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EXPERIMENTAL ANALYSIS OF BIELANY WASTEWATER TREATMENT PLANT HYDRAULIC LOAD VARIABILITY

EKSPERYMENTALNA ANALIZA ZMIENNOŚCI OBCIĄŻENIA HYDRAULICZNEGO OCZYSZCZALNI ŚCIEKÓW W BIELANACH

Abstract

In the performed research, the variability of sewage inflow to the Wastewater Treatment Plant in Bielany during dry and wet weather in different years and months in the period of 2008–2012 was analyzed. Particular attention was paid to the problem of accidental water which inflows to the sewage system in Bielany. Considering the period of observation, the hydraulic capacity of wastewater treatment plant was most frequently exceeded in 2010 (172 cases), least frequently in 2012 (54 cases). The probability of the appearance of daily sewage inflows, which exceed the hydraulic capacity of wastewater treatment plant in the period between 2008 and 2012 was 42%. The performed research has shown that, after eliminating the inflow of accidental water to the sewage system, the average-daily hydraulic load would not exceed 78.1% of the designed hydraulic capacity.

Keywords: hydraulic capacity, sewage, wastewater treatment plant

Streszczenie

W wykonanych badaniach przeanalizowano zmienność dopływu ścieków do oczyszczalni ścieków w Bielanach podczas pogody suchej i mokrej w poszczególnych latach i miesiącach 2008–2012. Szczególna uwaga została poświęcona problemowi wód przypadkowych dopływających do systemu kanalizacji w Bielanach. W całym okresie obserwacji najczęściej przepustowość hydrauliczna oczyszczalni ścieków była przekraczana w 2010 roku (172 przypadki), a najrzadziej w 2012 roku (54 przypadki). Prawdopodobieństwo pojawienia się dobowych dopływów ścieków, przekraczających przepustowość hydrauliczną oczyszczalni ścieków w latach 2008–2012, wyniosło 42%. Wykonane badania wykazały, że po wyeliminowaniu dopływu wód przypadkowych do systemu kanalizacji średniodobowe obciążenie hydrauliczne nie przekraczałoby 78,1%.

Słowa kluczowe: przepustowość hydrauliczna, ścieki, oczyszczalnia ścieków

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1. Introduction

Proper design of wastewater treatment plant and its further exploitation requires the knowledge of characteristic changes of quantitative sewage inflow. The inequality of sewage outflow from sewage systems appears both in daily, weekly and yearly cycle [1]. The most important factors, which determine the quantitative characteristics of sewage produced in settlements are dependent primarily on the quantity of households equipment with sanitary facilities and its condition, the method of water supply, the method of sewage disposal, the price of water and the cost of sewage drainage, people's lifestyle, the number of people living in the area, different types of manufacturing present, service and administration facilities which are not equipped with their own sewage disposal systems, and the degree of influence the infiltration and accidental water has on sewage systems [2].

Objects which are affected by improper dimensioning, by incorrectly defining the reliable flow can have problems with hydraulic underload. In this case, the challenge is to maintain the activated sludge in good condition with very low, or even evanescent, sewage inflow. Small amounts of sewage inflows to wastewater treatment plant cause the increase of the time of their retention in different technological objects of a wastewater treatment plant [3, 4]. Apart from the objects which have problems with hydraulic underload, one can also meet objects which even several times exceed the designed capacity. On such state, the uncontrolled inflows of foreign water – accidental and infiltration water – has influence. These waters cause dilution of pollutants contained in the sewage and cause reduced sedimentation ability of sludge as a result of too high sewage flow speed and the reduction of organic substance content susceptible to biodegradation in raw sewage [5]. Increasing sewage inflows to wastewater treatment plant contributes to the reduction in the efficiency of the equipment such as sand traps, and initial and secondary clarifiers. They can also cause flushing of the activated sludge from the biological reactor [6] and can increase the financial expenses of transportation and sewage aeration [7].

2. Research purpose

The main purpose of the executed research was the analysis of hydraulic load of Wastewater Treatment Plant in Bielany in terms of design capacity in specific years and months of period between 2008 and 2012 for the dry and wet weather. Very important was also to show the frequency and probability of sewage inflows appearance, the values of which exceeded the design capacity of the object. Particular attention was paid to foreign waters, mostly accidental water, which inflows to the sanitary sewage system in Bielany. Knowledge of the real quantity and the inflow inequality of wastewater to the sewage system is important due to the choice of a suitable method of their disposal and the proper exploitation of technological objects of the wastewater treatment plant.

3. Characteristics of the research object

The Wastewater Treatment Plant in Bielany is located in the southern part of the Bielany settlement, located in District VII "Zwierzyniec" in the western part of Cracow. It is estimated

that this wastewater treatment plant is used by about 1500 inhabitants. It is a mechanical – biological treatment plant, purifying domestic wastewater. The design capacity of this object is equal to 225.0 $m^3 \cdot d^{-1}$. To the sanitary sewage system in Bielany, the length of which is 10 km, 330 buildings are connected. The length of the storm water drainage in this area equals 1 km.

4. Research methodology

Based on the measurement results of daily sewage inflows to the Wastewater Treatment Plant in Bielany in the period from 1.01.2008 to 31.12.2012, the analysis of hydraulic load variability were conducted. The basis for the study was to determine the maximum, average, and minimum daily sewage inflows to the wastewater treatment plant. To measure the inflows, the measuring system installed in measuring recess, located in the wastewater treatment plant area was used.

In addition, this study took into account the daily precipitation. Knowledge of this parameter was necessary to determine which of the days of the period between 2008 and 2012 were dry, which were wet, and what was the degree of influence the foreign waters had on sewage system in the days with rainfalls. The amount of daily precipitation was measured by sensor trough, which was installed in the wastewater treatment plant area.

5. Research results and analysis

The first stage of research focused on the presentation of the shape of the average daily sewage inflow to the wastewater treatment plant in days with rain and days without rainfall, in each year of the period between 2008 and 2012 (Fig. 1). Inflows of sewage in days with rain in all years were much higher than in days without rainfall. The analysis showed that the average amount of daily sewage inflow to the wastewater treatment plant in the days of rainless weather in the study period was 175.8 $m^3 \cdot d^{-1}$ and was lower than the design capacity of the object (225.0 $m^3 \cdot d^{-1}$) by 21.9%. In the period between 2008 and 2012, accidental water caused the increase in the average daily sewage inflow by 37.1%, compared to the average daily inflow sewage during dry weather. The largest average daily sewage inflow to the wastewater treatment plant in the days of rain was recorded in 2010 (average 278.6 $m^3 \cdot d^{-1}$), while the lowest average daily inflow was recorded in 2012 (average 218.4 $m^3 \cdot d^{-1}$). Considering the values of the average daily sewage inflows in days without precipitation, there was no excess of design capacity of the wastewater treatment plant in any year of the analyzed period.

In the next stage of the study it was shown (Fig. 2) that the average daily inflow of the proper sewage to wastewater treatment plant in the period between 2008 and 2012 reaches the level 186.4 $m^3 \cdot d^{-1}$ and is lower than the design capacity of the object by 17.2%. In a multi-year period, accidental water caused an increase in the average daily sewage inflow in relation to the average daily proper sewage inflow by 19.5% which was probably primarily caused by precipitation. Annual total precipitation increased from 609 mm in 2008 to 895 mm in 2010 and then decreased to about 500 mm in the next years of the analyzed period. In turn, the average

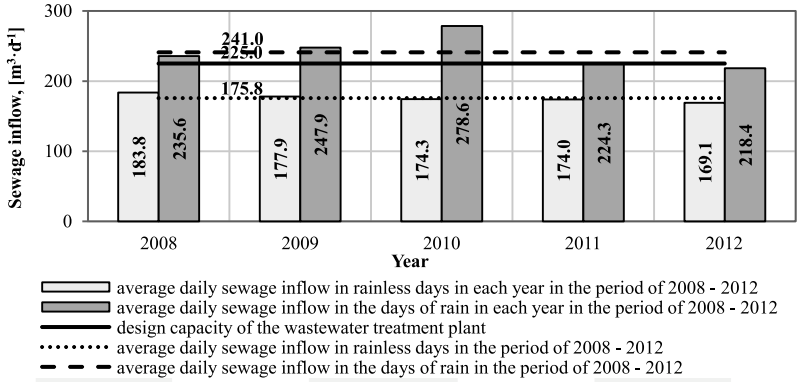

Fig. 1. The average daily sewage inflow to Wastewater Treatment Plant in Bielany in the days of rain and in rainless days in each year in the period between 2008 and 2012

annual total precipitation in the period between 2008 and 2012 was about 650 mm. The largest average daily sewage inflow, equal to 260.3 $m^3 \cdot d^{-1}$ and the largest part of accidental water was recorded in 2010. Accidental water were 27.4% of the average daily sewage inflow. The lowest average daily sewage inflow equaled 196.6 $m^3 \cdot d^{-1}$ and the lowest part of accidental water was recorded in 2012. Accidental water was only 10% of the average daily sewage inflow.

Considering the rate of the hydraulic load the object in each month in the period between 2008 and 2012, the largest average daily sewage inflow to wastewater treatment plant in the days of rain was usually observed in May (average 309.4 $m^3 \cdot d^{-1}$) and was higher than the design capacity of Bielany Wastewater Treatment Plant by 37.5% and in June (average 251.8 $m^3 \cdot d^{-1}$) when the design capacity was exceeded by 11.9%. The lowest average daily sewage inflow in the days of rain was recorded in January (average 225.8 $m^3 \cdot d^{-1}$) and November (average 221.8 $m^3 \cdot d^{-1}$). Based on the average daily sewage inflows in days without precipitation, the design capacity was not exceeded in any month of the analyzed period (Fig. 3).

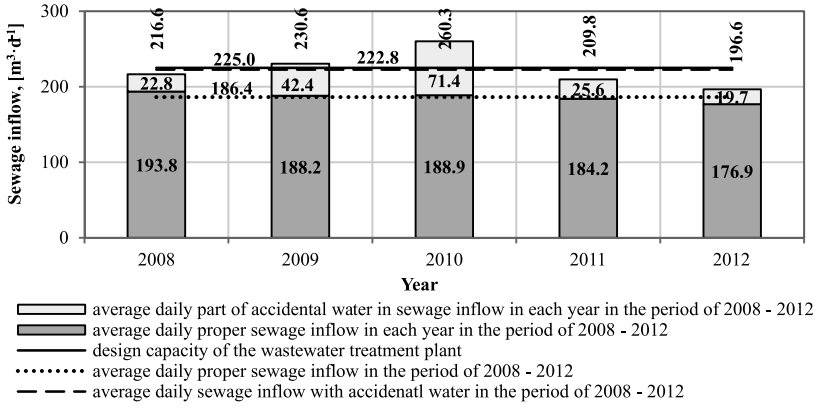

Fig. 2. The fraction of accidental water in average daily sewage inflow to Wastewater Treatment Plant in Bielany in each year in the period of 2008–2012

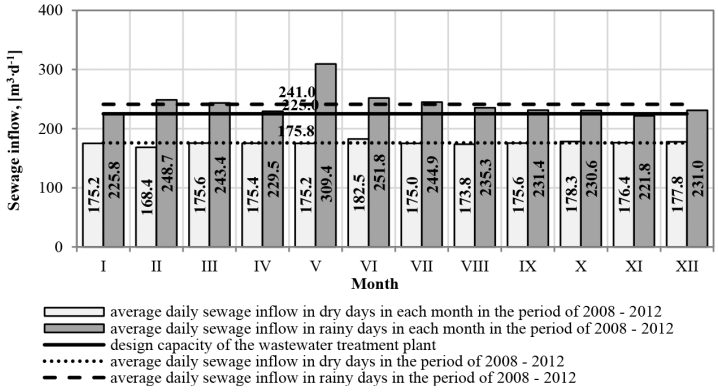

Fig. 3. Average daily sewage inflow to Bielany Wastewater Treatment Plant in the days of rain and in rainless days in each month of period 2008–2012

The final stage of the research was to determine the frequency and probability of the appearance of sewage inflows of specified sizes. From 2008 to 2010, an increase in the number of cases when the object design capacity has been exceeded was noted. In 2010, 172 cases of exceeding the design capacity of the wastewater treatment plant were reported, while the smallest number of these events was reported in 2012 (54 cases). Over the five years of research, 534 cases of exceeding the design hydraulic capacity were reported, so the probability of this event was 42%.

6. Conclusions and statements

1) Throughout the research period the design capacity of wastewater treatment plant was not exceeded only in days of rainless weather.
2) In the period between 2008 and 2012, accidental water caused an increase in the hydraulic load of the wastewater treatment plant in comparison to the rainless period by 37.1%.
3) Performed research has shown that, from 2008 to 2010, there was a gradual increase in the number of cases in which the design capacity (225.0 $m^3 \cdot d^{-1}$) was exceeded. After 2010, the number of cases exceeding the hydraulic capacity decreased.
4) The design capacity of the wastewater treatment plant was most frequently exceeded in 2010 (172 cases), while in 2012 (54 cases) it was least frequently exceeded. In the period between 2008 and 2012 the total amount of events exceeding the design capacity was equal to 534.
5) In the analyzed multi-year period of 2008–2012, the probability of exceeding the design capacity of the object was 42%. The high probability of this event shows that it is necessary to eliminate inflowing of accidental water to the sanitary sewage system in Bielany, the large amounts of which appear during heavy rain or spring snowmelt. The completed research has shown that after eliminating accidental water inflow to the sanitary sewage system, daily average hydraulic load would not exceed 78.1%.

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