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EVALUATION OF THE QUALITY OF SURFACE WATER IN THE VICINITY OF WASTEWATER TREATMENT PLANTS BASED ON BACTERIOLOGICAL CONTAMINATION

OCENA JAKOŚCI WÓD POWIERZCHNIOWYCH W OKOLICACH OCZYSZCZALNI ŚCIEKÓW NA PODSTAWIE ZANIECZYSZCZENIA BAKTERIOLOGICZNEGO

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Streszczenie. Chociaż rozbudowa kanalizacji i powstające liczne oczyszczalnie ścieków na terenie południowej Polski w sposób istotny wpłynęły na poprawę jakości wód powierzchniowych, eliminując stały i niekontrolowany dopływ zanieczyszczeń z indywidualnych gospodarstw, to jednocześnie same oczyszczalnie mogą być przyczyną lokalnego pogarszania się stanu sanitarnego cieków na odcinkach za zrzutem wód. Celem badań była ocena wpływu ścieków oczyszczonych odprowadzanych z oczyszczalni na jakość mikrobiologiczną i występowanie *Escherichia coli* w wodach rzek. Punkty badawcze zlokalizowano przed lokalnymi oczyszczalniami i za nimi na sześciu rzekach, które są odbiornikami ścieków oczyszczonych: Wisła, Dłubnia Chechło, Minóżka, Krzeszówka i Prądnik. W wodach oznaczano liczebność bakterii mezofilnych i psychrofilnych metodą seryjnych rozcieńczeń oraz liczebność *Escherichia coli* metodą filtracji membranowej. Na podstawie uzyskanych wyników stwierdzono, że dopływ ścieków oczyszczonych znacznie zwiększa liczebność bakterii mezofilnych i psychrofilnych w wodzie, co świadczy o tym, że oczyszczanie nie pozbawia ścieków wszystkich zanieczyszczeń mikrobiologicznych. W próbkach wód pochodzących ze stanowisk zlokalizowanych za oczyszczalniami wykrywano również liczniejsze występowanie *E. coli*. Na stopień zanieczyszczenia wód ściekami miała wpływ wielkość oczyszczalni i objętość rzeki. Przeprowadzone analizy wskazują na konieczność stałego monitorowania pracy oczyszczalni oraz kontroli jakości bakteriologicznej odprowadzanych do wód powierzchniowych oczyszczonych ścieków.

Key words: surface waters, bacteriological contamination, treated wastewater.
Słowa kluczowe: wody powierzchniowe, zanieczyszczenie bakteriologiczne, ścieki oczyszczone.

INTRODUCTION

Poland is among the countries that have a significant deficit of water, and per capita ranks in the final places among European countries (Gutry-Korycka et al. 2014), therefore, the attention to quality, including microbiological, is particularly important for the water resources which the country offers. Surface waters are a source of drinking water for people and animals or are use to irrigate fields, therefore bacteriological contamination, particularly by pathogenic bacteria, can be a health hazard. Microbiological contamination is therefore a one of most important parameter affecting the quality of the water.

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Based on microbiological quality most of surface water (80%) in Poland at the end of the twentieth century was classified as "out of class" and there was no water placed in the first class of purity (Raport… 2006). In the first decade of the twenty-first century, the situation has slightly improved, however, a first-class quality water are a rarity (Raport… 2014).

In the Regulation of the Minister of the Environment (Rozporządzenie Ministra Środowiska z dnia 11 lutego 2004 r.) we find guidance on the classification of surface water to five classes based on bacteriological indicators – coliform bacteria and faecal coliforms – *Escherichia coli*, an indicator is still widely used in the assessment of water. Commonly used criterion for assessing the quality of water is also the total number of mesophilic and psychrophilic bacteria (Libudzisz and Kowal 2000; Chmiel 2013).

Most bacteria are being supplied to waters with sewage because they contain not only faeces, but also food waste and other pollutants (Chełmicki 2013). Most sewage goes now to the treatment, however, the classic methods of purification and sewage treatment plants, which do not undertake any specific disinfection reduce the number of fecal bacteria only by up to 3 orders of magnitude. Since the initial contamination (raw sewage) is very high, faecal bacteria are in huge quantities discharged with purified sewage into the environment (George et al. 2002). Even high-efficient treatment of wastewater, with removal of nutrients (nitrogen and phosphorus) does not provide an effective simultaneous removal of microorganisms because the effectiveness of reducing the number of bacteria in the purification process depends mainly on the amount of bacteria in raw sewage. Treated wastewater discharged into surface waters often contain faecal bacteria in quantities of 10^3 or even 10^5 in 100 cm^3 (Olańczuk-Neyman 2003; Smyłła et al. 2003), which – many times – is the direct reason for the deterioration of the water by inflow of wastewater from sewage treatment (Lewandowska--Robak et al . 2011; Chmiel 2013; Mosteo et al. 2013).

Lesser Poland is one of the highly urbanized areas which have an impact on the environment. Although the construction of sewerage systems and a number of sewage treatment plants has significantly influenced the improvement of water quality by limiting the point input of pollutants, however, the problem of bacteriological contamination of water associated with the inflow of faeces and a wastewater to rivers has not been completely resolved. Surface waters have always been comfortable receivers of wastewater, also now sewage discharge treated wastewater to the rivers. Although their quality is much better than before, but they still may contain contaminants which could not be removed during the purification process and adversely affect the water quality.

Considering the importance of bacteriological pollution of surface waters in the assessment of environmental and health risks of users the aim of this study was to evaluate the impact of treated wastewater discharged from the wastewater treatment plant on the microbiological quality of river waters and the frequency of occurrence of *Escherichia coli* in surface waters.

MATERIAL AND METHODS

Water samples were collected in 12 sampling points located on rivers of varying sizes: the longest in Poland – Wisła, two medium: Dłubnia i Chechło, and small, local streams Minóżka, Krzeszówka and Prądnik which are receivers of effluent from the local wastewater treatments.

Sampling points were located before and after the discharge of sewage was released into the rivers (Table 1). As a result, it was possible to verify the extent to which treatment contribute to the microbiological contamination of watercourses.

Table 1. Water sampling points location
Tabela 1. Lokalizacja punktów pobrania wody

River Rzeka	Sampling points before the treatment Punkty pobrania przed oczyszczalnią	Sampling points by the treatment Punkty pobrania za oczyszczalnią
Wisła	20º09'58.1" E 50º04'72.4" N	20º11'82.4" E 50º04'24.7" N
Dłubnia	19º97'44.1" E 50º20'78.8" N	19º97'42.0" E 50º20'87.0" N
Chechło	19º39'64.9" E 50º12'78.8" N	19º37'73.0" E 50º11'04.8" N
Minożka	19º90'07.0" E 50º24'42.6" N	19º90'10.0" E 50º24'376" N
Krzeszówka	19º63'04.0" E 50º12'65.9" N	19º64'86.2" E 50º12'61.4" N
Prądnik	50º14'75.8" N 19º46'50.0" E	50º14'12.6" N 19º48'94.1" E

In the tested waters there was determined the number of mesophilic and psychrophilic bacteria and evaluated the sanitary condition of the rivers on the basis of the number of indicator bacteria *Escherichia coli.*

Water samples were taken three times in the spring in the two following years as recommended by standards (PN-ISO 5667-6 : 2003; PN-EN ISO 19458 : 2007).

During the sampling water and air temperature was measured. To determine the number of bacteria microbiological quantitative analysis was performed by serial decimal dilutions method on medium TSA – Tryptic Soy Agar (BTL). For for growth of mesophilic bacteria samples were incubated for 24 hours at 37°C and psychrophilic bacteria for 72 hours at 22°C. The number of bacteria is given as CFU · $1cm^{-3}$ (CFU – colony forming units). For determination of *Escherichia coli* number the membrane filtration technique and the serial dilution method were used For quantification was used TBX – Tryptone Bile Agar with X-Glucuronide (Biocorp), a chromogenic medium for the detection of *E. coli*. Colonies were counted after 24 hours incubation at 44°C. To confirm identity randomly selected colonies were isolated in pure cultures and identified by using biochemical test API20E (bioMerieux). Results have been recalculated and presented as CFU · 100 cm^{-3} as recommended (Cabejszek et al. 1960; DzU 2004, no. 32, 284; Pepper and Gerba 2005; PN-EN ISO 8199 : 2010; PN-EN ISO 9308-1 : 1014-12; Chmiel 2013).

RESULTS AND DISCUSSION

Due to protection of water resources, before the introduction of wastewater to the receiver decontamination is necessary. The amount of pollutants should be within the acceptable limits as defined by regulations. As a final step of water purification is used process of self--purification, but to make it effective, river (receiver) can not be charged too much by sewage (Pawlaczyk-Szpilowa 1978).

One of the factors affecting the survival of the bacteria in the water is the temperature, paradoxically in case of *E. coli*, the temperature below 10°C significantly increases the survival of microorganisms, e.g. in temperature 28–30°C survive 10 days but in 4°C about 40 days (Smith et al. 1994; Smyłła 2002; Olańczuk-Neyman 2003). Other available literature data identify the ability of *E. coli* to survive in the environment for about 30–80 days, in favorable conditions (thermal and nutritional) this time can be longer, and in extreme cases re-growth of bacteria can take place (Bordalo et al. 2002; Whitman et al. 2003; Van Elsas et al. 2011).

During the study air and water temperature did not differ significantly regardless of the sampling point location (Fig. 1), so it should be noted that the temperature was not a factor with a significant impact on the differentiation of bacteria number in the period covered by the analysis.

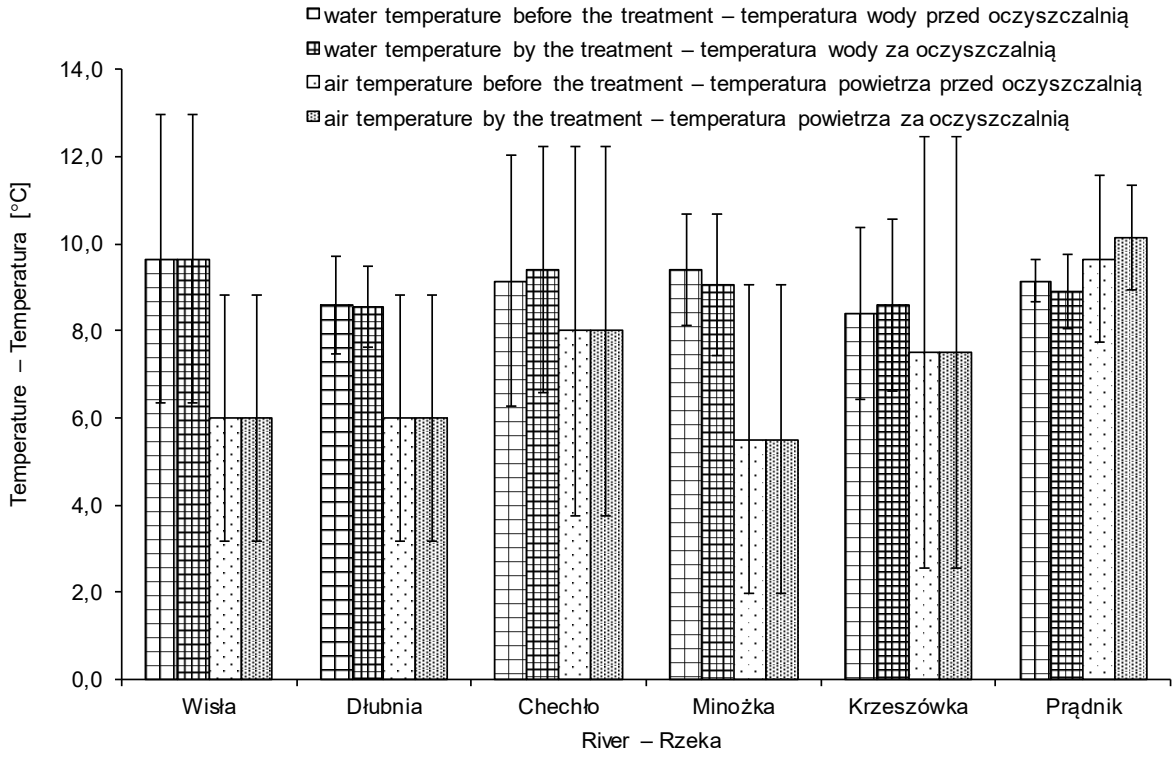

Fig. 1. Mean water and air temperature during sampling
Ryc. 1. Średnia temperatura wody i powietrza w trakcie pobierania próbek

Water contaminated with bacteria, particularly pathogenic species, is not safe for human use or consumption by animals, and often can't be used in industry. Therefore the continuous control of microbiological contamination of various types of water reservoirs, monitoring of wastewater discharge to surface water, and limiting the flow of sewage from illegal sources, is very important.

Municipal management in Małopolskie province, including consumption of drinking water, is based mainly (about 67%) on surface waters, therefore very important is the quality of water and its protection against pollution, especially above intakes.

Water is a very important component of the environment and on the quality and quantity depends both: health and safety of the population, as well as condition of natural environment and the development of many sectors of industry (Burek et al. 2011).

During the past 20 years the quality of water has significantly improved but still the amount of pollutants produced by people is too high to allow self-cleaning of the river (Kundzewicz et al. 2010). According to the Polish Central Statistical Office 94% of the modern sewage treatment plant is currently used by city dwellers but only 37% of rural population (GUS 2015).

Based on the results of analyzes carried out as part of this work, in accordance with the Regulation of the Minister of the Environment (Rozporządzenie Ministra Środowiska z dnia 11 lutego 2004 r.), all investigated rivers in sections before sewage may be classified as 3rd and periodically even as 2nd class water, but by the inflows of sludge from sewage treatment water condition decreases significantly in all rivers (Fig. 2) which makes the purity class change into 4th and in the case of the river Chechło even 5th – water of bad quality, since the amount of *E. coli* exceeds $2 \cdot 10^4$ CFU · 100 cm^{-3}.

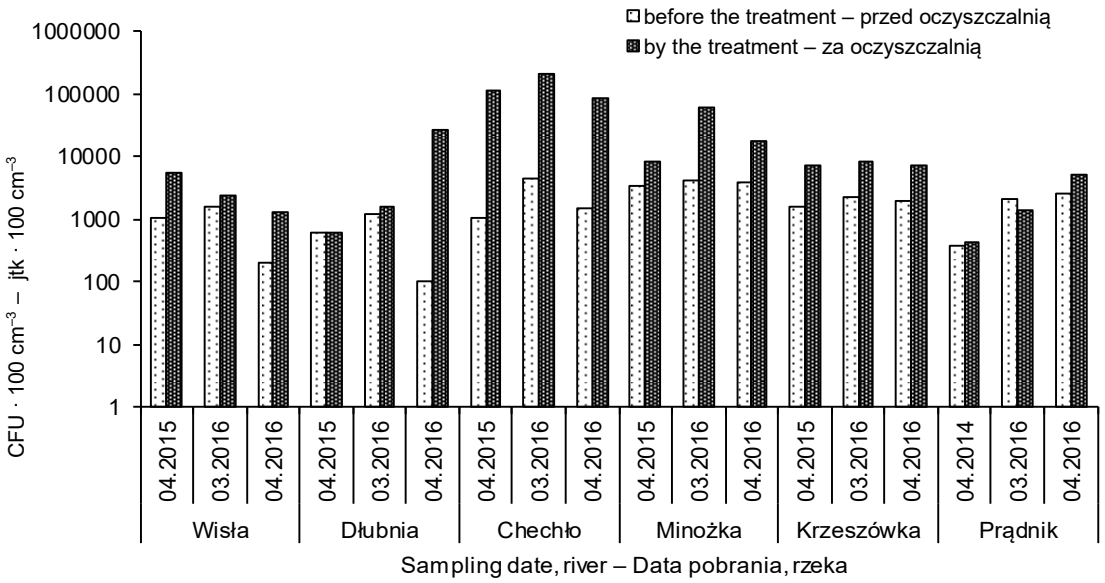

Fig. 2. Number of *Escherichia coli* in examined water samples
Ryc. 2. Liczebność *Escherichia coli* w badanych próbkach wody

The results clearly illustrate the negative impact of the disposal of sewage from wastewater into surface waters. In all the sampling points can be observed an increase of the number of bacteria (mesophilic and psychrophilic) and, above all, the number of *Escherichia coli*, which is the main indicator of faecal pollution.

Lewandowska-Robak et al. (2011) obtained similar results during testing the effect of effluent discharged from the sewage treatment plant in Tuchola on the quality of the water in the stream of Kicz as well as Chmiel (2013) researching the water of the river Prądnik.

Frąk (2010) in her work about bacteriological pollution of the river Biebrza also draws attention to the increase of fecal coliforms as well as proteolytic and ammonifying bacteria in sections of the river where the waste water is discharged. She also observed that the

numbers of *E. coli* can be affected by proximity of rural areas and uncontrolled discharges of municipal wastewater and inflow of pollutants from crop fields or pastures with rainwater.

Taking into account the total number of bacteria (Fig. 3 and Fig. 4) according to the criteria proposed by Cabejszek et al. (1960) water slightly polluted before wastewater treatment plant becomes distinctly contaminated by the inflow of wastewater in all tested rivers and in the case of the river Chechło and Minożka even heavily polluted because number of mesophilic bacteria exceeds $5 \cdot 10^3$ CFU $\cdot$ 1 cm^{-3} and psychrophilic bacteria $1 \cdot 10^4$ CFU $\cdot$ 1 cm^{-3}.

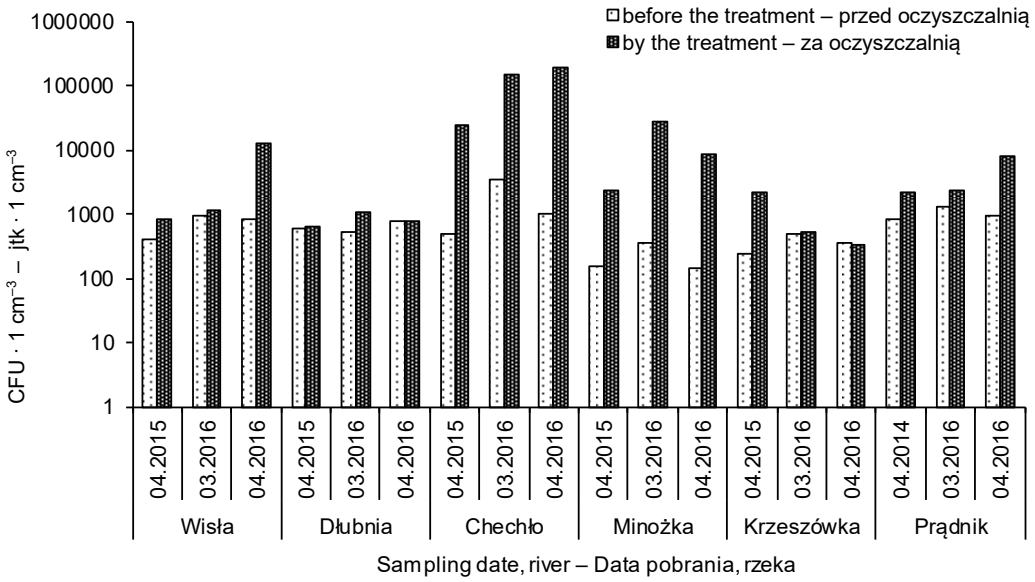

Fig. 3. Number of mesophillic bacteria in examined water samples
Ryc. 3. Liczebność bakterii mezofilnych w badanych próbkach wody

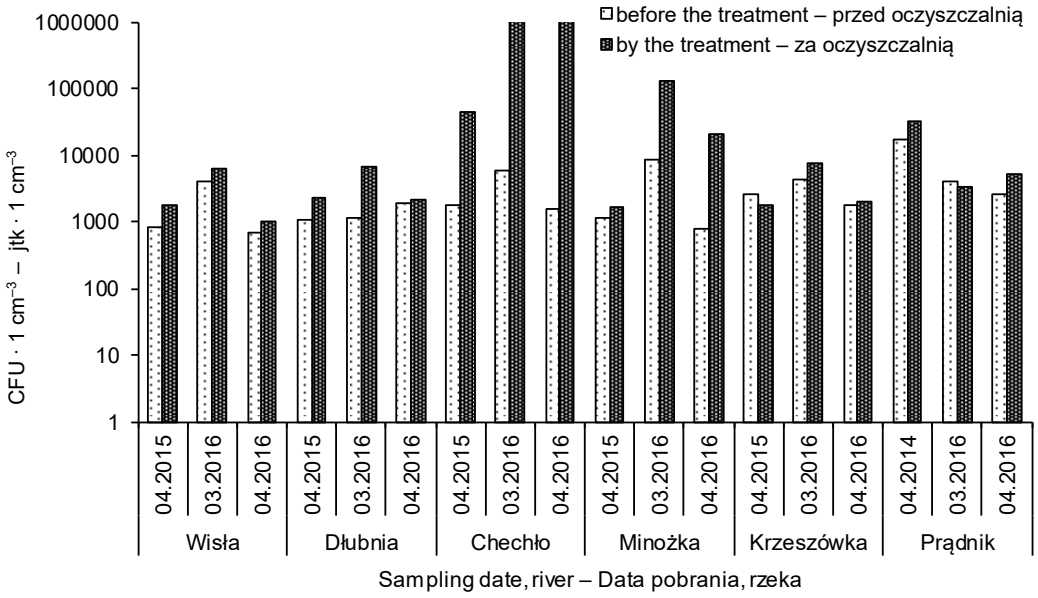

Fig. 4. Number of psychrophillic bacteria in examined water samples
Ryc. 4. Liczebność bakterii psychrofilnych w badanych próbkach wody

It is alarming that in some cases the bacteriological contamination of water by sewage treatment plants increase by several hundred or even tens of thousands percent (Fig. 5), suggesting that treatment plants which discharge water into the rivers Chechło and Minożka likely are not able to meet the requirements of normative and discharge pollutants unduly burdening small watercourses.

Although to the river Wisła where effluent is discharged from two sewage treatment facilities (Kujawy and Płaszów) the microbiological quality of the water is not so drastically deteriorated as in the two previously mentioned cases – most likely in a large volume of river water effluents are diluted or treatment plants work more efficiently.

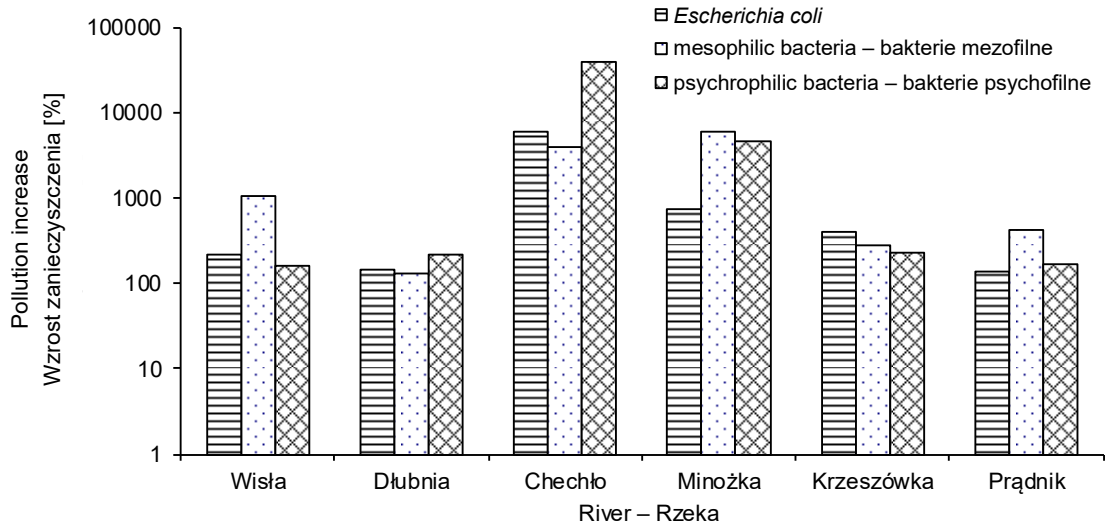

Fig. 5. Mean percentage bacteriological pollution increase as a result of discharg of treated sewage
Ryc. 5. Średni procentowy wzrost zanieczyszczenia bakteriologicznego w wyniku zrzutu ścieków oczyszczonych

These results suggest that the degree of surface water pollution by waste water discharged from the plant may be affected by the volume of the receiver (e.g. Wisła) and the volume of processed waste water – the size of the sewage: the small treatment did not cause significant contamination of Dłubnia river, but in the case of the river Chechło, which is a receiver of waste water from a large sewage treatment plant, fed about 15 000 m^3 of wastewater per day, from Chrzanow, Trzebinia and many other surrounding places, pollution increase is much higher comparing to other examined rivers.

CONCLUSIONS

Inflow of water from sewage treatment did not cause changes in water temperature, however, the water samples from the sampling points located by wastewater treatment were found significantly more polluted by bacteria which indicates that the treatment plants are important sources of microbiological contamination.

The analysis allowed to assign the water of most rivers in sites located before wastewater treatment plants to 3rd quality class, but by the inflows of sewage only to 4th or even 5th class.

The degree of water pollution by sewage was affected by the size of treatment plant and volume of the of the river – receiver.

Results suggest the need for constant monitoring of plant operation and more precise control of the bacteriological quality of treated wastewater discharged into surface waters.

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Abstract. Although the extension of canalization and the building of numerous sewage treatment plants in southern Poland significantly affected the water quality by eliminating the constant and uncontrolled inflow of pollutants from individual farms, it is also the same treatment that can cause local deterioration of the watercourses sanitary state in sections after the discharge of water from the treatment plant. The aim of this study was to evaluate the effect of effluent discharged from sewage treatment on the microbiological quality and the presence of *Escherichia coli* in the waters of the rivers. Sampling points were located upstream and downstream of discharge on 6 rivers: Wisła, Dłubnia i Chechło, Minóżka, Krzeszówka and Prądnik which are receivers of effluent from the local wastewater treatments. In the tested watercourses the number of mesophilic and psychrophilic bacteria was determined by serial dilution method as well as the presence of Escherichia coli by membrane filtration method. The results show that the flow of wastewater greatly increases the number of bacteria in the water which indicates that the purification of waste water does not eliminate all of the microbial contaminants. In water samples from the sampling points located by sewage the presence of numerous *E. coli* was also confirmed. The size of wastewater and the volume of the river had an impact on the degree of microbiological water pollution. The analysis indicate the need for continuous monitoring of plant operation and control of the bacteriological quality of wastewater discharged into surface waters.