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THE EFFICIENCY OF POLLUTANT ELIMINATION IN THE DOBRA TREATMENT PLANT

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Summary

This study was aimed to conduct an analysis of the efficiency of pollutant elimination in the Dobra treatment plant, which operates based on the SBR reactor. The object purifies domestic sewage and pre-treated industrial sewage from a slaughterhouse within the Dobra municipality. The source material for the analysis comprised the values of pollution indicators: BOD_5, COD_{Cr}, total suspended solids (TTS) in raw sewage (19 samples) and treated sewage (34 samples). The results of chemical analyses were obtained in the period 2007-2014. The results were compared with the limit values imposed by the Regulation (2014). The coefficient of reliability of the treatment plant was also calculated in this study. The average efficiency of pollutant elimination in the treatment plant was: BOD_5 – 98.6%, COD_{Cr} – 94.9%, total suspended solids – 97.6%. These results demonstrate that the studied facility operates flawlessly and the treatment efficiency is high. On the other hand, the reliability coefficient values indicate that the operation of this object is unstable.

Key words: sewage treatment plant, domestic sewage, SBR.

INTRODUCTION

The development of water and sewerage systems, progressing for many years, results in a significant increase in the amount of sewage discharged to sewerage networks. The Central Statistical Office reports that the amount of sewage discharged to sewerage network from rural areas in Małopolska in 2012 increased by 7% as compared to the preceding year (CSO 2013). Such trend forces investments related to the expansion and modernization of the existing sewage treatment plants in order to allow discharge of treated sewage of adequate quality to the receiver.

Consequently, there is a need for conducting broad evaluation of these facilities, both in terms of the efficiency of pollutant removal, reduction of contaminants, operational reliability of the object and statistical analysis of the laboratory results. An extensive analysis of the results of studies conducted during the operation of a treatment plant allows to predict abnormalities and to eliminate them in the future. This is important in terms of surface water protection, as it allows for the effective protection of flowing waters and the natural environment.

The sewage treatment process should be conducted in such a way that the highest possible degree of purification is achieved at minimum of cost (Łomotowski and Szpindor 1999, Dymaczewski 2011). In rural areas sewage is characterized by large variation in flow and pollution loads, therefore the selection of sewage treatment technologies is not easy. In rural households, where either agricultural or animal production is carried out, water is consumed not only for domestic purposes but also for the needs of animals, farming or for dilution of crop-spraying chemicals and washing of farming machines (Pawełek and Bergel 2002). This type of sewage should not enter domestic treatment plants, because animal waste is characterized by high concentrations of contaminants (Szpindor, 1998). On the other hand, sewage treatment plants may receive sewage from septic tanks of household treatment plants and spill-holding tanks. They are characterized by very high concentration of contaminants and may increase values of raw sewage treated at the facility. Thus, properly designed sewage treatment plant should operate successfully at different loads of sewage.

This article aims at assessing the effectiveness of pollutant elimination in the sewage treatment plant in Dobra near Limanowa in the Małopolska voivodeship. The studied facility operation is based on an SBR sequential reactor. The analysis of results was conducted in order to determine the efficiency of the facility operation in the period of 2007-2014. Three pollution indicators were taken into consideration: BOD_5, COD_{Cr} and TSS. The efficiency and reliability of the treatment plant was evaluated and statistical analysis of data was conducted. Additionally, hydraulic load of the treatment plant for the period from January 2012 to December 2013 was determined.

DESCRIPTION OF THE STUDIED FACILITY

The analyzed treatment plant is located in the Małopolska voivodeship in Dobra locality near Limanowa. The tested facility was designed for 2,375 PE which qualifies it to the second group of treatment plants [Regulation 2014].

Mean daily flow is 250 $m^3 \cdot d^{-1}$ and maximum daily flow is 326 $m^3 \cdot d^{-1}$. The plant receives sanitary effluent from the sewerage system, transported sewage and pre-treated industrial sewage from a slaughterhouse. A liquid waste storage point is equipped with automatic monitoring system of transported sewage, where information is recorded on who, and when transported sewage, as well as on the amount of sewage that was introduced into the treatment plant. The technological chain consists of a vertical spiral sieve with 6 mm perforation, drum sieves with 4 mm perforation, sequential SBR reactor comprising two chambers, each with a capacity of 248.4 m^3, phosphorus precipitation coagulant dosage station and a settlement pond. Treated sewage, disinfected with sodium hypochlorite is discharged into the Łososina river at km 45.350. The sequential biological reactor operates based on five stages: filling, mixing with agitators, aeration by diffusers placed in the bottom of the reactor cooperating with blowers hall, which dose air thus maintaining the oxygen content in the range of 1.5 to 2.5 $gO_2 \cdot m^{-3}$, sedimentation and sewage drainage to the settlement pond, where sewage retention time is 3 hours. Figure 1 shows a simplified technological diagram of the plant.

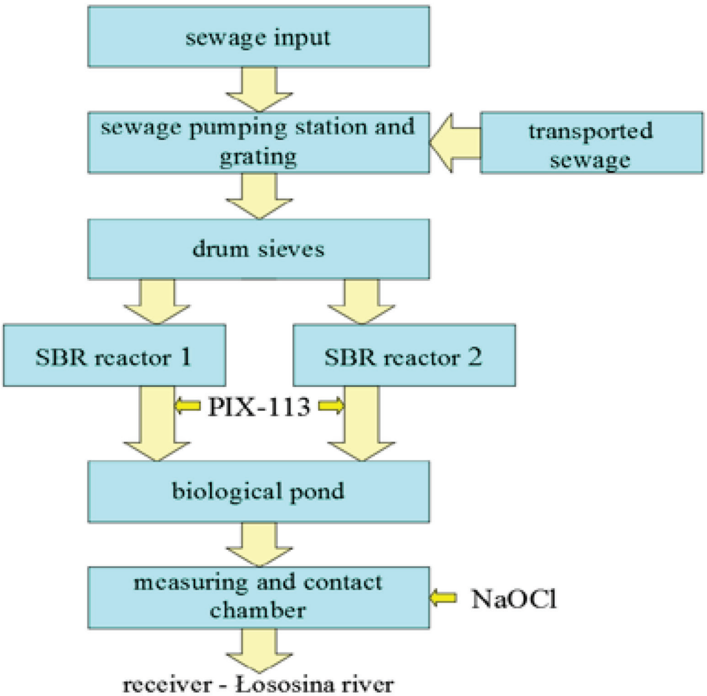

Figure 1. A simplified technological diagram of the sewage treatment plant in Dobra near Limanowa (Chmielowska 2014)

METHOD

During the study period of 2007-2014 physicochemical analyses of 19 raw sewage samples were conducted at a frequency of twice per year and of 34 treated sewage samples 4 times per year. The values of the analyzed parameters (BOD_5, COD_{Cr}, TSS) were compared to the current limits for treated sewage given in the Regulation (2014). In this study some basic statistical characteristics of the analyzed pollution indicators were determined: mean, median, variance, standard deviation, minimum and maximum value and the coefficient of variation. Based on the calculated statistical characteristics the coefficient of reliability (COR) was determined according to the formula (Andarka 2011):

$$COR = \frac{x_m}{X_l} \ [-] \tag{1}$$

where:

x_m – mean value of each indicator in treated sewage [mg·dm^{-3}],

x_l – limit value of each indicator in treated sewage [mg·dm^{-3}].

Calculation of the sewage treatment efficiency:

$$\eta = \frac{C_d - C_0}{C_d} \cdot 100 \ [\%] \tag{2}$$

where:

C_d – concentration of component or the value of indicator for sewage flowing into the treatment plant [g·m^{-3}],

C_0 – concentration of component or the value of indicator for sewage flowing out of the treatment plant [g·m^{-3}],

Moreover, the analysis of hydraulic load of the treatment plant in the period from January 2012 to December 2013 was conducted. The daily hydraulic load was compared on a graph against the mean and limit values. Basic descriptive statistics of sewage flow for each year and for the entire study period were summarized in tables. Mean, minimum and maximum values, standard deviation and coefficient of variation were determined.

ANALYSIS OF THE RESULTS

Firstly, hydraulic load of the sewage treatment plant in Dobra is presented. Figure 1 shows the course of daily flow of raw sewage in the period from January 2012 to December 2013 against the mean and limit values. According to the water permit (2003) the limit hydraulic load for the treatment plant in Dobra is 326 m^3·d^{-1}.

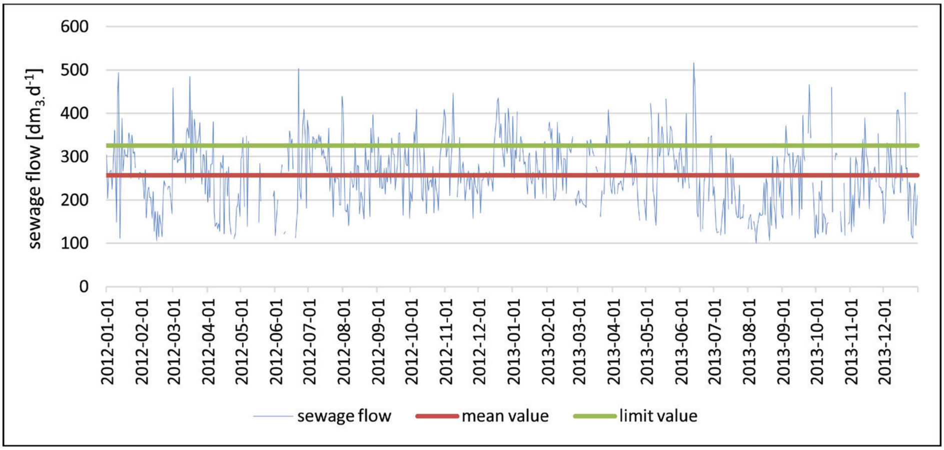

Figure 2. Daily flows of sewage for the treatment plant in Dobra in the study period

The analysis of data summarized in Figure 2 indicates fluctuations in hydraulic load of the treatment plant. Similarly uneven load of the treatment plant was observed by other researchers (Krzanowski and Wałęga 2004, Kaczor 2012, Chmielowski et all. 2012). Figure 1 shows numerous events of exceedance of limit value for the hydraulic load. They occurred mainly during snowmelt periods in spring. Improperly constructed sewerage system may contribute to uncontrolled infiltration and inflow (Kaczor 2012). In Table 1 are presented basic descriptive statistics for the hydraulic load of the sewage treatment plant in Dobra.

Table 1. Basic descriptive statistics of the sewage flow in the Dobra treatment plant

No.	Flow statistic	Symbol	Unit	Study period		
				2012	2013	2012-2013
1	Mean flow	Q_m	$[m^3 \cdot d^{-1}]$	266.17	250.66	258.46
2	Maximum	Q_{max}	$[m^3 \cdot d^{-1}]$	503.00	517.00	517.00
3	Minimum	Q_{min}	$[m^3 \cdot d^{-1}]$	106.00	100.00	100.00
4	Standard deviation	O_{st}	$[m^3 \cdot d^{-1}]$	76.01	78.00	77.34
5	Coefficient of variability	C_v	-	0.29	0.31	0.30
6	Number of samples	N	-	334	330	664

The results of physicochemical analyses show that the indices of treated sewage samples varied in the studied treatment plant and did not exceed the limit values, except for one sample of BOD_5, which exceeded the limit value by 7 $mgO_2 \cdot dm^{-3}$. The values of coefficient of variation range from 0.44 for COD_{Cr} to 0.82 for BOD_5, which proves high instability of the operation of the studied sewage treatment plant (Table 3). Such large differences in the values of sewage inflow to the Dobra treatment plant may result from the inflow of infiltration and accidental water. In order to confirm these hypothesis additional tests should be conducted, e.g. taking into consideration the measurement of sewage inflow at night. This would answer the question of what is the percentage of inflow in the period of decreased activity of citizens connected to the sewerage system. Illegal connections of gutters draining rainwater from roofs of houses may also contribute to a significantly increased inflow to the sewerage system during rainfall. In this respect the municipality authorities should provide trainings for local residents, which on one hand would demonstrate the benefits resulting from the collection of rainwater within properties and on the other – would show the users of sewerage system the drawbacks of illegal discharge of rainwater to the sanitary sewerage system.

Large variations within values are also observed in the samples of raw sewage. The coefficient of variation ranges from 0.56 for COD_{Cr} to 0.97 for total suspended solids (Table 2).

Table 2. Statistical characteristics of the analysed pollution indicators in raw sewage

No.	Parameter		BOD_5 [$mgO_2 \cdot dm^{-3}$]	COD_{Cr} [$mgO_2 \cdot dm^{-3}$]	TSS [$mg \cdot dm^{-3}$]
1	Sample size	n	19	19	19
2	Mean value	X_m	505	933	349
3	Median	m_x	487	836	210
4	Standard deviation	S	322	525	337
5	Minimum value	*min*	113	224	52
6	Maximum value	*max*	1270	2142	1360
7	Coefficient of variation	C_v	0.64	0.56	0.97

Data shown in Table 2 indicate that all analysed indicators are significantly scattered. The minimum value of BOD_5 is 113 $mgO_2 \cdot dm^{-3}$ and the maximum is 1270 $mgO_2 \cdot dm^{-3}$, similarly as in the case of COD_{Cr} (minimum value of 224.2 $mgO_2 \cdot dm^{-3}$ and the maximum of 2142 $mgO_2 \cdot dm^{-3}$) and total suspended solids (minimum value of 52 $mgO_2 \cdot dm^{-3}$ and the maximum of 1360 $mgO_2 \cdot dm^{-3}$).

After comparing the results obtained in this study with the BOD_5 values reported by other authors (Łomotowski and Szpindor 1999, Henze et al. 2002, Heidrich and Witkowski 2005) it can be concluded that they are high. According to Błażejewski [2003], BOD_5 of raw sewage falls within the range of 230-500 $mgO_2 \cdot dm^{-3}$, with an average of 300 $mgO_2 \cdot dm^{-3}$. On the other hand, Tchobanoglous et al. [2003] determine the average value of BOD_5 to be only 190 $mgO_2 \cdot dm^{-3}$. This indicates that as a result of efficient water consumption for household purposes the value of BOD_5 in raw sewage increased compared to the results of studies from previous years. Significant fluctuations in the values of basic indicators of sewage contamination may result from the inflow of infiltration and accidental water. This results in dilution of sewage inflowing through the sewerage system to the Dobra treatment plant (minimum value of BOD_5 – 113 $mgO_2 \cdot dm^{-3}$, COD_{Cr} – 224 $mgO_2 \cdot dm^{-3}$, total suspended solids – 52 $mg \cdot dm^{-3}$). On the other hand, liquid waste transported withemptiers to the sewage collection stations of the Dobra treatment plant may result in extremely high values of indexes (maximum value of BOD_5 – 1270 $mgO_2 \cdot dm^{-3}$, COD_{Cr} – 2142 $mgO_2 \cdot dm^{-3}$, total suspended solids – 1360 $mg \cdot dm^{-3}$). According to Kaczor (2012), infiltration and accidental water inflow often causes unfavourable values of COD_{Cr}/BOD_5 ratio, which determines the ease of sewage decomposition in biological processes.

Table 3 shows statistical characteristics of the analysed pollution indicators of the treated sewage.

Table 3. Statistical characteristics of the analysed pollution indicators in treated sewage

No.	Parameter		BOD_5 [$mgO_2 \cdot dm^{-3}$]	COD_{Cr} [$mgO_2 \cdot dm^{-3}$]	TSS [$mg \cdot dm^{-3}$]
1	Sample size	n	34	34	34
2	Mean value	X_m	7.0	47.8	8.2
3	Median	m_x	4.9	44.5	7.2
4	Variance	S^2	32.9	433.4	23.8
5	Standard deviation	S	5.7	20.8	4.9
6	Minimum value	*min*	1.2	18.6	2.0
7	Maximum value	*max*	32.0	107.7	20.0
8	Limit value	X_l	25	125	35
9	Coefficient of variability	C_v	0.82	0.44	0.60
10	Coefficient of reliability	*COR*	0.28	0.38	0.23
11	Mean effectiveness	η [%]	98.6	94.9	97.6

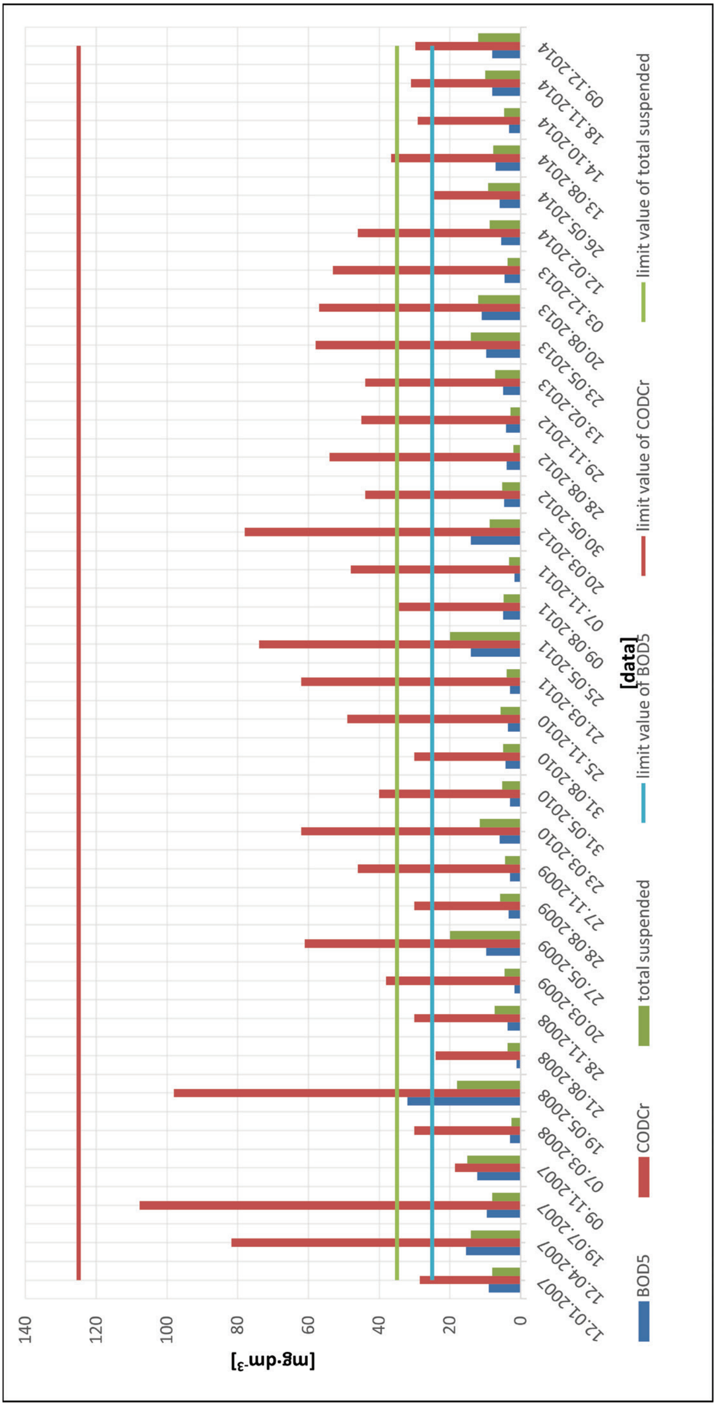

Figure 3. Variation in BOD_5, COD_{Cr} and TSS in treated sewage and limit values for these indicators

Based on Table 3 and Figure 2 it can be concluded that the maximum value of BOD_5 in treated sewage was 32 $mgO_2 \cdot dm^{-3}$, while the minimum was 1.2 $mgO_2 \cdot dm^{-3}$. Mean value of this indicator equaled 7.0 $mgO_2 \cdot dm^{-3}$. Only one measurement showed the excess of the permitted level of BOD_5, which according to the Regulation (2014) should not exceed 25 $mgO_2 \cdot dm^{-3}$ (tab. 3). The maximum value of COD_{Cr} in treated sewage was 107.7 $mgO_2 \cdot dm^{-3}$, while the minimum value was 18.6 $mgO_2 \cdot dm^{-3}$. The mean value of this indicator was equal to 47.8 $mgO_2 \cdot dm^{-3}$. None of the measurements showed exceedance of the permitted level. The results of analyses of total suspended solids ranged from 2.0 to 20.0 $mg \cdot dm^{-3}$ and the mean value was 8.2 $mg \cdot dm^{-3}$. The effectiveness of sewage treatment in the studied facility was high: for BOD_5 it was 98.6%, for COD_{Cr} – 94.9% and for total suspended solids 97.6%. When comparing these results with literature (Chmielowski et al. 2011, Miernik 2007) it can be concluded that the analysed facility has been working very effectively. The results of the sewage treatment efficiency are very high and comparable with the assessment results of the treatment plants operating based on the activated sludge method in the SBR reactor.

When analysing data shown in Figure 3, it is evident that the values of BOD_5 in treated sewage were in general below the limit (25 $mgO_2 \cdot dm^{-3}$). This could be caused by the amount of sewage transported by the cesspool emptier fleet from the nearby spill-holding tanks. It is therefore important that the staff operating the liquid waste storage station watches carefully in order not to discharge sewage with excessive pollutant load into this plant.

SUMMARY AND CONCLUSIONS

The paper presents the results of studies on the sewage treatment plant in Dobra which operates based on the SBR reactor. Data on raw and treated sewage from the study period of January 2007 to December 2014 were collected.

Based on the conducted analysis of the results the following conclusions can be drawn:

1. The mean values of BOD_5, COD_{Cr} and total suspended solids in raw sewage, obtained as a result of this study, were higher than the mean values presented in the analyzed literature.
2. Different levels of hydraulic load of the sewage treatment plant were observed, which may evidence infiltration and inflow during rainy periods.
3. Low values of the analysed indicators were found in treated sewage, amounting on average to: 7.0 $mgO_2 \cdot dm^{-3}$ for BOD_5, 47.8 $mgO_2 \cdot dm^{-3}$ for COD_{Cr} and 8.2 $mg \cdot dm^{-3}$ for total suspended solids. There has been only one exceedance of the limit value.

4. The effectiveness of sewage treatment is satisfactory and is as follows: BOD_5 – 98.6%, COD_{Cr} – 94.9%, TSS – 97.6%.
5. It needs to be acknowledged that the treatment plant in Dobra operates properly and the stability of its operation can be affected by uneven inflow of sewage and discharge of sewage transported by cesspool emptiers.
6. The operation of the analyzed sewage treatment plant should be assessed positively, due to high reduction of pollutants and the technological reliability index values, which contributes to the effective protection of water quality in the receiver from pollution.

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