting properties and have been associated with primary liver cancer (Falconer, 1994, 2005). Cyanobacterial blooms may therefore limit ecosystem services, including the provision of drinking water, due to difficulties and increased costs for water treatment (Jurczak et al., 2005). Because of its potential hazard, the World Health Organization established a guideline value of $1\,\mu g\,L^{-1}$ for microcystin-LR in drinking water (WHO, 2006). However, this guideline still only covers one of the many different cyanobacterial toxins. Given the fact that under natural circumstances cyanobacterial blooms are not uni-algal, there is

Abbreviation: AOA, Algae Online Analyser.

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a significant risk that mixtures of toxins will occur. Since conventional drinking water treatment processes are not always fully effective in toxin removal, humans may risk exposure to toxic substances.

Bartram et al. (1999) proposed an Alert Level Framework (ALF) for cyanobacteria. This framework provides a monitoring and management action sequence for water treatment plant operators and managers. The framework assesses the development of a potentially toxic cyanobacterial bloom through a monitoring programme with associated actions in four stages that are linked to 'Alert Levels'. The actions accompanying each level cover categories such as additional sampling and testing, operational measures, consultation with health authorities and other agencies, and media releases (House et al., 2004). The ALF is based on cyanobacterial cell counts and chlorophyll *a* concentration. The threshold levels presented by Bartram et al. (1999) are a continuation of those determined by Burch (1993) and modified by House et al. (2004) (Table 1).

Cyanobacterial densities can rapidly increase under favourable conditions, so continuous monitoring is essential for responding adequately to changes in water quality. Currently available methods for cyanobacterial cell counts and chlorophyll *a* analysis are time-consuming and unsuitable for on-line monitoring. Additionally, the chlorophyll *a* analysis method does not differentiate eucaryotic phytoplankton from cyanobacteria, which is especially important for selective detection of cyanobacteria in mixed phytoplankton assemblages. Phycocyanin is an acknowledged indicator of cyanobacteria (Osutki et al., 1994; Lee et al., 1994, 1995; Ahn et al., 2002; Brient et al., 2008) and the application of a modern analytical technique, which enables its quick and easy detection, is an important tool for monitoring cyanobacterial blooms. Izydorczyk et al. (2005) and Gregor et al. (2007) indicated that the measurement of phycocyanin fluorescence is an effective early warning system for cyanobacteria in reservoir intake water.

The Algae Online Analyser (AOA, bbe Moldaenke, Kiel, Germany) is a fluorometer, which measures chlorophyll fluorescence of algae in water, and allows for separate determination of Chlorophyceae, Bacillariophyceae, Cyanophyceae and Cryptophyceae. The operation procedure is the same as that of the FluoroProbe, which is used in the field, but the AOA is a cuvette and/or on-line laboratory-fluorometer. It measures the fluorescence of different pigments, each characteristic of a certain phytoplankton group. The AOA contains five Light Emitting Diodes, which excite these pigments by emitting pulsated light at wavelengths of 450, 525, 570, 590 and 610 nm. For further information on this instrument and the measuring principle, see Beutler et al. (2002).

The main goal of the presented research was to show the application of cyanobacterial chlorophyll *a* measurement, using the AOA, to detect potentially toxic cyanobacteria in raw water at the drinking water study site of Sulejow Reservoir. Additionally, we used concentrations of cyanobacterial chlorophyll *a* to assess the hazard of cyanobacterial toxins in the raw water, and to define thresholds for an Alert Level Framework for this location.

2. Materials and methods

The Sulejow Reservoir is a shallow, lowland dam reservoir situated in central Poland in the middle course of the Pilica River. At full capacity, the reservoir covers 23 km^2, has an average depth of 3.3 m and has a volume of 75×106 m^3. The mean retention time is about 30 days. The dominant cyanobacterial species is *Microcystis aeruginosa* (Zalewski et al., 2000; Izydorczyk and Tarczynska, 2005). Analysis of cyanobacterial bloom samples confirmed their highly hepatotoxic character (Tarczynska et al., 2001; Jurczak et al., 2004, 2005; Mankiewicz-Boczek et al., 2006; Izydorczyk et al., 2008a,b). The Sulejow Reservoir is an important fresh water resource for the city of Łódź. The drinking water intake point is located in the central part of the reservoir at the end of a narrow bay called Bronisławow.

On-line fluorescence measurements were carried out at the drinking water intake point (sampling station V). The AOA measured the raw water going to the treatment plant. The AOA was used as an on-line sensor from April 17 to June 26, 2003, and from August 19 to October 9, 2003. During these periods, fluorescence data were automatically collected every 15 min (30 ml sample) and recorded by the AOA (daily profile presented in Fig. 5). To eliminate the problem of sealing the measuring chamber, the automatic cleaning device periodically cleans the measuring cell and removes any particles and biofilms. This procedure guarantees the well-defined optical properties of the cell and extends the maintenance-free period. The detection limit of AOA is 0.05 μg chlorophyll *a* L^{-1}.

Additional samples were taken at four sampling points in the Sulejow Reservoir (Fig. 1). Sampling station number I was situated in the lower, lacustrine part of the reservoir; II in the central, transitional part, and III in the upper, riverine part. Sampling point IV was located in the narrow bay directly in front of the water intake point. Water samples were collected

Table 1 – Comparison of threshold definitions for Alert Levels proposed by different authors.

Level	Burch (1993)	Bartram et al. (1999)			House et al. (2004)	
	[cells mL^{-1}]	[cells mL^{-1}]	[mm^3 L^{-1}]	[μg chl *a* L^{-1}]	[cells mL^{-1}]	[mm^3 L^{-1}]
Detection Level	–	200	–	0.1	500	–
Alert Level 1	500	2000	0.2	1.0	2000	
Alert Level 2	2000	100 000	10.0	50.0	5000	1
Alert Level 3	15 000	–	–	–	50 000	10

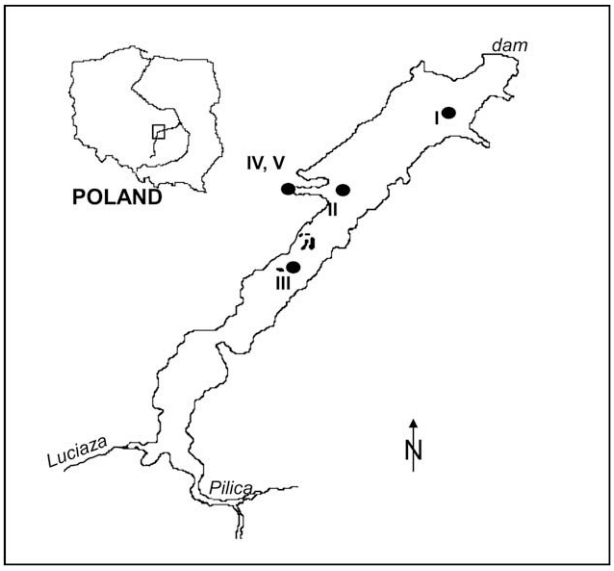

Fig. 1 – Location of the sample stations in the Sulejow Reservoir.

five times during the spring (April 30; May 7, 21, 28; June 11) and five times during the summer (August 20; September 3, 10, 17, 24). Integrated water samples were taken using a 5-litre sampler from each meter of the entire water column. At the same time, at sampling station V, 5 L of the raw water was taken.

Samples from all station were analysed for biovolume assessment, chlorophyll *a* and toxin concentrations. Fluorescence measurements were also performed: each sample was measured at 3 replicates.

Chlorophyll *a* concentrations were analysed by a method based on acetone extraction and determination by spectrophotometry (Lawton et al., 1999). Water samples for the determination of phytoplankton biovolume were preserved in Lugol's solution and sedimented in the laboratory. Phytoplankton were counted in concentrated samples, using a Fusch–Rosenthal counting chamber and a Nikon Optiphot-2, 102 (400× magnification). At least 400 cells or filaments were counted to reduce the error to less than 10% ($p = 0.05$). Phytoplankton biovolume ($mm^3\,L^{-1}$) was determined based on a volumetric analysis of cells using geometric approximation.

Microcystins were analysed in two forms – dissolved in water (extra-cellular) and cell-bound in suspended matter (intra-cellular). For the high-performance liquid chromatography (HPLC) analysis, 1-litre water samples containing cyanobacterial material were filtered immediately after sampling, using Whatman GF/C filters (pore size 0.45 μm). The preparation of cyanobacterial material and determination of microcystins by reversed-phase HPLC coupled with photodiode-array UV detection (HPLC-DAD) were performed according to descriptions in Jurczak et al. (2005) and Meriluoto and Codd (2005). Microcystins were identified by their characteristic absorption spectra and retention times against the following microcystin standards: MC-LR, MC-RR, demethyl(dm)-MC-RR, MC-YR, MC-LY, MC-LW, MC-LF. Microcystin concentrations were expressed as the sum of all varieties. The HPLC method enables the detection of microcystin at the 0.01 $\mu g\,L^{-1}$ level after concentrating the samples.

Statistical analyses were performed using the Statistica® software (Statsoft Inc., Tulsa, USA). For statistical analysis (Figs. 3–5) were used dates from all sampling station, without on-line measurement.

3. Results

3.1. *Seasonal changes of phytoplankton biovolume and community structure*

During spring, the phytoplankton community, as found at almost all sampling stations, was dominated by diatoms, namely, *Cyclotella comensis*, *C. radiosa*, *Fragilaria capucina*, *F. crotonensis* and *Asterionella formosa*. The highest diatom biovolume was observed at station III, which varied between 20 and 58 $mm^3\,L^{-1}$. Diatoms also dominated at station II, where total phytoplankton biovolume oscillated between 1.6 and 34 $mm^3\,L^{-1}$. Low phytoplankton biovolume was observed at stations IV and V. Unfortunately, the April 30 sample from station IV was not analysed, although high biovolume was expected as chlorophyll concentration indicted. At station I, the diatoms and cryptophytes (*Cryptomonas ovata*, *Campylomonas marssonii*, *C. platyuris*) dominated in early spring, while cyanobacterial densities increased in late spring.

During summer, the phytoplankton community was dominated by cyanobacteria, mainly *Microcystis aeruginosa*. Maximum cyanobacterial biovolume was observed at station IV and amounted to 485 $mm^3\,L^{-1}$ on September 10. Biovolume levels at station I were in the same range as station II, varying between 4.2 and 31 $mm^3\,L^{-1}$. Lower values were observed at station V, where the maximum phytoplankton biovolume reached 5.7 $mm^3\,L^{-1}$. At station III, domination of cryptophytes (max. 18.5 $mm^3\,L^{-1}$) followed by diatoms (max. 17.8 $mm^3\,L^{-1}$) was observed.

3.2. *Seasonal changes of chlorophyll a concentration measured by spectrophotometry method*

During spring, a gradual increase of total chlorophyll *a* concentrations was observed at stations I, II, and III, where values ranged from 2.5 to 71 $\mu g\,L^{-1}$. The spring maximum chlorophyll *a* concentration was 157 $\mu g\,L^{-1}$, observed at station IV. Lower values were observed at station V, ranging from 0.3 to 11.7 $\mu g\,L^{-1}$.

During late summer, similar chlorophyll levels at stations I and II varied between 3.5 and 58 $\mu g\,L^{-1}$. Higher values were found at station III (13.8–52 $\mu g\,L^{-1}$). The summer maximum was observed at station IV, where values ranged from 4.6 to 251 $\mu g\,L^{-1}$, whereas the lowest chlorophyll concentration was found at station V (1.6 $\mu g\,L^{-1}$).

3.3. *Seasonal changes of chlorophyll a concentration and phytoplankton community structure measured by the Algae Online Analyser*

During spring, the maximum concentration of total chlorophyll *a*, 76 $\mu g\,L^{-1}$, was observed at station IV. The chlorophyll

a concentrations at station I, II, and III were within a similar range, varying between 5.5 and 43.7 $\mu g L^{-1}$. The lowest value was observed at station V (0.9 and 9.6 $\mu g L^{-1}$). During spring, the total chlorophyll originated mostly from Bacillariophyceae and Cryptophyceae. In late spring, an increased contribution to total chlorophyll *a* levels from green and blue-green algae was observed.

During late summer, increased chlorophyll *a* levels from cyanobacteria were observed at all sampling stations, with the exception of station III. At this station, chlorophyll *a* from Cryptophyceae and Bacillariophyceae dominated. The summer maximum concentration of total chlorophyll *a* was observed at station IV and amounted to 214 $\mu g L^{-1}$ (including 198 $\mu g L^{-1}$ chlorophyll *a* from cyanobacteria). Total chlorophyll *a* concentrations at other stations varied between 2.7 and 40 $\mu g L^{-1}$.

3.4. *Seasonal changes of microcystins concentrations*

During spring, the maximum concentration of intracellular microcystins (17.5 $\mu g L^{-1}$) was observed at station IV. The spring maximum concentrations at stations I, II, III, and V amounted to 2.86, 0.85, 0.40, and 0.45 $\mu g L^{-1}$, respectively. Microcystins dissolved in water were only observed at station I, and amounted to 0.2 $\mu g L^{-1}$.

During late summer, microcystins dissolved in water were observed at station IV (0.83 $\mu g L^{-1}$) and station V (0.10 $\mu g L^{-1}$). The maximum summer concentration of microcystins in cells (6.49 $\mu g L^{-1}$) was observed at station IV. The summer maximum concentration at stations I, II, and III amounted to 1.72, 0.78 and 0.04 $\mu g L^{-1}$, respectively. At station V, the intracellular microcystin concentrations varied between 0 and 0.28 $\mu g L^{-1}$.

4. Discussion

4.1. *Relationship between concentrations of chlorophyll a measured by fluorescence (AOA) and by spectrophotometric method*

Chlorophyll *a* concentration is used as an indirect method for determination phytoplankton biovolume (Lawton et al., 1999). However, the spectrophotometric and HPLC methods used to determine total chlorophyll *a* concentrations are generally time-consuming. The application of a rapid and simple fluorometric method like AOA can be a valuable tool for monitoring cyanobacterial blooms.

A correlation was found between chlorophyll *a* measured by spectrophotometric analysis and by fluorescence measurements using the AOA ($r = 0.96$, $n = 47$, $p < 0.05$; Fig. 2A). However, two higher values of chlorophyll *a* have not been included in the correlation analysis because of the statistically insignificant number of days with intensive blooms. Fig. 2A shows also two points that deviate from the correlation line. Without these 4 points, the correlation coefficient (r) between chlorophyll *a* measured by spectrophotometric analysis and by fluorescence measurements using the AOA amounted 0.97 ($n = 45$, $p < 0.05$; Fig. 2B).

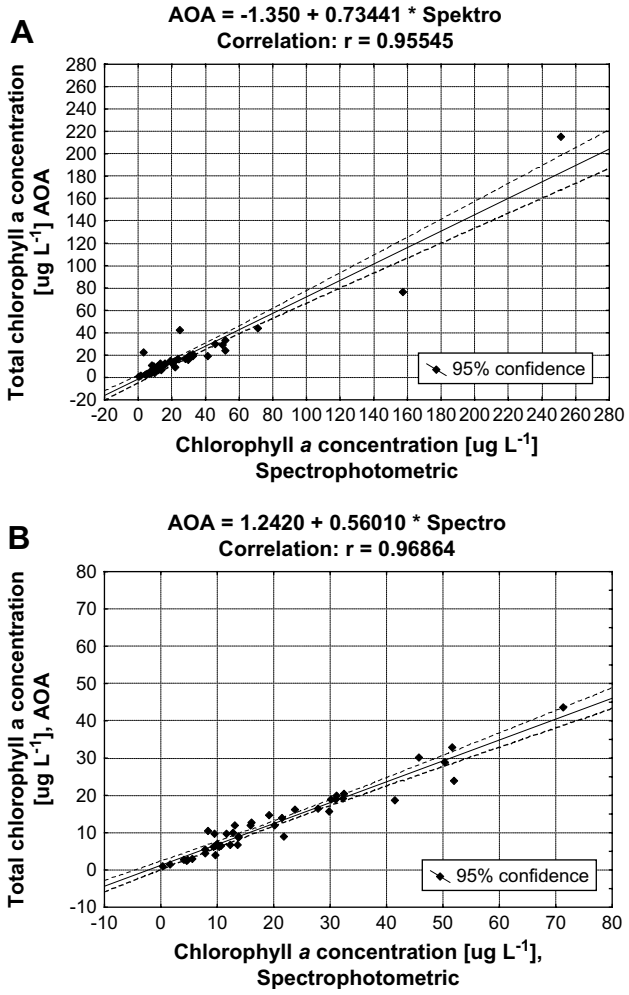

Fig. 2 – Relationship between chlorophyll *a* concentrations measured by fluorescence (AOA) and by spectrophotometry; all data points (A), without 4 outliers (B).

Fig. 2A shows that the relationship between total chlorophyll *a* concentration measured by AOA and measured through spectrophotometry does not follow the correlation $y = x$. The values obtained from the fluorescence method are lower than those of the spectrophotometric method. This deviation was expected, because of the two different methods of measuring chlorophyll *a*. The spectrophotometric method analyses total chlorophyll *a* after the destruction of cells by the extraction step. The fluorescence method, however, analyses only active chlorophyll *a* in the living cells. Inactive chlorophyll from dying cells, or cells that are shaded by others, does not show fluorescence and is therefore undetected. Because of shading, this effect is more prominent at higher phytoplankton densities.

We found similar correlation between total chlorophyll *a* concentration measured by AOA and measured through spectrophotometry like Gregor and Maršálek (2004) and Gregor et al. (2005) while testing the submersible probe (based on the same measuring principle as the AOA; FluoroProbe®, bbe Moldaenke, Kiel, Germany) for the measurement of total

chlorophyll *a* in a reservoir and several rivers. They also showed a high correlation between total chlorophyll *a* measured by the FluoroProbe and chlorophyll *a* measured by the spectrophotometric method ($r = 0.97$, $n = 18$ and $r = 0.95$, $n = 96$, respectively). Leboulanger et al. (2002) showed worse correlation between total chlorophyll *a* measured by a submersible fluorescence probe and chlorophyll *a* measured by a spectrophotometric method during a bloom of *Planktothrix rubescens* in Bourget lake ($r = 0.77$, $n = 55$).

Gregor and Maršálek (2004) suggested that the maximum detection limit for *Microcystis* blooms by field monitoring of fluorescence is about 50–60 $\mu g\,L^{-1}$. At higher densities, the increased shading effect will reduce field measurement accuracy. During our own research, algal blooms with densities in this range were observed only twice. Due to low amounts of data, no conclusion could be drawn. Beutler et al. (2002) estimated that this shading effect can cause a 10% deviation of results.

4.2. *Relationship between cyanobacterial biovolume and concentration of chlorophyll* a *of cyanobacteria determined by fluorescence (AOA)*

The total chlorophyll *a* measurements do not describe the composition of the phytoplankton community. The fluorometer AOA, which determines the chlorophyll *a* concentration per phytoplankton group (green algae, diatoms, blue-green algae and cryptophytes), enables preliminary taxonomic determination. This is especially useful for selective detection of cyanobacteria in mixed phytoplankton assemblages. The cyanobacterial pigments are characterized by maximal excitation at 610 nm, caused by the photosynthetic antenna pigment phycocyanin. This appears to be a useful indicator for determining the density of cyanobacteria in water samples (Watras and Baker, 1988).

This study demonstrates a statistically significant correlation between cyanobacterial biovolume and concentration of cyanobacterial chlorophyll *a* measured by AOA ($r = 0.68$, $n = 46$, $p < 0.05$; Fig. 3). This correlation was demonstrated for conditions when cyanobacterial biovolume was below 40 $mm^3\,L^{-1}$ and the phytoplankton was dominated by *Microcystis aeruginosa*. Values of biovolume higher than 40 $mm^3\,L^{-1}$ have not been included in the correlation analyses because of the statistically insignificant number of days with intensive blooms.

The precision of the counting method for cyanobacterial cells and/or filaments should be considered when interpreting the results. For counting colonial cyanobacteria such as *Microcystis aeruginosa*, precision reaches more than 50% (House et al., 2004). However, new methods, in which the mucilage of colonies of chroococcal cyanobacteria is hydrolysed and a homogeneous cell suspension is counted, give much better results, because the uncertainty in counting decreases significantly (Hoogenboezem et al., 2004).

Additionally, the fluorymetric cyanobacteria analysis is less effective as compared to other phytoplankton group. It is hampered by variability of the cyanobacterial excitation spectra. Cyanobacteria are not uniform group in respect of photosynthetic apparatus: some of them contain phycoerytrin (red group) and some of them contain phycyanin,

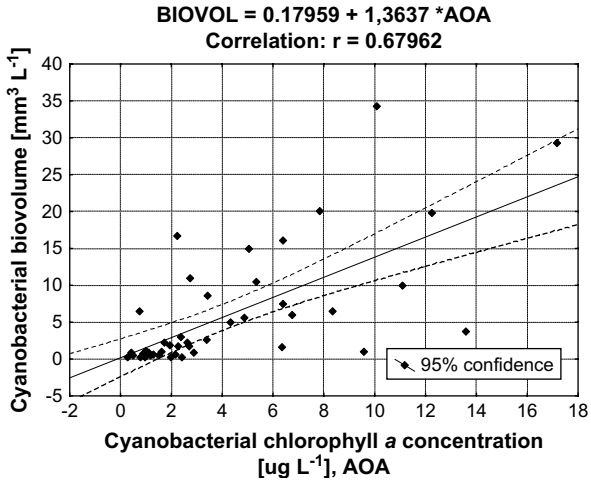

Fig. 3 – Relationship between cyanobacterial biovolume determined by cell counts and concentration of cyanobacterial chlorophyll *a* measured by AOA.

phycobiliproteins, allophycocyanin (blue group). The detection of cyanobacteria can be disturbed by interference with Cryptophyta (red group; for details see Beutler et al., 2004) or by adaptation to varying environmental conditions (blue group, for details see Beutler et al., 2003). The variation of data points in the correlation (Fig. 3) may result from differences in the phycocyanin concentration per cyanobacterial cell. This could be due to either nitrogen levels (Rapala, 1998) or light intensities (Grossman et al., 1994) affecting the phycocyanin content per cell.

4.3. *Estimation of hazard from cyanobacterial toxins based on the concentration of cyanobacterial chlorophyll* a *measured by fluorescence (AOA)*

The Alert Levels Framework is based on the occurrence of cyanobacterial cells. All cyanobacteria should be treated with

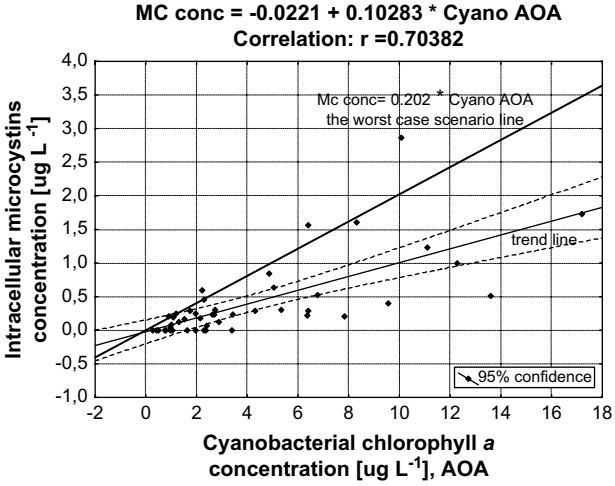

Fig. 4 – Relationship between concentrations of cyanobacterial chlorophyll *a* and intracellular microcystins: linear correlation and the 'worst-case scenario' line.

Table 2 – Comparison of contain intracellular microcystins in cyanobacterial cells.

	μg microcystins per μg chlorophyll *a* of cyanobacteria measured by AOA
Maximum	0.284
90 percentile	0.202
Average	0.083

caution, until either testing confirms the absence of toxicity or past local knowledge indicates the absence of hazard (Bartram et al., 1999). For this reason, this research also investigated the estimation of hazard from cyanobacterial toxins based on levels of chlorophyll *a* from cyanobacteria (measured by fluorescence: AOA).

This study demonstrated a positive correlation between the chlorophyll *a* concentration from cyanobacteria (measured by AOA) and the concentration of intracellular microcystins ($r = 70$, $n = 46$, $p < 0.05$; Fig. 4). The variation of data points in this correlation may result from differences in the microcystins content in cyanobacterial cell. Investigations of *Microcystis* cultures have shown that microcystin production by cyanobacteria depends on such parameters as light intensity, temperature and availability of nutrients (for a review see Rapala, 1998) and also contact with zooplankton or chemicals released by zooplankton (Jang et al., 2003). However, changes in microcystin content of cyanobacteria are still not fully understood, especially if natural ecosystems are considered (Kotak et al., 2000; Giani et al., 2005; Izydorczyk et al., 2008a). For example, in the Sulejow Reservoir, the toxicity of bloom demonstrated seasonal variability, reaching its maximum at phase of bloom generation (Izydorczyk et al., 2008b). Additional, coexistence of toxic and non-toxic strains within a single bloom has been reported.

The trendline shows average values of microcystins in cells from all results; however, in early warning systems, averages are of only limited value. It is better to use the maximum value (meaning, the maximum value of toxins in cells) or 'the worst-case scenario' (defined as the 90th percentile of results, to exclude outliers). The ratio between concentration of intracellular microcystin and chlorophyll *a* concentrations of cyanobacteria measured by AOA was calculated. Next, the 90th percentile value was determined in order to indicate the worst-case scenario (Table 2). The 90th percentile proportion was obtained from our data: 1 $\mu g L^{-1}$ cyanobacterial chlorophyll *a* corresponded to 0.202 $\mu g L^{-1}$ intracellular microcystins; this means that 4.94 $\mu g L^{-1}$ chlorophyll *a* from cyanobacteria corresponded to 1 $\mu g L^{-1}$ intracellular microcystins. To achieve a more realistic maximum value than one based on a single data point; these values are based on the total dataset.

Table 3 shows threshold definitions for the Alert Levels proposed by House et al. (2004) based on cyanobacterial cell counts. Thresholds for microcystin concentration were also included using the abovementioned conversion factors, as proposed by Falconer et al. (1994). They proposed a safety value of 5000 cells mL^{-1}, which corresponds to 0.2 pg toxins $cell^{-1}$. This is equal to a dose of 1 μg toxins per litre. The thresholds for Alert Levels based on concentrations of cyanobacterial chlorophyll *a* were defined specifically for our drinking water intake (Table 3). However, due to the procedure presented in the manuscript, the thresholds of Alert Level can be estimated for any other location. The specified for location, calibration based on microscopic and HLPC analysis, should be done.

The advantages of the AOA are its potential for adjusting sampling frequency, as well as the fact that all measurements are performed on-line. Those features are especially important for monitoring the drinking water intake point, where toxic algae blooms may appear suddenly, requiring immediate action. The dynamics of cyanobacterial chlorophyll *a* concentrations determined by AOA confirmed the importance of continuous measurements (Fig. 5). Until now, the drinking water intake point was monitored once or twice per day using the chlorophyll *a* spectrophotometric method and biovolume assessment. Because daily cycles were not taken into account, this provided insufficient information about changes in plankton abundance throughout the day. Nevertheless, the on-line measurement by AOA does not exclude the microscopic identification and counting, because these two methods should be considered as complementary.

An additional important advantage of using the AOA for monitoring is the short time necessary to obtain results (because of on-line measurements). This allows for the maximum possible time to take the necessary actions (increase of treatment substances dosage, starting additional treatment processes or closing the intake). Additionally, the AOA is a small instrument that can be installed almost anywhere. If desired, it could be installed after each treatment

Table 3 – Thresholds for cyanobacterial chlorophyll *a* concentrations, measured by the AOA in the Alert Levels Framework for Sulejow Water Intake (note: column 2 and 3 based on House et al. (2004) and Falconer et al. (1994), respectively).

Levels	The cyanobacterial cell numbers	Concentration of microcystin-LR	Concentration of cyanobacterial chlorophyll *a*, AOA
	[cells mL^{-1}] (House et al., 2004)	[$\mu g L^{-1}$] (Falconer et al., 1994)	[$\mu g L^{-1}$]
Detection Level	500	0.1	0.5
Alert Level 1	2000	0.4	1.9
Alert Level 2	5000	1.0	4.9
Alert Level 3	50 000	10.0	49.4

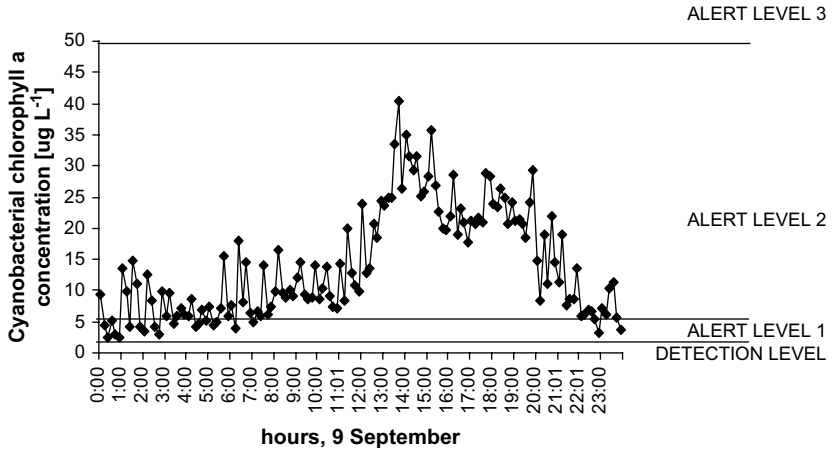

Fig. 5 – Daily profile of concentrations of cyanobacterial chlorophyll *a* determined by AOA with indicated thresholds of specific Alert Levels for Sulejow Water Intake; Note: case in which the cyanobacterial chlorophyll *a* concentration changed within one day.

step in order to determine its effectiveness in the removal of algae.

5. Conclusion

1. According to our results and experience, the AOA is a useful tool for monitoring potentially toxic cyanobacterial blooms at the drinking water intake point.
2. We defined thresholds for Alert Levels based on concentrations of cyanobacterial chlorophyll *a*, specifically for the case of surface water used for the production of drinking water. These thresholds were defined specifically for our drinking water intake, but the procedure can be adapted to any other location.

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