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Analysis of COD Fractions in Raw Wastewater Flowing into Small and Large Wastewater Treatment Plants

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ABSTRACT
The aim of the study was to determine and compare the amount and biodegradability of organic compounds determined by the COD measure contained in raw sewage inflowing to small sewage treatment plants and municipal sewage wastewater treatment plants with high personal equivalent (P.E.). Raw sewage samples were collected in three chosen facilities. The research presented in the article were conducted with two small plants: constructed wetland plant with an average capacity of 4 m^3/d and the treatment plant with rotary biological contactor (RBC) with an average capacity of 5 m^3/d. Also big municipal wastewater treatment plant (WWTP) with activated sludge in Bialystok with a capacity of about 63 000 m^3/d was checked. The lowest percentages of dissolved fraction of soluble organic non-biodegradable substances S_I was founded in raw sewage in small wastewater treatment plants (CW and RBC).

Keywords: COD fractions, treatment plants, rotary biological contactor, constructed wetland, activated sludge

INTRODUCTION

Proper exploitation of even small wastewater treatment systems enables effective removal of nitrogen, phosphorus and carbon compounds. Extending the evaluation of the treatment process by additional COD fraction measurements allows us to determine, in detail, the content of biodegradable nutrients in wastewater. Thanks to this, it is possible to intensify the processes of treatment of sewage in already existing facilities. [Henze, Harremoes, 2000; Klimiuk, Łebkowska 2008, Sulżyk-Cieplak at al., 2018]

The amount of organic matter defined as COD of wastewater, broken down by fractions, can be calculated according to the relation: [Płuciennik-Koropczuk, 2009; Sadecka, Myszograj 2004; Struk-Sokołowska, 2014; Zdebik, Głodniok, 2010]:

$$COD = S_S + S_I + X_S + X_I$$

where: S_S – COD of dissolved organic compounds which is readily biodegradable (COD soluble readily biodegradable substrates),
S_I – COD of dissolved non-biodegradable compounds (COD inert soluble organic material),
X_S – COD of insoluble slowly biodegradable compounds (COD particulate, slowly biodegradable substrates),
X_I – COD of insoluble non-biodegradable organic compounds (COD inert particulate organic material).

Depending on the size of the unit to be operated, different wastewater treatment technologies are used. In non-urbanized areas, constructed wetland treatment plants (CW) are often used, where the root system of plants creates a specific biocenosis, rich in various organisms, comparable to the biocenosis of natural swamp systems. This type of wastewater treatment plant is particularly recommended for holiday resorts, as it tolerates interruptions in wastewater supply very well, even when the interruptions are longer than the actual period of operation, e.g. in the summer season. Wastewater is treated through biochemical processes and filtration. These wastewater treatment plants are characterized by a very high efficiency, simple construction, possibility of using the filter as a decorative element on the plot, high resistance to unevenness or even periodical lack of sewage inflow, possibility of using local swamp vegetation, possibility of economic use of treated sewage and possibility of using the existing septic tanks [Błażejewski, 2005].

Another type of wastewater treatment plant used for small amounts of wastewater are trickling filter or rotary biological contactor (RBC). A characteristic feature of this type of plant is its high susceptibility to the adjustment to variable loads while maintaining operational stability. The principle of operation is based on the inflow of pollutants, which in the course of oxygenation, e.g. by the rotation of the deposit and by enzymatic processes of microorganisms, are decomposed. Taking into account its simple and fast technological start-up, this type of wastewater treatment plant can be successfully used in rural areas or in seasonally active centers up to 20,000 P.E. (with a flow rate of about 5000 m^3/d) [Ignatowicz, Puchlik, 2011; Kania-Surowiec, 2013; Piasny 2012].

An important aspect of small and medium-sized wastewater treatment plants is their technical and technological simplicity. The operation of this type of wastewater treatment plant is also, in most cases, transparent and simple [Ignatowicz, Puchlik, 2011].

MATERIALS AND METHODS

The aim of the study was to determine and compare the amount and biodegradability of organic compounds determined by the COD measure contained in raw sewage inflowing to small sewage treatment plants and municipal sewage wastewater treatment plants with high personal equivalent (P.E.). Raw sewage samples were collected in three chosen facilities.

The first object of the analysis was a constructed wetland sewage treatment plant (CW) at the female Monastery. It serves about 35 people, and the average daily wastewater flow is about 4.0 m^3/day. The sewage is discharged by gravity from the monastery building to a septic tank consisting of two chambers. Then the sewage is discharged to the aeration chamber, the sludge chamber and the sewage pumping station. The sewage is distributed above a surface of 9 by 12 m, consisting of soil and vegetation, which is covered with reeds and other hydrophilic plants. The treated sewage is collected and discharged to a pond located next to a constructed wetland [Smyk, Ignatowicz at all. 2015, 2017].

The second of the analyzed plants is a KOS-2 type container treatment plant, installed at the Social Welfare Home (SWH) in the Podlaskie Voivodeship. This type of wastewater treatment plant is standardly equipped with a three-stage biological rotary biological contactor (RBC). It serves about 40 inhabitants and operates under unencumbered conditions. The average daily inflow of raw sewage to the treatment plant during the measurement period was about 5 m^3/d. The sewage treatment plant is equipped with a retention-averaging tank and an oxygen-type biological pond with a volume of about 240 m^3. The recipient of the treated wastewater is the Płoska River [Ignatowicz, Puchlik, 2011].

The third facility is a mechanical-biological wastewater treatment plant (WWTP) in Białystok, which uses the sludge activated system for biological treatment. The average flow in the plant is about 63 000 m^3/d. The wastewater treatment plant receives domestic and industrial sewage from the city of Białystok and adjacent areas. The area from which the sewage flows is characterized by a low degree of industrialization. The main source of pollution discharged into the sewage system is sewage from Białystok [Smyk, Ignatowicz, 2015; Kogut at al., 2014].

RESULTS AND DISCUSSION

The results presented in the tables and figures are the arithmetic mean of five intakes. Table 1. summarizes the COD and BOD_5 values of raw sewage in the analyzed sewage treatment plants. The presented data show that the COD to BOD_5 ratio for raw wastewater in all wastewater treatment plants is lower than 2.5, which indicates that the wastewater is easily biodegradable. The highest COD and BOD_5 values were founded for the SWH (operating with RBC) with value of COD – 650.0 mgO_2/dm^3 and in the case of BOD_5 – 420.0 mgO_2/dm^3. The value of COD in municipal wastewater from the activated sewage treatment plant (WWTP) in Bialystok was 649.0 mgO_2/dm^3 similar to that of wastewater from rotary biological contactor (RBC). In the case of BOD_5 from activated sludge treatment plant (WWTP) and constructed wetland plant (CW) the values were similar and differed only by 10 mgO_2/dm^3.

In Figure 1 the values of COD fractions in raw wastewater in the analyzed wastewater treatment plants are presented, whereas in Table 2 the percentage shares of individual COD fractions in raw wastewater in the analyzed wastewater treatment plants are presented.

The highest share in raw sewage from all analyzed plants is held by the decomposable insoluble (suspended) COD fraction, which was marked with the X_S symbol. This includes slowly biodegradable substrates that can be assimilated by microorganisms in biochemical processes after prior extracellular hydrolysis. In the raw wastewater from biological sewage treatment plants (WWTP), the content of this fraction was as high as 53.90% of the total COD. In the raw wastewater from a large municipal wastewater treatment plant (WWTP) and a constructed wetland treatment plant (CW), the X_S fraction values are already lower in comparison to a biological treatment plant with rotary biological contactor (RBC), and the percentage is almost the same at 41%.

The dissolved COD fraction, which most easily assimilates S_S, is the most desired fraction in the sewage composition. It includes organic compounds that can be immediately and directly absorbed by heterotrophic microorganisms. The highest content of this fraction was found in the raw wastewater from SWH in the biological sewage treatment plant with rotary biological

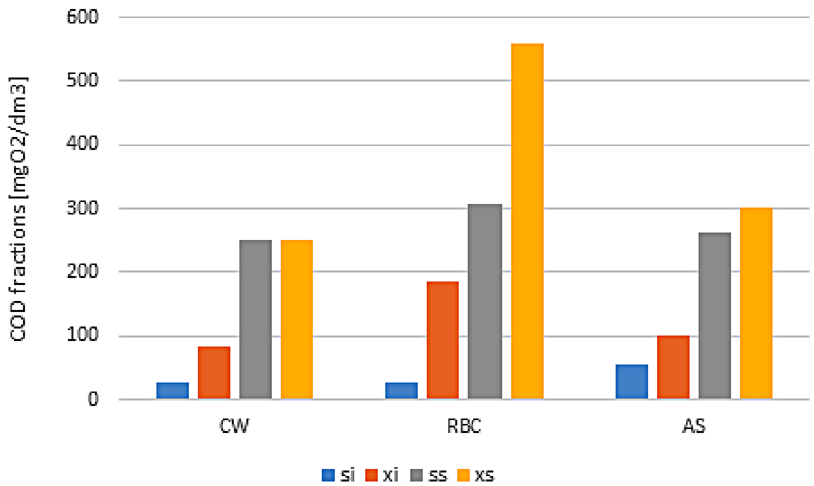

Fig. 1. Fractions of COD in raw sewage in the analyzed wastewater treatment plants: CW constructed wetlands, RBC – rotary biological contactor, AS – WWTP with sludge activated system

Table 1. COD and BOD_5 raw and treated sewage in the analyzed wastewater treatment plants.

Technology	Q, m^3/d	$\frac{COD}{BOD_5}$	COD, mgO_2/dm^3			BOD_5, mgO_2/dm^3	
			Influent	Mechanically treated wastewater	Treated wastewater	Influent	Treated wastewater
Constructed wetland (CW)	4	1.65	512	–	42	310	3.0
Rotary biological contactor (RBC)	5	1.55	650	–	47	420	4
Actived sludge (WWTP)	63000	2.16	649	308	20	300	2.3

Table 2. Percentage fractions of COD in raw sewage in the analyzed wastewater treatment plants

COD fraction	Wastewater plant		
	Constructed wetland (CW)	Rotary biological contactor (RBC)	Actived sludge (WWTP)
	%	%	%
S_I	5.42	3.40	6.7
X_I	12.65	16.30	15.9
S_S	40.16	26.40	33.4
X_S	41.77	53.90	44.0

contactor (RBC) – over 300 mgO_2/dm^3. However. despite the highest content compared to other treatment plants. the percentage share of S_S in the raw wastewater from this biological treatment plant is only 26.40%. In the wastewater from the monastery of the constructed wetland plant (CW) and municipal wastewater from the activated sludge treatment plant (WWTP). both the content of S_S fraction (about 250 mgO_2/dm^3) and the percentage share (40.16 and 33.4% respectively) were similar.

The highest content of insoluble, non-degradable fraction. marked with X_I symbol, was recorded in raw wastewater from SWH plant with rotary biological contractor (RBC) (almost 200 mgO_2/dm^3). The lowest values were found in the raw sewage from the constructed wetland treatment plant (CW) – about 80 mgO_2/dm^3. The percentage share of fraction X_I in the wastewater from the analyzed plants ranges from 12.65 to 16.30% of the total COD. The content of this fraction is unfavorable in wastewater because it can remain in the system by incorporating microorganisms into the biomass, increasing its mass.

The lowest percentage of all COD fractions in raw wastewater is found in the fraction of dissolved non-biodegradable S_I compounds. Despite the low percentage of this fraction, it should be remembered that its content in raw wastewater is also unfavorable, as it will be in the effluent and will not be disposed of in biological processes. The lowest values of S_I fractions were recorded in the raw wastewater from the monastery (constructed wetland system CW) and in the SWH (rotary biological contactor RBC) with biological – about 30 mgO_2/dm^3. In the case of sewage from biological sewage treatment plants (rotary biological contactor RBC), the S_I fraction accounted for only 3.40% of the total COD of raw sewage. Values more than twice as high were found in wastewater from a large municipal wastewater treatment plant with sludge activated (WWTP) – 60 mgO_2/dm^3, representing 6.7% of the total COD of raw wastewater.

CONCLUSIONS

1. Similar percentages of insoluble. non-dissolvable, non-degradable waste water marked with symbol X_I were found in raw sewage from all analyzed plants.
2. Raw wastewater from the DPS treatment plant with rotary biological contactor deposits was characterized by a higher share of X_S fraction in comparison to other plants. This results from specific nature of the sewage from SWH.
3. The lowest percentages of soluble non-biodegradable S_I compounds in raw wastewater were recorded in small sewage treatment plants operating with constructed wetland or rotary biological contactor.
4. On the basis of the available data. no significant dependencies between the fractions X_I, S_S, X_S in raw wastewater and the amount of generated wastewater were established.

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