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## MODELLING OF STORMWATER QUANTITY AND QUALITY ON THE EXAMPLE OF URBANISED CATCHMENT IN KIELCE

### MODELOWANIE IŁOŚCI I JAKOŚCI ŚCIEKÓW DESZCZOWYCH NA PRZYKŁADZIE ZLEWNI ZURBANIZOWANEJ W KIELCACH

**Abstract:** Due to the stochastic character of precipitation phenomena, and also the accumulation of pollutants in the catchment area and their washoff, predicting the stormwater quantity and quality is a very complex task. That can lead to massive calculation errors at selection and design stages of technological lines in stormwater treatment plants. For hydraulic sewerage systems, the guideline ATV A-118 and the PN-EN 752 standard recommend using hydrodynamic modelling for the catchment area of more than 200 ha, but also for cases when surface flooding caused by excess stormwater occurs, which happens quite often in urban areas. As a majority of computational software tools (SWMM, Mouse, Mike Urban, Civil Storm), in addition to modules for runoff simulations also have those dedicated to wastewater quality assessment, it is justifiable to conduct complex analyses. The paper aims to discuss the results of stormwater quality and quantity numerical simulations obtained with the SWMM software for Si9 sewer catchment located in the area of Kielce. For the paper, hydrogram computations were made for the catchment runoff and the suspension concentrations at the assumption of constant intensity of the rainfall of the duration of  $t_d = 15\text{--}180$  min and the precipitation occurrence probability of  $p = 20$  %. In addition, a mathematical model of stormwater treatment plant was developed. That allowed the determination of the pollutant load of the existing technological line, and of volume and load of suspended solids discharged by the stormwater overflow structure directly into the receiver. The computations that were conducted showed a limited impact of a specific runoff on the mass of suspended solids delivered from the catchment under consideration.

**Keywords:** hydrodynamic modelling, SWMM, stormwater, suspended solids

Evaluating the amount of pollutant load in the stormwater discharged to the receiver is of key importance for sizing the stormwater treatment plant (STP). Both the quality

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and quantity of stormwater from the catchment determine the type and capacity of the devices used. In a majority of cases, the systems comprise a sedimentation tank or a grit chamber and a separator. At the design stage, it is necessary to account for the maximum rate of stormwater flow. When sizing the separator, the permissible concentration of suspensions at the device inlet also needs to be taken into account [1].

The basic criterion for an adequate selection of technological tools is the correct determination of the amount of stormwater delivered to the treatment facility. Although the Regulation of the Minister of Environment of 24 July 2006 [2] specifies the minimum value of runoff that must be treated ( $q = 15 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ ), the document does not state whether constant or varied rainfall intensity should be assumed. The issue is relevant because when the quantity of runoff from the catchment is larger than the value of specific runoff stipulated in the Regulation [2], the stormwater can be directly discharged into the receiver, which can be done no more than five times a year. The Regulation [2] also gives the maximum permissible pollutant concentration in the discharge from the treatment plant. For suspensions, pollutant concentration cannot exceed  $100 \text{ mg} \cdot \text{dm}^{-3}$ , and for oil-derived substances –  $15 \text{ mg} \cdot \text{dm}^{-3}$ .

The methods commonly used in Poland for calculating the runoff hydrograms (limit rain intensity, time delay factor) involve very simplified models, and they do not account for many contributing factors. Those include, among others, variation in the catchment soil moisture during the rain event, the length of the rainless period, uneven distribution of rainfall intensity, direction of the precipitation front movement [3]. Disregarding those factors may lead to substantial computational errors [3–5], and thus to inadequate sizing of the technological devices.

In view of the foregoing, it is advisable to determine the quantity and quality of stormwater through mathematical modelling [6–9]. The existing stochastic models [10–12], however, are usually local in nature, and the parameters defined in those will be significantly changed for each catchment, which leads to erroneous predictions. Deterministic models [7, 13], which provide the opportunity to examine the effect of various parameters on the results obtained, constitute another group. In those models, however, it is necessary to know many input data describing the accumulation of pollutants on the catchment surface and the washoff of pollutants in precipitation events. The Storm Water Management Model (SWMM) is a widely used deterministic tool. It offers the possibility of determining the surface runoff and the pattern of pollutant (eg, suspensions, heavy metals and biogenic compounds) variation during the rain event [14].

Exponential and exponential models are often used to calculate pollutant depositions and washoff. The models are described by the respective equations:

$$B = C_1 \cdot (1 - e^{-C_2 \cdot t}) \quad (1)$$

$$W = C_3 \cdot q^{C_4} \cdot B \quad (2)$$

Literature data [6, 12, 15, 16] indicate that the values of parameters  $C_i$  employed in the equations above range as follows:  $C_1 = 12.4\text{--}225.0 \text{ kg} \cdot \text{ha}^{-1}$ ,  $C_2 = 0.01\text{--}5.50$ ,  $C_3 = 0.025\text{--}0.130$ ,  $C_4 = 1.0\text{--}2.2$ . Those data confirm enormous variation, with respect to

suspended solids, in quality and quantity of stormwater flowing from the catchment. In order to describe the random character of phenomena that affect the prediction of stormwater quality, the authors [17–21] developed probabilistic models, in which the stochastic character of the analysed phenomena is often accounted for by means of the Monte Carlo method.

The aim of the paper is to analyse, on the example of urbanised catchment in Kielce, the possibility of applying the SWMM software to the modelling of the quantity and quality of stormwater. The degree to which the existing STP is loaded with pollutants was evaluated. Also, the volumes of stormwater flowing from the catchment and transported to the STP, and discharged, via the stormwater overflow structure, directly to the receiver were determined. Additionally, the content of suspended solids load delivered to the STP relative to the total content of pollutants washed off the catchment surface was determined in the study.

## Materials and methods

### Facility description

The object of analysis is the sewer Si9 catchment, located in the central – eastern part of the city of Kielce with a total area of  $F = 62$  ha. The sewer of concern receives stormwater and snowmelt from the part of the city lying in the left-hand side basin of the river Silnica. The total length of the sewer network is 5583 m, including the main collector ( $\phi 600$ –1250 mm) 1569 m, and lateral sewers ( $\phi 300$ –1000 mm) 4014 m in length. The slope of the collector ranges from 0.04 to 3.90 %, and that of lateral sewers is up to 2.61 %. In this area, housing estates, public buildings, main and side streets are predominant. A detailed description of the catchment can be found in studies by Dabkowski et al [22], Gorska and Sikorski [23], and Bak et al [24].

Stormwater delivered by the sewer Si9 is directed to the stormwater treatment plant, which consists of a separation chamber (SC), two-chamber settling tank (ST) and coalescence separator (SEP), which remove suspended solids and oil derivatives. When the SC is filled below 0.42 m (overflow height) the stormwater is transported via four sewers  $\phi 400$  mm exclusively to the longitudinal settling tank, which has a length of 30 m. The stormwater from the treatment facility flows simultaneously through the sewer  $\phi 200$  mm to the SEP, and through two sewers  $\phi 500$  mm to the connection chamber (CC), to which stormwater is also delivered after it has gone through the separator (via the sewer  $\phi 350$  mm). In the final stage, from the CC, the stormwater flows through the sewer  $\phi 650$  mm to the receiver. However, when the filling of the separation chamber exceeds 0.42 m, a part of the stormwater is discharged through the overflow structure, via the collector  $\phi 1250$  mm, directly into the receiver, which is river Silnica.

The ultrasonic flow meter (TELEDYNE ISCO 2150) measuring the stormwater flow rate is installed in the sewer Si9, at a distance of about 7 m above the separation chamber. The stormwater samples were collected using ISCO 6712 automatic sampler.

At approx. 2 km from the northern border of the catchment, a rainfall gauging station is located [22–24].

## Methodology of investigations

To make computations of the quantity and quality of stormwater, the hydrodynamic model of the sewer Si9 catchment was constructed using the SWMM software. Detailed information on the software tool can be found in studies by Huber and Dickinson [7], Zoppou [8], Rossmann [25], Zawilski and Sakson [26]. The hydrodynamic model used in the investigations consists of 92 partial catchments, the areas of which range from 0.12 ha to 2.10 ha, 200 sewerage wells and 72 sewer segments (Fig. 1). The content of sealed area in individual partial catchments ranged from 5 to 85 %, additionally, it constituted 53 % of the total catchment area. To calibrate the model, the results of the tests on the quantity and quality of stormwater (suspended solids) from the period of three years were used.



Fig. 1. Diagram of the urbanized catchment of the sewer Si9

To assess the degree of the fitting of runoff hydrograms, those measured and obtained from numerical simulations, the following parameters were used:

- the ratio of the measured surface runoff volume to that obtained by simulations:

$$R_V = \frac{V_{c(\text{pom})}}{V_{c(\text{sym})}} \quad (3)$$

- the ratio of the peak values of flow rate:

$$R_Q = \frac{Q_{d \max(\text{pom})}}{Q_{d \max(\text{sym})}} \quad (4)$$

– Nash coefficient:

$$NC = \frac{\sum_{i=1}^n (Q_{i(\text{pom})} - Q_{i(\text{sym})})^2}{\sum_{i=1}^n (Q_{i(\text{sym})} - Q_{i(\text{sr, pom})})^2} \quad (5)$$

To describe the process of pollutant accumulation and washoff from the surface of the catchment of concern, the respective equations (1) and (2) were employed. Parameters  $C_1$ ,  $C_2$ ,  $C_3$  and  $C_4$  in the equations were determined by the model calibration. The model of stormwater treatment plant was constructed and the values of local resistances at inlets and outlets of the sewers were provided on the basis of field measurements, the planning document, and photographic images. Due to the fact that the sewers connecting different objects of the facility may be pressurised, the main force model was employed for analyses. The model makes it possible to determine the flow resistances in the sewers on the basis of indicated surface roughness. In the model, the settling tank and the separator are defined as detention tanks.

### Pollutant loads

On the basis of computations performed with the SWMM software, the mass of suspended solids (pollutant load given in kg) delivered from the catchment was obtained from the following formula:

$$M = \frac{(I_i + I_{i+1})}{2} \cdot \Delta t \quad [\text{kg}] \quad (6)$$

Additionally, the percentage content of the following quantities was calculated: the volume of stormwater flowing to the STP ( $V_{STP}$ ) relative to the total volume the high water stage ( $V_c$ ), mass of the suspension transported to the STP ( $M_{STP}$ ) relative to the total mass of mineral pollutants delivered by the sewerage system ( $M_c$ ). Those parameters were computed on the basis of the dependence:

$$\eta_V = \frac{V_{OWD}}{V_c} \quad (7)$$

$$\eta_M = \frac{M_{OWD}}{M_c} \quad (8)$$

### Model calibration

The developed quantitative hydrodynamic model was calibrated on the basis of selected seven rainfall-runoff events of the period from July 2009 to July 2011. The characteristics of the events are presented in Table 1.

Table 1

Characteristics of the rainfall events and fitting parameters for measured and simulated hydrograms

Date	P [mm]	$t_d$ [min]	$V_c$ [m <sup>3</sup> ]	$R_Q$ [-]	$R_V$ [-]	NC [-]
08 July 2011	8.6	60	1733	0.95	0.92	0.84
15 Sept. 2010	9.2	286	2221	0.83	0.90	0.90
30 July 2010	12.5	107	1908	0.90	0.93	0.80
08 July 2009	16.5	270	3415	0.92	0.98	0.75
03 July 2009	4.2	26	2133	0.95	0.95	0.72
31 May 2010	5.4	56	684	0.90	0.90	0.70
26 April 2010	3.6	92	327	0.80	0.82	0.67

The qualitative model was calibrated using data on the 13 precipitation events measured in the time interval from 9 May 2009 until 4 June 2010. For 10 events, the ratio of the measured suspension mass to the one obtained from computations ranged 0.20–0.52, for three events (26 April 2010, 30 May 2010, 31 May 2010), the ratio was 0.97, 0.88 and 0.67, respectively. Parameters of the quantitative and qualitative models obtained by means of calibration are presented in Table 2.

Table 2

Summary of hydrodynamics model (quantitative and qualitative) parameters for the analyzed catchment

Model	Parameter	Unit	Value	
Surface runoff	runoff width $W$	m	$1.35 \cdot F^{0.50}$	
	retention of sealed areas $d_{imp}$	mm	1.50	
	retention of unsealed areas $d_{per}$	mm	6.0	
	roughness coefficient for sealed areas $n_{imp}$	$m^{-1/3} \cdot s$	0.015	
	roughness coefficient for unsealed areas $n_{per}$	$m^{-1/3} \cdot s$	0.15	
	roughness coefficient of the sewer $n_{sewer}$	$m^{-1/3} \cdot s$	0.015	
	maximum infiltration rate $f_{max}$	$mm \cdot h^{-1}$	90	
	minimum infiltration rate $f_{min}$	$mm \cdot h^{-1}$	15	
	coefficient of infiltration decrease $\gamma$	$h^{-1}$	3.0	
	the total time of drying out	d	3.0	
Qualitative	deposition	maximum amount of pollutants accumulated in the catchment area $C_{1imp}$	$kg \cdot ha^{-1}$	100
		minimum amount of pollutants accumulated in the catchment area $C_{1per}$	$kg \cdot ha^{-1}$	35
		rate of pollutant loss $C_2$	$d^{-1}$	0.07
	washoff	washoff coefficient $C_3$	—	0.10
		power exponent $C_4$	—	1.73

In the model, constant rainfall intensity was assumed for hydrodynamic simulation. The maximum precipitation amount was determined using the Bogdanowicz and Stachy

formula [3], for the rainfall duration  $t_d = 15\text{--}180$  min (15 min time step) and event occurrence probability  $p = 20$  %. On this basis, the specific surface runoff was determined, which is expressed as:

$$q = Q_{d \max} \cdot F^{-1} \quad [\text{dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}] \quad (9)$$

## Results and discussion

The conducted simulations produced catchment runoff hydrograms, and also patterns of variation in concentrations of suspended solids during the events under consideration. Those made it possible to plot the figures that illustrate the effect of specific surface runoff ( $q$ ) on the stormwater volume ( $V$ ), instantaneous loads ( $I_t$ ) and mass of suspended solids ( $M_c$ ) transported to the stormwater treatment plant, and also discharged through the stormwater overflow. The results of analyses are presented in Figs. 2–6.

Figure 2 indicates that an increase in  $q$  from  $15.0$  to  $49.8 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  is accompanied by a decrease in the volume of stormwater flowing from the catchment (curve A) from  $9845$  to  $4598 \text{ m}^3$  (a drop by  $53.3$  %). Additionally, an increase in  $q$  from  $15.0$  to  $36.5 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  results in a fall in the volume of stormwater delivered to the STP (curve B) from  $6790$  to  $3368 \text{ m}^3$  (a drop by  $49.6$  %). When the value of  $q$  increases, ranging  $15.0\text{--}26.7$  and  $26.7\text{--}36.5 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ , for the stormwater overflow (curve C), that leads to a change in the volume of stormwater discharged directly to the receiver from  $3054$  to  $3560 \text{ m}^3$  and from  $3560$  to  $3368 \text{ m}^3$ , respectively. An increase in  $q$  from  $36.5$  to  $49.8 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  is accompanied by a fall in  $V$  as regards stormwater delivered to the STP and discharged through the overflow from  $3350$  to  $2237 \text{ m}^3$  and  $2362 \text{ m}^3$ , respectively (a drop by approx.  $29.8$  %).

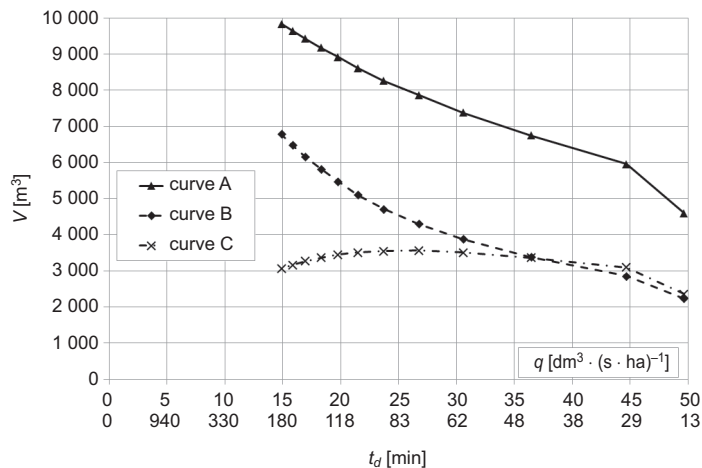


Fig. 2. Effect of specific surface runoff ( $q$ ) for the rainfall duration ( $t_d$ ) on the volume of storm water ( $V$ ) flowing from the catchment (curve A), delivered to the STP (curve B), and discharged through the storm overflow (curve C)

The concentration of suspended solids (Fig. 3) in the range  $q = 15.0\text{--}36.5 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  (the same as in Fig. 2) grows from 204 to  $378 \text{ mg} \cdot \text{dm}^{-3}$ . For  $q$  values above  $36.5 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ , however, an increase in  $c_{\text{suspended}}$  from 378 to  $400 \text{ mg} \cdot \text{dm}^{-3}$  is observed.

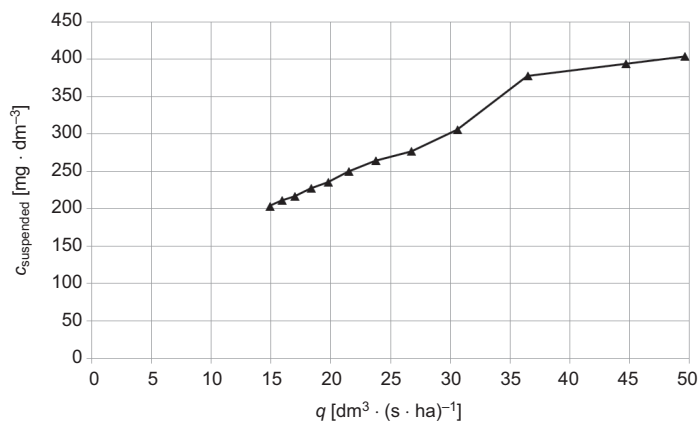


Fig. 3. Effect of specific surface runoff ( $q$ ) on the maximum concentration of the suspended solids delivered from the catchment ( $c_{\text{suspended}}$ )

For  $q$  range under consideration, the load of suspended solids (Fig. 4) transported by sewer Si9 to the section closing the catchment (curve 1) varies in a narrow range  $L_{\text{max}} = 527\text{--}589 \text{ kg}$ . A substantial drop in the load delivered to the STP (curve 2) from 388 to 207 kg is observed when  $q$  grows. At the same time, an increase from 201 to 330 kg (curve 3) is noted in the suspension load discharged directly into the receiver.

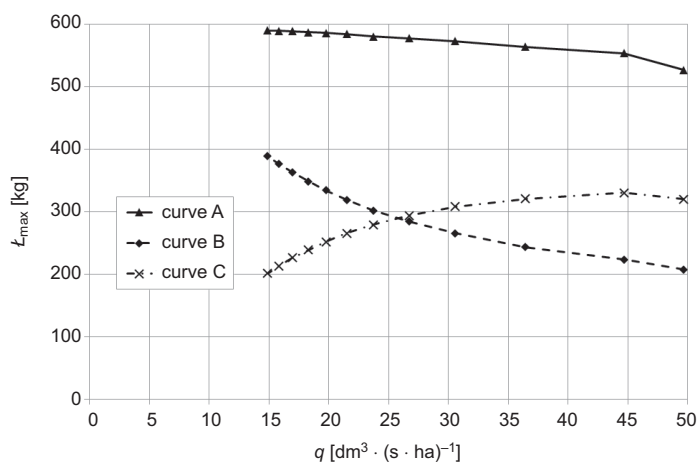


Fig. 4. Effect of specific surface runoff ( $q$ ) on the load of suspended solids ( $L_{\text{max}}$ )



An increase in  $q$  value is accompanied by a drop in stormwater volume and in mass of suspended solids delivered to the STP (Fig. 5). For the maximum surface runoff that equals  $q = 49.8 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ , treatment is applied to only 48 % of the total volume of the highwater wave, which carries merely 39 % of the total mass of pollutants.

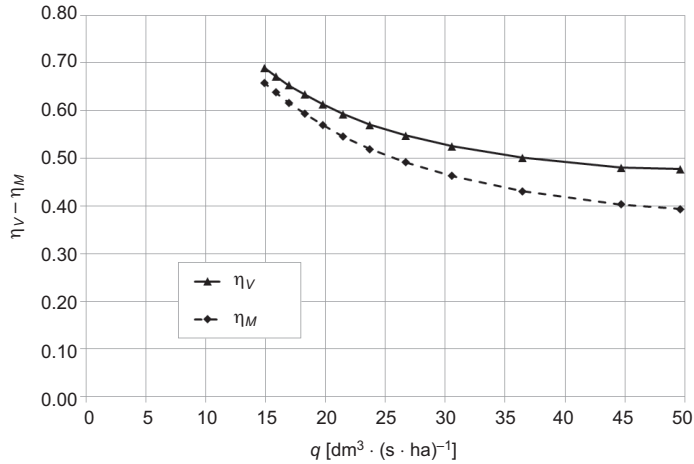


Fig. 5. Distribution, depending on  $q$ , of the volume ( $\eta_V$ ) and mass of suspended solids ( $\eta_M$ ) in the stormwater flowing into the STP

Figure 6 illustrates the impact of the magnitude of specific surface runoff ( $q$ ) on the maximum instantaneous loads ( $I_{\max}$ ) of pollutants given in  $\text{kg} \cdot \text{s}^{-1}$ . For instance, for  $q = 15.0 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  ( $t_d = 180 \text{ min}$ ) and  $q = 36.0 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  ( $t_d = 45 \text{ min}$ ), loads of suspended solids delivered to the STP (curve A) and discharged directly to the receiver

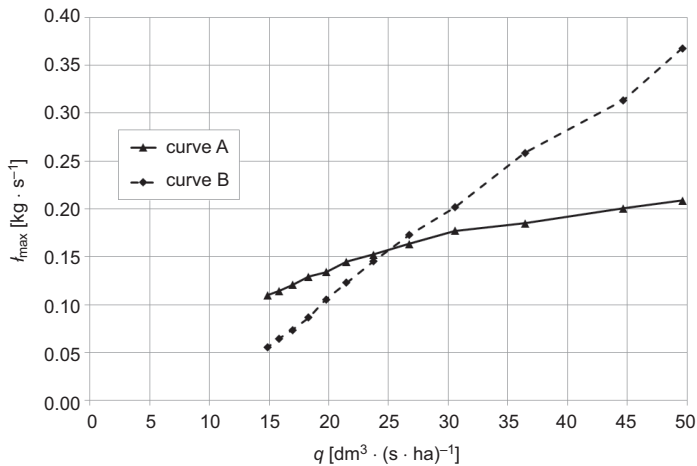


Fig. 6. Effect of specific surface runoff ( $q$ ) on the maximum instantaneous loads ( $I_{\max}$ ) of suspended solids transported to the STP and discharged through the stormwater overflow

(curve B) amount to  $0.1$  and  $0.06 \text{ kg} \cdot \text{s}^{-1}$ , and also  $0.26$  and  $0.18 \text{ kg} \cdot \text{s}^{-1}$ , respectively. Additionally, it can be observed that an increase in  $q$  from  $15.0$  to  $49.8 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$  leads to an increase in  $I_{\text{max}}$  transported to the STP by  $90\%$  (from  $0.11$  to  $0.21 \text{ kg} \cdot \text{s}^{-1}$ ), and also more than six times increase in  $I_{\text{max}}$  passing through the stormwater overflow. It should be noted that when  $q = 26 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ , the maximum instantaneous loads of suspended solids are identical for both curves and are equal to  $0.16 \text{ kg} \cdot \text{s}^{-1}$ .

## Conclusions

The investigations performed for the study confirmed that the SWMM software is a suitable tool for modelling the quantity and quality of stormwater in the urbanized catchment in Kielce. On the basis of numerical simulations, the runoff and concentration ( $c_{\text{suspended}}$ ) hydrograms, and also loads of suspended solids ( $L_{\text{max}}$ ) washed off the catchment area were determined. The constructed mathematical model of the stormwater treatment plant made it possible to determine the amounts of stormwater flowing into individual components of the technology line, and also to compute the volume of untreated stormwater discharged directly into the receiver via the storm overflow. On the basis of the analyses, it can be stated that:

- specific surface runoff significantly affects the concentration of suspended solids contained in the stormwater washed off the catchment area; the higher is the value of  $q$ , the greater is the amount of suspended solids in  $1 \text{ m}^3$  of precipitation water,
- the rainfall duration, at the assumption that rainfall intensity is constant, produces a low impact on the magnitude of the load of suspended solids washed off the catchment area,
- at heavy rainfalls ( $q = 49.8 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ ),  $48\%$  of the total stormwater volume and  $39\%$  of the mass of suspended solids flow into the STP,
- at moderate intensity precipitation ( $q = 15 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ ), approx.  $69\%$  of the total load of suspended solids and  $66\%$  of the stormwater volume are transferred to the STP,
- in the range  $q = 15\text{--}25 \text{ dm}^3 \cdot (\text{s} \cdot \text{ha})^{-1}$ , for the rainfall duration  $t_d = 82\text{--}180$  min, instantaneous loads of suspended solids flowing into the treatment facility are higher than the values of  $I_{\text{max}}$  transferred through the stormwater overflow,
- in order to reduce the amount of pollutants discharged through the stormwater overflow, it is necessary to raise the edges of the overflow structure, or to increase the throughput of the stormwater treatment plant (*ie* expand the diameters of sewers that deliver stormwater to the STP, or extend their number).

## Nomenclature

- $B$  present accumulation of pollutants [ $\text{kg} \cdot \text{ha}^{-1}$ ]  
 $W$  intensity of pollutant washoff [ $\text{kg} \cdot (\text{ha} \cdot \text{s})^{-1}$ ]  
 $C_1$  maximum amount of pollutants accumulated on the catchment area [ $\text{kg} \cdot \text{ha}^{-1}$ ]  
 $C_2$  pollutant deposition velocity [ $\text{days}^{-1}$ ]  
 $C_3$  coefficient of washoff rate [-]  
 $C_4$  power factor [-]

$t$	time step [s]
$q$	specific surface runoff [ $\text{mm} \cdot \text{h}^{-1}$ ]
$R_V$	ratio of the measured surface runoff volume to that obtained by simulations [-]
$R_Q$	ratio of the peak values of flow rate [-]
$V_{c(\text{pom})}$	measured volume of runoff hydrogram [ $\text{m}^3$ ]
$V_{c(\text{sym})}$	volume of the runoff hydrogram obtained from simulations [ $\text{m}^3$ ]
$Q_{d\text{max}(\text{pom})}$	measured peak flow [ $\text{m}^3 \cdot \text{s}^{-1}$ ]
$Q_{d\text{max}(\text{sym})}$	peak flow received from computations using the SWMM software [ $\text{m}^3 \cdot \text{s}^{-1}$ ]
$NC$	Nash coefficient [-]
$Q_{n(\text{pom})}$	measured flow rate [ $\text{m}^3 \cdot \text{s}^{-1}$ ]
$Q_{n(\text{sym})}$	flow rate obtained from simulations [ $\text{m}^3 \cdot \text{s}^{-1}$ ]
$Q_{n(\text{sr,pom})}$	mean value of measured flow rate [ $\text{m}^3 \cdot \text{s}^{-1}$ ]
$i_{i, i+1}$	instantaneous load of pollutants [ $\text{kg} \cdot \text{s}^{-1}$ ]
$V_c$	total volume of stormwater determined from catchment runoff hydrogram [ $\text{m}^3$ ]
$V_{STP}$	volume of stormwater delivered to the STP determined on the basis of simulations with the SWMM software [ $\text{m}^3$ ]
$M, M_c$	mass of suspended solids delivered from the catchment [kg]
$M_{STP}$	mass of suspended solids transported to the STP [kg]
$\eta_V$	content of the volume of stormwater flowing to the STP relative to $V_c$ [-]
$\eta_M$	content of the mass of transported suspended solids relative to $M_c$ [-]
$Q_{d\text{max}}$	maximum stormwater runoff rate [ $\text{dm}^3 \cdot \text{s}^{-1}$ ]
$F$	runoff area [ha]
$P$	total amount of precipitation [mm]
$t_d$	rainfall duration [min]

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## MODELOWANIE ILOŚCI I JAKOŚCI ŚCIEKÓW DESZCZOWYCH NA PRZYKŁADZIE ZLEWNI ZURBANIZOWANEJ W KIELCACH

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**Abstrakt:** Ze względu na stochastyczny charakter zjawisk opadowych, a także akumulacji oraz zmywania zanieczyszczeń zgromadzonych na powierzchni zlewni, prognoza jakości i ilości ścieków deszczowych jest bardzo złożona, co może prowadzić do znacznych błędów obliczeniowych na etapie doboru i projektowania ciągów technologicznych oczyszczalni wód deszczowych. Wytoczna ATV A-118 oraz norma PN-EN 752 zalecają do obliczeń hydraulicznych systemów kanalizacyjnych, zastosowanie modelowania hydrodynamicznego dla zlewni o powierzchni przekraczającej 200 ha, ale również w przypadku występowania w sieci zjawiska wylania ścieków na powierzchnię terenu, co zdarza się na terenach miejskich stosunkowo często. Ponadto, ze względu na to, że w większości opracowane programy obliczeniowe (SWMM, Mouse, Mike Urban, Civil Storm) mają oprócz zaimplementowanych modułów do symulacji splywu, także moduły określania jakości ścieków, wydaje się wskazane przeprowadzenie kompleksowych analiz w tym kierunku. Celem artykułu jest omówienie wyników symulacji numerycznych jakości i ilości ścieków uzyskanych przy pomocy programu SWMM dla zlewni kanału Si9 zlokalizowanej na terenie Kielc. W artykule wykonano obliczenia hydrogramów odpływu ze zlewni i stężeń zawiesiny przy założeniu stałego natężenia deszczu dla czasu trwania  $t_d = 15-180$  min i prawdopodobieństwa wystąpienia opadu  $p = 20$  %. Ponadto opracowano model matematyczny oczyszczalni ścieków deszczowych, który pozwolił określić obciążenia ładunkiem zanieczyszczeń istniejącego ciągu technologicznego oraz ustalić objętość i ładunek zawiesiny ogólnej zrzucanej przelewem burzowym bezpośrednio do odbiornika. Przeprowadzone obliczenia wykazały nieznaczny wpływ jednostkowego splywu na masę zawiesiny ogólnej odpływającej z przedmiotowej zlewni zurbanizowanej.

**Słowa kluczowe:** modelowanie hydrodynamiczne, SWMM, ścieki deszczowe, zawiesina ogólna