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EVALUATION OF A BIOCOMPACT SEWAGE TREATMENT PLANT OPERATING UNDER LOW HYDRAULIC LOADING CONDITIONS

The aim of the research was to evaluate the rural BIOCOMPACT sewage treatment plant. The sewage treatment plant of interest has been operating under low hydraulic loading conditions, specifically sewage inflow from a sewerage system that remains below 45% of designed capacity for 3 years. The evaluation of the system was based on physicochemical analyses of raw sewage collected in the channel before mechanical grates and analyses of treated sewage collected from the measuring bed before the outflow of the sewage to the collector. The research showed that although operating conditions are difficult, mean concentrations of each pollutant are below admissible values defined by the water quality regulations for this type of system. During the research period only in one sewage sample admissible values were exceeded, namely – total phosphorus – with a concentration of 0.34 mg $P_{tot} \cdot dm^{-3}$. It should be noted that this deviation occurred in winter at low sewage temperatures. The research showed that the sewage treatment plant obtained very good results in pollutant removal, despite working under low hydraulic loading conditions.

1. INTRODUCTION

The most important factors in designing sewage treatment plants are the quantitative–qualitative balance of raw sewage and requirements imposed on the quality of treated sewage [1], [2], [3]. The quantitative–qualitative balance is defined by the designer or is forced under public tendering conditions. In the second case, the designer cannot make changes in the requirements without the investor's permission. Once the tender is closed, the defined values are fixed.

Sewage treatment plants vary in terms of system design and operation. Poland does not have legally binding regulations for sewage treatment plant dimensioning. Thus, designers apply different dimensioning methods, often using guidelines from Western

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countries, e.g. ATV norms [4]. Most often sewage treatment plants are dimensioned for mean daily or maximal hourly sewage flow [5]. In Poland, as well as in other European countries, the designer is responsible for technical propriety.

Presently in Poland, new sewage treatment plants are being built in rural communes with EU co-financing funds. From 2000 to 2006, 661 new sewage treatment plants were commissioned (on average 110 each year) [6]. These plants are technically comparable to treatment plants in Western countries. Out of a total of 2999 sewage treatment plants in Poland, 1143 have a designed capacity in the range of 101–500 $m^3 \cdot d^{-1}$ [6]. Treatment plants in rural communes are designed most often for this level of sewage flow.

A common problem connected with rural sewage treatment plant operation is improper hydraulic loading. Often after a new treatment plant is built, the commune is unable to gain additional funding in a short time for sewerage system extension. Thus, for a period of time the sewage treatment plant may operate in hydraulic underloading conditions. Low hydraulic load of the sewage treatment plant may also be connected with oversizing the treatment plant. Often, project mistakes originate from using overstated (with presently common water saving) unitary sewage quantity which is 150 $dm^3 \cdot d^{-1}$ per inhabitant [7].

The most common causes of hydraulic overloading for rural treatment plants lie in the overdevelopment of the sewerage system in relation to the treatment plant capacity, poor construction or a bad technical state of the sewerage system which can result in infiltration or accidental inflow, and the presence of illegal connections of roof pipes to household sewage canalization [8].

2. RESEARCH PROCEDURES

The aim of the research was to evaluate the operation of the BIOCOMPACT rural sewage treatment plant under low hydraulic loading conditions. This sewage treatment plant has been operating for 3 years with sewage inflow below 45% of its designed capacity.

The sewage treatment plant is located in a rural community situated in the western part of Kraków district in Lesser Poland voivodeship. The commissioning of the treatment plant with a designed capacity of 100 $m^3 \cdot d^{-1}$ was performed in 2004. The treatment plant consists of the following sections: basket grates, BIOCOMPACT biological reactor which is divided into 2 chambers with a volume of 50 m^3 each, an excessive sludge collector, PIX dosing station, a blower station, control, and social accommodations. The biological reactor BIOCOMPACT has compartmentalized areas for predenitrification, denitrification, and nitrification. Sewage treatment occurs with low-loaded activated sludge having an extended oxygenation time.

Household sewage from a 9.7 km long sewerage system is discharged into treatment plant. Presently, the sewerage system serves only 7% of commune tenants

(141 households). Residents are mainly employed in the agriculture sector with agricultural areas covering 83% of the commune. Household water is supplied to 98% of households using a water-pipe network of 88 km in length. Five drilled wells act as the water intake.

The evaluation of the system was based on physicochemical analyses of raw sewage (collected in the channel before mechanical grates) and treated sewage (taken in measuring channel before outflow of sewage into the collector). Analyses of raw and treated sewage (drenched samples) were performed in the Laboratory of Water and Sewage Analyses located at the treatment plant. The pollutant indexes BOD_5, COD, total suspended solids, total nitrogen and total phosphorus were indicated.

Sewage samples were taken from 01.01.2005 to 29.06.2007 in two-month intervals.

3. RESULTS AND DISCUSSION

The characteristics of raw sewage inflow in terms of the five pollutants indexes are shown in table 1. In the case of BOD_5, COD and total suspended solids, their values for raw sewage do not differ from the values typical of rural communities [9], [10]; however, the occurrence of high concentrations of total nitrogen was found. On the other hand, the concentration of total phosphorus in raw sewage was low. The most common total phosphorus concentrations in rural community sewage are in the range from 8 to 40 mg $P_{tot} \cdot dm^{-3}$.

Table 1

Characteristics of raw sewage that flows in the system and is discharged to the collector during the treatment process

Pollutant index	Parameter of pollutant index		Unit	Pollutant index values		Admissible value of pollutant index according to water-law permission
				Raw sewage	Treated sewage	
BOD_5	value	maximal	$mg\ O_2 \cdot dm^{-3}$	440.0	14.6	25
		mean		358.7	11.8	
		minimal		280.6	7.0	
	standard deviation			56.4	2.2	
COD	value	maximal	$mg\ O_2 \cdot dm^{-3}$	946.0	58.0	125
		mean		821.3	45.1	
		minimal		698.0	36.0	
	standard deviation			89.4	6.3	
Total suspended solids	value	maximal	$mg \cdot dm^{-3}$	405.0	12.0	35
		mean		354.7	9.7	
		minimal		285.0	8.0	
	standard deviation			37.4	1.4	

Total nitrogen	value	maximal	mg $N_{tot}\cdot dm^{-3}$	90.0	25.3	30
		mean		78.7	22.0	
		minimal		68.5	19.3	
	standard deviation			7.6	1.9	
Total phosphorus	value	maximal	mg $P_{tot}\cdot dm^{-3}$	5.9	2.8	2.5
		mean		5.3	1.8	
		minimal		5.0	1.1	
	standard deviation			0.3	0.6	

To evaluate the potential biodegradation of rural community sewage, the ratios of COD:BOD_5 (reached 2.3), BOD_5:N_{tot} (reached 4.6), and BOD_5:P_{tot} (reached 67) were determined. All of the values obtained have optimal pollutant concentration proportions for biogenic compound removal using the activated sludge method.

Inflow of residential sewage from sewerage system to the treatment plant was approximately 45 $m^3\cdot d^{-1}$. Taking into account the designed system capacity of 100 $m^3\cdot d^{-1}$, the treatment plant is hydraulically loaded at only 45% of its capacity. A considerable daily variability of sewage inflow, discharged from only 141 households, imposes conditions that strongly inhibit a proper system operation.

The analysis of treated sewage showed that even though operational conditions are difficult, mean concentrations of each pollutant are lower than admissible values defined by the regulations for this system (table 1). In treated sewage, the mean values of BOD_5, COD, total suspended solids, total nitrogen, and total phosphorus are 45, 36, 28, 73, and 71%, lower, respectively, than their admissible values. In one sewage sample taken in January 2005, the admissible value of total phosphorus was exceeded in the sample showing about 0.34 mg $P_{tot}\cdot dm^{-3}$; however, it should be noted that this occurred under winter conditions at low sewage temperature.

Table 2

The effectiveness of pollutant removal from sewage in the treatment plant of interest

Pollutant index	Effectiveness of pollutant removal in the treatment process (%)			Mean effectiveness of treatment plant pollutant removal (%)
	Maximal	Mean	Minimal	
BOD_5	98.2	96.6	95.0	95
COD	95.3	94.5	93.1	79
Total suspended solids	97.8	97.2	96.1	95
Total nitrogen	75.0	71.9	68.4	73
Total phosphorus	78.5	67.0	45.7	89

In table 2, the parameters characterizing the effectiveness of the treatment plant of interest are shown in terms of pollutant removal. The mean effectiveness of pollutant removal in terms of BOD_5, COD and total suspended solids is higher than that assumed in the project (6.4% approximately). Low effectiveness of treatment plant

biogenic compound removal in relation to the designed presumptions results from lower concentrations of these pollutants in raw sewage than was assumed in the project.

4. SUMMARY

To summarize, it may be ascertained that the BIOCOMPACT type treatment plant achieved very good results in sewage pollutant removal while operating under low hydraulic loading conditions. This treatment plant effectively removes pollutants described by oxygen index values (BOD_5, COD) as well as eutrophic values (total nitrogen and total phosphorus). The mean value of BOD_5 in treated sewage during the research period was 11.8 mg $O_2 \cdot dm^{-3}$, COD – 45.1 mg $O_2 \cdot dm^{-3}$, total suspended solids – 9.7 mg$\cdot dm^{-3}$, total nitrogen – 22 mg $N_{tot} \cdot dm^{-3}$, total phosphorus – 1.8 mg $P_{tot} \cdot dm^{-3}$. During the research period, only one pollutant index in a single sewage sample exceeded admissible values (total phosphorus).

Taking into consideration the results from the analyses and system advantages, including homogeneous construction which occupies small area, the placing of the biological reactor in a closed room protecting sewage from low temperatures, and the system architecture linking it to rural architecture, this type of treatment plant may be recommended other decision-makers to consider when selecting a living sewage treatment system for rural settlements.

REFERENCES

[1] MYSZOGRAJ S., PANEK E., *Bilansowanie ilości ścieków dopływających do oczyszczalni*, Gaz, Woda i Technika Sanitarna, 2007, 5, 9–12, Wydawnictwo Sigma NOT, Warszawa.

[2] CHOTKOWSKI W., LIS G., *Krótkoterminowe prognozowanie dopływu ścieków do oczyszczalni na podstawie zużywanej wody*, Gaz, Woda i Technika Sanitarna, 2006, 5, 13–18, Wydawnictwo Sigma NOT, Warszawa.

[3] KACZOR G., *Jednostkowe odpływy ścieków z kanalizacji wiejskiej w gminie Koszyce*, Infrastruktura i Ekologia Terenów Wiejskich, 2006, Nr 2/1, PAN, Oddział w Krakowie.

[4] BARTOSZEWSKI K., *Proces projektowania oczyszczalni – praktyka i problemy*, Materiały seminarium szkoleniowego, Lem Projekt s.c., Kraków, 2000, 7–11.

[5] HEIDRICH Z., WITKOWSKI A., *Urządzenia do oczyszczania ścieków. Projektowanie, przykłady obliczeń*, Seidel–Przywecki Sp. z o.o., Warszawa, 2005.

[6] *Ochrona Środowiska*, GUS, 2007.

[7] BERGEL T., KACZOR G., *The volume of wastewater discharged from rural households to the sewer system in the light of tap water consumption structure*, Polish Journal of Environmental Studies, Hard Olsztyn, 2007, Vol. 16, No. 2A, Part II, 109–112.

[8] KACZOR G., BUGAJSKI P., *The influence of incidental waters on the effectiveness of pollution reduction in rural wastewater treatment plant*, Polish Journal of Environmental Studies, Hard Olsztyn, 2007, Vol. 16, No. 2A, Part III, 450–452.

[9] BŁAŻEJEWSKI R., *Kanalizacja wsi*, PZITS, Oddział Wielkopolski, Poznań, 2003.
[10] SZPINDOR A., *Zaopatrzenie w wodę i kanalizacja wsi*, Arkady, Warszawa, 1998.

OCENA FUNKCJONOWANIA OCZYSZCZALNI ŚCIEKÓW BIOCOMPACT PRACUJĄCEJ W WARUNKACH NISKIEGO OBCIĄŻENIA HYDRAULICZNEGO

Celem przeprowadzonych badań była ocena działania wiejskiej oczyszczalni ścieków typu BIOCOMPACT. Oczyszczalnia ta od 3 lat pracuje w warunkach niskiego obciążenia hydraulicznego (dopływ ścieków z kanalizacji nie przekracza 45% jej przepustowości projektowej). Ocenę pracy obiektu oparto na analizach fizyczno-chemicznych ścieków surowych (pobieranych w kanale przed kratą mechaniczną) i ścieków oczyszczonych (pobieranych w korycie pomiarowym przed wylotem ścieków do odbiornika). Przeprowadzone badania wykazały, że pomimo trudnych warunków eksploatacyjnych średnie stężenia poszczególnych zanieczyszczeń są niższe od wartości dopuszczalnych określonych w pozwoleniu wodno-prawnym dla tego obiektu. W okresie badań tylko w jednej próbce ścieków stwierdzono przekroczenie wartości dopuszczalnych, a mianowicie fosforu ogólnego o 0.34 mg $P_{og} \cdot dm^{-3}$. Miało to miejsce w warunkach zimowych, w niskiej temperaturze ścieków. Przeprowadzone badania wykazały, że oczyszczalnia uzyskała bardzo dobre wyniki w usuwaniu zanieczyszczeń zawartych w ściekach, pomimo że działała w warunkach niskiego obciążenia hydraulicznego.