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Research Article

COD FRACTIONS CHANGES DURING SEWAGE TREATMENT WITH CONSTRUCTED WETLAND

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ABSTRACT
The purpose of the presented research work was to find out COD fractions in raw wastewater and during treatment with constructed wetland (CW) system. The tests were performed in CW system with average flow of about 4 m^3/day. In raw wastewater the highest concentration of fraction in organic suspended solid easy biodegradable (X_S – 250 mg O_2/l) was observed. The same situation was with dissolved organic easy biodegradable matter (S_S – 250 mg O_2/l). Lower quantity of non-biodegradable fractions dissolved and in suspended solids were observed (S_I – 27 mg O_2/l, X_I – 83.33 mg O_2/l). More than 80% of total COD was as biodegradable fractions (S_S + X_S). After treatment with CW system the highest concentration was observed for dissolved non-biodegradable fraction (S_I – 27 mg O_2/l). Lower concentration was for biodegradable fraction in suspended solid (X_S – 3.33 mg O_2/l). More than 89% of total COD was in biological non-biodegradable fraction (S_I + X_I).

Keywords: COD, sewage treatment, wetland.

INTRODUCTION

Proper use of modern, even small, purification systems that enable removal of carbon compounds, requires control of many parameters and indicators. In order to characterize the amount of organic matter in municipal sewage, values of BOD_5, COD, and TOC are determined. The COD expresses the total amount of organic substances, while BOD_5 – total (dissolved and suspended) biodegradable part of the organic matter. The susceptibility of organic compounds to biodegradability can be assessed on the basis of the COD to BOD_5 ratio.The high value of the ratio (above 2.5) indicates a slow decay and high content of non-biodegradable substances. In turn, the low ratio (lower than 1.8) indicates a susceptibility of pollutants to biological decomposition. However, none of these indicators inform about the quantitative participation of biologically degradable fraction. The COD fractionation allows to identify easily and hardly biodegradable COD fractions. The identification and tracking COD changes during stages of wastewater treatment allows to assess the effectiveness of various biological processes and the regularity and efficiency of wastewater treatment plant work. Extensive quality control of wastewater during the purification process is crucial in intensifying its various stages. The extension of assessment of the purification process with COD fraction measurements would allow for precise determination of biodegradable nutrients contents. This would allow to intensify the processes of small wastewater quantities purification in existing facilities [3, 14, 8, 4].

COD FRACTIONS

By determining the COD fraction in wastewater, more accurate characterization of organic substances may be achieved. Among them, there are readily biodegradable substrates and those that slowly hydrolyze. The remainder of the organic matter is not biodegradable or slowly biodegradable. The COD of sewage, divided into fractions,

can be calculated in a simplified manner according to the formula [14, 15, 12]:

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

where: S_S – COD of soluble organic easily biodegradable substances,
S_I – COD of soluble organic non-biodegradable substances,
X_S – COD of organic slowly biodegradable suspensions,
X_I – COD of organic non-biodegradable suspensions.

Biodegradable fractions ($S_S$and X_S) are mainly important at designing the systems for biological removal of nitrogen and phosphorus. The soluble fraction (S_S) consists of substances directly available by microorganisms. Fraction of suspensions (X_S), prior to be used by microorganisms, has to be decomposed by extra-cellular enzymes. Non-biodegradable fractions (S_I and X_I) are not subject to any conversion. In a system for sewage treatment, concentration of soluble fraction (S_I) in the inlet is equal to that in the outlet, while suspended fraction (X_I) can remain in the system due to building into the microorganism biomass or be a subject to mechanical processes.

MATERIAL AND METHODS

The aim of the research was to determine the COD fraction in raw sewage and their changes in the effluent after subsequent treatment processes. The study was conducted in wetland sewage treatment plant in Zwierki at female Monastery of the Nativity of the Most Holy Mother of God. The constructed wetland was built in 2011 on the RLM 35–40 persons – and average daily wastewater flow was 4.0 m^3/day (Figure 1).

Wastewater is discharged by gravity from a convent to the septic tank consisting of two chambers. So-called "scum" (made up of pollutants lighter than water – usually fats) forms on the surface of sewage in the septic tank. Then, the wastewater flows through the aeration chamber, which is uncommon for the wastewater treatment plants of this type. It was built to prevent sewage from rotting before flowing into the constructed wetland.Sewage flows from the sludge chamber to the pumping station. The pump is activated when the sewage level reaches the desired height in the well. Wastewater flowing through the bed and the root zone of plants are treated mechanically and biologically. The constructed wetland bed with the subsurface system has dimensions of 9×12 meters. It is populated with reeds and other wet-tolerating plants. Filling of the deposit is made of:

- washed gravel of diameter 8–16 mm, layer thickness 20 cm,
- washed sand of diameter 0.5–2 mm, layer thickness 60 cm.

Treated sewage is collected by a drainage and discharged into the pond located on the plot next to the constructed wetland.

In order to determine the composition of treated wastewater, samples were collected in accordance with the flow direction along the cross section of the treatment plant: from the septic tank, aerated wells, pumping station, and directly after the constructed wetland. BOD_5 and COD were determined in collected samples of raw and filtered sewage in accordance with current methodology. The COD fractions (S_S, S_I, X_S, X_I) were determined on a base of ATV-A 131 guidelines [18]:

- Concentration of organic soluble contaminants $S_{COD}$was determined in raw sewage as COD of wastewater.

Figure 1. Constructed wetland sewage treatment plant

- In order to determine the soluble non-biodegradable fraction S_I (COD'), sewage sample was filtered through a hard paper filter 0.45 μm, and then COD of sewage was determined.
- Easily biodegradable fraction S_S was determined as a difference between the total amount of soluble organic contamination and organic non-biodegradable contaminationS_I:

$$S_S = S_{COD} - S_I \text{ [mg } O_2\text{/l]}$$

- In order to determine the slowly degradable organic suspensions X_S, BOD_5 for raw non-filtered sewage was experimentally determined, and then the total BOD (BOD_C) was calculated assuming the rate of biochemical decomposition $k_1 = 0.6$:

$$BOD_C = BOD_5 / 0.6 \text{ [mg } O_2\text{/l]}$$

Having value of $BOD_C$and value of soluble easily biodegradable fractionS_S, slowly degradable suspension fraction $X_S$was calculated using the formula:

$$X_S = BOD_C - S_S \text{ [mg } O_2\text{/l]}$$

- The total concentration of organic substances in the suspension was determined by using the dependence given in the norm ATV-131 [33] :

$$X_I = A \times X_{COD} \text{ [mg } O_2\text{/l]}$$

However, depending of the sewage type, or the sewage retention time in preliminary sedimentation tank, value of A coefficient can vary from 0.2 to 0.35. For household wastewater, it is accepted as A = 0.25 [33]. Substituting dependence:

$$X_I = 0.25 \times X_{COD,}$$

into the equation:

$$X_{COD} = X_S + X_I$$

we achieve:

$$X_{COD} = X_S/0.75 \text{ [mg } O_2\text{/l]}$$

- Fraction of non-degradable suspensions $X_I$was determined from the difference of parameters X_{COD} and X_S:

$$X_I = X_{COD} - X_S \text{ [mg } O_2\text{/l]}$$

RESULTS

The study results (as a mean from 4 measurements) are listed in Table 1. Average BOD_5 value was 300 mg O_2/l, while COD – 434 mg O_2/l. The COD to BOD_5 ratio for raw sewage was 1.45 – it is lower than 2 indicating that the wastewater is easily biodegradable.

The greatest removal of organic compounds determined by values of COD and BOD_5 took place during the flow of sewage through the constructed wetland. The purification effect for BOD_5 was 99%, and 85% for COD. A high percentage effect of organic compounds removal confirms proper functioning of wastewater treatment, and concentrations reached in the outflow to the receiver comply with the requirements imposed by the Regulation of the Minister of Environment of 18 November 2014 on the conditions to be fulfilled when introducing wastewaters into water or ground and on substances particularly harmful to the aquatic environment.

According to the procedure for determining the COD fraction given in point 4, values of the individual fractions were determined. The results regarding values and share of each fraction in the wastewater are given in Table 2 and Figure 2. Percentage of individual fractions in wastewater is shown in Figure 3.

Table 1. Mean values of contaminants in sewage

Parameter	Sample							
	septic tank		aeration chamber		pumping station		after constructed wetland	
COD [mg O_2/l]	434	277	385	186	342	159	52	27
BOD_5 [mg O_2/l]	300	–	220	–	200	–	2	–

Table 2. Values and percentage of COD fraction in wastewater

Fraction COD	Septic tank		Aeration chamber		Pumping station		After constructed wetland	
	mg O_2/l	%	mg O_2/l	%	mg O_2/l	%	mg O_2/l	%
S_I	27	4.42	27	5.83	27	6.32	27	85.88
X_I	83,33	13.65	69.22	14.95	67.11	15.7	1.11	3.53
S_S	250	40.96	159	34.35	132	30.88	0	0
X_S	250	40.96	207.67	44.86	201.33	47.1	3.33	10.59

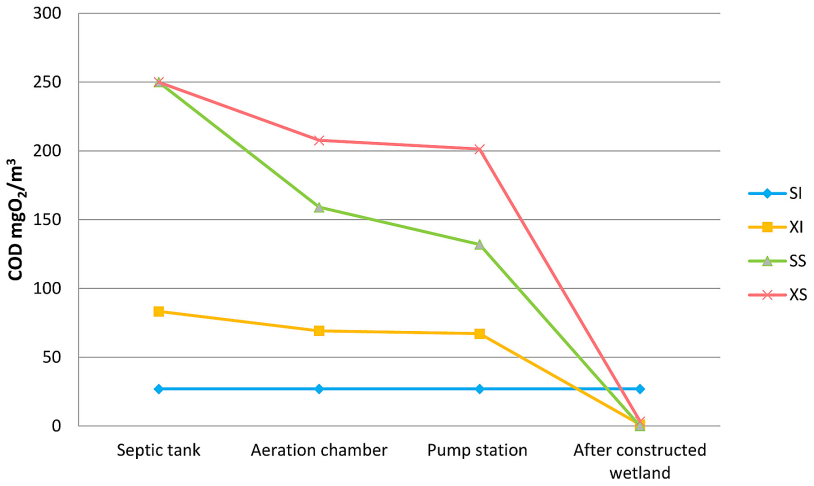

Figure 2. Changes in values of COD fraction in wastewater during treatment

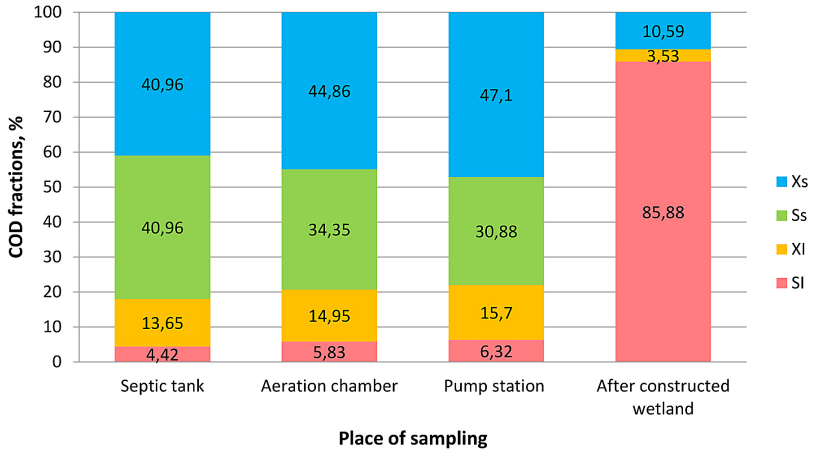

Figure 3. Mean percentage of individual COD fractions in total COD of sewage

Based on the obtained results, it was found that organic, slowly biodegradable fraction X_S (250 mg O_2/l) and organic, soluble, easily biodegradable substances S_S (250 mg O_2/l) were present at the highest concentrations in raw sewage at the beginning of the system. In a septic tank, over 80% total COD consisted of biodegradable fractions (S_S+X_S). Non-biodegradable soluble as well as suspension fraction S_I (27 mg O_2/l) and X_I (83.33 mg O_2/l) occurred at much lower amounts. The percentage of fraction in biologically decomposable suspension X_I in raw sewage was almost 14%, while the lowest percentage was made up by fraction of dissolved organic biologically degradable substances (4.42%). The percentage of tested soluble fractions was 45.38%, whereas 54.62% in the suspension. These values are different than the results reported by Sadecka [11, 13], Ekama [16], Kalinowska [6], or IWA group [5], according to whom, the amount of soluble substances was minimum 70%, while about 20% in suspension. Comparison of the percentage of particular COD fractions in raw sewage recorded by Myszograj and Sadecka [9, 11, 13], Henze [2], Keppler and Gujer [1, 7], IWA group [5] with simplified methods by Ekama [16] and Kalinowska [6] are presented in Table 3. The most similar results of the percentage of individual fractions were obtained by Keppler and Gujer as well as Henze, where easily and hardly biodegradable fractions are the majority of the shares. The results illustrate that wastewater from small units has different composition than municipal sewage from large units. It should be kept in mind that in rural areas the sewage composition constantly changes due to the habits of people using the sewage treatment plants, which affects the unevenness of supplying wastewater [10].

In the aeration well, the highest concentrations were still reached by organic slowly biodegradable suspensions X_S (207.67 mg O_2/l) and organic soluble easily biodegradable substances S_S (159.0 mg O_2/l). In the well after treatment in the septic tank, where anaerobic decomposition of or-

Table 3. Percentage of individual fractions in total COD concentration for raw sewage determined in measurements as compared to literature data [1, 2, 5, 6, 7, 9, 11, 13, 16]

Fraction	Smyk. Ignatowicz	Myszograj Sadecka	Henze	Kappeler. Gujer	Grupa IWA	Ekama	Kalinowska
	%						
S_I	4.4	22.6	13.0	9.0	25.0	20.0–25.0	12.5–25.0
S_S	41.0	56.0	22.0	58.0	45.0	60.0–65.0	50.0
X_S	41.0	18.7	54.0	22.0	15.0	5.0–7.0	15.0
X_I	13.7	2.7	11.0	11.0	10.0	8.0–10.0	8.0–10.0

ganic matter and sedimentation of insoluble particles occurred, 79.21% of total COD was made up by biodegradable fractions (S_S+X_S). Much lower quantities revealed soluble non-degradable fractions S_I (27 mg O_2/l) and suspensions X_I (69.22 mg O_2/l). Share of fractions in non-biodegradable suspension $X_I$in wastewater amounted to almost 15%, while the lowest percentage was shown by soluble organic non-biodegradable substances (5.83%). Percentage of tested soluble fractions made up 40.18%, whereas in suspension 59.82%.

The flow of wastewater by aerated well to the pump station resulted in a further slight decrease in the amount of organic matter referred to as COD. Concentration of insoluble organic compounds decreased slightly by 8.45 mg O_2/l, while soluble by 27 mg O_2/l.

It was found that in purified wastewater after constructed wetland, the highest concentration was reached by soluble non-biodegradable fraction S_I (27 mg O_2/l). Over 89% of total COD made up non-biodegradable fractions (S_I+X_I). Lower amounts were recorded for degradable fraction in suspension X_S (3.33 mg O_2/l). Percentage of fraction in non-biodegradable suspension X_I in treated wastewater amounted to only 3.53%, while the lowest share was revealed by fraction of soluble organic biodegradable substances (0%). Percentage of tested soluble fractions was 85.88%, while in suspension 14.12%.

Based on the results, it was found that during treating the wastewater by means of constructed wetland, all soluble substances biodegradable by microorganisms were removed, and suspended biodegradable substances were removed to a significant degree. These compounds were decomposed and assimilated or absorbed by organisms colonizing the wetland. The amount of insoluble organic non-biodegradable substances was effectively reduced. In this case, it was probably achieved due to sedimentation and sorption within the bed as well as in part in septic tank. According to literature the data confirmed by own studies, soluble non-biodegradable substances were not removed [1, 2, 5, 9–11, 12, 13–16]. The soluble non-biodegradable fraction S_I is not available for microorganisms, nor is subject to sorption on particles of the ground filters and constructed wetland [17].

CONCLUSIONS

1. In raw wastewater, the dominating percentage was recorded for fractions of biodegradable contaminants (SS and XS) reaching about 80% of the total COD of sewage.
2. Due to the treatment by means of constructed wetland, amount of soluble easily biodegradable fraction S_S and suspended slowly degradable contamination X_S decreased, which confirms high efficiency of the object.
3. Changes in organic suspended slowly biodegradable fraction amount were influenced by preliminary mechanical treatment of wastewater in septic tank, in particular sedimentation and sorption in constructed wetland.
4. Low value of non-biodegradable fraction in suspension X_I in the treated sewage can indicate the sedimentation of contaminants in ground-plant filter.

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