Pol. J. Environ. Stud. Vol. 21, No. 6 (2012), 1797-1805

Original Research

Efficiency of Drinking Water Treatment Processes. Removal of Phytoplankton with Special Consideration for Cyanobacteria and Improving Physical and Chemical Parameters

Marlena Piontek[1]*, Wanda Czyżewska[2]**

[1]Institute of Environmental Engineering, University of Zielona Góra,
Prof. Szafrana 15, 65-516 Zielona Góra, Poland
[2]Water and Wastewater Plant in Zielona Gora, Poland Sp. z o.o.,
Zjednoczenia 120A, 65-120 Zielona Góra, Poland

Received: 29 July 2011
Accepted: 25 June 2012

Abstract

The goal of our research was to show efficiency of the micro-sieves during the water treatment process in the water treatment plant (WTP) in Zawada near the city of Zielona Góra, Poland. This paper presents changes in water quality after particle-filtration (filtration above 10 μm).The samples were collected in the Zawada WTP from January to December. The reduction of the amount of phytoplankton, including cyanobacteria, caused by micro-sieves varied throughout 2009 and was between 21.2 and 93.3%. The maximum concentration of cyanobacteria in raw water was observed May 6 and amounted to about 400,000 org. (organisms)/L and microcystins (MCs) content in raw water was below 0.2 μg/L and were absent in potable water. That day we observed a reduction of cyanobacteria after particle-filtration amounted to 83% and reduction of phytoplankton 84%. The particle-filtration process reduced organoleptic water parameters: color, turbidity, and total suspended solids. As a result of the decrease of suspend content, decreases of iron, manganese, and chemical oxygen demand (COD) were observed.

Keywords: surface water, drinking water intakes, water quality, water treatment, cyanobacteria blooms, cyanotoxins

Introduction

Public water systems (PWSs) come in all shapes and sizes, and no two are exactly the same. While their designs may vary, they all share the same goal: providing safe , reliable drinking water to the communities they serve. To do this , most water systems must treat their water. The types of treatment provided by a specific PWS vary depending on the size of the system, whether they use groundwater or surface water, and the quality of the source water. Around 32 percent of the population served by community water systems (CWSs) drink water that originates as groundwater. Groundwater is usually pumped from wells ranging from shallow to deep (50 to 1000 feet). The remaining 68 percent of the population served by CWSs receive water taken primarily from surface water sources like rivers, lakes, and reservoirs.

*e-mail: M.Piontek@iis.uz.zgora.pl
**e-mail: wgrochowiecka@zwik.zgora.pl

Because surface water systems are exposed to direct wet weather runoff and to the atmosphere and are therefore more easily contaminated, federal and state regulations require that these systems treat their water. Disinfection of drinking water is one of the major public health advances [1].

Cyanobacterial Toxins

The consequences of eutrophication of surface water are phytoplankton blooms (phytoplankton proliferations). The blooms are frequently dominated by cyanobacteria and occur in summer and early autumn. Cyanobacteria blooms are usually formed on the surface of water reservoirs assuming the form of scum or foam, causing the deterioration of sanitary, organoleptic, and aesthetic conditions of water. One of the negative effects of cyanobacteria in a water tank is their ability to synthesize toxins harmful to humans and animals [2]. The most common toxins synthesized by freshwater cyanobacteria are hepatotoxins called microcystins. A result of poisoning with hepatoxins is the rapid and irreversible destruction of the liver, which is caused by a mass influx of blood to the liver and hemorrhagic shock and finally causing death of animals. The consumption of water with hepatotoxins by humans can cause symptoms such as dermal rash, fever, vomiting, diarrhoea, and acute liver damage [3].

Cyanobacteria can produce not only hepatoxins but also neurotoxins (afanatoxins, saxitoxins, neosaxitoxins) and cytotoxins (acutificine, scytoficine, cyanobacterine) [4].

Symptoms of poisoning with neurotoxins are tremors, dizziness, heavy breathing, and intermittent convulsions. Constant exposure to low doses of neurotoxins causes the body to become more sensitive to their action [5].

Cytotoxins are not very toxic to animals but show significant bioactivity to algae, bacteria, fungi and mammalian cells. Their biochemical properties have been used in pharmaceutical and agrochemical enzyme preparations, antibiotics, and anticancer reagent production [4].

Constant exposure to even low concentrations of cyanobacterial toxins (microcystins) in drinking water can cause cancer promotion. Cyanobacterial toxin has adverse impacts not only on human and animal health but also can reduce crop yields [6].

Influence of the Occurrence of Cyanobacteria in Water on Human and Animal Health

A negative effect on the natural ecosystem is connected with the possibility of microcystins accumulating in phytoplankton, zooplankton, freshwater mussels, freshwater clams, and freshwater fish. Further transfer of cyanobacteria toxins through the food chain is possible. Humans may swallow contaminated water during swimming or drinking [7].

Cases of poisoning humans with cyanotoxins in the 20th century have been recorded worldwide. In 1996 in Caruaru, Brazil there was a fatal case of poisoning people in a dialysis unit. Seventy-six persons died as a result of the use of water contaminated with cyanobacteria *Aphanizomenon* sp. and *Oscillatoria* sp. for dialysis. Results of such a situation include: enlarged liver; jaundice; a prolonged blood coagulation meter rate; excessive concentrations of glycerides in the blood; damage to the liver lobes; the deformation, necrosis, and apoptosis of hepatocytes; and intracellular swelling [5].

Effectiveness of theWater Purification Process in Removing Plankton and Its Products

The quality of raw water has a direct impact on the effectiveness of water treatment and the cost of its production and distribution. The possibility of obtaining good quality water is a priority for waterworks. It is not always possible because of the deterioration of the quality of surface water as a result of the ongoing process of eutrophication. Therefore, it is necessary to take measures to improve the quality of water by using a two-step strategy: the reduction of eutrophication and the adjustment of the water purification process to the extent of danger caused by the presence of cyanobacteria and cyanobacterial toxins in water [2].

The removal of live and dead microorganisms and their metabolic products from water intended for human consumption is necessary. However, the effectiveness of the conventional surface water treatment system is inadequate, especially in relation to bio toxins and other organic pollutants. In order to strengthen the effects of water treatment, advanced technological systems containing additional chemical oxidation, adsorption on activated carbonate, and an increased dose of chemical reagents are necessary, as well as a very careful observance of the technological regime [8].

Technological difficulties with the removal of phytoplanktonic organisms from water are caused by the fact that they are adapted to live in the water column. Phytoplanktonic organisms can reduce their volume of the body relative to their surface throughout various outgrowth formations or concentrating cells in the colonies. Additionally, the separation of phytoplankton is very difficult because of their ability to produce oxygen during photosynthesis. It may induce flotation of agglomerated micro organism during the coagulation process. Raw water consisting cyanobacteria cells is particularly difficult to treat of because cyanobacteria have gas vacuoles that help them drift on the reservoir surface [9].

Surface water treatment consists of the following unit processes: initial and intermediate oxidation, coagulation, sedimentation, filtration, sorption on granulated active carbon, and disinfection. Chlorine used as an oxidant is most common. However, as a result of chlorination halogenated hydrocarbons may be formed, mainly THMs (trihalomethans) [10].

The processes of coagulation, sedimentation, and filtration on gravel filters are highly efficient in removing cyanobacterial cells. However, the process of coagulation does not result in the elimination of microcystins dissolved in the water. An optimum coagulant dose depends largely on the type of algae, in particular on the surface of cells or colonies of microorganism and their mutual affinity [11].

Under the influence of coagulants, cyanobacteria are more sensitive to chemicals and they release toxins into the water. The filtration process of sand filters in conjunction with filtration using granular-activated carbon significantly increase the efficiency of the elimination of cells of cyanobacteria up to 42%. However, cell lysis of cyanobacteria retained during filtration may result in the concentration of cyanobacterial toxins released into the water. The phase of slow filtration is much more effective in reducing the cells of cyanobacteria (up to 99%). Unfortunately, these filters are clogged very quickly by phytoplankton and are not effective [12].

The stage of disinfection may be a helpful tool for removing cyanobacterial toxins. For example, ozone can ensure the complete decomposition of MC-LR and MC-RR with doses of about 0.02 gO_3/m^3 on condition that of the process is carried out at a pH <7. But the effect of ozone on MC-YR turns out to be ineffective. Sodium hypochlorite can enable an efficient elimination of microcystin LR. However, doses required for its complete removal are relatively large [13].

An innovative method of removing microcystin RR is connected with the UV-hydrogen peroxide (H_2O_2) technique. The removal efficiency of MC-RR by means of this method may reach above 90% [14].

A new idea for the elimination of plankton in raw water is the use of biological agents such as seeds as a coagulant. Pioneering studies have been conducted in Egypt with the application of surface water from the Nile. *Moringa oleifera* Lam seeds were used (order: *Brassicales*, family: *Moringaceae*) for the purification of water. This method requires further verification and validation in terms of diversity of the quantitative and qualitative composition of plankton in surface waters [15].

Also, an interesting and inexpensive approach is the use of natural populations of bacteria in MC-LR biodegradation [16]. The microorganisms were classified as *Arthrobacteria* sp., *Sphingomonas* sp, *Brevibacterium* sp, and *Rhodococcus* sp, which could metabolise different forms of microcystin (MC-LR, MC-RR, MC-YR, MC-LA). However, even this method requires further validation [17].

Filtration on micro-sieves was used for the first time in England in 1946. In 1948-53 micro-drawl was used in England in 17 waterworks, and in 1954-58 in an additional 54 waterworks [18].

Micro-sieves can be found in many water treatment plants and sewage treatment plants, for example Sipplinger-Berg on Lake Constance and Berlin-Tegel Wasser/Saatwinkel (Germany), where they are used to remove plankton and fine suspension during initial water treatment, in Eskilstuna (Sweden) prior to infiltration ponds, Jonkoping/Haggenbergswerk (Sweden) as a shield to slow filters [19].

Also in Spannenburg (Netherlands), micro-sieves are used in the pre-filtration process [20].

Micro-sieves are used not only in Europe. For 50 years they have also been used in New Zealand [21].

Depending on the quality of raw water and the required degree of purification, micro-sieves may be used as a basic device for removing suspended solids, as an initial device cooperating with, for example, sand filters, or as a terminal device enhancing the effect of treatment received in the preceding devices. During the treatment of water obtained from stagnant water reservoirs where there are periodic massive phytoplankton proliferations, the use of micro-sieves makes much sense. Plankton that is not removed before the settlers and filters is an intolerable burden to those devices and causes specific operational problems. The removal of organisms and organic and inorganic suspensions prior to chemical water treatment and filters improves the work of the equipment used after the micro-sieves and reduces the frequency of filter cleaning. The result is the longer durability and time of operation of the filters, as well as saving water used for rinsing. A smaller quantity of suspensions that still need to be treated by the next treatment devices increases the efficiency of the process. The application of micro-sieves as pre-filtration devices can satisfy the growing demand for water without the need to extend treatment stations. The application of micro-sieves also causes a significant reduction in the cost of water treatment because it decreases the amount of chemicals needed for water treatment [18].

The Water Treatment Plant (WTP) in Zawada

The main source of raw water for the water supply system in Zielona Góra is the Obrzyca river, the right-hand tributary of the Oder river. The catchment area of the Obrzyca river is almost 1,800 km^2 located in the areas of the provinces: Lubuskie and Wielkopolskie. Zielona Góra uses three sources of water:

- The Obrzyca river – shot boundary
- Groundwater in the proglacial stream of the Oder river – shot siphon
- Groundwater in the city – water wells

The share of individual sources in the total water production in 2007 was:

- Surface water – about 45%
- Groundwater derived from shot siphon – about 48%
- Grounwater derived from water wells – about 7.5%

In WTP groundwater from shot siphons and surface water from the Obrzyca river is purified.

The poor quality of raw water supplied to the station and the need for the treatment of groundwater and surface water simultaneously cause many problems in the process of purifying water. Surface water pollution is characterized by: high color, chemical oxygen demand, periodic blooms, and considerable bacteriological contamination, which are typical of eutrophic waters. Underground water from the siphon intake has a high content of iron and manganese, including some in the form of complexes with humic compounds.

The drinking water treatment process in WTP is presented in Fig. 1. Surface water is filtrated on grates and sieves. Then the water is pumped by a pipeline to the first element of the technological system i.e. micro-sieves, where it is filtrated on three drum micro-sieves where a net with pores of 10 microns is mounted. Water from the siphon intake is combined with oxygenated surface water. Next the water is treated with coagulant. After that a chlorine dioxide solution is dosed to the clarified water. The next step is filtering through open filters and the next is filtration through chambers filled with fluid filters, an open active deposit of dolomite ($CaCO_3$ × MgO). This process enriches the water with calcium and magnesium and reduces its turbidity.

Then chlorine dioxide solution and soda ash are dosed to the water in the reservoir with multifunctional pumps in order to bind the remaining aggressive carbon dioxide (reduced corrosiveness of water). Water purified in this way is sent by a pipeline to the city [22].

The goal of our research was to show efficiency of the micro-sieves during water treatment process in the Zawada WTP (near Zielona Góra). This paper presents the impact of the particle-filtration process on the amount of phytoplankton, with special consideration for cyanobacteria and physical (temperature, total suspended solids, conductivity, turbidity, color) and chemical (dissolved oxygen, pH, ammonium nitrogen, nitrate and nitrite nitrogen, orthophosphate, chemical oxygen demand, iron, manganese) water quality parameters.

Experimental Procedures

For the purposes of the study samples were collected once a week throughout 2009. The samples were taken in the building with the micro-sieves in the Zawada WTP and in the laboratory (Fig. 1) [23-32].

Methods

Samples for hydrobiological and physical-chemical testing were collected with a bucket. Samples for microscopic analysis were additionally concentrated (10 L water) using mesh plankton with pores of 10 microns in diameter. The quantitative and qualitative analysis of phytoplankton in 0.001 L was carried out using a Sedgewick Rafter chamber and a OPTA-TECH MN 358/5 microscope [33].

Samples of raw water for the determination of cyanobacterial toxins were collected in a bucket in the building with micro-sieves. Treated water samples for the determination of cyanobacterial toxins were collected in a sample room in the Research Laboratory of Water and Wastewater in the Zawada WTP. Those samples were not concentrated. Tests for the presence of dissolved and intracellular MCs were performed by high-performance liquid chromatography (HPLC) using an Agilent Model 1100 liquid chromatograph with diode-array detection (DAD) [34]. The remaining physical-chemical indicators and methods used in this research are presented in Table 1.

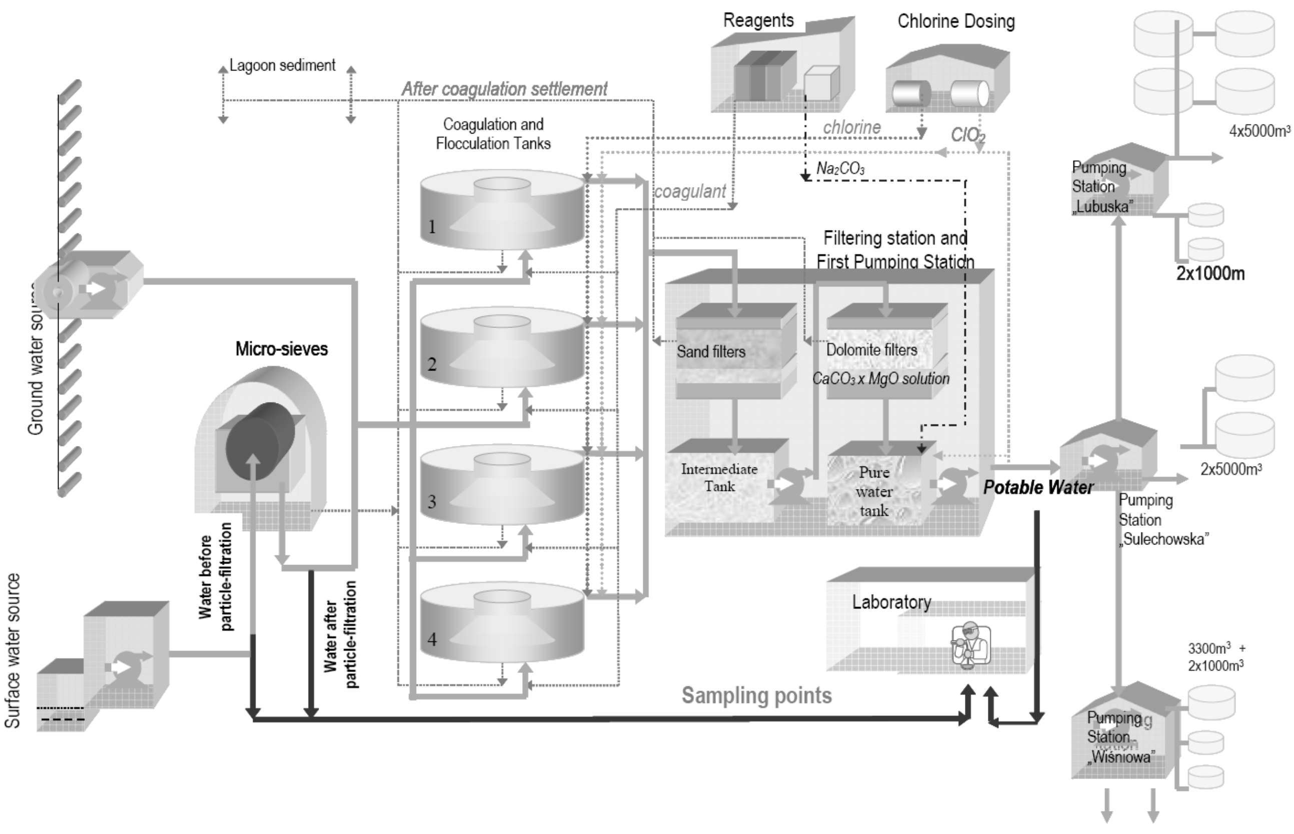

Fig. 1. Drinking Water Treatment process in Zawada WTP.

Table 1. Physical and chemical parameters and methods used during the study.

No.	Physical and chemical parameters	Measurement	Methods/device
1	Color	visual	PN EN ISO 7887:2002
2	Conductivity	electrochemical	PN EN 27888:1999
3	Turbidity	nephelometric	turbidimeter HACH 100 AN IS
4	Ammonium nitrogen	spectrophotometric	Met. HACH no. 8038
5	Nitrate nitrogen	ion chromatography	PN EN ISO 10304-1:2009
6	Nitrite nitrogen	ion chromatography	PN EN ISO 10304-1:2009
7	Dissolved oxygen	electrochemical	PN EN 25814:1999
8	pH	electrochemical	PN-90/C 04540.01
9	Orthophosphate	ion chromatography	PN EN ISO 10304-1:2009
10	Total suspended solids	weight	PN EN 872:2007
11	Chemical oxygen demand	spectrophotometric	PN-85/C-04578.02
12	Manganese	spectrophotometric	PN-92/C-04590/03
13	Iron	spectrophotometric	PN ISO-6332:2001 p. 7.2

Results and Discussion

Fifty hydrobiological analyses of plankton in raw water were carried.

Phytoplankton abundance changed in a dynamic way in a year [35]. The greatest amount of cyanobacteria in raw water was recorded in 6 May 2009. That day the density of cyanobacteria was more than 394,000 org./L before micro-sieves and about 67,000 org./L after particle-filtration. In April, (15.04 and 29.04) and May (20.05) densities of cyanobacteria exceeded 100,000 org./L. The 6 and 20 May cyanobacteria were the dominant group of phytoplankton in the Obrzyca river. Cyanobacterial bloom occur between spring and autumn [35].

The dominant species of cyanobacteria during blooms were *Oscillatoria redeckei* Cyanobacteria, order *Oscillatoriales* which are an important producer of microcystins in temperate waters, especially in the northern hemisphere, where they can occur year round [36].

Reduction of cyanobacteria after particle-filtration (Fig. 2, Table 2) was between 10-100%. Efficiency of micro-sieves depended on the amount of microorganisms (Fig. 4). Lack of reduction of cyanobacteria after particle-filtration was recorded on 22nd April and 13th May 2009 and caused smaller sizes of some groups of cyanobacteria than diameter of micro-sieve mesh. These days efficiency of phytoplankton reduction was good in general and was 69.2 and 51.4%.

The greatest abundance of phytoplankton was recorded in April (15.04 and 29.04), where the genus *Cyclotella* sp. was the dominant group (> 10^6 org./L). Blooms of diatoms were recorded on 1.04 and 22.04 (> 700,000 org./L), 6.05 (> 600,000 org./L), 8.04 (about 500,000 org./L), 13.05 (about 400,000 org./L), 25.03, and 17.06 (about 300,000 org/L). During the mass development of plankton, cells of microorganisms in the water may exceed 10^9 org. In spring and autumn there are diatom blooms and during summer there are numerous cyanobacteria and green algae [37]

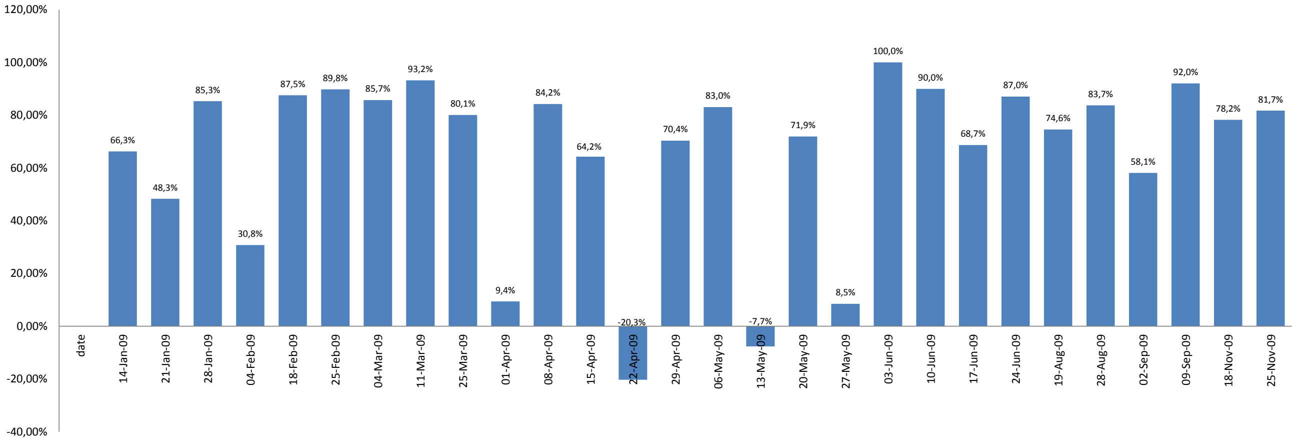

Fig. 2. Reduction of cyanobacteria after particle-filtration in 2009 in WTP Zawada.

Table 2. Amounts of plankton and the efficiency of particle-filtration in 2009.

Micro organism	Abundance before micro-filtration	Abundance after micro-filtration	reduction of various groups of plankton
	[org./L]	[org./L]	[%]
Cyanobacteria	165÷394,355	0÷256,802	9.4÷100
Diatoms	2,022÷914,033	562÷243,964	15.2÷94.1
Green algae	297÷58,258	30÷10,733	8.2÷98
Other	471÷67,984	41÷6,799	29.2÷95.2
General amount of phytoplankton	7,646÷1,059,756	1,607÷256,802	21.2÷93.3

The reduction of phytoplankton amount (Fig. 3, Table 2) by micro-sieves was between 23-91%. The lowest reduction (expressed in org./L) occurred when abundance was high and the highest when the amount of plankton was low (Fig. 5).

Green algae was the dominant group in the second half of August. The reduction of that group is similar to others (Table 2). The highest reduction (shown in Table 2) was obtained by particle-filtration in the group of "other" (zooplankton-rotifers, ciliates, euglenine, cryptomonads). That could have been caused by larger sizes of some species of that group.

In July, the middle of August, September, October, and December hydrobiological analyses were not performed due to the treatment of only underground water.

Despite the large effectiveness of the micro-sieves for reduction of phytoplankton amounts, there is still a need to eliminate it – particularly cyanobacteria cells during further steps of the water treatment process. The presence of cyanobacteria cells in water causes potential risk for the presence of cyanobacterial toxins [38].

Two samples originated from raw and potable water collected 6 May that were quantified cyanobacterial toxins. The results are presented in Table 4. The presence of intracellular MCs was recorded only in raw water and amounted to 0.094 (MC-LR) and 0.105 µg/L (MC-YR). Dissolved MCs were absent in raw and potable water. MCs were removed during the drinking water treatment process and cyanobacterial toxins were a bsent in potable water.

Intracellular cyanotoxins can be removed effectively by conventional treatment and membrane filtration. Chlorine effectively degrades extracellular cyanotoxins (both microcystins and cylinrospermopsin between pH 6.0 and 8.0) [39].

Micro-sieves are a good method for drinking water pretreatment because they reduce a large amount of plankton. Different phytoplankton species (including both eukaryotic algae and cyanobacteria) cause problems in drinking water treatment. The majority of taste-odor problems in drinking water are caused by cyanobacterial production of geosmin and other substances. Moreover, various colonial chrysophytes, dinoflagelates, cryptomonads, and diatoms can cause periodic outbreaks of fishy or floral taste or odour problems in fresh waters [40]. Low phytoplankton amounts at the beginning of the drinking water treatment process cause lower consumption of coagulant at a later stage in the process. Properly operated micro-sieves should provide from 40 to 90% plankton reduction [37] .

The physical and chemical results (minimum and maximum values) originated from 26 samples are presented in Table 4. The results concern surface water before and after particle-filtration.

In this work, as in previous publications, in water after particle-filtration we observed a decrease in color intensity (in 77% analyzed samples), turbidity (in 92% analyzed samples), and the total content of suspended solids (in 92% analyzed samples) [8]. Improving these parameters could be a result of phytoplankton removal during micro-sieve

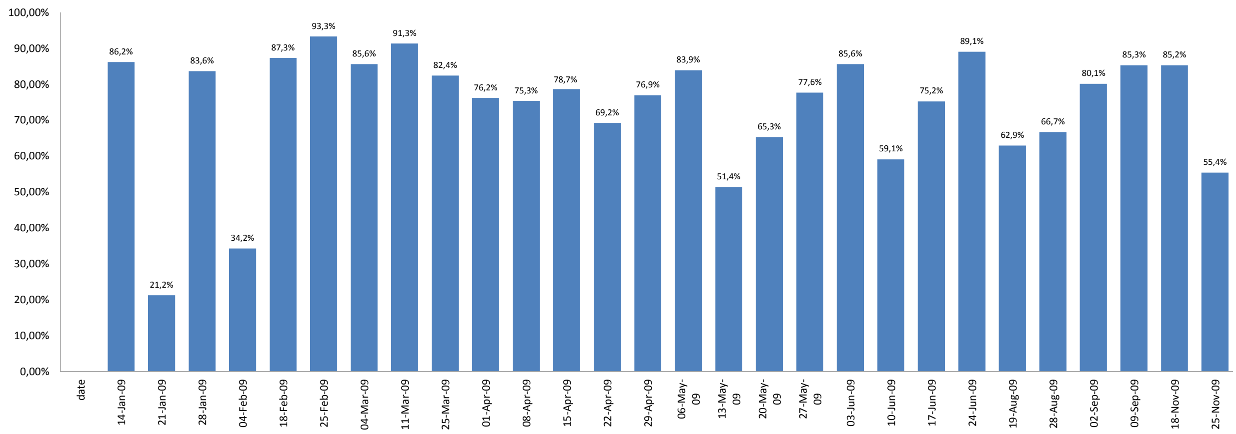

Fig. 3 Reduction of phytoplankton after particle-filtration in 2009 in WTP Zawada.

Table 3. The content of dissolved and intracellular MCs in raw and potable water in 2009.

	Microcystins dissolved in water [μg/L]				Intracellular microcystins [μg/L]			
Sample type	RR	YR	LR	Other	RR	YR	LR	Other
Raw water (Obrzyca river)	0	0	0	0	0	0.105	0.094	0
Potable water	0	0	0	0	0	0	0	0

operation. Also, Scheifhacken and co-authors stated a correlation between turbidity and plankton abundance [40]. Membrane systems are attractive since they provide an absolute barrier for pathogens and remove turbidity, thus increasing the palatability of the water [41].

Moreover, in 80% of analyzed samples we observed a decrease of iron content in water after particle filtration. Iron can be present not only in dissolved form but also as a suspension [37]. In 92% of collected specimens was stated a decrease of chemical oxygen demand and manganese content and in 85% tested samples we observed a decrease of ammonium nitrogen after micro-sieving. The changes of these parameters also are associated with the decrease of content of suspended solids [37].

Water after particle-filtration obtained higher dissolved oxygen content. Such a situation is caused by mixing groundwater and surface water after particle-filtration. It was not an observed correlation between pH and conductivity and micro-sieve filtration.

Conclusions

1. The reduction of phytoplankton including cyanobacteria, caused by micro-sieves varied throughout the year and was between 21.2 and 93.3%.
2. The effectiveness of the particle-filtration process in removing phytoplankton increased simultaneously with

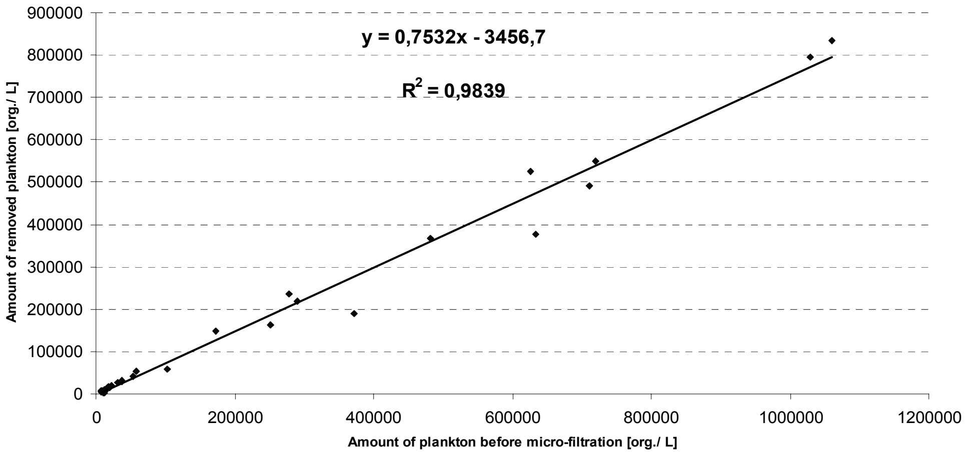

Fig. 4. The relationship between the abundance of phytoplankton in raw water and the effectiveness of its removal during particle filtration.

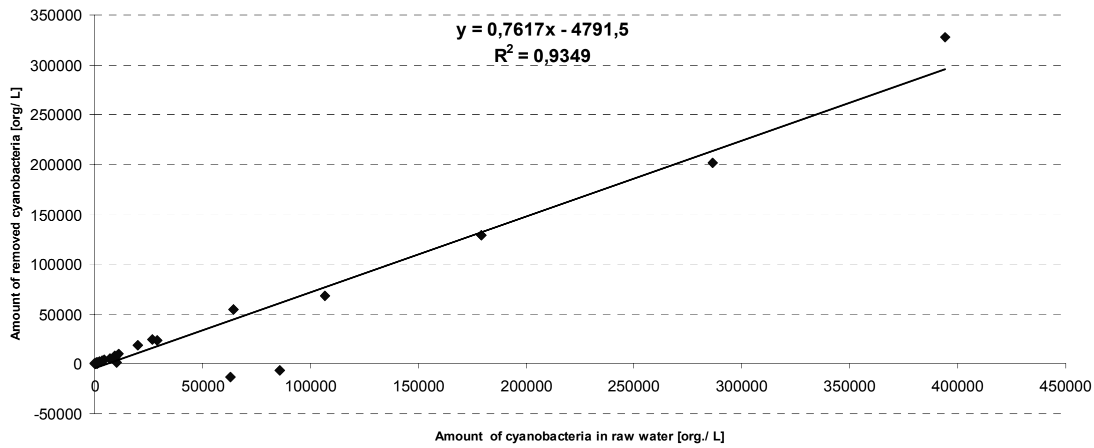

Fig. 5. The relationship between the abundance of cyanobacteria in raw water and the effectiveness of their removal during particle filtration.

Table 4. Results of physical and chemical water quality indicators for surface water from the Obrzyca river before and after particle-filtration in 2009.

Indicator	Unit	Raw water	Water after particle-filtration	Percentage of samples with decreased value after particle-filtration
pH	pH	7.55÷8.27	7.10÷8.20	42%
Dissolved oxygen	mg O_2/L	2.63÷13.08	0.43÷13.98	13%
Color	mg Pt/L	25÷60	28÷50	77%
Turbidity	NTU	2.04÷56.5	1.49÷25.5	85%
Ammonium nitrogen	mg NH_3/L	0.11÷1.31	0.11÷0.78	85%
Nitrate nitrogen	mg NO_3/L	0.5÷10.0	No data	Not analyzed
Nitrite nitrogen	mg NO_2/L	0.09÷0.145	No data	Not analyzed
Total suspended solids	mg/L	2.3÷18.2	1.4÷10.0	92%
Orthophosphate	mg PO4/L	0.02÷0.88	No data	Not analyzed
Conductivity	μS/cm	578÷726	546÷725	38%
COD	mg O_2/L	7.24 12.9	7.18 11.48	92%
Manganese	mg Mn/ L	0.06÷0.27	0.06 ÷0.27	92%
Iron	mg Fe/L	0.18÷2.74	0.18÷2.26	80%

an increase in the amount of individual groups of microorganisms.

3. As a result of phytoplankton removing water organoleptic, parameters such as color, turbidity, and total suspended solids were improved in most samples.
4. Decreases of iron, manganese, and chemical oxygen demand were associated with lower values of suspension after particle filtration.
5. The largest occurrence of cyanobacteria was reported in the spring (May 2009) and amounted to more than 394,000 org./L.
6. Dissolved MC-LR, MC-YR, MC-RR were not detected in the raw and potable water in samples collected in May.
7. Intracellular MC-YR and MC-LR were stated only in the raw water and content of the MCs was approximately 0.1 μg/L.

Acknowledgements

The author is a scholar within Sub-measure 8.2.2 Regional Innovation Strategies, Measure 8.2 Transfer of knowledge, Priority VIII Regional human resources for the economy Human Capital Operational Program co-financed by the European Social Fund and state budget

References

1. EPA Drinking Water Treatment. Safe Drinking Water Act 1974-2004. Protect our health from source to tap. 1-3. **2009**. EPA 816-F-04-034.
2. JURCZAK T. Application of cyanotoxins monitoring in water treatment and dam reservoirs. In: 9th National Conference, 7th International Conference: Water demand, quality and protection. Vol. 2nd. Poznań- Zakopane, Poland. pp. 139-153, **2006** [In Polish]
3. RAPALA J., SIVONEN K., LYRA CH., NIEMELA S.I. Variation of microcystins, cyanobacterial hepatotoxins in *Anabaena* spp. as a function of growth stimuli. Appl. Environ. Microbiol. **63**, 2206, **1997**.
4. PIONTEK M. PIONTEK R. Hazards to humans and animals caused by the presence of Cyanobacteria in aquatic ecosystems. Natura. **8**, 79, **2003** [In Polish].
5. CARMICHAEL W., AZEVEDO S., AN J., MOLICA R., JOCHIMSEM E., LAU S., RINEHART K., SHAW G., EAGLESHAM G. Human fatalities from Cyanobacteria: chemical and biological evidence for cyanotoxins. Environ. Heath Perspect. **109**, 663, **2001**.
6. WAYA S., NAPATTARONG S., WEERACHAI P. Microcystin-LR content in Microcystis aeruginosa Kutz collected from Sri Sakhett, Thailand. Chaing Mai J. Sci. **33**, (2), 231, **2006**.
7. ROMANOWSKA-DUDA Z., MANKIEWICZ J., TARCZYNSKA M., WALTER Z., ZALEWSKI M. The effect of

HUMAN CAPITAL
HUMAN – BEST INVESTMENT!
Lubuskie
Worth your while
EUROPEAN UNION
EUROPEAN
SOCIAL FUND

toxic cyanobacteria (blue green algae) on water plants and animal cells. Pol. J. Environ. Stud. **11**, (5), 561, **2002**.
8. GROCHOWIECKA W., ŚWIDERSKA-BRÓŹ M., WOLSKA M. The effectiveness of the microdraw process in removing phytoplankton microorganisms and selected contaminants from surface water. Ochrona Środowiska. **31**, 25, **2009** [In Polish].
9. JODŁOWSKI A. Phytoplankton removing in surface water treatment processes. Ochrona Środowiska **3**, (44), 15, **1991** [In Polish].
10. JACHIMKO B. Use of surface in Polish waterworks. Water supply of cities and villages. Poznań **1**, 177, **1998** [In Polish].
11. SCHMECHTIG-GAUDEN E., DEJEWSKA B., BUCZKOWSKI R. Pilot studies on the effectiveness of removal of algae on the water intake in Lubicz near Toruń. Ochrona Środowiska. **4**, (24), 33, **2002** [In Polish].
12. TARCZYŃSKA M. Toxicity of cyanobacterial blooms and the efficiency of water treatment processes in the elimination of cyanobacterial toxins. Conference: Eutrophication and the opportunity to improve the quality of drinking water Łódź. Tresta. Nagórzyce, **2000** [In Polish]
13. JODŁOWSKI A. Ozone and chlorine effect on the microcystin in the aquatic environment. Ochrona Środowiska. **3**, (25), 49, **2003** [In Polish]
14. QIAO R.P., MA Y.M., QI X.H., LI N., JIN X.C., WANG Q.S., ZHUANG Y.Y. Degradation of microcystin-RR by combination of UV/H_2O_2 technique. Chinese Chemical Letters. **16**, (9), 1271, **2005**.
15. SHEHATA .S.A, ALI G.H., WAHBA S.Z. Distribution pattern of Nile water algae with reference to its treatability in drinking water. J. Appl. Sci. Res. **4**, (6), 720, **2008**.
16. MANAGE P.M., EDWARDS CH., LAWTON L.A. Biodegradation of microcystin-LR by natural bacterial populations in: Interdisciplinary Studies on Environmental Chemistry- Environmental Research in Asia ed.: Obayashi Y., Isobe T., Subramanian A., Suzuki S. and Tanabe S. Terrapub, pp. 277-285, **2009**.
17. MANAGE P., EDWARDS C., LAWTON L.A. Bacterial degradation of microcystin. In Interdisciplinary Studies on Environmental Chemistry – Biological Responses to Contaminants, ed.: Hamamura N., Suzuki S., Mendo S., Barroso C.M., Iwata H. and Tanabe S. Terrapub, pp. 97-104, **2010**.
18. Heidrich Z. Application of micro-sieves and slow filters to treat surface water. 2nd Scientific and Technical Conference: Recognition of surface water for water supply of cities and settlements. Zielona Góra. pp. 96-117, **1988** [In Polish].
19. JILEK B. Phytoplankton and zooplankton removing on the micro-sieves Conference: Water supply of cities and villages. Poznań. pp. 779-788, **1994** [In Polish].
20. SALEHI F., WINTGENS T., MELIN T. Ultrafiltration with pre-coagulation Survey on operational strategies. 7th ed. Techneau, pp. 1-65, **2007**.
21. Ministry of Heath. Chapter 12 Treatment proceses, pretreatment w: Draft Guidelines for Drinking-water Quality Management for New Zealand 2nd ed; Wellington: Ministry of Health. New Zealand, **2005**.
22. STANISŁAWIAK R. Water supply system in the city of Zielona Góra. Conference: Training workshops for operators of water treatment. 10-12.09.2008 Boszkowo. 19-29, **2008** [In Polish].
23. PN EN ISO 7887:**2002** Water quality. Examination and determination of color. [In Polish].
24. PN EN 27888:1999. Water quality. Determination of electrical conductivity. [In Polish].
25. PN EN ISO 10304-1:**2009** Water quality. Determination of dissolved anions by ion chromatography – Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate. [In Polish].
26. PN EN 25814:**1999**. Water quality. Determination of dissolved oxygen – Method of electrochemical sensor [In Polish].
27. PN-90/C 04540.01 The study of pH, acidity and alkalinity. Determination of pH of water and wastewater for proper conductivity 10 μS/cm and above using electrometric method [In Polish].
28. PN-85/C -04578.02 The study oxygen demand and organic carbon content. Determination of chemical oxygen demand (COD) by potassium permanganate (KMnO4) method. [In Polish].
29. PN-92/C-04590.-3 Studies of the manganese content. Determination of manganese by formaldoxime method. [In Polish].
30. PN ISO 6332:**2001**. Water quality. Determination of iron - spectrometric method with 1,10-phenanthroline. [In Polish].
31. PN EN 872:**2007**. Water quality. Determination of suspended solids - Method by filtration through glass fiber filters. [In Polish].
32. USEPA Nitrogen. Ammonia. Nessler method. No. 8038.
33. HUTOROWICZ A. Methods of sampling and quantitative and qualitative analysis of phytoplankton in lakes. WIOŚ Olsztyn. Olsztyn, **2004** [In Polish].
34. JURCZAK T. TARCZYNSKA M. IZYDORCZYK K., MANKIEWICZ J., ZALEWSKI M., MERILUOTO J. Elimination of microcystins by water treatment processes examples from Sulejow Reservoir, Poland. Water Res. **39**, 2394, **2005**.
35. KOZAK A. Seasonal changes occuring over four years in a Reservoir's phytoplankton composition. Pol. J. Environ. Stud., **14**, (4), 4451, **2005**.
36. BŁASZCZYK A. TORUŃSKA A. KOBOS J., BROWARCZYK-MATUSIAK G., MAZUR-MARZEC H. Ecology of toxic cyanobacteria. Kosmos. **59**, (1-2), 173, **2010** [In Polish].
37. KOWAL A., ŚWIDERSKA-BRÓŻ M. Water purification. PWN:Warszawa-Wrocław, pp. 553-571, **1996** [In Polish].
38. KABZIŃSKI A., JUSZCZAK R., MIEKOŚ E., TARCZYŃSKA M., SIVONEN K., RAPALA J. The first report about the presence of cyanobacterial toxins in Polish lakes. Pol. J. Environ. Stud. **9**, (3), 171, **2000**.
39. WESTRICK J.A. Cyanobacterial toxin removal in drinking water treatment processes and recreational waters chapter13 in: Cyanobacterial harmful algal blooms. State of the science and research needs. ed.: Kenneth Hudnell H, Springer, pp. 275-290, **2008**.
40. SCHEIFHACKEN N., HORN H., PAUL L. Comparing *in situ* particle monitoring to microscopic counts of plankton in a drinking water reservoir. Water Res. **44**, (11), 3496, **2010**.
41. PETER-VARBANETS M., ZURBRÜGG C., SWARTZ C., PRONK W. Decentralized systems for potable water and the potential of membrane technology. Water Res. **43**, (2), 245, **2009**.