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# Removal of Organic Matter from Water During the Biofiltration Process – a Full Scale Technological Investigation

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## 1. Introduction

Increasing requirements for drinking water quality and the constantly depleting resources of high quality water make it necessary to intake and treat water polluted by many substances, including organic compounds. Currently one of the major challenges of water treatment technology is the effective removal of colloidal or dissolved organic pollutants from water. Particular attention is given to the removal of biodegradable organic matter fractions that are ubiquitous in aquatic ecosystems. This fraction includes a heterogeneous mixture of organic compounds with different physicochemical properties, including humic and fulvic substances, proteins, amino acids, lipids, polysacharides and biopolimers (Huber et al., 2011; Gibert et al., 2013; Gibert et al., 2015; Pruss, 2015; Pruss and Pruss, 2016). The presence in the water of a biodegradable fraction of organic matter can cause the secondary development of microorganisms in the water supply network and thus worsen the organoleptic characteristics of water directed to the consumer (Shaw et al., 2014; Szuster-Janiaczyk, 2016; Prest et al., 2016;). Biodegradable organic carbon is also a precursor of harmful disinfection byproducts (Włodyka-Bergier and Bergier, 2011; Rosińska and Rakocz, 2013; Wolska, 2014; Włodyka-Bergier et al., 2016). One of the methods of removing biodegradable organic carbon from the water which reduces the doses of disinfectants and ensures biological stability of water in water distribution systems, is the filtration of water through the beds of biologically active carbon filters (Zimoch and Szostak, 2006; Seredyńska-Sobecka et al., 2006; Simpson, 2008; Lu et al., 2013;

Tian et al., 2014; Outi et all., 2015; Prest et al., 2016; Papciak et al., 2016; Holc et al., 2016; Kołaski et al., 2017, Liu et al., 2017, Holc et al., 2018; de Vera et al., Domoń et al.,2018, Wolska et al., 2019). For microorganisms colonizing biologically active filter beds, a biologically active source of carbon and energy is biodegradable dissolved organic carbon (BDOC). Removal of organic matter from water is a result of oxidation in the respiratory processes of microorganisms and the increase of their biomass. Decrease in oxygen concentration and following increase in carbon dioxide concentration in the treated water indicates the development of microorganisms in the filter bed (Laurent et al., 1999; Mołczan, 2006; Pruss et al., 2009; Liao et al., 2012; Holc et al., 2016; Elhadidy et al., 2017; Kołaski et al., 2018). Biocenosis that inhabits biologically active carbon filters are mainly bacteria, fungi, and flagetes, ciliates and crawlers. Bacteria colonizing the filter beds are mainly psychrophilic, both auto- and heterotrophic, but only the heterotrophic bacteria are responsible for the decomposition of organic compounds adsorbed on the surface of activated carbon grains. Among the bacteria predominate are bacteria of the genus *Pseudomonas sp. (Maltophila, P. cepacia, Ps. Acidoverans) and Acinetobacter sp., Flavobacterium and Bacillus sp.* (Olesiak and Stępniak, 2014). The colonization of filters by microorganisms has vertical stratification. This is due to the difference in oxygen concentration and nutrient content at different depths of the filter bed (Simpson, 2008; Velten et al., 2011; Gerrity et al., 2018). The biological activity of the filter bed is related to the presence of microorganisms in the water and consists of forming of the biological layer on the surface of the filter grain. This process lasts from several to several weeks and depends on many factors such as: water temperature, type and concentration of organic compounds, oxygen concentration and type and granulation of the filter material. The pH of the incoming water, the type of pollutants and the concentration of toxic substances are also important (Pruss et al., 2009; Kołwzan, 2011; Liao et al., 2013; Lautenschlager et al., 2014; Olesiak and Stępniak, 2014; Kaarela et al., 2015; Oh et al., 2018). The rate of biological layer development also depends on the amount and type of bacteria and other microbes present in the water. Under natural conditions biofilm forming takes a lot of time. It takes several weeks for this to develop, but this time may be shortened if favorable conditions for the development of microorganisms, such as the supply of sufficient organic substances (Holc et al., 2016), are provided. Studies show that in waters with a small amount of organic compounds, the process of filter bed adaptation took much more time (Kiedryńska, 2004). The longer filters are operating the thicker the biological layer becomes and the more intense the microbial growth is. This happens until the filter bed is backwashed. Backwashing the filter results in partial scouring of the biological layer, so after the backwashing the microbial activity of the filter bed is reduced (Pruss et al., 2009). The

development of microorganisms on the surface of the bed should be controlled to prevent clogging of the filter bed, but also because of the risk of pathogenic microorganisms growth (Liao et al., 2012; Lin et al., 2014; Kaarela et al., 2015; Oh et al., 2018).

The aim of the study was to assess the impact of the microbiological activity on the efficiency of organic compounds removal from water treated on recently launched carbon filters of analyzed Water Treatment Plant. In addition to traditional culturing methods, the metabolic activity assay (FDA method) was used to evaluate the microbiological activity of the filter bed. The test is fast, simple and inexpensive, so it can be an effective tool in the routine control of biodegradation of organic matter in biofilter beds.

## 2. Materials and methods

The research was carried out on the full scale Water Treatment Plant. Treated water is characterized by a high content of organic pollutants. In order to eliminate them from water and ensure the biological stability of water in the water supply network, in January 2015 a second stage of water treatment was launched, based on integrated ozonation and filtration through carbon filter beds. Every month between January and May 2016, water and a filter bed samples were collected from four activated carbon carbon filters operating in the same technological line of WTP. The filtration velocity varied between 2.5 to 3.0 m/h, contact time varied between 40 to 48 min.

### 2.1. Drinking water treatment plant and characteristics of GAC filters

The Water Treatment Plant (WTP) is supplied with a mixture of groundwater and infiltration water. Maximum capacity of water production is 150 000 $m^3$/d. The treatment technology is based on typical technological processes such as aeration, Iº filtration through anthracite-quartz filter bed, chemical oxidation with ozone, IIº filtration through activated carbon filter bed and disinfection. Aeration and simultaneous degassing of water takes place in system of 30 cascades. The aerated water flows into the reaction chambers located under the cascades and then into the IIº reaction chambers, where, in a situation of deterioration of water quality, there is a possibility of dosing powdered activated carbon (PAC). Another technological process is the chemical oxidation with ozone. Gas ozone is produced from technical oxygen in three ozonators and is dosed into the water. Static mixers placed in water pipes provide complete mixing of water with ozone. The required contact time of water with ozone is provided by labyrinth reaction chambers. After the ozonation process, the water is degassed and then the water is pumped into the carbon filters building. The carbon filters building consists of 24 filter chambers, each filled with 2 m of active carbon, the filtration area of one

filter is equal to 39.33 $m^2$. The filtration chambers are filled with WG-12 activated carbon (manufacturer: Gryfskand Sp. z o.o., Hajnówka, Poland) made of special, low-ash coal, connected by a binder and activated by water vapor (iodine quantity 1,100 mg/g, methylene blue adsorption 30 g/100 g; total surface area B.E.T 1,100 $m^2$/g; particle size 1.5-0.75 mm). The maximum hydraulic load of filtration equals 9.0 $m^3/m^2 \cdot h$. Carbon beds are backwashed every 24 days with both air and water. Filter water backwashing intensity is equal to 35-50 $m^3/m^2 \cdot h$, air backwashing intensity is equal to 60 $m^3/m^2 \cdot h$. The backwash water is drained by the wash troughs. Each filter chamber has 3 backwash troughs. The filter chambers were equipped with a panel underdrain system which enabled the filter chambers to be filled without the gravel bed (Pruss et al., 2011). Because of the restrictions for carbon filters, the chambers are separated from the rest of the water treatment plant.

Before the treated water flows to the water distribution system it is disinfected. Disinfection is carried out with chlorine dioxide in the suction piping and with sodium hypochlorite in discharge piping. Carbon filter exploited on the analyzed WTP were first launched in January 2015. In the initial phase of their exploitation efficiency of organic matter removal from treated water was high and process of chemisorption was dominating. Over time, the effectiveness of the TOC removal gradually decreased until it stabilized. By the end of March 2015, the biosorption process began.

A detailed description of the WTP is presented in earlier publications (Kołaski et al., 2017; Kołaski et al., 2018; Wołowiec et al., 2019).

The scheme of the Water Treatment Plant was presented in Figure 1.

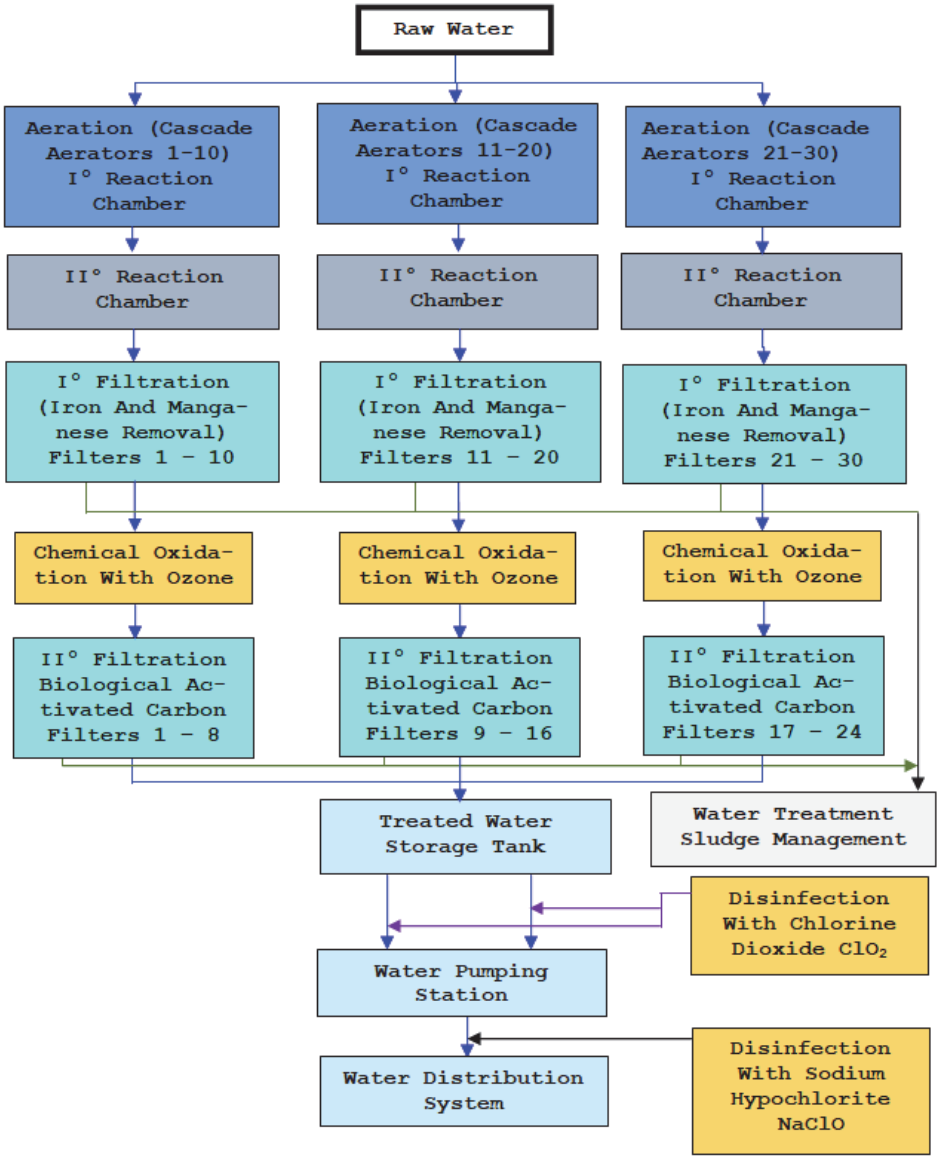


**Fig. 1.** The scheme of the Water Treatment Plant

### 2.2. Sampling

Granular activated carbon samples were collected from five specific sampling points on the bed surface – three points located along the filter side and two points between the wash troughs. Figure 2 illustrates the location of the bed sampling points.

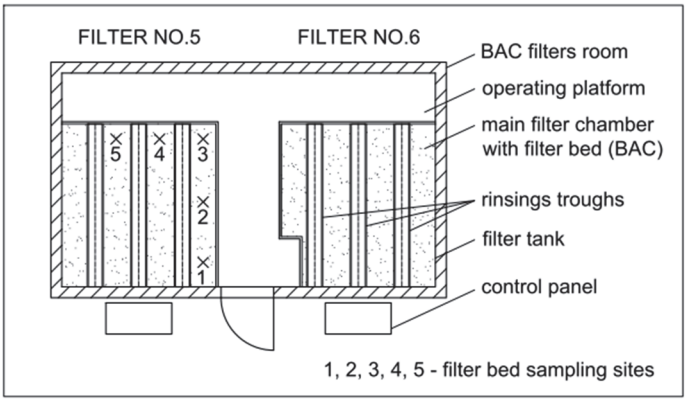


**Fig. 2.** Location of the sampling points: 1-5 – filter bed sampling points

### 2.3. Water and filter bed analyses

Water samples were collected directly from above the filter bed and from the outflow from the filter. In these samples pH, dissolved oxygen concentration, temperature and total alkalinity were determined directly after the samples had been collected. After transporting samples to the laboratory, the total organic carbon, oxygen consumption, microbial activity and total bacteria count at 22 °C were determined. The collected bed samples were shaken for 30 min. in 100 ml of sterile water. Water was then inoculated and to determine the number of bacteria per gram of dry matter of the filter bed, the shaken bed was placed in a dryer it's weight was measured. The number of psychrophilic bacteria was determined after their deep inoculation and growth on enriched agar (HPC method) and the metabolic activity of biomass was measured by the FDA method (Leszczyńska & Oleszkiewicz 1996; Kijowska et al., 2001, Mądrecka et al. 2018). The HPC method is a basic and relatively simple method of determining the number of heterotrophic microorganisms. In practice, when examining the microbial activity of bed-settling bacteria, the most commonly determined factor is the total number of microorganisms incubated at 22°C for 72 hours or saprotrophic psychrophilic bacteria. The precise method of the determination of psychrophilic bacteria in drinking water is described in Polish standard no. PN-EN ISO 6222:2004.

The FDA is a not fluorescent compound, but as it penetrates through the cell membrane and reaches the esterase it is converted to fluorescein. Fluorescein remains inside the cells, which is used to analyze the amount of live cells present in the sample. Flueorescein is rapidly removed from dead cells, making them colorless in the microscopic image (Battin, 1997; Breeuwer & Abee, 2000; Adam & Duncan, 2001; Green et al., 2006).

Samples of the filter bed weighing approximately 2 g were put into a 250 mL volumetric flask filled with sterile water (prepared in advance) and then placed in a shaker for 30 minutes. Afterwards, the liquid formed as a result of shaking was collected from above the filter bed grains. The 3 mL of slurry was pipetted and poured into a cuvette. Just before the measurement, 120 μL of fluorescein diacetate in acetone (FDA) was added. Each sample was stirred and placed in a fluorimeter for 10 minutes.

The assay used the LS 55 Luminescence Spectrometer from Perkin and the FL WinLab program for visualization and interpretation of results. In order to identify microorganisms colonizing the upper layers of biologically active filer (BAF) bed, water and filter bed samples were diagnosed with biochemical diagnostic automated system Vitek 2 Compact (bioMerieux).

## 3. Results and discussion

Selected parameters of the raw water are presented in Table 1.

Water flowing into the carbon filters were pH equal to 7.3-7.5, dissolved oxygen concentration 10.53-11.43 mg $O_2/dm^3$, temperature 9.4-13.5°C, total alkalinity 96-278 mg $CaCO_3$ / $dm^3$ and TOC 3.5-4.1 mg $C/dm^3$.

**Table 1.** Quality parameters and concentrations found in the raw water

| Parameter | Unit | Range | Average value | Standard deviation |
|---|---|---|---|---|
| Temperature | °C | 7.6-13.0 | 10.85 | 0.424 |
| pH | - | 7.2-7.5 | 7.271 | 0.075 |
| Total alkalinity | mg $CaCO_3/dm^3$ | 195-245 | 219 | 12 |
| TOC | mg $C/dm^3$ | 3.9-4.8 | 4.29 | 0.283 |
| UV 254 | $cm^{-1}$ | 9.2-14.0 | 10.99 | 0.889 |

Selected parameters of the treated water are presented in Table 2. Treated water fulfilled the requirements for the quality of water intended for human consumption.

**Table 2.** Quality parameters and concentrations found in the treated water

| Parameter | Unit | Range | Average value | Standard deviation |
|---|---|---|---|---|
| Temperature | °C | 8.5-13.0 | 11.629 | 0.778 |
| pH | - | 7.2-7.6 | 7.348 | 0.087 |
| Total alkalinity | mg $CaCO_3/dm^3$ | 190-245 | 4.281 | 0.141 |
| TOC | mg $C/dm^3$ | 3.1-4.8 | 3.623 | 0.354 |
| UV 254 | $cm^{-1}$ | 4.7-7.5 | 5.920 | 1.273 |

Figure 3 shows both the change in the concentration of TOC which is a measure of the organic compounds concentration in water, directly above the filter bed and in filtered water, and the removal efficiency of the TOC in filtration process through a biologically active carbon filter bed. The concentration of TOC in the outflow water from the filters varied over time. In January, the TOC removal efficiency for individual filters was almost the same and was equal to 13% for filter 5 and 14% respectively for filters 6, 7 and 8. Exactly 0.5 mg C/ $dm^3$ was removed during the filtration process on each filter. The concentration of TOC in water inflow from the filters was equal to 3.6-3.9 mg $C/dm^3$, and 3.1-3.4 mg C/ $dm^3$ in outflow water. In February, the removal efficiency varied from 14 to 19%. With the highest efficiency the TOC was removed on filter 5, with the lowest on filter 8. The filtration removed between 0.5-0.7 mg $C/dm^3$ respectively for filters 8 and 5. The concentration of TOC in water entering filters varied from 3.5 to 3.7 mg $C/dm^3$ and was equal to 3.0 mg $C/dm^3$ in the effluent. In March, TOC was removed from treated water with efficiency of 16-21%, respectively for filters 6, 7 and 5, which equals a 0.6-0.8 mg $C/dm^3$ decrease in TOC concentration. The concentration of TOC in the water entering filters was 3.8-3.9 mg $C/dm^3$ and 3.1-3.2 mg $C/dm^3$ in effluent. In May, the TOC was removed with the largest ever registered efficiency. The TOC removal efficiency varied from 23 to 27%, respectively for filters 6, 8 and 7. 0.9-1.1 mg $C/dm^3$ was removed from water in the filtration process. The TOC concentration in water entering filters was equal to 4.0-4.1 mg $C/dm^3$ and 3.0-3.1 mg $C/dm^3$ in the filtered water. The longer the filters have been operating the more effectively the TOC was removed from treated water. During the study, the TOC removal efficiency was variable and ranged from 13 to 27%. These values are equal to respectively a 0.5 mg $C/dm^3$ decrease for the January analysis for filter 5 and 1.1 mg $C/dm^3$ for analysis carried out in May for filter No. 7. All filters removed the TOC with comparable efficiency, which was dependent on total filter operating time. There was no relation between the concentration of TOC in the water

entering the filters and the operating time of the filters since the last flushing and the removal efficiency of the TOC.

All tested filters worked with similar efficiency despite significant differences in microbial activity and microbiological analyzes. It was probably due to the fractions of organic matter entering the carbon filters. Biodegradable organic carbon, despite the ozonation process, was only a small fraction of organic matter, which was successfully removed by biodegradation even by small numbers of bacteria.

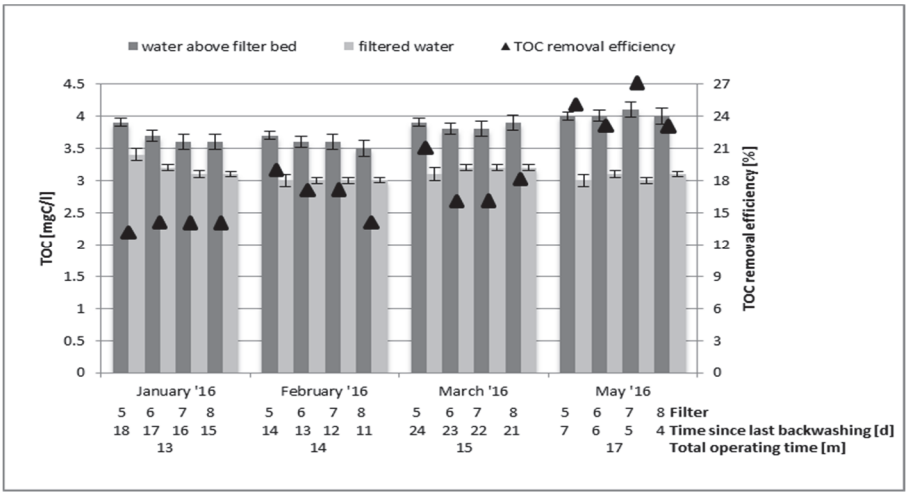


**Fig. 3.** TOC concentration in water entering the filters and in effluent – BACF exploited on WTP

Table 3 shows the total number of bacteria in the surface layer of the filter beds of filters 5, 6, 7 and 8. In none of the sampling points there were favorable conditions for the development of microorganisms than in any other sampling point. The number of microorganisms per gram dry weight of the filter bed varied from 5760 to 1106072 cfu/gdw. The minimum value was observed in May for point 1 in filter 8, while the maximum was observed in February for point 5 in filter 7. The decrease in total organic carbon concentration during filtration process was neither dependent on the time of filters operation since the last backwashig or on the number of bacteria colonizing the filter beds.

**Table 3.** Total number of psychrophilic bacteria colonizing the surface layer of filter bed

| Filter | Sampling points | Total number of psychrophilic bacteria [cfu/gdw] | | | |
|---|---|---|---|---|---|
| | | January | February | March | May |
| 5 | 1 | 497500 | 584200 | 849300 | 13900 |
| | 2 | 718100 | 335800 | 891900 | 22100 |
| | 3 | 69300 | 502100 | 729200 | 36800 |
| | 4 | 451300 | 387800 | 645800 | 10300 |
| | 5 | 186400 | 755200 | 618900 | 25100 |
| 6 | 1 | 3587 | 1133 | 5304 | 214 |
| | 2 | 3888 | 318 | 4733 | 758 |
| | 3 | 4105 | 649 | 5283 | 362 |
| | 4 | 2868 | 268 | 7436 | 589 |
| | 5 | 3074 | 923 | 3539 | 1362 |
| 7 | 1 | 781 | 3249 | 8153 | 216 |
| | 2 | 1061 | 2960 | 4611 | 104 |
| | 3 | 1578 | 4375 | 4631 | 175 |
| | 4 | 1452 | 4518 | 5013 | 133 |
| | 5 | 444 | 11061 | 2398 | 202 |
| 8 | 1 | 944 | 2310 | 5041 | 58 |
| | 2 | 991 | 3694 | 2451 | 95 |
| | 3 | 5158 | 1687 | 4707 | 76 |
| | 4 | 1906 | 1183 | 2540 | 99 |
| | 5 | 1867 | 4540 | 2636 | 69 |

Fig. 4 shows the total number of psychrophilic bacteria in water above the filter bed and in the effluent for filters 5, 6, 7 and 8. It was found that for these filters there is no relation between the operating time since the last backwashing and the total operating time and the number of bacteria present in the water above the filter bed and in the effluent. The number of psychrophilic bacteria in the water above the filter bed in most cases was far greater than in the filtered water. The maximum number of bacteria in the water above the filter bed was equal to 27500 cfu/ml in February for filter 7, while the maximum number of bacteria in the filtered water was 2347 cfu/ml in March for filter 5.

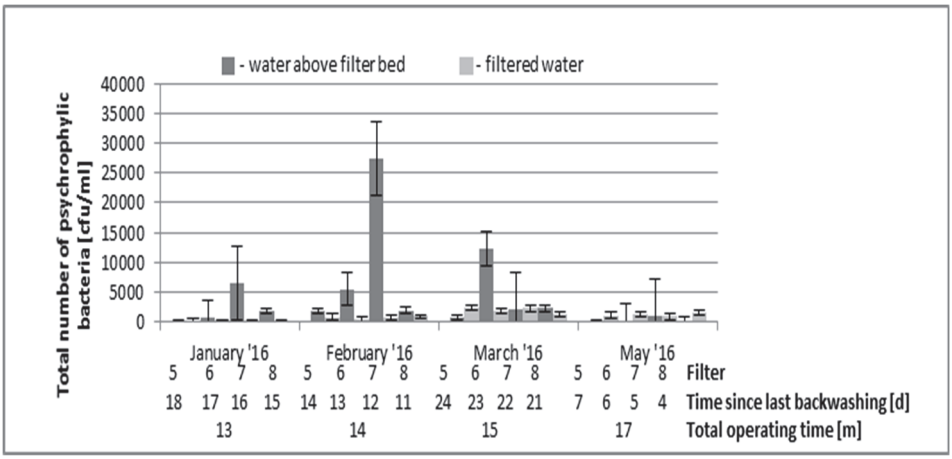


**Fig. 4.** Total number of psychrophilic bacteria in water above the filter bed and in effluent

Table 4 summarizes the results of performed biochemical diagnostics. It has confirmed the presence of species of bacteria such as *Pseudomonas fluorescens*, *Pseudomonas oleovorans, Acinetobacer lwoffi, Aeromonas salmonicida* and *Sphingomonas paucimobilis*. These are bacteria that are characteristic for biologically active carbon filters. *Pseudomonas fluorescens* are Gram-negative bacteria belonging to the genus *Pseudomonas*. They inhabit aquatic and soil environments. Aerobic conditions and temperatures of 25-30°C are optimum for their development. Having the ability to decompose hydrocarbons these bacteria have a significant impact on the biodegradation process of carbon compounds present in water fed to biologically active carbon filters. *Pseudomonas oleovorans* are aerobic Gram-negative bacteria. The optimum for their development is in the range of 35°C. They live in soil and water environments. These are opportunistic pathogens that can cause meningitis and pneumonia. *Acinetobacter lwoffi* is a Gram-negative rod belonging to the genus *Acinetobacter.* Aerobic conditions are optimal for their development. This bacterium is a typical bacterial flora of the skin and esophagus in about 25% of healthy people. It can be source of infections when people have their immunity system impaired. *Aeromonas salmonicida* is a Gram-negative rod living ubiquitously in the aquatic environment. These are optional anaerobes that do not cause infection in humans. *Sphingomonas paucimobilis* is an aerobic Gram-negative rod found in the soil environment. Rarely, people with impaired immunity can suffer non-life-threatening infections caused by *Sphingomonas paucimobilis.*

**Table 4.** Identified microorganisms – BAC exploited on WTP

| Date | Filter | Sampling points | Identified microorganism | Probability % |
|---|---|---|---|---|
| January | 5 | 4 | *Pseudomonas oleovorans* | 95 |
| | 5 | 2 | *Acinetobacter lwoffi* | 96 |
| | 5 | 3 | *Acinetobacter lwoffi* | 96 |
| | 7 | 2 | *Aeromonas salmonicida* | 97 |
| | 7 | effluent | *Pseudomonas fluorescens* | 94 |
| | 7 | water above filter bed | *Pseudomonas fluorescens* | 95 |
| | 7 | water above filter bed | *Aeromonas salmonicida* | 98 |
| | 8 | water above filter bed | *Pseudomonas fluorescens* | 96 |
| February | 5 | 1 | *Sphingomonas paucimobilis* | 98 |
| | 8 | 1 | *Acinetobacter lwoffii* | 96 |
| March | 8 | effluent | *Acinetobacter lwoffii* | 96 |
| | 8 | 2 | *Pseudomonas fluorescens* | 95 |
| | 8 | 4 | *Pseudomonas fluorescens* | 95 |
| April | 5 | 5 | *Pseudomonas fluorescens* | 99 |
| May | 8 | 1 | *Sphingomonas paucimobilis* | 97 |

Table 5 shows the microbial activity of water after shaking the bed samples from the sampling points 1-5 for the filters 5, 6, 7 and 8. The highest microbial activity was registered for samples collected from filter 6 reaching about 1.0 r.u./s for the sampling point 4. The microbial activity recorded for the samples taken from the filters 5, 7 and 8 was close to each other, and their values reached 0.35121-0.65678, 0.327720-0.567940 r.u./s and 0.363000- 0,738545 r.u./s. The microbial activity for the water used for shaking the filter bed samples was significantly higher than the microbial activity for the water samples from above the filter bed and the filtrate.

**Table. 5.** Microbial activity of surface layer of filter bed

| Sampling points | Microbial activity of surface layer of filter bed [r.u./s] | | | |
|---|---|---|---|---|
| | Filter 5 | Filter 6 | Filter 7 | Filter 8 |
| 1 | 0.62959 | 0.775615 | 0.443715 | 0.520615 |
| 2 | 0.60886 | 0.614075 | 0.567940 | 0.738545 |
| 3 | 0.65678 | 0.588585 | 0.530925 | 0.466600 |
| 4 | 0.46200 | 0.998000 | 0.327720 | 0.363130 |
| 5 | 0.35121 | 0.913275 | 0.481550 | 0.363000 |

Table 6 shows the microbial activity of water above the filter bed and filtered water for filters 5, 6, 7 and 8. The microbial activity measured for water above the filter bed significantly (about twice) exceeded the values measured for the filtered water. The microbial activity of the water above the filter bed was equal to 0.012610-0.14615 r.u./s and the microbial activity of filtered water was equal to 0.005675-0.010195 r.u./s. The microbioal activity of the water above the filter bed and filtered water for all filters was comparable, except for the maximum value reached for filter 5.

**Table 6.** Average microbial activity of surface layer of filter bed, water above the filter bed and filtered water

| Filter | Average microbial activity [r.u./s] | | | | | |
|---|---|---|---|---|---|---|
| | Surface layer of filter bed | Standard deviation | Water above the filter bed | Standard deviation | Filtered water | Standard deviation |
| 5 | 0.54169 | 0.1305 | 0.146160 | 0.120945 | 0.005680 | 0.002025 |
| 6 | 0.77791 | 0.1798 | 0.012805 | 0.002015 | 0.006095 | 0.002285 |
| 7 | 0.47037 | 0.0927 | 0.012610 | 0.004300 | 0.008590 | 0.004300 |
| 8 | 0.49038 | 0.1545 | 0.021825 | 0.003025 | 0.010195 | 0.002025 |

Fig. 5-8 shows the correlation between the average microbiological activity and the total number of psychrophilic bacteria in the surface layers of the filter beds analyzed in May. No linear correlation was found between these results.

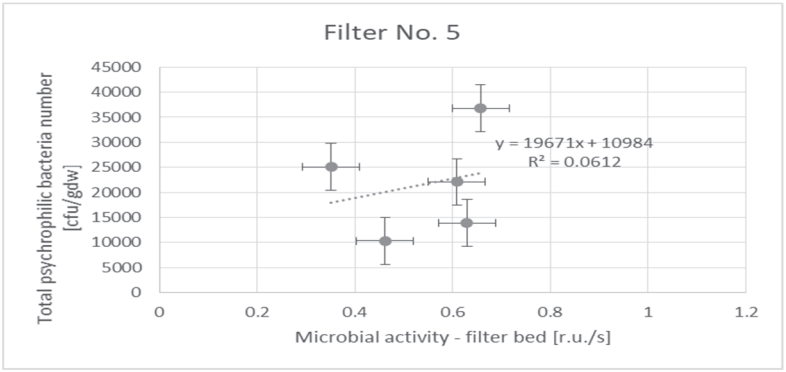


**Fig. 5.** Correlation between total number of psychrophilic bacteria and microbial activity in the Filter no. 5

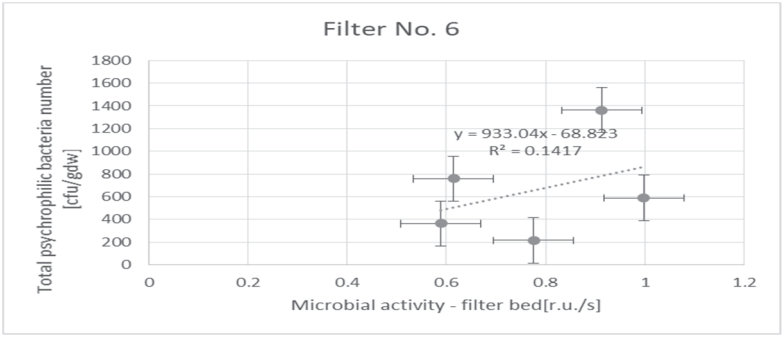


**Fig. 6.** Correlation between total number of psychrophilic bacteria and microbial activity in the Filter no. 6

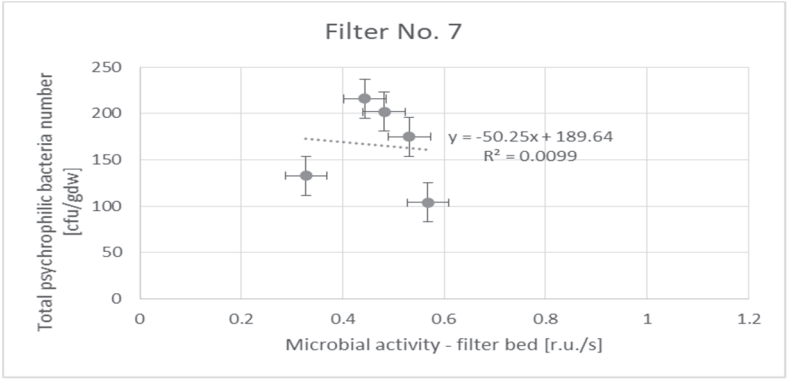


**Fig. 7.** Correlation between total number of psychrophilic bacteria and microbial activity in the Filter no. 7

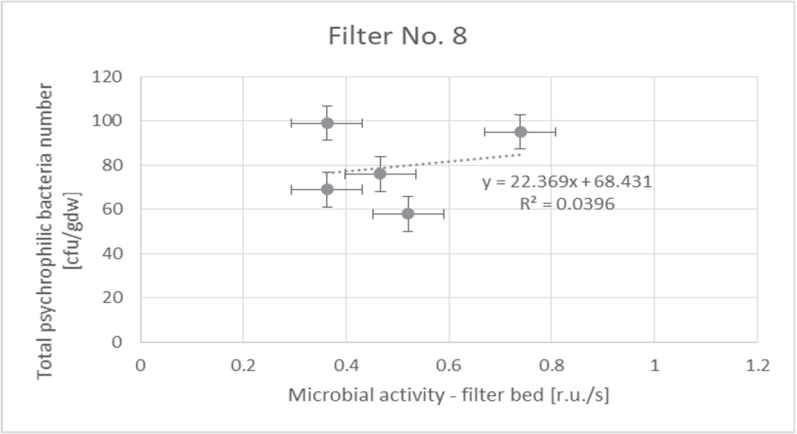


**Fig. 8.** Correlation between total number of psychrophilic bacteria and microbial activity in the Filter no. 8

## 4. Conclusion

Carbon filters operated on a full scale Water Treatment Plant during the study were biologically active. It was confirmed by the decrease in the concentration of total organic carbon and the microbial activity.

Activated carbon filtered bed proved to be very effective for the development of microorganisms. As a result of microbiological identification, it has been proven that filter beds were colonized by species of bacteria such as *Pseudomonas fluorescens, Acinetobacter lwoffii, Aeromonas salmonicida.* These are bacteria that often colonize the beds of biologically active carbon filters. What is more strains of the *Enterobacteriaceae* family which may be hazardous to the health of consumers, especially those with impaired immunity have not been bred.

During the study in the filtration process on biologically active carbon filters, 14-27% of the TOC was removed from treated water. The effectiveness of organic matter removal in this process was neither dependent on the number of bacteria colonizing the upper parts of the filter bed nor the time of filter's operating time since the last backwashing.

The conducted tests did not show a linear correlation between the number of psychrophilic bacteria and microbiological activity of the deposits in all of the analyzed filters.

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## Abstract

The research was carried out on the full scale Water Treatment Plant with maximal capacity of 150 000 $m^3$/d. Treated water is characterized by a high content of organic pollutants. In order to eliminate them from water and ensure the biological stability of water in the water supply network, in January 2015 a second stage of water treatment was launched, based on integrated ozonation and filtration through carbon filter beds. Between January and May 2016, samples of water and a filter bed were collected from four carbon filters and then physicochemical and bacteriological analysis were done. The FDA test and biochemical diagnostics were made to prove the microbiological activity of the filter bed. The studies showed a decrease in the content of organic compounds, meassured as TOC and COD ($KMnO_4$), and the biological activity of the analyzed carbon filters. The carbon filter beds were populated by *Pseudomonas fluorescens, Acinetobacter lwoffii, Aeromonas salmonicida* and *Sphingomonas paucimobilis.* In none of the analyzed filters were found strains

of the *Enterobacteriaceae* family which may have a potential threat to health of the consumers. The application of carbon filters has reduced the organic matter content in treated water.

**Keywords:**
biologically active carbon filters, filtration, full scale technical investigation, identification of microorganisms, organic matter, water treatment

## Usuwanie związków organicznych z wody w procesie biofiltracji – badania w skali technicznej

### Streszczenie

Badania prowadzono w skali technicznej na Stacji Uzdatniania Wody (SUW) o maksymalnej wydajności 150 000 $m^3$/d. Woda dopływająca do SUW charakteryzuje się zawartością specyficznych zanieczyszczeń organicznych. W celu ich eliminacji z wody oraz zapewnienia biologicznej stabilności wody w sieci wodociągowej, w styczniu 2015 r. uruchomiono drugi stopień oczyszczania wody, oparty o zintegrowane procesy ozonowania i filtracji przez złoże węglowe. Co miesiąc, w okresie od stycznia do maja 2016 r., pobierano próbki wody oraz złoża filtracyjnego z czterech filtrów węglowych. Próbki wody pobierano bezpośrednio znad złoża filtracyjnego oraz na odpływie z filtrów. Próbki złoża filtracyjnego pobierano z jego górnej warstwy, w pięciu punktach każdej komory filtracyjnej. Przeprowadzono analizy fizyczno-chemiczne i bakteriologiczne wody oraz złóż filtracyjnych. W celu wykazania aktywności mikrobiologicznej złóż wykonywano test aktywności esteraz z dwuoctanem fluoresceiny FDA. W próbkach wody i węgla aktywnego w celu zidentyfikowania mikroorganizmów prowadzono diagnostykę biochemiczną z wykorzystaniem zautomatyzowanego systemu Vitek 2 Compact (bioMerieux). Przeprowadzone badania wykazały obniżenie zawartości związków organicznych wyrażonych jako OWO i ChZT ($KMnO_4$) oraz biologiczną aktywność analizowanych filtrów węglowych. Złoża filtrów węglowych zasiedlone były przez *Pseudomonas fluorescens, Acinetobacter lwoffii, Aeromonas salmonicida* oraz *Sphingomonas paucimobilis*. W żadnym z analizowanych filtrów nie wyhodowano natomiast szczepów z rodziny *Enterobacteriaceae* stanowiących potencjalne zagrożenie dla zdrowia konsumentów. Wprowadzenie filtrów węglowych do ciągu technologicznego SUW spowodowało obniżenie zawartości materii organicznej w wodzie uzdatnionej.

**Słowa kluczowe:**
biologicznie aktywne filtry węglowe, badania w skali technicznej, filtracja, oczyszczanie wody, związki organiczne, identyfikacja mikroorganizmów