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Effects of precipitation on the amount and quality of raw sewage entering a sewage treatment plant in Wodzisław Śląski

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Abstract

The study presents the effects of precipitation on the amount and quality of raw sewage entering a sewage treatment plant in Wodzisław Śląski. It covers a six-year period between January 2010 and December 2015. The research period was divided into seven classes of precipitation intensity. The classes were characterized for their basic descriptive statistics of the raw sewage entering the investigated sewage treatment plant (STP). Data obtained from the collected material and derived from an analysis indicated a considerable influence of precipitation on the amount of sewage entering the investigated facility. Mean amount of sewage entering the STP was by 10.5% (884.9 $m^3 \cdot d^{-1}$) greater in B class and by 69.6% (6,153.9 $m^3 \cdot d^{-1}$) greater in G class than during dry weather.

Individual classes of precipitation intensity were compared for their mean values of raw sewage contamination. Precipitation intensity was found to significantly affect concentrations of the investigated parameters of raw sewage contamination.

Basic parameters of sewage contamination (BOD_5, COD_{Cr}, total suspended solids) were determined and their basic descriptive statistics, such as median, mean, minimum and maximum value, standard deviation and coefficient of variation were calculated.

Key words: *accidental waters, domestic sewage, sewage quality, precipitation*

INTRODUCTION

Human settlements generate sewage that is discharged via sewerage system into a collective sewage treatment plant (STP). Currently, the most popular approach is a construction of separate sewage system with domestic sewage and precipitation water discharged separately. The sewerage network is well developed all around Poland but precipitation drainage system is present mainly in large cities. Sanitary sewage system is often penetrated by accidental and infiltration water [KACZOR 2012]. This is unfavorable from a sewage-treatment plant perspective, as this water negatively affects wastewater treatment. The supply of accidental and infiltration water generates also additional pumping-related costs. Infiltration water may enter a leaky sewerage system in areas with high level of groundwater, while accidental water is precipitation water that penetrates into the sewerage system. It is important to limit the amount of accidental water as much as possible. Proper dimensioning of the sewerage network depends primarily on correct determination of water demand [BERGEL, PAWEŁEK 2005; CHOTKOWSKI, LIS 2006]. Overload or underload of a sewage treatment plant may adversely affect wastewater treatment processes, and thus deteriorate the quality of treated discharged into a receiver. Increased amount of sewage entering a treatment plant may be also due to other factors, such as mechanical damage or leaks in the sewerage pipes that carry on infiltration waters [KACZOR 2009; KACZOR, PRZEBINDA 2009]. In extreme cases, the water entering the sewerage system from outside the pipes may cause even fivefold increase in average daily sewage admission [KACZOR, PAWEŁEK 1999]. The aim of the research was to analyse the collected material and determine how the precipitation water shapes the amount of raw sewage entering the sewage treatment plant Wodzisław Śląski. The study was conducted in the years 2010–2015. The analysis was based on daily supply of raw sewage and included basic descriptive statistics of sewage supply. It also determined the effects of precipitation on the amount of sewage supplied to the investigated facility. Finally, mean values of the indicators of raw sewage contamination for the assumed classes of precipitation intensity were provided.

DESCRIPTION OF THE STUDY OBJECT

The investigated sewage-treatment plant is located in Wodzisław Śląski, Wodzisław district, Silesian province (Fig. 1).

Technological system of the devices included in the sewage treatment plant in Wodzisław Śląski is shown in Figure 2.

According to a report of the National Programme for Municipal Waste Water Treatment [MŚ 2003] the actual number of inhabitants in Wodzisław Śląski urban agglomeration is 59,325; of which 56,125 (94.6%) are connected to a sewerage system. There are 285 on-site sewage treatment facilities in the agglomeration that treat domestic sewage for 1,140 inhabitants. The sewerage network is 313.4 km long, of which 300.2 km (95.8%) account for a sanitary sewage system, and the remaining 13.2 km constitute a combined sewage system. The urban agglomeration generates 3,614.9 thousand m^3 of municipal sewage per year. The design capacity of the investigated sewage treatment plant is 15,000 $m^3 \cdot d^{-1}$. Total population equivalent is 93,649; of which 11,906 is industry-related population equivalent. This is complemented by the number of inhabitants served by the sewerage system The sewerage system includes the town of Wodzisław Śląski and municipalities such as: Marklowice, Radlin and partly the Gorzyce municipality. The STP is supplied with municipal sewage that is a mixture of domestic and household sewage, rainwater, and industrial sewage. In addition, it is a collecting point for the sewage delivered by vacuum trucks from non-sewered areas. According to the Water Quality Impact Assessment of 2008, the share of accidental water is 20%. Hydraulic loads for specific conditions are presented in Table 1.

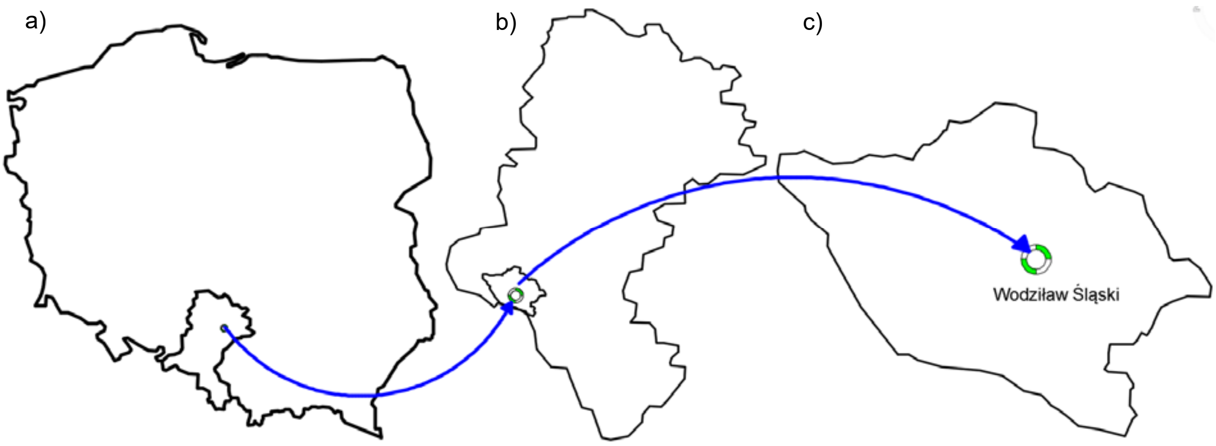

Fig. 1. The facility location in Poland (a), Silesian province (b), Wodzisław district (c); source: own elaboration

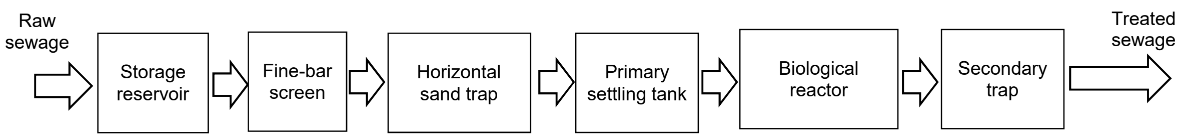

Fig. 2. Simplified flow chart for the sewage treatment plant in Wodzisław Śląski; source: own elaboration

Table 1. Maximum permissible amount of sewage entering the sewage treatment plant

Parameter	Symbol	Unit	Value
Mean daily sewage supply for dry weather	$Q_{d\acute{s}r}$	$m^3 \cdot d^{-1}$	15,000
Maximum hourly sewage supply for dry weather	$Q_{h\max}$	$m^3 \cdot h^{-1}$	1,438
Maximum sewage supply to a pump house for rainy weather	$Q_{d\text{pomp}}$	$m^3 \cdot h^{-1}$	3,169
Maximum sewage supply to mechanical devices for rainy weather	$Q_{d\text{mech}}$	$m^3 \cdot h^{-1}$	2,641
Maximum sewage supply to biological devices for rainy weather	$Q_{d\text{biol}}$	$m^3 \cdot h^{-1}$	2,042

Source: own elaboration based on PWiK [2008].

MATERIALS AND METHODS

The study period covered the years 2010–2015. The days of the study period were divided into seven classes depending on precipitation intensity:

- group A – no precipitation (N = 1,216 number of samples),
- group B – precipitation below 5 $mm \cdot d^{-1}$ (N = 581),
- group C – precipitation between 5 $mm \cdot d^{-1}$ and 10 $mm \cdot d^{-1}$ (N = 110),
- group D – precipitation between 10 $mm \cdot d^{-1}$ and 15 $mm \cdot d^{-1}$ (N = 32),
- group E – precipitation between 15 $mm \cdot d^{-1}$ and 20 $mm \cdot d^{-1}$ (N = 11),
- group F – precipitation between 20 $mm \cdot d^{-1}$ and 25 $mm \cdot d^{-1}$ (N = 8),
- group G – precipitation exceeding 25 $mm \cdot d^{-1}$ (N = 19).

Rainwater enters the separate sewer system mainly as a result of illegal connections of roof gutters to the sewer wells (accidental water). Thus, a small precipitation may generate outflow from the roof slopes to the sewerage systems by illegal connections. Interviews conducted directly in the field indicated that this is a common practice among the sewerage system users. The outflow coefficient for the roof slopes is close to 1.0 so days with no precipitation were adopted as group "A". Then, the groups of precipitation intensity were divided by every 5 mm. Such division was made because the distribution of days with precipitation was uneven. Days with no precipitation formed the largest group (group "A" accounted for 61% of cases) and events with precipitation intensity above 25 $mm \cdot d^{-1}$ accounted for only 19 cases, which gives a share of 1%. This solution proved to be effective in another study [CHMIELOWSKI *et al.* 2016a, b]. These classes were used to determine the relationship between sewage supply to the STP in Wodzisław Śląski and precipitation intensity. Basic descriptive statistics were determined for each class. An attempt was made to compute the values of basic indicators of raw sewage contamination for each class of precipitation intensity. Precipitation data collected in Racibórz (rainfall station nearest to the investigated facility) were used to find out mean daily precipitation for individual months in the years 2010–2015. The mean annual sum of precipitation in the multi-year period according to the documents elaborated for Gmina Racibórz for Racibórz is 695 mm [Gmina… 2005; Urząd… 2006]. According to the division proposed by KACZOROWSKA [1962] concerning the annual sum of precipitation in the considered period of the multi-annual period, only the year 2010 was extremely wet (sum of precipitation, 814 mm) while the remaining years were average or dry.

The study focused on the variability in sewage supply to the STP in Wodzisław Śląski. Basic descriptive statistics computed for this parameter were as follows: mean value ($Q_{d\acute{s}r}$), median (M_o), minimum value ($Q_{d\min}$), maximum value ($Q_{d\max}$), standard deviation (σ), coefficient of variation (V_{zm}), range (R_o). Daily mean sewage supply values were compared for individual years, months and week days of 2010–2015 research period. Moreover, mean values of basic indicators of raw sewage contamination (BOD_5, COD_{Cr}, total suspended solids) were determined depending on the intensity of precipitation. The values of sewage contamination indicators were determined once per week. The sewage samples for the analyses were taken according to the standards: PN-74/C-04620-11:1974 and PN-EN ISO 5667-1:2007. On the other hand, physicochemical analyses of sewage contamination indicators were conducted in an accredited laboratory based on the following standards: total suspended solids – the measurements were conducted according to the standard PN-EN 872:2007, BOD_5 – according to the standard PN-EN 1899-1:2002, COD_{Cr} – PN-ISO 6060:2006. Each day of the research period was assigned a precipitation intensity group. The following numbers of physicochemical analyses were assigned to the rainfall intensity groups: A – 133, B – 63, C – 11, D – 5, E – 3.

RESULTS AND DISCUSSION

Table 2 contains basic descriptive statistics of sewage supply to the treatment plant in Wodzisław Śląski. Its analysis indicated high variability in sewage supply over the entire research period. Mean sewage supply for the multi-year period 2010–2015 was 9,392.61 $m^3 \cdot d^{-1}$ and accounted for 62.6% of the design supply ($Q_{\acute{s}rd}$ = 15,000 $m^3 \cdot d^{-1}$). Therefore, the STP may operate at much higher hydraulic load than the present one and consequently the existing sewerage system may be expanded and new users may be connected. Hydraulic underload is a common issue reported by many authors [BUGAJSKI 2009; BUGAJSKI, ŚLIZOWSKI 2006; MŁYŃSKI *et al.* 2016].

The greatest mean daily supply was recorded for 2013 (10,050.1 $m^3 \cdot d^{-1}$) and the smallest for 2011 (8,970.02 $m^3 \cdot d^{-1}$). Maximum daily sewage supply was observed in 2010. The reason for such high values was intense rainfalls that between May and August

Table 2. Basic descriptive statistics for sewage supply to the STP in Wodzisław Śląski

Parameter			Parameter value in individual years						
name	symbol	unit	2010	2011	2012	2013	2014	2015	2010–2015
Max. daily supply	Q_{dmax}	$m^3 \cdot d^{-1}$	45,455.10	19,411.00	19,172.40	29,173.00	16,164.40	17,209.50	45,455.10
Mean daily supply	$Q_{dśr}$	$m^3 \cdot d^{-1}$	9,972.20	8,970.02	9,121.67	10,050.13	9,291.42	9,079.29	9,392.61
Min. daily supply	Q_{dmin}	$m^3 \cdot d^{-1}$	5,029.10	5,371.20	6,151.90	6,076.90	6,489.90	5,528.10	5,029.10
Standard deviation	s	$m^3 \cdot d^{-1}$	3,887.76	1,786.45	2,034.46	2,277.95	1,582.30	1,449.42	2,269.48
Coefficient of variation	V_s	–	0.39	0.20	0.22	0.23	0.17	0.16	0.24
Median	M_o	$m^3 \cdot d^{-1}$	9,027.00	8,521.40	8,635.45	9,489.40	8,980.10	8,785.65	8,917.00
Range	R	$m^3 \cdot d^{-1}$	40,426.00	14,039.80	13,020.50	23,096.10	9,674.50	11,681.40	40,426.00
Max. peaking factor	N_{dmax}	–	4.56	2.16	2.10	2.90	1.74	1.90	4.84
Min. peaking factor	N_{dmin}	–	0.50	0.60	0.67	0.60	0.70	0.61	0.54
Number of samples	N	items	271.00	365.00	360.00	364.00	364.00	344.00	2,068.00

Source: own elaboration.

2010 caused a number of consecutive floods. Exceptionally low values of sewage supply (5,029.1 $m^3 \cdot d^{-1}$) were observed in the years 2010–2015 during dry weather. High variability of sewage supply to the investigated facility was manifested by high value of range that for the study period was R = 40,426.0 $m^3 \cdot d^{-1}$. Moreover, sewage supply was analysed for its peaking factor. Maximum peaking factor for the analysed years was 4.84, and it was high as compared with other reports [CHMIELOWSKI *et al*. 2016a; MIERNIK, MŁYŃSKI 2014a, b]. This might be affected by the values from 2010, when the greatest sewage supply was observed.

Table 3 presents basic descriptive statistics of sewage supply in the sewage treatment plant in Wodzisław Śląski depending on the class of precipitation intensity. The collected data demonstrate that increased precipitation intensity was associated with higher mean amount of sewage entering the facility. Graphic interpretation of mean sewage supply to the treatment plant in Wodzisław Śląski for different classes of precipitation intensity is presented in Figure 3.

Table 3. Basic descriptive statistics for sewage supply in the sewage treatment plant in Wodzisław Śląski depending on the class of precipitation intensity

Parameter			Sewage supply for individual classes of precipitation intensity						
name	symbol	unit	group A	group B	group C	group D	group E	group F	group G
Mean daily supply	$Q_{dśr}$	$m^3 \cdot d^{-1}$	8,840.0	9,724.9	11,344.9	11,777.1	13,898.0	14,845.9	14,993.9
Max. daily supply	Q_{dmax}	$m^3 \cdot d^{-1}$	18,857.9	20,009.6	22,966.1	19,020.6	29,173.0	27,747.4	45,455.1
Min. daily supply	Q_{dmin}	$m^3 \cdot d^{-1}$	5,029.1	5,528.1	6,136.4	5,371.2	8,981.6	11,040.5	8,053.9
Standard deviation	s	$m^3 \cdot d^{-1}$	1,503.8	2,096.9	3,072.4	2,708.3	5,993.0	5,409.1	7,907.7
Coefficient of variation	V_s	–	0.17	0.22	0.27	0.23	0.43	0.36	0.53
Median	M_o	$m^3 \cdot d^{-1}$	8,619.4	9,283.1	10,644.2	11,782.8	11,110.1	13,478.7	14,248.6
Range	R	$m^3 \cdot d^{-1}$	13,828.8	14,481.5	16,829.7	13,649.4	20,191.4	16,706.9	37,401.2
Max. peaking factor	N_{dmax}	–	2.13	2.06	2.02	1.62	2.10	1.87	3.03
Min. peaking factor	N_{dmin}	–	0.57	0.57	0.54	0.46	0.65	0.74	0.54
Number of samples	N	items	1,216	581	110	32	11	8	19

Explanations: A–G as in the text (p. 87).
Source: own elaboration.

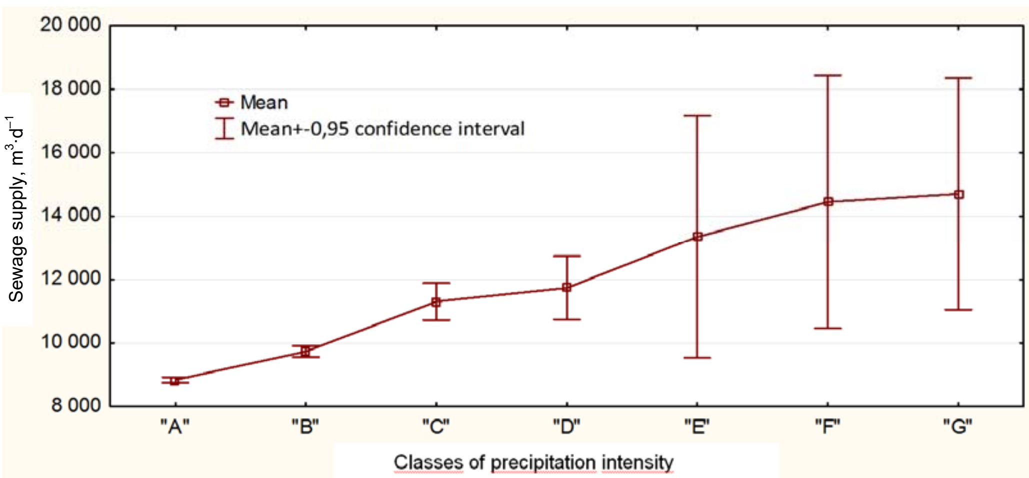

Fig. 3. Mean sewage supply to the sewage treatment plant in Wodzisław Śląski for different classes of precipitation intensity; A–G as in the text (p. 87) source: own study

Classification criteria for individual classes are presented in the methodology chapter. Figure 3 clearly shows growing values of mean sewage supply with increasing rainfall intensity. Mean sewage supply for group A (dry weather) was 8,840 $m^3 \cdot d^{-1}$, while for the last group G with precipitation intensity exceeding 25 $m^3 \cdot d^{-1}$ it was as high as 14,993 $m^3 \cdot d^{-1}$. Therefore, the amount of sewage entering the investigated facility rose by 7,275 $m^3 \cdot d^{-1}$, that is by 69.6% as compared with the supply during dry weather. The number of days without precipitation was 1,216 for the entire study period, which accounted for 56.6% of the investigated multi-year period. Even for the smallest precipitation below 5 $m^3 \cdot d^{-1}$ mean daily sewage supply was by 884 $m^3 \cdot d^{-1}$ (10%) greater than during the rainless days. For the other classes, a considerable increase in sewage supply was observed along with growing precipitation intensity. This demonstrated high sensitivity of the sewerage network to precipitation. It might be to some extent due to the 13 km section of the combined sewage system. However, it only accounts for 5% of total length of the sewerage network. Huge majority of the sewerage system in Wodzisław Śląski is a distribution network that should collect domestic sewage. Such a high supply of precipitation water may indicate illegal connections of roof gutters on the premises belonging to the agglomeration. According to KACZOR *et al.* [2013], accidental water is infiltrated through leaks in the sewerage system or holes in the manholes or is illegally discharged from roof gutter outlets and yard gullies connected to the sanitary sewerage system. The inhabitants should be educated on the management of precipitation water on their premises, which should improve rainfall water retention on the place of its falling and limit the illegal practice of connecting roof gutters to the sanitary sewage system [CHMIELOWSKI *et al.* 2016]. Bearing in mind that growing volume of sewage increases operating costs borne by the sewage treatment plant, the inhabitants should consider alternative ways of retaining the precipitation water on their premises for future use. The amount of sewage entering the sewage treatment plant might be also affected by infiltration water but confirming its influence would require an hourly analysis of sewage supply. Based on this information, the amount of sewage entering the sewage treatment plant at night may be determined, which would help define the percentage value of infiltration water entering the sewerage system.

On the basis of the data presented in Figure 4, slightly higher inflows (by 10%) can be observed in the first half of the year – for the months from January to June – as compared to the second half of the year. The highest sewage supply of 10,507 $m^3 \cdot d^{-1}$ was recorded in May. In the second half of the year, the amount of sewage supplied to the STP gradually decreased and the lowest mean supply was noticed in August. Relatively low amount of raw sewage was supplied in the autumn and winter months (September–December). This is reflected in precipitation height presented in Figure 7. The highest mean daily precipitation of 3.24 $mm \cdot d^{-1}$ was recorded in May and the lowest of 0.52 $mm \cdot d^{-1}$ in February. Similarly as in previous situations, the variability in sewage supply to the STP in Wodzisław Śląski was due to precipitation.

Figure 5 shows mean daily precipitation for the Racibórz station in individual months.

The data on supply allowed us to conclude that sewage supply to the STP in Wodzisław Śląski followed normal distribution, as evidenced by low values of a probability test that did not exceed 0.05. May was identified as the month with the highest value of mean precipitation (3.3 $mm \cdot d^{-1}$). Since May, a systematic reduction in mean value of precipitation was noticed in consecutive months of the year. Similar reduction was observed regarding sewage supply to the investigated facility (Fig. 4).

Based on the data presented in Figure 6, varying values of precipitation in the studied period can be noted. The number of days without precipitation in the analysed period accounted for 61.0%. In contrast, the precipitation above 25 $mm \cdot d^{-1}$ represented only

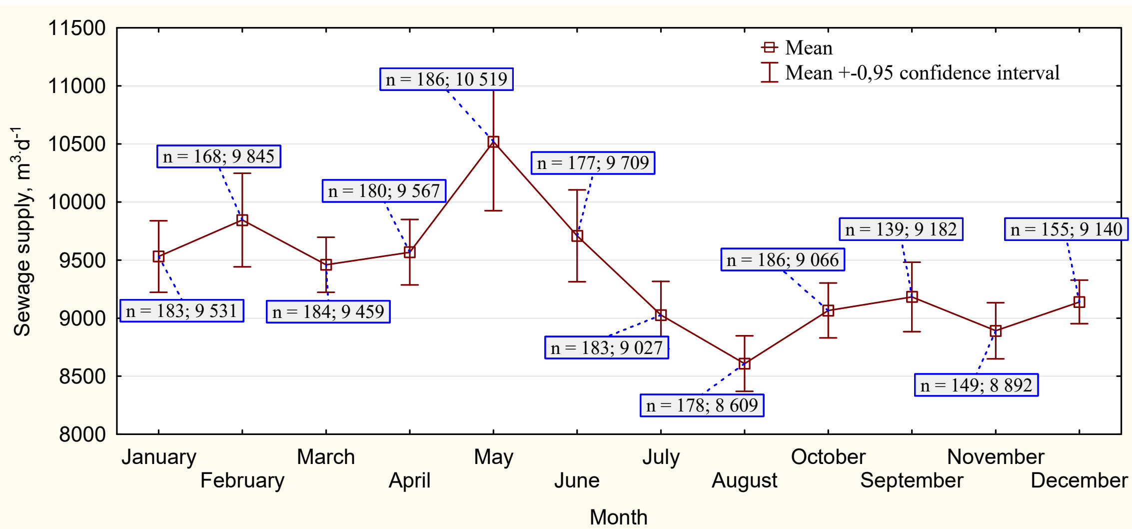

Fig. 4. Mean sewage supply to the sewage treatment plant in Wodzisław Śląski for individual months; source: own study

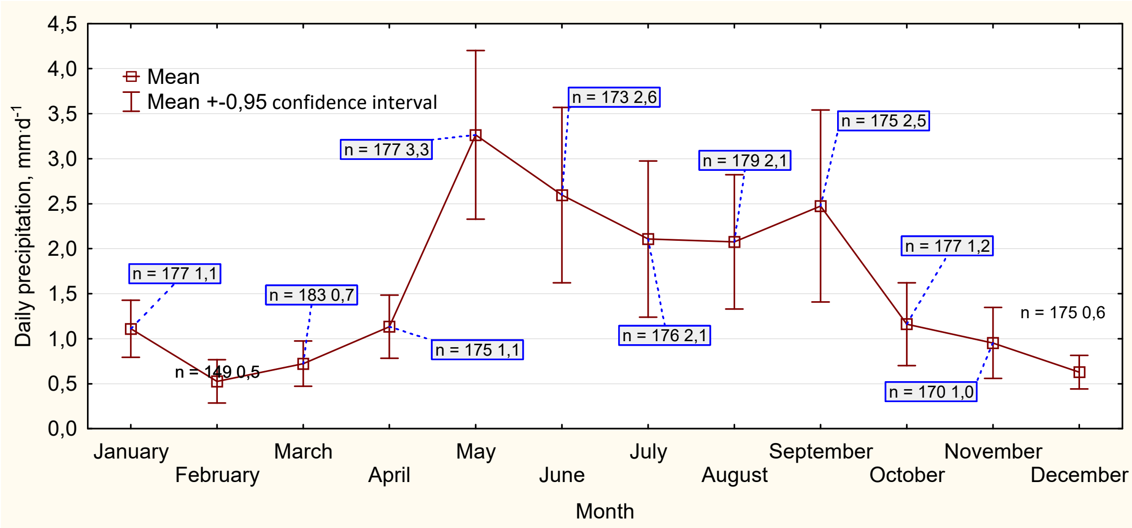

Fig. 5. Mean daily precipitation for the Racibórz station in individual months; source: own study

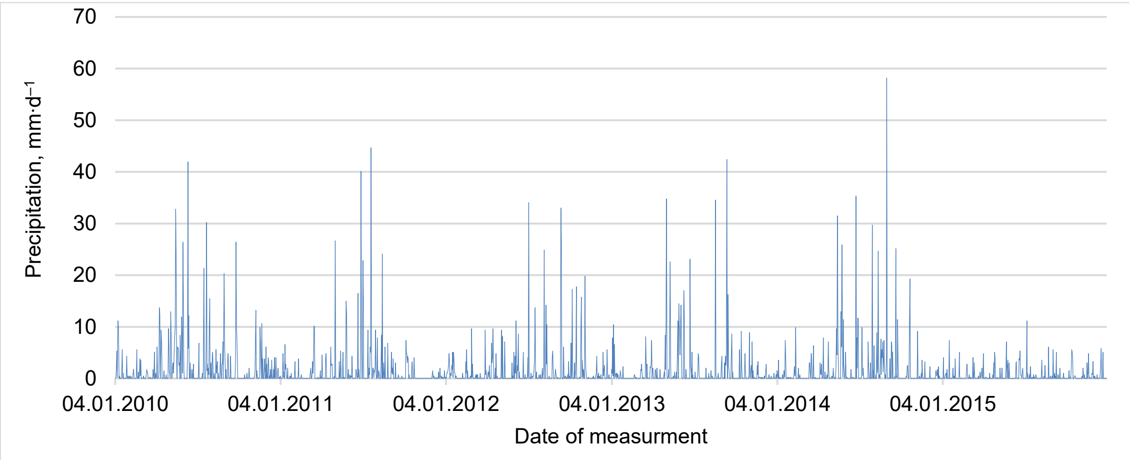

Fig. 6. Summary of daily precipitation for the precipitation station in Racibórz in 2010–2015; source: own study

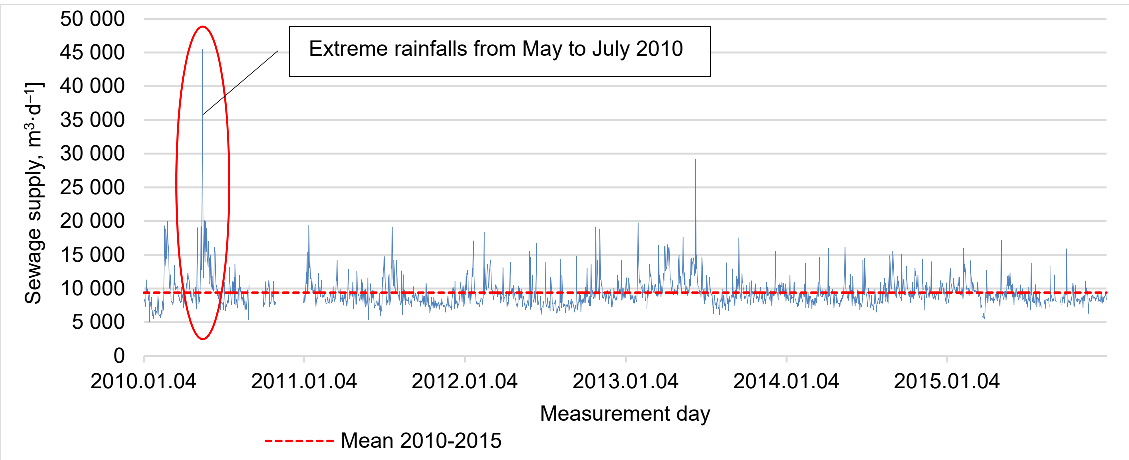

Fig. 7. Daily sewage supply to the STP in Wodzisław Śląski in the multi-year period 2010–2015; source: own study

1.0% of all measured values. The division into groups of precipitation intensity (groups A to G), presented in the research methodology, allowed to capture the upward trend for the mean values of sewage inflow to the treatment plant in Wodzisław Śląski. With extreme precipitation values, high values of sewage inflow to the treatment plant were observed. For example, the precipitation on 02.09.2014 was 58.2 mm·d^{-1} and sewage inflow to the treatment plant in that day was 15,557.7 m^3·d^{-1}. As compared to the mean value of sewage inflow for the days without precipitation (8,840.0 m^3·d^{-1} for group A) this flow was higher by

176%. A similar situation occurred during the period of increased rainfall in 2010, in the period from May to June.

Figure 7 presents daily sewage supply to the STP in Wodzisław Śląski in the multi-year period 2010–2015.

Apart from daily supply, mean supply for the entire multi-year period, mean design supply and maximum design supply were determined. Data presented in Figure 7 indicated considerable variability in sewage supply to the sewage treatment plant in Wodzisław Śląski. This might be due to the presence of precipitation water that illegally entered the sanitary sewage system, as evidenced particularly for the period between May and August 2010 characterized by extremely intense precipitation. Daily sewage supply in this period exceeded maximum design supply of the facility.

In addition to determining the effect of precipitation on the amount of sewage supplied to the facility, an attempt was made at calculating mean values of basic indicators of sewage contamination depending on the class of precipitation intensity. Figure 8 presents mean values of basic indicators of raw sewage contamination (BOD_5, COD_{Cr}, total suspended solids) for individual classes of precipitation intensity.

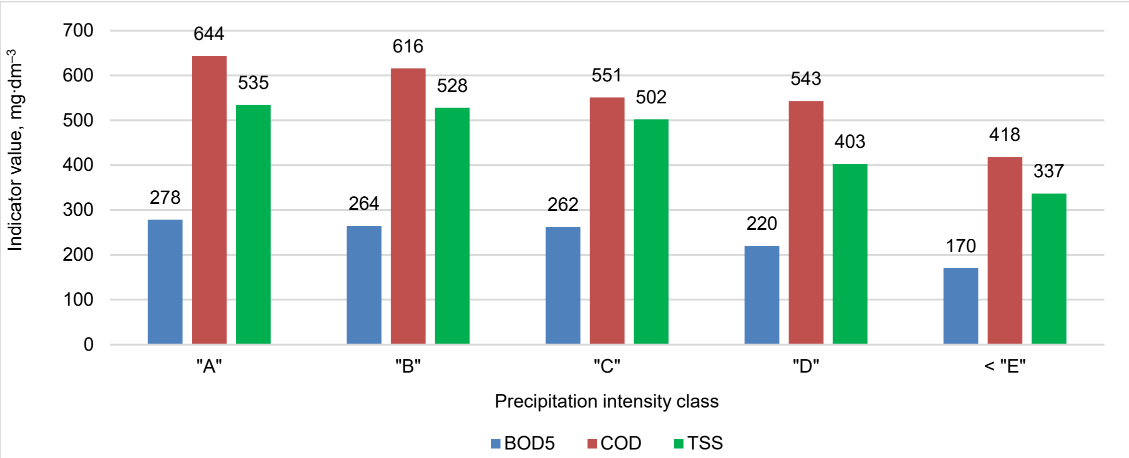

Fig. 8. Mean values of basic indicators of raw sewage contamination (BOD_5, COD_{Cr}, total suspended solids) for individual classes of precipitation intensity; source: own study

Mean BOD_5 values in the sewage entering the sewage treatment plant were the highest (278 mg $O_2 \cdot dm^{-3}$) during dry weather, and the lowest during rainfalls of high intensity (in classes F and G). The difference in mean BOD_5 of raw sewage for dry weather and intense rainfalls was 108 mg $O_2 \cdot dm^{-3}$, which constituted a reduction of this indicator by 61.1%. Similar situation was observed for mean COD_{Cr} values in the sewage supplied to the sewage treatment plant. Mean value of this indicator was considerably reduced from 644 mg $O_2 \cdot dm^{-3}$ for dry weather to 418 mg $O_2 \cdot dm^{-3}$ for the most intense precipitation. Analogous trend was observed for total suspended solids, the concentration of which in raw sewage was by 198 mg·dm^{-3} higher during dry weather than during the most intense precipitation.

SUMMARY AND CONCLUSIONS

Summing up, abnormal situations that threaten natural environment will happen until people gain sufficient environmental awareness. Discharging rainwater from roofs and paved areas of residential properties to the sanitary sewage system should not take place and inhabitants should be educated in this field from the very beginning. According to PAPUZIŃSKI [2006], environmental awareness is a part of public awareness related to information and beliefs about the natural environment and to the perception of relationships between the state and type of the natural environment and the conditions and quality of human life, especially with reference to ecological threats. Therefore, proper education that would shape ecological awareness of new generations should be introduced as early as possible (in primary and junior high schools).

The study yielded the following conclusions.

1. There is a noticeable increase in the amount of incoming sewage as the rainfall intensity increases. Taking into consideration that the examined facility in Wodzisław Śląski receives only sewage from the separate sewer system (95.8%), it can be suggested that the collective sewer system receives predominantly precipitation water due to illegal roof gutter connections.

2. The sewerage system operator should carry out random checks in the area of the agglomeration sewerage system in Wodzisław Śląski, aiming at checking where the roof gutters have their discharge sites. In the case of detection of illegal connections, they should be removed and the property owners should be made aware of their harmful effects. Lower values of sewage inflow to the treatment plant will result in lower operating expenditure on sewage treatment. The problems associated with accidental waters are indicated by BUGAJSKI [2009] and KACZOR [2009].

3. In order to precisely determine whether infiltration or accidental water enters the sewerage system, additional analyses of sewage inflow during the night should be carried out. High values of sewage inflow at night may indicate the infiltration of groundwater into the sewerage system.

4. Obeying legal regulations is very important but such undesirable situations that threaten natural environment will happen until people gain sufficient environmental awareness.

5. Introducing various forms of retention of precipitation water on a household premises and then using it for various purposes may limit the amount of precipitation water entering the separate sewage system.

6. The inhabitants should be educated on proper management of precipitation water so that it is retained mainly at the place of its falling. This will reduce the consumption of tap water, allow for more uniform supply of sewage to the sewage treatment plant and reduce the dilution of sewage entering the treatment facilities.

7. Lower concentrations of raw sewage contamination indicators were observed in the group with the highest precipitation intensity. Similar correlations were obtained by KACZOR [2012]. However, the Authors had only few sewage samples in this group at their disposal and it is recommended that detailed analyses should be carried out with greater number of sewage samples collected in the days with extreme precipitation.

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Analiza wpływu opadów atmosferycznych na ilość i jakość ścieków surowych dopływających do oczyszczalni w Wodzisławiu Śląskim

STRESZCZENIE

W pracy przedstawiono analizę wpływu opadów atmosferycznych na ilość i jakość ścieków surowych dopływających do oczyszczalni w Wodzisławiu Śląskim. Badania przeprowadzono w okresie od stycznia 2010 r. do grudnia 2015 r. (6 lat). Dokonano podziału okresu badawczego na 7 grup intensywności natężenia opadu atmosferycznego. Dla analizowanych grup określono podstawowe statystyki opisowe wartości dopływu ścieków surowych do oczyszczalni. Na podstawie zebranego materiału i przeprowadzonej analizy stwierdzono istotny wpływ opadu atmosferycznego na ilość ścieków dopływających do badanego obiektu. Średni przyrost ilości dopływających ścieków w stosunku do dopływu ścieków w okresie bezdeszczowym wyniósł od 10,5% (884,9 $m^3 \cdot d^{-1}$) dla grupy „B” do 69,6% (6 153,9 $m^3 \cdot d^{-1}$) dla grupy „G”.

Dokonano porównania średnich wartości wskaźników zanieczyszczenia ścieków surowych w poszczególnych grupach intensywności opadu atmosferycznego. Stwierdzono istotny wpływ natężenia opadu atmosferycznego na stężenia badanych wskaźników zanieczyszczenia ścieków surowych.

Określono podstawowe wskaźniki zanieczyszczenia ścieków (BZT_5, $ChZT_{Cr}$, zawiesina ogólna). Określono podstawowe statystyki opisowe wartości badanych wskaźników: mediana, wartość średnia, minimalna, maksymalna, odchylenie standardowe, współczynnik zmienności.

Słowa kluczowe: *jakość ścieków, opad atmosferyczny, ścieki bytowe, wody przypadkowe*