Pollution load assessment in the form of TSS and COD emitted from an urbanized catchment in the aspect of administrative pollutant discharge fees on the example of the activity of the J1 CSO in Lodz (Poland)

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Abstract: The article presents the possibility of reducing fees for wastewater discharge from combined sewer overflows (CSOs) into the aquatic environment by minimizing the load emission of total suspended solids (TSS) and chemical oxygen demand (COD). The analysis was conducted based on limiting the wastewater volume discharged to the receiving water by one of the viable options, i.e., raising the overflow crest. The assessment was made on the example of the functioning J1 CSO in Lodz (in Polish: Łódź) in the years 2013–2015. An analysis of rainfall recorded in the J1 catchment area was also performed for this period. For the determination of the TSS and COD load emitted to the receiver, a predictive model based on rainfall parameters and the volume of discharged wastewater was used. To determine the wastewater volume emitted during individual activations of the J1 overflow, the model of the sewer network serving this catchment was calibrated in the EPA SWMM software. Simulations were conducted, considering different heights of the weir crest (static change). The results of the analyzes showed that raising the crest by 5 cm reduced the total fee for the J1 activity by 35% compared to its existing height in 2013 and about 40% for 2015. Raising the crest by 10 cm in 2015 enabled, for example, the J1 overflow activity to be in accordance with the applicable law. Reducing the amount of wastewater discharged to the receiver by using the overflow crest height adjustment method presented in the article may bring measurable financial and ecological benefits.

Keywords: environmental engineering, CSO management, sewer system, weir crest level, environmental pollutant discharge fees

INTRODUCTION

The development of cities, progressive urbanization, and climate change, manifested, inter alia, by an increase in the number of intense rainfalls contribute to the overloading of existing combined sewage systems (CSS) built even 70–100 years ago, and designed for completely different conditions of their functioning than those encountered today. To protect cities against, among others, urban floods, combined sewer overflows (CSOs) were equipped. During heavy rainfall, these structures direct the excess mixture of domestic, industrial and stormwater immediately to receiving water, usually without any treatment.

Due to the need to improve surface water quality which has been affected by human activity, as well as restrictive regulations regarding the wastewater quality discharged into them, it is necessary to limit the activity of CSOs not only from the perspective of ecotoxicity and the health of ecosystems, but also considering the protection of drinking water resources and preservation of recreational values of waters. During heavy rainfall, apart from surface runoff and the erosion of contaminated soil, CSOs and rainwater drainage outlets are the main source of surface water pollution. Untreated wastewater transported directly to receiving water may include, among others, pathogens, excess nutrients, chemicals, pharmaceuticals, heavy metals, hormones, and micropollutants. Therefore, among others, the activation CSOs is a problem of public health and the environment (Radke et al. 2010, Zgheib et al. 2012, Zawilski & Sakson 2013, Górska et al. 2014, Iqbal & Baig 2015, Madoux-Humery et al. 2015, 2016, Dienus et al. 2016, Launay et al. 2016, Markiewicz et al. 2017, Björklund et al. 2018, Becouze-Lareure et al. 2019, Petrie 2021, Sojobi & Zayed 2022) The type, composition and concentration of the discharged pollutants also depend on the type of drainage system, its maintenance, the cleanliness of the sewer network (Reyes-Silva et al. 2020), and the management of the catchment area from which the untreated wastewater is directed into the receiving body. Of course, the number of CSO activations, and the pollutants concentration level in the discharges are also dependent on the character of rainfall (Berggren et al. 2012, Langeveld et al. 2013, Bi et al. 2015).

The study conducted by Abdellatif et al. (2015) for 19 selected CSOs in the Crewe urban catchment aimed to determine the impact of different climate change scenarios on CSO frequency. A scenario involving the intensive use of fossil fuels (high emission scenario) and a scenario emphasizing global solutions for economic, social, and environmental sustainability were considered. The authors investigated the impact of global warming on future rainfall (projected for 2070–2099), which was then used as input for a sewerage model to determine the frequency of CSOs. In the Crewe urban catchment, under the high emissions scenario, the maximum predicted annual increases were: 37% in spill volume, 32% in spill duration and 12% in number of rainfall events for future conditions.

Due to the negative impact on the aquatic environment and health mentioned here, several studies, activities and methods have been undertaken in many European countries to reduce CSO activity (Dirckx et al. 2011, Garofalo et al. 2017, Fu et al. 2019, Bachmann-Machnik et al. 2021, Quaranta et al. 2022).

Regarding the treatment of urban wastewater, the member states of the European Union should base their policy for reducing pollution from overflows on the European Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment (Directive 1991). It shows that member states are free to choose and apply methods to minimize the pollutant load directed to surface waters. The legal act that tries to harmonize the requirements for wastewater discharge in the European Union, and thus the functioning of CSOs, is the Water Framework Directive of 23 October 2000. In Poland, the Regulation of the Minister of Maritime Economy, and Inland Navigation of July 12, 2019 on substances particularly harmful to the aquatic environment and the conditions to be met when discharging wastewater into water or the ground, as well as discharging rainwater or meltwater to waters or to water facilities (Rozporządzenie 2019) is currently in force. Unfortunately, the Polish law does not consider the direct relationship between discharges of pollutants from CSOs and rainwater drainage outlets and receiving water condition. There is no record of a limit on the load of pollutants discharged into surface waters. The limitation of the operation of CSO's only consists of the limitation of their activation to 10 per year (Rozporządzenie 2019). In Poland, the quality of surface waters is constantly deteriorating. This is influenced by, among other things, the excessive activation of CSOs and a significant proportion of untreated rainwater directed via stormwater drainage outlets to nearby receiving waters.

Currently, the changes proposed by the new directive (Directive 2022) introduce the obligation to establish locally integrated urban wastewater management plans to combat pollution from rain waters (urban runoff and storm water overflow) and this is being widely discussed in Poland.

According to Art. 5 of the above-mentioned directive, CSO discharges may constitute no more than 1% of the annual volume and load collected of urban wastewater, calculated in dry weather conditions. Implementing regulations for such an approach have not yet been developed in Poland.

In Poland, the general assessment of the condition of rivers in 2020, carried out for a total of 4,585 river surface water bodies (JCWP) in terms of biological and chemical status, showed a good condition for a negligible number of them, amounting to only 1.1% (Główny Inspektorat Ochrony Środowiska 2020). One of the elements influencing such a state is the activity of CSOs and the significant pollutant load discharged by this way into the Polish rivers (Brzezińska 2016). Taking into account the ongoing climatic changes which are being manifested, among others, by the increase in the number of heavy rainfall episodes and, on the other hand, progressive urbanization, it is becoming necessary to develop local relationships between rainfall and runoff (for e.g., a specific city or region). This will allow the implementation of solutions in both the catchment area and in drainage systems aimed at increasing rainwater retention and, consequently, the reduction of CSO activity. One of the factors influencing the intensification of work in this direction, apart from the legal aspects, is an economic issue, i.e., environmental charges for discharging pollutants into the aquatic environment.

Due to the lack of sufficient knowledge about the possible amount of fees for discharging untreated wastewater by combined sewer overflows, it was decided to tackle this subject in this paper.

The aim of the article was, inter alia, to present the possibility of reducing administrative pollutant discharge fees from an urbanized catchment into the aquatic environment by taking into account the minimization of discharging wastewater volume and, consequently, the TSS and COD load. The analysis was made on the example of the J1 CSO in Lodz. It was proposed to reduce the discharged wastewater volume by the option of regulation the overflow crest (static change). The period of three years (2013–2015) for the analyses was used due to the considerable completeness of data. It should be mentioned that the activity of this overflow has been similar in recent years to the previous years. Therefore, it can be assumed that the estimated fees for the overflow operation, calculated in accordance with the existing law, will be of a similar amount. The estimated amount of administrative pollutant discharge fees was presented, considering different variants their calculations and the adopted interpretation of current legal regulations.

MATERIAL AND METHODS

Description of the research object

In terms of population, Lodz is the fourth largest city in Poland (Central Europe) (672,185 inhabitants) and the fourth in terms of its area (293.25 km^2). The city is in the central part of the Lodz Province. The entire Lodz agglomeration has about 1.1 million inhabitants. Due to its location and the difference in height level inside the city borders (from 163.6 m to 284.1 m a.s.l.), the combined sewer system (CSS) was created here as the first one, occupying central part of the city of 43 km^2 area and the mean imperviousness of 0.43. Other districts are equipped with separate systems. The CSS is equipped with 18 overflows which, during rainfall periods, expel excess untreated wastewater to smaller rivers located within the contemporary city borders. In a highly urbanized part of the city, the smaller rivers of Lodz are transformed into covered sewers.

To assess the total mass of the load emitted from the urbanized catchment into the aquatic environment, an analysis of the J1 CSO was conducted. The J1 catchment, which discharges the surface runoff into the CSS including the analyzed overflow, is characterized by multi-family buildings with a few industrial plants and green areas. The catchment area covers an area of 211 ha with an average imperviousness of 0.33. Nearly 11,000 people (Fig. 1) inhabit this area.

Fig. 1. *Location of the J1 catchment area in the city (based on: localization of Lodz city – http://pl.maps-of-europe.com/maps-of-poland/, localization of subcatchment J1 – https://mapa.lodz.pl/portal/apps/webappviewer/index.html?id=6e4ff8e1825e4cebb-331987689d24c6c)*

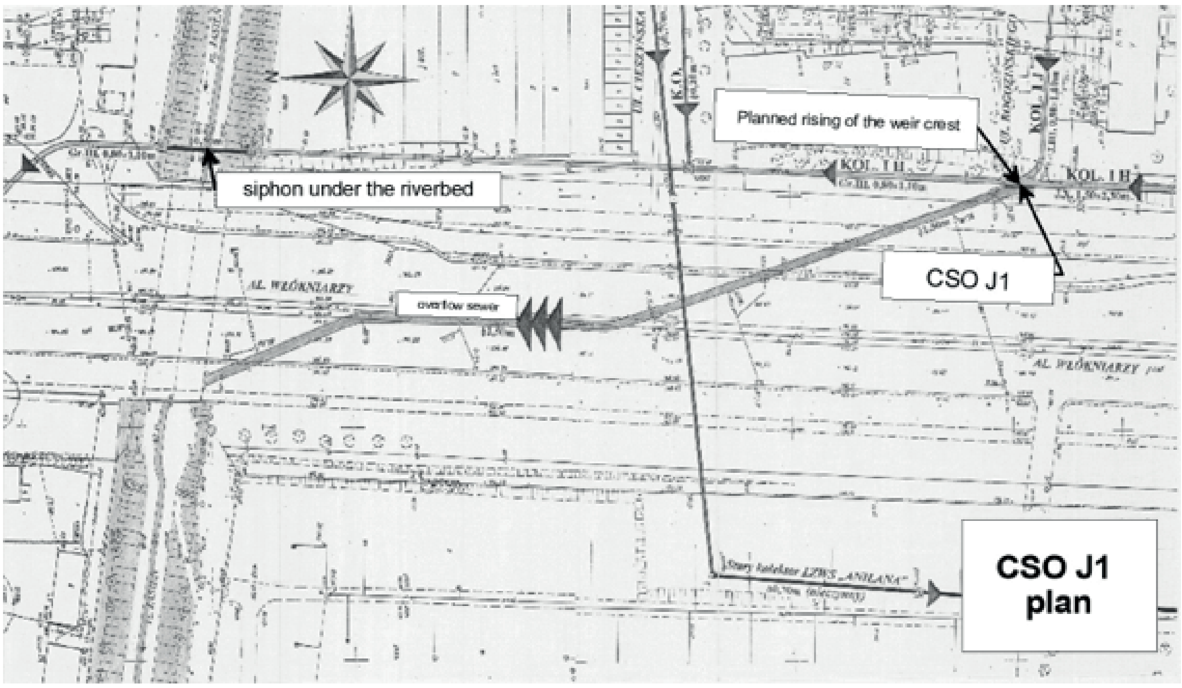

Fig. 2. *CSO J1 (Projekt generalny przelewów burzowych... 2003); KOL – sewer*

The J1 overflow was constructed as a side overflow with a crest length of 4.92 m, and height of 0.57 m (the overflow crest ordinate is 182.59 m a.s.l.), which at the activation discharges wastewater to the Jasień River (Fig. 2). The average dry weather flow inside the overflow chamber was determined as 0.09 m^3/s. Two collectors JIII (0.80 m × 1.40 m) from Rogozińskiego Street (ul. Rogozińskiego) and JX (1.50 m × 2.30 m) from Włókniarzy Avenue (al. Włókniarzy) come to the overflow chamber, which in the chamber connect into one sewer directing wastewater to the treatment plant (JIII – 0.80 m × 1.40 m) (Fig. 2).

Hach on-line sensors for measuring selected pollution indicators in the form of total suspended solids (TSS) – (SOLITAX sc) and chemical oxygen demand (COD) – (UVAS plus) were installed in raw wastewater in J1 overflow chamber. These devices have been calibrated for both dry and wet weather, obtaining an average coefficient of determination equal to $R^2 = 0.87$ (Brzezińska et al. 2014, 2016). The measurement techniques are presented in Table 1.

Table 1
Measurement techniques used by online sensors from the Hach Company (http://pl.hach.com/)

Name of the sensor	Measurement technique of sensor
SOLITAX sc	measurement based on a combination of adsorption and diffusion of rays in the infrared according to DIN EN ISO 7027 / equivalent DIN 38414
UVAS plus	measurement of UV absorption at the wavelength of 254 nm according to DIN 38 402 C3

The sensors record the data every minute, which enables a precisely accurate observation of temporal variations taking place in the concentration and the load of the examined indicators.

Research methodology and scope

Measurement data

Rainfall data came from a rain gauge placed in the “Organika” chemical factory which is in the center of the J1 overflow catchment. This rain gauge gives results in 5-minute intervals and is adapted to record the depth and intensity of rainfall with a resolution of 0.1 mm (0.1 L/m^2). According to the manufacturer, the accuracy of the device is ±0.1 mm (for precipitation <5 mm, with its intensity 10 mm/h), ±0.2 mm (for precipitation >5 mm, with its intensity >10 mm/h). The analysis was conducted for the years 2013–2015.

For this research period, data from water and sewage company in Lodz on the frequency, duration, and volume of discharged wastewater by the J1 CSO has also been obtained. These data were recorded with a 1-minute step. Based on the obtained results, a database to perform further analyses of the functioning of the J1 CSO was created.

Pollution load estimation model

A pollutant emission prediction model was used to estimate the pollutant loads (Brzezińska et al. 2018). A simplified model developed for a single rainfall event for the period 2010–2013 using the Statistica 10.0 software and multiple regression allows, based on three variables, to estimate of the TSS and COD load with high coefficients of determination (at a level close to 0.8–0.9). The variables determining the form of the model are rainfall depth, maximum rainfall intensity, volume of wastewater discharged by CSO. The form of the model is presented below:

$$L_{\mathrm{COD}} = 1.6 \cdot R_{\mathrm{depth}}^{-0.3} \cdot i_{\max}^{0.22} \cdot V_{\mathrm{CSO}}^{0.95} \quad (1)$$

$$L_{\mathrm{TSS}} = 1.8 \cdot R_{\mathrm{depth}}^{-0.37} \cdot i_{\max}^{0.21} \cdot V_{\mathrm{CSO}}^{0.97} \quad (2)$$

where:
L_{COD} – COD load discharged by CSO [kg/event],
L_{TSS} – TSS load discharged by CSO [kg/event],
R_{depth} – rainfall depth [mm],
$i_{\max}$ – rainfall maximum intensity [mm/h],
V_{CSO} – volume of discharged wastewater [m^3].

Use of the SWMM software

To estimate the amount of fees for the over normative activity of the J1 CSO, it was also necessary to determine the volume of the discharged wastewater. It was assumed that the volume of discharged wastewater would be reduced by raising the overflow crest by 5 cm, 10 cm and 15 cm (statistic change). For this purpose, calibration of the J1 catchment model together with sewer network using the EPA SWMM software (Fig. 3) was made (Zawilski 2012). The catchment sewer model consists of 382 subcatchments, 311 nodes and 311 sewers, with a total length of 14.72 km and sewer sizes ranging between 200 mm and 3000 mm (216 pipes), 800 mm × 1100 mm (seven pipes – pear shape), and between 600 mm ×1 100 mm and 1500 mm × 2300 mm (88 pipes – egg shape). Simulations, considering the three individual heights of overflow crest given above for three years of continuous rainfall data (2013–2015), were conducted. The obtained wastewater volume results for individual variants were used in the pollutant load estimation model.

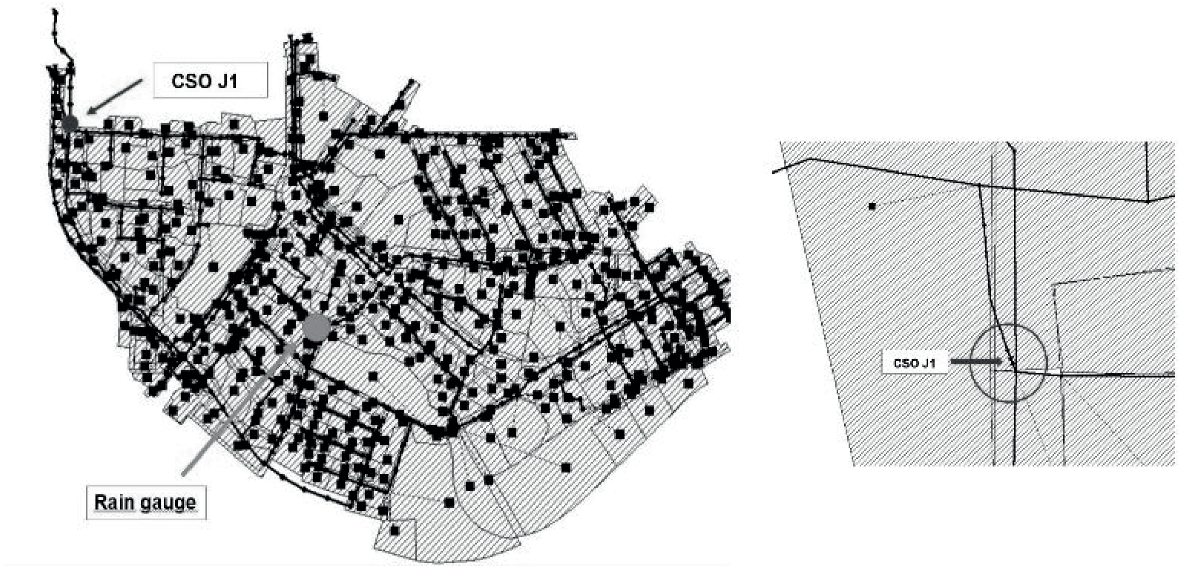

Fig. 3. *Location of the rain gauge and CSO J1 in the catchment area introduced into the EPA SWMM model*

RESULTS AND DISCUSSION

Rainfall events analysis recorded in the J1 catchment during 2013–2015

Due to the protection of the rain gauge and the need to disassemble it for the winter period, the measurement data mostly covered the months from March to December of each year. A rainfall episode was considered as a single precipitation phenomenon when the reading from the pluviometer before and after the rainfall showed the value equal 0. A time of less than 4 h before the next rainfall classifies it as belonging to the previous one. During the study period, 252 rainfall episodes were distinguished. The number of rainfalls occurring in individual months of the year is shown in Figure 4. The most frequent rainfall occurred in May and June, and in November in the case of 2013 and 2015. In May – June the difference in the number of rainfalls was similar and ranged depending on the year between 11–17 and 13–18, respectively. However, in September and November there were significant differences in their number, and it ranged between 1–12 and 3–16. Also, the total rainfall depth (R_{depth}) in individual months indicated that May and June were months with the highest values, e.g., 145.1 mm in June 2013 (Fig. 5). In remaining months, R_{depth} ranged from 24.5 mm to 41 mm, depending on the year. The number of rainfalls in one year during the three-year study period did not change much (2013 – 82, 2014 – 81, 2015 – 89), but the annual total rainfall depth was the highest for 2013 and amounted to 372 mm, for 2014 – 350.2 mm, and for 2015 the lowest value of 294 mm was recorded. In addition, it should be noted that during the research period (2013–2015) the rain gauge only worked from the spring months, therefore even higher values of R_{depth} can be expected. It follows that the 2013 year was characterized by a more intense character of rainfall than others.

Table 2 presents the rainfall statistics from the research period.

Table 2
Rainfall statistics for 2013–2015

Statistical values	$R_{duration}$ [h]	i_{mean} [mm/h]	i_{max} [mm/h]	R_{depth} [mm]
min	0.08	0.07	0.12	0.09
max	42.08	16.51	78.18	35.21
mean	4.08	1.60	7.24	4.03
median	2.17	0.78	2.82	1.80
SD	5.52	2.19	11.81	5.94

n = 252 (total number of rainfalls).

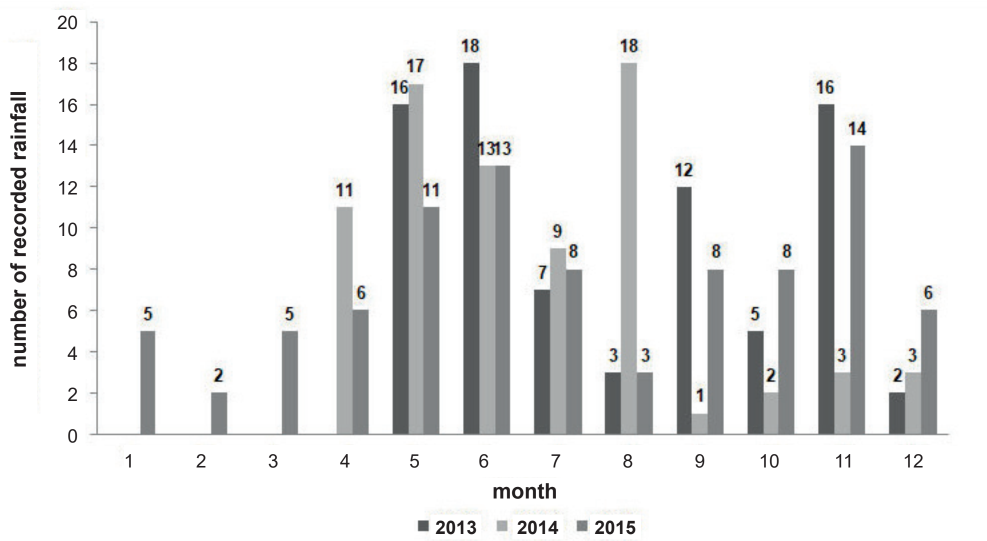

Fig. 4. *The frequency distribution of rainfall occurrence in months in years 2013–2015 recorded in the J1 catchment area*

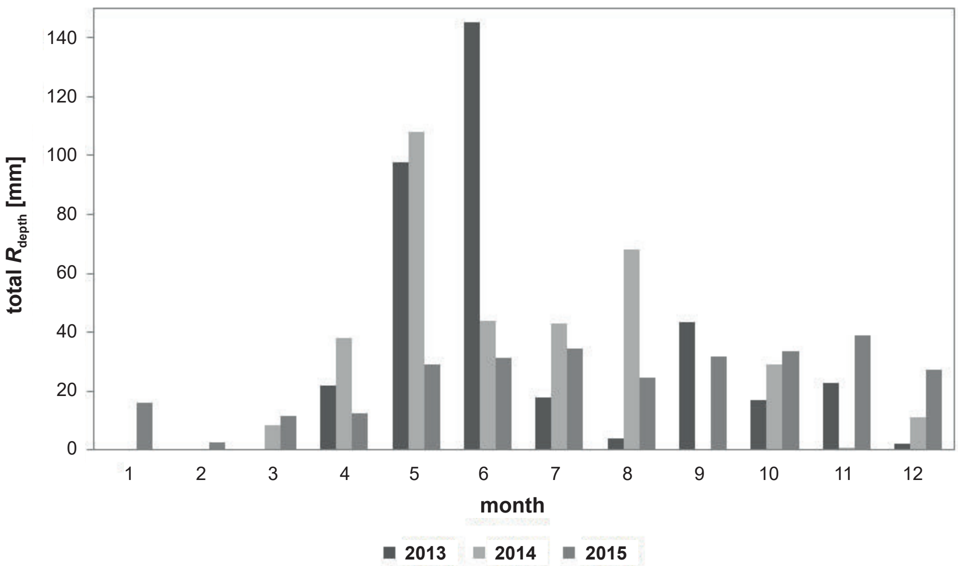

Fig. 5. *The total rainfall depth (R_{depth}) in years 2013–2015 recorded in the J1 catchment area*

Considering the three-year research period, the most numerous groups of rainfall in terms of rainfall depth (R_{depth}) were rainfall of $R_{depth} \leq 1$ mm (36.1%), which has been not significantly affected the dynamics of wastewater flow. Rainfall with a depth in the range of 2–5 mm was 22.2% of the data collection and it was the second largest group of rainfall for this parameter. The most numerous groups of rainfall in terms of rainfall intensity were rainfalls of medium intensity $i_{mean} < 0.5$ mm/h (30.56%) and in the range of 0.5–1.0 mm/h (26.59%). Taking into account the maximum intensity (i_{max}), rainfall in the range of 2–5 mm/h accounted for the most, i.e., 30.16% of all rainfall events. Rainfall lasting less than 0.5 h was the most common (19.84%).

J1 CSO activity in 2013–2015

CSO activity depends primarily on the character of rainfall and the current wastewater depth inside the CSO chamber, which is related to the time of day regarding the dry weather flow. When analyzing the character of rainfall, significant differences between them are noticeable, which undoubtedly affects both the amount of rainwater inflowing to the CSS and the total composition of the wastewater flowing there. The R_{depth} ($R_{duration}$) dependence shows that activation of the CSO J1 causes already a rainfall of R_{depth} = 2.51 mm.

Each CSO activation with the volume of discharged wastewater greater than 100 m^3 was assumed as a single event and was taken into account in the further analyses. Smaller volumes of wastewater than 100 m^3 have been ignored, treating such events as measurement errors or e.g., backflow inside the overflow sewer.

For each individual rain event, the following parameters were determined:

- total volume of discharged wastewater, V_{CSO} [m^3],
- total TSS load discharged by the CSO, L_{TSS} [kg],
- total COD load discharged by the CSO, L_{COD} [kg].

As it can be seen in Table 3, in each of the analyzed years (despite the lack of data completeness of the facility operation during several months of a given year), the J1 CSO exceeded ten activations permitted by law. The quantitative characteristics of the registered discharges showed that in 2013 there was the highest number of overflow activations in the three-year research period, with the maximum frequency of activity in May (seven times) and June (ten times). October 2014 saw the last activation of the J1 CSO, also with the maximum number of activities in May – July. However, it is possible that CSO might still be working in the next months. This is due to incomplete measurement data from the second half of this year. 2015 was a slightly different year, where the CSO activity was at the level of 1–2 activations per month from May to December, with the maximum activation in July and November (in the number of 3). From the data collected in Table 3 the 2013 was the most stressful year for the aquatic environment, both in terms of the volume of discharged wastewater and the load of TSS and COD.

Based on the data obtained from the rain gauge, a probability plot (Fig. 6) of the overflow activation depending on the duration ($R_{duration}$) and R_{depth} of the rainfall has been prepared.

Table 3
Summary of selected parameters of wastewater discharged through the J1 CSO in Lodz in 2013–2015

Month	*n*			V_{CSO} [m^3]			L_{TSS} [kg]			L_{COD} [kg]		
	2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
January	–	–	–	–	–	–	–	–	–	–	–	
February	–	–	–	–	–	–	–	–	–	–	–	–
March	0	1	–	–	224	–	–	315	–	–	278	–
April	1	2	–	3,227	2,924	–	2,674	3,259	–	2,528	3,026	–
May	7	4	2	11,169	15,639	2,282	11,421	12,973	2,421	10,801	12,637	2,270
June	10	4	2	25,455	2,467	2,201	26,599	2,233	2,788	25,332	2,069	2,620
July	2	4	3	926	4,343	2,388	1,036	5,518	3,148	954	5,025	2,939
August	0	3	1	–	1,349	4,617	–	8,273	5,179	–	7,990	5,035
September	0	1	2	–	9,549	3,443	–	1,944	3,274	–	1,656	3,115
October	1	1	1	910	4,454	935	1,111	3,115	650	1,005	3,025	623
November	1	0	3	447	–	1,770	505	–	1,983	465	–	1,769
December	0	0	1	–	–	605	–	–	610	–	–	547
2013	22			42,132			43,346			41,084		
2014	20			40,949			37,631			35,706		
2015	15			18,241			20,053			18,920		

n – number of CSO activations, *V* – measured value, *L* – loads come from the model.

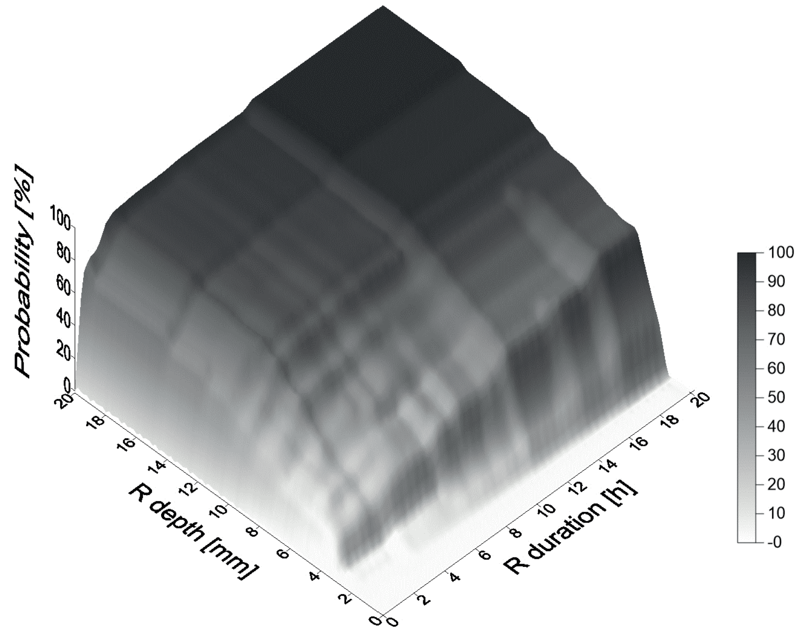

Fig. 6. *Probability distribution of J1 CSO activity*

The probability graph shows that here are possibilities of combining the values of the considered rainfall parameters, which may cause overflow activation. The analysis showed that, taking into account the rainfalls from 2013–2015, the risk of the J1CSO activating appears already with R_{depth} about 2.5 mm. With rainfall events lasting more than 10 h, the J1 overflow activation is caused by more than 50% of the rainfall, even at a low R_{depth} value. With rainfall events lasting up to 30 h, the CSO activation may already occur in 80% of cases. The R_{depth} of rainfall about 15 mm causes the probability of overflow activation at the level of 65%, and in the R_{depth} of 20 mm it reaches ca. 75%.

Based on Figure 6, it can be concluded that the exceeding of the limit values of individual rainfall parameters does not always have to result in the activation of the overflow, however, it can be seen how the probability of activation increases for longer time duration of rainfall and with the increase in the total depth of rainfall.

Economic aspects of the CSO J1 activity

The permissible limit of the annual CSOs activity in each country is adopted individually based on different criteria, but their operation must not violate European directives regarding surface waters. Each country also develops its own methods of fees and other charges for various activities of these facilities.

The provisions of the Water Law in force in Poland do not contain separate regulations regarding fees for the discharge of wastewater from CSOs. Calculation of fees for the CSO operation was based on the conditions contained in the water permit and on legal acts listed below:

- Act of July 20, 2017 – Water Law (Ustawa 2017),
- Regulation of the Minister of Maritime Economy and Inland Navigation of July 12, 2019 on substances particularly harmful to the aquatic environment and the conditions to be met when discharging sewage into waters or ground, as well as when discharging rainwater or meltwater into waters or into devices water (Rozporządzenie 2019),
- Regulation of the Council of Ministers of December 22, 2017 on unit rates of water services (consolidated text of April 8, 2021, Journal of Laws of 2021, item 736) (Rozporządzenie 2021),
- Regulation of the Council of Ministers of December 27, 2017 on the determination of increased fees for exceeding the conditions for discharging sewage into waters or into the ground (Rozporządzenie 2017).

Due to the lack of clear guidelines in the Polish regulations regarding the method of determining the legal number of CSO activations (only its number is known – 10 per year), two variants of adopting fees assumptions were taken into account. In the first option (variant a), the first ten activations in a given calendar year have been accepted as allowed in the water permit. For the next, increased fees have already been charged for overflowing wastewater discharges.

In the second option (variant b), ten activations with the largest volume of discharged wastewater were accepted as permitted by law, and the increased fee was calculated for the remaining, smaller discharges.

According to the wording of Art. 271 sec. 5 of the Act of July 20, 2017 – Water Law (i.e. Ustawa 2017), the amount of the fixed fee for discharging wastewater into waters or into the ground is the product of: the unit rate of the fee, time expressed in days and specified in the water law permit or in the integrated permit, the maximum amount of wastewater expressed in cubic meters per second. The number of days per year is assumed when, in accordance with the water law permit, wastewater may be discharged into waters, and is used to determine the fee for the discharge of wastewater from CSOs. Therefore, if the water law permit specifies the average annual number of discharges as no more than ten, then this indicator reflects the actual permissible, and therefore legal, number of days in a year, on the basis of which the amount of the fixed fee can be determined.

As a rule, when determining the amount of the variable fee for the wastewater discharge, the following indicators as BOD, COD, TSS, $Cl+SO_4$ are taken into account. The indicator resulting in the highest fee from the above-mentioned indicators is adopted, referred to in Art. 278 section 1 of the cited act. In order to determine the amount of the variable fee, it is appropriate to adopt the differentiation coefficient set out in § 10 sec. 6 of the Regulation of the Council of Ministers of April 8, 2021 on unit fees for water services (Rozporządzenie 2021), which was used in the calculations for COD (Table 4 on the interleaf).

The aim of this analysis was to show how increasing the height of the overflow crest (reducing discharged wastewater volume) will affect the amount of environmental charges. In Table 4, the results of those analyzes are presented. According to the Polish regulations, the highest value of the calculated penalties for individual pollution indicators included in the Regulation of the Council of Ministers on unit rates of water services (Rozporządzenie 2021), i.e., in this case the COD load, is the one to be paid. Table 4 shows that in the real scenario, accepting the first 10 CSO activations as permitted by law (first assumption) results in the charging of total fees in the amount of approx. PLN 400,000 PLN in 2013, 170,000 PLN in 2014 and almost 40,000 in 2015. If, on the other hand, ten activations with the highest volume of discharged wastewater as permitted by law would be accepted, and increased fees for the remaining activations, the total fees' amount decreases. In the case of 2013, fees account for approximately 33% of the total amount of money imposed in the first assumption, but in 2014 it was 62% of this sum. Of course, the fee value depends on the number of activations of overflows in a given year. At the same time, it should be noted that the applicable provisions of the Water Law do not contain separate regulations regarding fees for wastewater discharge through storm overflows. In addition, the determination of the increased fee for the use of water services more than the conditions specified in the water permit is the responsibility of the Environmental Protection Inspectorate (Inspekcja Ochrony Środowiska) (Art. 282 sec. 8 and Art. 283 sec. 4 of the Water Law) and is determined by way of a decision.

According to Art. 271 of the Water Law, the fixed fee is annual and is determined based on a water permit for an overflow considering its hydraulic capacity, and the rules for determining the fee are provided for in Art. 271 of the Water Law. The variable fee is charged quarterly, which is regulated by Art. 272 of the Water Law. Therefore, the estimated fee for the functioning of the J1 CSO according to variant (a) becomes real, i.e., the first ten activations remain legal. In this sense, the total environmental fee is significant (Table 4).

Using the SWMM program, the impact of the possible raising of the overflow crest by 5 cm, 10 cm and 15 cm (static change) on the sewer system operation and wastewater treatment plant (WWTP) was analyzed. The analysis showed that this will not cause problems with flooding the area and will not significantly affect the work of the WWTP.

The analysis shows that raising the overflow crest by 5 cm resulted in a decrease of the volume of discharged wastewater by approx. 22% compared to the real variant. This allowed the total fee in 2013 to be reduced from over 391,000 PLN to approx. 255,000 PLN, i.e., by approx. 35%. The analysis conducted for 2015 showed that raising the J1 overflow crest by 10 cm allowed its activity to be limited below the frequency permitted by Polish law and therefore did not generate any additional increased fees. This type of interference in the structure of CSOs by water and sewage companies often may not be accepted due to the overload of WWTPs and trunk sewers during heavy rainfall. Comparable effects reducing the wastewater volume in the sewer system and at the same time allowing to limit the CSO activities and be obtained by using, among others, solutions directly in the catchment. It is a matter of the proper management of rainwater in the place where it is generated.

Striving to reduce the discharged wastewater volume will not only pay off in terms of reducing environmental charges (Table 4) but will also significantly improve the condition of the receiving water. It therefore follows that interpretation of the regulations is an important aspect not only in terms of the methodology of calculating the CSO activation, but also the calculation of increased fees for their excessively over-normative activity.

CONCLUSIONS

Using the proprietary load discharge model presented in the article based on rainfall data and the volume of discharged wastewater, it was possible to estimate the pollutant emissions load of selected indicators in the form of TSS and COD into surface waters. The use of this model also allows, among others, to significantly reduce the work related to the collection and laboratory analyses of wastewater samples.

The frequency of CSO activity does not clearly define the pollutant load discharged into the receiving water, but according to the currently applicable law it is important for determining the economic effects of pollutant emissions as significantly as their volume. In order to effectively reduce wastewater discharges from the CSOs into receiving waters, it is necessary, among others, to implement rainfall monitoring systems, develop a catchment model, quantitative and qualitative monitoring, and real-time control methods for sewer systems. The cost analysis of the functioning of the CSO with the use of two ways of calculating increased fees, currently beyond the scope permitted by Polish law, showed significant differences in their amount. Due to quarterly settlements, variant a) of charging fees seems more probable. Using only one of practical solutions in the sewer system consisting in reducing the wastewater discharge volume by for example, adjusting of the overflow height crest, can already bring measurable financial and ecological benefits. Those benefits can be further increased by the construction of storage tanks, increasing retention in sewers, and managing of rainwater directly in the catchment area (e.g., infiltration into the ground, reuse of rainwater, application of low impact development (LID) devices, blue-green infrastructure, etc.) (Fletcher et al. 2015, Suresh et al. 2023). Use of monitoring, observations and data coming from long term measurement allows us to know the range of the variability of the studied parameters much more precisely, which may result in the evolution of both research and computational methodology. It is necessary to conduct further research on the analyzed topic because this problem significantly interferes with the natural environment and not only applies to Poland, but to all countries with combined sewage systems.

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