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THE IMPACT OF THE SEWER SYSTEM RINSING ON THE WASTEWATER COMPOSITION

The paper presents the results of research on the influence of the operational rinsing of a sewer system on the composition of raw sewage, the effectiveness of the operation of the mechanical part of a wastewater treatment plant and changes in the technological parameters of the biological reactor. The results of the research have shown an increase in sewage pollution during the rinsing of the sewer system. The value of the COD indicator increased from 799 to 1306 mg/dm^3, BOD$_5$ from 538 to 1044 mg/dm^3, and total suspended solids from 259 to 1508 mg/dm^3. The calculations indicate that an increase in the concentrations of pollution during the rinsing of the sewer system requires a high working efficiency of the mechanical part of the wastewater treatment plant. With a low efficiency the volume of the biological reactor can increase even by 30%.

1. INTRODUCTION

The flow of sewage in the sewer network is accompanied by biological and chemical processes taking place not only in the sediment layer but also in the sewage [1]. Decomposition processes can take place both in anaerobic or aerobic conditions with the participation of various groups of microorganisms. The effectiveness of these processes depends on the conditions in sewer systems, and they are accompanied by such processes, noticed by network users, as: digestion, emission of hydrogen sulfide or methane, and corrosion [2, 3]. The canal supplying sewage to the sewage treatment plant can be regarded as a sewage inflow receiver, where hydrolysis, changes of fractions of organic substance, the sedimentation of solid components and the growth of biomass of organisms take place. The following factors influence the rate of aeration of sewage, and the settlement of anaerobic or aerobic conditions: turbulence and amount of inflow, ventilation of the sewer system, and the depth of sewage in the

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sewer [4]. Because of high concentrations of pollution, changes will take place slowly, and their results will determine the maintenance of the network including rinsing. Changes in the composition of sewage during the rinsing of the sewer network influence the load of pollution coming into the water treatment plant connected to the sewer network.

Solids accumulated in sewer systems constitute major problems in terms of the reduction of sewer capacity and as a source of pollution during wet weather overflow events in watercourses. In order to maintain sewer system capacity, it is necessary to periodically clean the sewer system. Regular flushing may be an economic and ecologic method of keeping sewer systems clean over long periods. The procedure of flush cleaning may be used as an alternative measure to cost intensive chemical methods of cleaning [5].

Sewer cleaning has been gaining importance recently. Sediments will harden on the sewer base and the material layers grow more and more over the course of time. There are a number of reasons for sedimentation on the sewer base. Regular retention combined with a slow flow velocity especially in combined sewer systems leads to sedimentation of material which may contain also a huge amount of organic material [6, 7]. Negative effects of solid accumulation are: an increase in storm water overflow quantity discharged into the receiving water courses, high peak loads arriving at the wastewater treatment plant, sewer damage caused by wrong handling of high-pressure cleaners. However systematic flushing of sewer systems can prevent some of negative effects such as high peak loads arriving at the wastewater treatment plant and odours, and it minimises energy consumption and costs of sewage treatment [8].

Flushing of sewer systems also reduces emission of hydrogen sulfide. Hydrogen sulfide emission in sewer systems is associated with several problems, including the biogenic corrosion of concrete, release of obnoxious odours and toxicity of sulfide gas to sewer workers [9–11]. According to Zhang et al. [12], the biogenic corrosion of sewers represents a cost of about 10% of the total sewage treatment cost and it is further increasing.

An increase in the concentration of pollution in the sewage during the rinsing of the network should be taken into account while designing new sewage treatment plants and modernizing old ones. In the existing units the function of buffering irregularities in the inflow of pollution loads is performed by the well-designed mechanical part of the sewage treatment plant. An inflow into the biological part of more loads of pollution than the ones specified in the design may cause an increase in: the costs of aeration, the minimum required capacity of bioreactors as well as an amount and costs of sediment processing [2, 3].

The paper presents results of research on the impact of rinsing the sewer system of the composition of raw wastewater flowing into a mechanical-biological wastewater treatment plant. The effectiveness of the mechanical treatment of wastewater during its daily operation and during the sewer system rinsing is also analysed.

2. EXPERIMENTAL

Characteristics of the research object. The research object was a mechanical--biological municipal wastewater treatment plant (WWTP) in Poland with an output of 310 m^3/d. The WWTP was designed in 1991, and then modernized in 2005.

In the mechanical part of the system design contained gratings with washing and pressing screenings, raw sewage pumping station and an Imhoff clarifier. Biological part was based on activated sludge which provides oxygen removal of organic carbon. Wastewater treatment plant cooperated with pressure-gravity sewers supporting the village of community Lubniewice.

Sewer was equipped with 15 pumping zones, and the frequency of turning depended on water consumption. In the village there was no timetable for systematic rinsing of sewer. Rinsing took place in forced situations of operational problems.

Testing method. For testing wastewater samples flowing into the WWTP during its normal operation as well as samples of the influent wastewater after rinsing the sewer system were collected. The wastewater samples were taken at two measurement points: P1– raw wastewater and P2 – mechanically treated wastewater. The contents of pollutants in raw wastewater flowing into the plant and mechanically treated was analysed in time-proportional samples taken every two hours for five consecutive days. Simultaneously, the flow intensity of flowing wastewater within two hours was measured. Raw wastewater samples and mechanically treated ones were taken in accordance with PN-ISO 5667-10:1997.

The physico-chemical analyses of the sewage samples included: chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), total phosphorus, total Kjeldahl nitrogen (TKN), $N\text{-}NH_4$.

All of parameters were analysed in accordance with the Polish Norms [13–18].

3. RESULTS

The results of the research as mean values are presented in Tables 1, 2. The average daily flow of wastewater in the study period amounted to 310 m^3/d, and during rinsing the sewer system was 400 m^3/d. The research has shown that in raw wastewater flowing into the WWTP during its daily operation the content in organic pollutants was: COD = 605–1102 mg O_2/dm^3, BOD_5 = 377–1087 mg O_2/dm^3, while in the raw wastewater influent after flushing the sewer system the values of these indicators were on average twofold higher (COD = 622–1884 mg O_2/dm^3, BOD_5 = 507–1412 mg O_2/dm^3).

Rinsing the sewer resulted in a considerable increase in total suspended solids in raw wastewater flowing into the WWTP. The concentration of total suspended solids in raw wastewater influent to the WWTP varied from 106 to 466 mg/dm^3, while in raw wastewater after flushing the sewer system, the concentration of total suspended solids ranged from 400 to 2336 mg/dm^3.

Table 1

Physico-chemical composition of the raw wastewater and mechanically treated wastewater [mg/dm^3] during daily work (RW – raw wastewater; MTW – mechanically treated wastewater)

Parameter	COD		BOD_5		TSS		P_{tot}		$N\text{-}NH_4$		TKN	
	RW	MTW	RW	MTW	RW	MTW	RW	MTW	RW	MTW	RW	MTW
Measurment day	737	668	439	417	180	94	10.3	10.4	61.6	67.2	94.5	103.8
	605	653	377	383	106	84	10.3	8.9	64.4	51.8	70.5	61.1
	748	572	417	355	344	160	10.4	11.1	60.2	64.4	67.7	72.8
	1102	733	1087	451	466	74	11.1	12.6	56.0	60.2	72.3	81.2
	775	696	428	400	206	44	11.1	11.1	57.4	60.2	76.1	76.1
	830	722	479	439	252	128	11.3	11.3	57.4	56.0	77.0	72.8
Average	799.5 ±165.8	674 ±58.6	537.8 ±271.1	407.5 ±35.7	259.0 ±128.5	97.3 ±41.1	10.8 ±0.5	10.9 ±1.2	59.5 ±3.2	60.0 ±5.6	76.4 ±9.5	78.0 ±14.3

Table 2

Physico-chemical composition of the raw wastewater and mechanically treated wastewater [mg/dm^3] during rinsing sewer system (RW – raw wastewater; MTW – mechanically treated wastewater)

Parameter	COD		BOD_5		TSS		P_{tot}		$N\text{-}NH_4$		TKN	
	RW	MTW	RW	MTW	RW	MTW	RW	MTW	RW	MTW	RW	MTW
Measurment day	727	590	648	349	1604	166	9.5	10.0	73.1	74.3	75.2	77.0
	1632	594	1412	394	1496	162	14.0	9.9	74.2	78.6	77.0	78.7
	622	547	507	332	400	112	8.9	9.4	69.1	77.4	70.0	78.7
	1884	644	1257	152	2336	200	15.3	10.4	71.6	76.7	71.7	78.7
	1666	806	1398	473	1702	222	15.6	11.5	71.6	73.6	73.5	75.2
Average	1306.2 ±585.9	636.2 ±100.9	1044.4 ±433.4	340.0 ±118.4	1507.6 ±700.0	172.4 ±41.9	12.7 ±3.3	10.2 ±0.8	71.9 ±1.9	76.1 ±2.1	73.5 ±2.8	77.7 ±1.6

The differences in the values of COD, BOD_5 and total suspended solids in the raw wastewater influent to the WWTP during its daily work and in the wastewater flowing after rinsing the sewer system is shown in Fig. 1. The concentrations of nitrogen and phosphorus in the raw wastewater influent to the WWTP were: TKN = 67.7–94.5 mg/dm^3 and P_{tot} = 10.3–11.3 mg/dm^3. Rinsing the sewer system did not affect significantly the change of the concentration of nitrogen and phosphorus in the wastewater influent to the WWTP.

The concentrations of pollutants in mechanically treated wastewater are presented in Fig. 2. The wastewater samples were taken after the Imhoff clarifier.

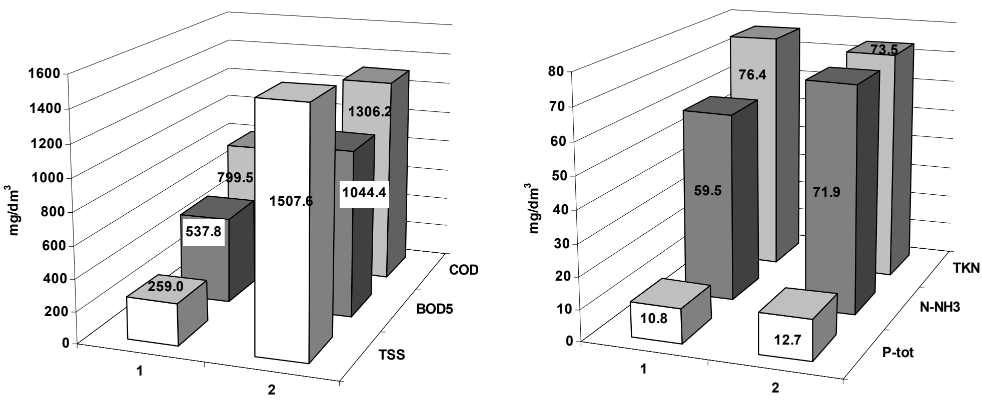

Fig. 1. Concentrations of pollutants in raw wastewater:
1 – composition of the wastewater, 2 – composition of the wastewater after rinsing the sewer system

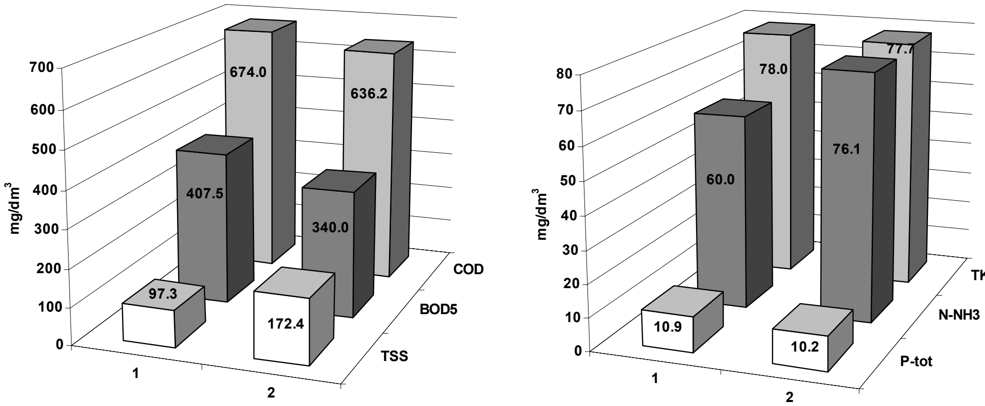

Fig. 2. Concentrations of pollutants in mechanically treated wastewater:
1 – composition of the wastewater, 2 – composition of the wastewater after rinsing the sewer system

The concentrations of organic pollutants (COD and BOD_5) in mechanically treated wastewater during its daily operation and after rinsing the sewer system were similar. The values of COD and BOD_5 for mechanically treated wastewater during daily working WWTP and after rinsing the sewer system were: COD: 572–733 mg O_2/dm^3 and 547–806 mg O_2/dm^3, BOD_5: 355–451 mg O_2/dm^3 and 152–473 mg O_2/dm^3. A slightly greater variation was found in the concentrations of total suspended solids. The concentration of TSS in mechanically treated wastewater during daily work varied from 44 to 160 mg/dm^3, while in mechanically treated wastewater after rinsing the sewer system the values were higher, ranging from 112 to 222 mg/dm^3.

4. DISCUSSION

Research on the impact of the sewer system rinsing to change the composition of raw wastewater flowing into the mechanical-biological wastewater treatment plant showed a significant increase in the concentrations of organic pollutants and total suspended solids, and small changes of the concentrations of nitrogen and phosphorus.

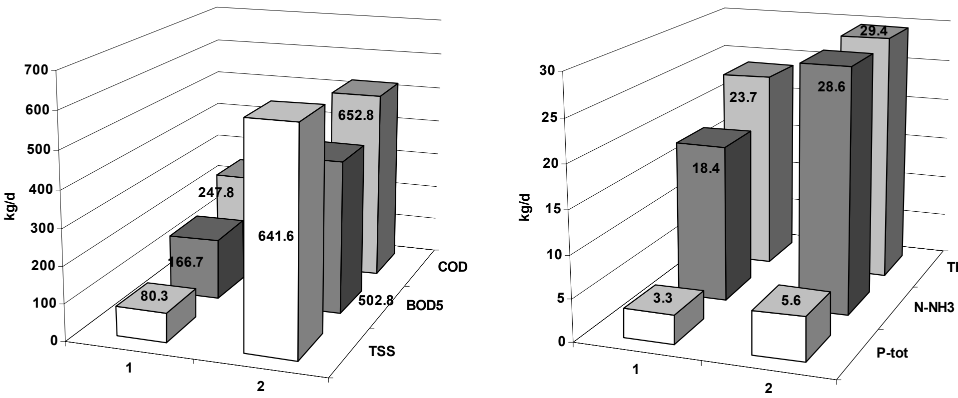

Fig. 3. Pollution loads in raw wastewater: 1 – composition of the wastewater
2 – composition of the wastewater after rinsing the sewer system

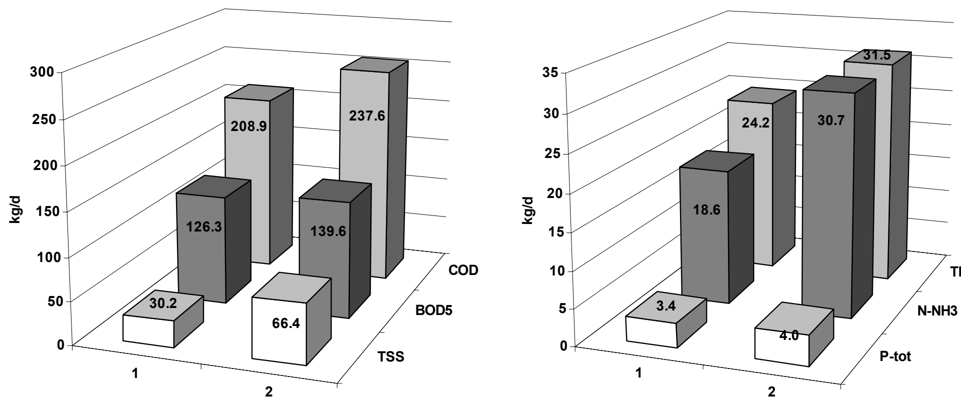

Fig. 4. The pollution loads in mechanically treated wastewater:
1 – average composition of the wastewater 2 – wastewater after rinsing the sewer system

Figures 3 and 4 present loads of pollutants in the wastewater based on daily average flow of wastewater to the WWTP. Rinsing the sewer system caused a significant increase in the load of total suspended solids and organic pollutants but did not cause a significant change in the loads of nitrogen and phosphorus (Fig. 3).

An increase in the load of total suspended solids and organic pollutants caused an especially heavy burden in the mechanical part of the wastewater treatment plant (Figs. 3 and 4). The efficiency of the removal of total suspended solids and organic pollution loads in mechanical treatment processes during daily work were: COD: 15.7%, BOD_5: 24.2% and TSS: 62.4%. We should note a very high efficiency of the removal of total suspended solids and organic pollutants during the sewer system rinsing. The efficiency of pollutant removal was: COD: 63.6%, BOD_5: 72.2% and TSS: 89.7%.

An increase in the efficiency of pollutant removal in mechanically treated wastewater during rinsing the sewer system indicates very good work of the Imhoff clarifier. Simultaneous increase in the efficiency of the removal of organic pollutants and suspended solids proves that a large quantity of organic pollutant is present in the suspension.

No significant difference was found between the nitrogen and phosphorus loads in raw and mechanically treated wastewater, both in the effluent during daily operation of the WWTP and during rinsing the sewer system. An increase in pollutants loads flowing into biological parts during rinsing the sewer system did not affect significantly the efficiency of biological treatment.

Increasing the concentration of suspended solids and BOD_5 in the effluent flowing into the biological part during rinsing the sewer system contributed to a periodical increase in the production of excess sludge and the required minimum volume of the biological chamber. Calculations were made for the assumed sludge age 5 d and sludge concentration in the chamber 3.5 kg/m^3. The growth of activated sludge in normal plant operation was 0.61 kg DM/kg BOD_5, and for an additional load of suspended solids during rinsing the sewer system it was 0.77 kg DM/kg BOD_5.

The effectiveness of biological wastewater treatment processes in the oxygen chamber depends on various factors such as e.g. appropriate concentration of activated sludge with respect to the load of organic pollution expressed as the BOD_5 ratio [19].

The values of this parameter were 0.23 and 0.29 kg BOD_5/(kg DM·d) for daily plant operation, and during rinsing the sewer system, respectively. According to the guidelines, effective removal of organic compounds requires the maintenance of this parameter in the range of 0.2–0.3 kg BOD_5/(kg DM·d). The required minimum volume of activated sludge chamber due to an increased inflow of pollutions loading and the quantity of sewage increase by 27% compared to the normal operating conditions of the plant. The calculation and analysis of data show that effective prevention against negative consequences of uncontrolled inflow of pollutants during rinsing the sewer system requires the use of high performance mechanical part of the WWTP, taking into account a temporary increase in pollutant loads.

5. CONCLUSIONS

Rinsing of the sewer system results in an increase in the concentration of organic pollutants and total suspended solids in raw wastewater flowing into the WWTP.

Rinsing the sewer system does not significantly change the concentration of nitrogen and phosphorus in the raw wastewater.

An increase in the load of total suspended solids and organic pollutants resulted in especially heavy burden of the mechanical part of the wastewater treatment plant.

The research has documented a very high efficiency of the Imhoff clarifier in the removal of organic pollutants and total suspended solids during the sewer system rinsing.

An increase in the quantity of sewage and pollutants loads during rinsing the sewer system increases the required volume of activated sludge chamber by about 30%. Therefore, a periodical deterioration in the quality of treated sewage should be expected.

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