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ALGAL BLOOMS AS A PROBLEM OF WATER MANAGEMENT IN THE INDUSTRY. A PRELIMINARY STUDY ON THE EFFICIENCY OF WATER TREATMENT LINE IN A COGENERATION POWER PLANT IN EASTERN POLAND

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Abstract. Cyanobacterial and algal blooms lead to the deterioration of freshwater ecosystems but also generate technical problems in water management in the industry. Power plants often use freshwater lakes and reservoirs as a source of cooling water and in the case of cogeneration stations (combined heat and power) also as a source of agents for heating energy distribution. A preliminary research in one of the heat and power stations in eastern Poland which uses water from suffering with algal blooms reservoir was carried out in April 2011. The study was focused on the changes in the phytoplankton quantitative and qualitative structure as well as in basic physico-chemical parameters along the water treatment line, which consists of several stages serving as sampling points (from the pump station to the purified water tank). The initial phytoplankton biomass in the reservoir was high (fresh biomass: 65.8 mg dm^{-3}, chlorophyll a: 146.7 µg dm^{-3}) with diatoms prevailing (98% of the total biomass) from which the most numerous were: *Cyclotella comta* and *Aulacoseira granulata*. After several stages of the purification process (sedimentation, biocide addition, flocculation, gravel filtering, ion exchange) the water still consisted a considerable amount of algae (fresh biomass: 2.48 mg dm^{-3}, chlorophyll a: 6.0 µg dm^{-3}). However, the final biomass in purified water tank (after reversed osmosis process) was very low (fresh biomass: 0.03 mg dm^{-3}, chlorophyll a: 0.1 µg dm^{-3}). Results had shown that high algal biomass in the water used in power generation plant is difficult to remove and consequently requires considerable technical (thus also economical) efforts to adjust the water for the industrial use.

Key words: water treatment, combined heat and power station, algal blooms, water quality

INTRODUCTION

Eutrophication is the main factor leading to the degradation of lakes and reservoirs in Europe. Nowadays, the phenomenon is more and more common and started to become a global problem [Smith 2003]. Overfertilisation (nutrients enrichment) which is the main reason of the process, results in phytoplankton (including cyanobacteria) domination, which in turn leads to the ecosystem maltfunctioning, and as a consequence, to the exclusion of the economical and social functions of lakes and reservoirs [Moss 1998]. Especially cyanobacterial blooms have brought the owners many problems in many recreational and water supply reservoirs in Poland [Bucka and Wilk-Woźniak 1999, Kabziński *et al.* 2000, Pawlik-Skowrońska *et al.* 2004, Rakowska *et al.* 2005].

Cyanobacterial and algal blooms lead not only to the deterioration of freshwater ecosystems, but also generate technical problems in water management in the power-generation industry. Electric power plants use huge amounts of water to complete the steam cycle and keep the electric turbines turning as well as an agent for heating energy distribution, thus freshwater lakes and reservoirs are the cheapest source of water supply for them [Feeley *et al.* 2008]. For example, it is known that 41% of total United States freshwater withdrawals in 2005 were for electricity generation, which gave an estimated consumption of 6270 m^3 per every second [Chandel *et al.* 2011]. However, in case of chemical and/or biological contamination of surface water it can cause reduced efficiency of the technological processes or even shut down the plant [Jenner *et al.* 1998]. Thus, power generation stations have to use a purification systems which enable efficient and safe use of their technical equipment. In the light of eutrophication of freshwaters and the occurrence of algal blooms (which both are increasing worldwide) the problem will become a considerable challenge for the power generating industry in the nearest future. However, the scientific knowledge of the role of phytoplankton blooms in the efficiency of water purification processes in power stations is scarce. To fulfill this gap we conducted a research in which we aimed to investigate an efficiency of algal removal in every step of the water treatment line in one of combined heat and power plants in eastern Poland.

MATERIAL AND METHODS

The research was conducted in the cogeneration plant (combined heat-and-power station) in Lublin (Eastern Poland). The water purification system in the studied plant consists of several consecutive steps in which we situated our sampling points (marked as 1–9 on Fig. 1). The line starts in the dam reservoir (1), from which water is withdrawed and carried to the pump station (2), located 200 m away. Before the water is pumped through ~3 km long pipe to the power plant, a biocide (a solution of tertiary amines in a isopropanol) is applied in the same building (3). After reaching the power station the water is treated with limewater which effects in decarbonisation and coagulation of contaminants (4). The next step covers the gravel filter which enables to stop the flocculates coagulated before (5). Then water is carried to the ion-exchanger (6) in which calcium and magnesium ions are removed. After treatment in steps 1–6, the water is used primarily to the replenishment of losses in the heat distribution system (a system of underground pipes transferring thermal energy throughout the city of Lublin). The same water is also periodically used to the replenishment of losses in the cooling circulation system in coal furnaces. The treatment line produce also more pure water which is used in a gas-steam turbine. This kind, after coagulation is carried to independent gravel filters (7), afterwards to the ion-exchangers (8) and after passing through two carbon filters finally goes to the reverse osmosis device (9). Thus, the final product of this process should have a chemical parameters of demineralized water.

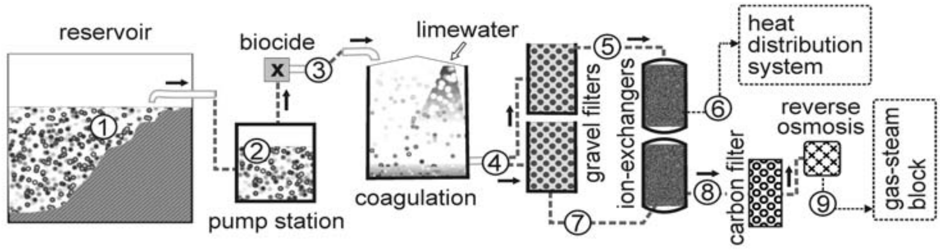

Fig. 1. Sampling points in the water treatment line in the studied heat and power station (detailed description of sites in Material and methods section)

Samples were taken in April 2011 in three replicates (0.5 dm^3 each) from every sampling site. In samples we have analyzed: dissolved oxygen, pH and conductivity by YSI 556 Multi Probe (MPS, USA), nitrates and total organic carbon concentration using the UV analyser (Pastel, France) and chlorophyll a (chl-a) concentration by the use of ethanol method. Analyzes of phytoplankton (including species composition, total abundance and fresh biomass) were based on microscopic analysis using an inverted microscope MBI 100T (Mikrolab, Poland) and the Ütermohl method [Vollenweider 1969]. The fresh biomass of algae was estimated by comparing counted species with the appropriate geometrical solid [Hillebrand *et al.* 1999].

RESULTS

The initial phytoplankton biomass in the reservoir (sampling site 1, Fig. 1) was very high (biomass: 65.8 mg dm^{-3}, chl-a: 146.7 µg dm^{-3}; Fig. 2) with diatoms prevailing (98% of the total biomass) from which the dominating one was *Cyclotella comta* (Ehrenberg) Kützing (95%). After several stages of the purification process (biocide application, flocculation, gravel filtering, ion exchange; sampling sites 2–6, respectively) the water still consisted a considerable amount of algae (biomass: 2.48 mg dm^{-3}, chl-a: 6.0 µg dm^{-3}; Fig. 2). The final biomass, after additional filtration (sampling sites 7–8) and reverse osmosis (sampling site 9) was very low (biomass: 0.03 mg dm^{-3}, chl-a: 0.1 µg dm^{-3}; Fig. 2).

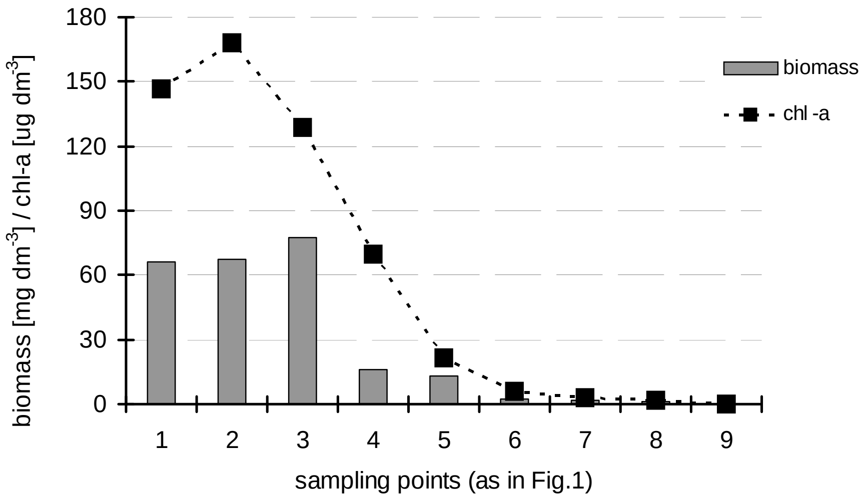

Fig. 2. Total phytoplankton biomass and chlorophyll *a* concentrations in consecutive sampling points in the water treatment line

Table 1. Values of basic physico-chemical water parameters at sampling points in a water treatment line (O_2 – dissolved oxygen, EC – electrolitycal conductivity, TOC – total organic carbon)

Parameters	1	2	3	4	5	6	7	8	9
O_2 mg dm^{-3}	19.4	12.4	12.7	11.9	6.8	6.5	6.9	6.5	7.0
EC µS cm^{-1}	366	367	370	255	211	218	218	220	3
pH	7.9	7.5	7.8	8.8	9.0	9.1	9.0	9.0	7.3
TOC mg dm^{-3}	8.7	9.1	7.8	8.3	6.9	6.4	6.6	6.1	8.2
NO_3 µg dm^{-3}	1.6	1.8	2.2	2.6	3.6	3.8	4.3	4.7	b.d. l.

b.d.l. – below detection limit

The water in the reservoir from which it is withdrawn was well oxygenated (19.4 mg dm^{-3}), had medium mineralization (electrolytic conductivity: 366 µS cm^{-1}) and slightly alkaline pH (7.9) and contained moderate amounts of total organic carbon (8.7 mg dm^{-3}) and nitrates (1.6 µg dm^{-3}) (Table 1). Values of almost all parameters decreased when water was passing through the treatment line, which was the most considerably shown in the case of electrolytic conductivity and dissolved oxygen. However, the pH values initially increased, then decreased and oscillated between 7.3 and 9.1. Also values of nitrates concentration increased at consecutive sampling sites (Table 1).

DISCUSSION

Considering the phytoplankton, the coagulation (after limewater application) appeared to be the most efficient process along the treatment line, reducing 79.4% of the fresh biomass and 54.1% of the chlorophyll a concentration. The success of this method is likely related to a high sedimentation rate of algal cells after limewater addition. This chemical is commonly used also in freshwater lakes and reservoirs restoration as an agent which promotes phytoplankton coagulation and sedimentation [Wąsowski and Kulesza 1999, Pęczuła 2012]. Gravel filtration was less efficient as of biomass reduction (17.1%) but effective in decrease of chl-a concentration (69.3%). It can be explained by the process of cells decaying which started at site 3 where the biocide was added. The application of this chemical reduced chl-a concentration by 23.5% and, what is interesting, caused the increase of phytoplankton biomass by 14.1%. This can be explained by the fact that the algal community was dominated by diatoms which disabled the differentiation between living and dead cells. However, the decrease in chlorophyll a concentrations pointed out that some part of algal cells had been killed. The domination of small diatoms in the phytoplankton (*Cyclotella comta*) can also explain the low efficiency of gravel filters in the studied treatment line. It is known that gravel filters with medium or high flow rate are usually less effective in small cells removal as compared to slow sand filters [El-Taweel and Ali 2000, Logsdon *et al*. 2002].

It is worth to highlight that the studied treatment line was designed primarily to the removal of undesirable chemical elements in the water i.e. calcium, magnesium and others. Regarding this function the purification of water in the studied cogeneration plant is effective. However, algal blooms in the reservoir serving as a water source (diatoms in the case of this research) may contribute to extra costs generated by the treatment line. For example, a huge amount of sedimentated algal cells (after limewater addition) cause problems with sludge storage or transportation outside the plant. According to the station engineers, the gravel filters require intense cleaning after spring or autumn usage, when diatoms dominate in the reservoir.

The improving of algal removal efficiency may be achieved by the application of microsieves. In one of water purification plants in Western Poland, after installation of this kind of device, the removal rate of algal cells increase up to 86% and as a result, the problem of gravel filter clogging was solved [Markowski *et al.* 1996].

In conclusion, the results of our study showed that high algal biomass in reservoirs serving as a water source for heat and power plants is quite difficult to remove and needs various technical and chemical methods to be used along the treatment line. Additionally it may contribute to an increase of economical costs which have to be beard by the cogeneration power plant.

CONCLUSIONS

1. The studied treatment line was very effective as regarding physico-chemical water parameters.
2. The coagulation (after limewater application) appeared to be the most efficient process in algal removal along the treatment line.
3. Algal blooms may contribute to an increase of technological and economical costs (problem of filter clogging, storage and transportation of sludge) which have to be beard by the cogeneration power plant.

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ZAKWITY GLONÓW JAKO PROBLEM GOSPODAROWANIA WODĄ W PRZEMYŚLE. WSTĘPNE BADANIA EFEKTYWNOŚCI LINII UZDATNIANIA WODY W ELEKTROCIEPŁOWNI WE WSCHODNIEJ POLSCE

Streszczenie. Zakwity sinic i glonów prowadzą do pogorszenia stanu ekosystemów słodkowodnych, a także generują problemy techniczne w przemyśle. Elektrownie korzystają z jezior i zbiorników słodkowodnych jako źródeł wody chłodzącej oraz w przypadku elektrociepłowni dodatkowo jako czynnika transportującego ciepło. Wstępne badania w jednej z elektrociepłowni we wschodniej Polsce, która wykorzystuje wodę z cierpiącego na zakwity fitoplanktonu zbiornika, zostały przeprowadzone w kwietniu 2011 r. Badania koncentrowały się na zmianach w strukturze ilościowej i jakościowej fitoplanktonu, jak również na zmianach podstawowych parametrów fizyczno-chemicznych wody w ciągu linii uzdatniania wody, na której umiejscowiono punkty poboru prób (od przepompowni do zbiornika wody demineralizowanej). W trakcie badań biomasa fitoplanktonu w zbiorniku była bardzo duża (65,8 mg dm^{-3}, chlorofil a: 146,7 µg dm^{-3}), a w strukturze taksonomicznej dominowały okrzemki z najliczniejszymi: *Cyclotella comta* i *Aulacoseira granulata*. Po kilku etapach procesu uzdatniania (sedymentacja, aplikacja biocydu, flokulacja, filtracja przez żwir, wymiennik jonitowy) woda nadal zawierała pewne ilości glonów planktonowych (biomasa: 2,48 mg dm^{-3}, chlorofil a: 6.0 µg dm^{-3}), jednak ostateczna biomasa w zbiorniku wody oczyszczonej po procesie odwróconej osmozy była bardzo mała (0,03 mg dm^{-3}, chlorofil a: 0,1 µg dm^{-3}). Wyniki naszych badań pokazały, że duża biomasa glonów w wodzie stosowanej w produkcji energii jest trudna do usunięcia, a tym samym wymaga znacznych technicznych i ekonomicznych nakładów w celu dostosowania wody do celów przemysłowych.

Słowa kluczowe: uzdatnianie wody, elektrociepłownia, zakwity glonów, jakość wody