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TRANSFORMATIONS OF ORGANIC COMPOUNDS IN THE OPEN INTERCEPTING SEWER

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The paper presents results of studies concerning the designation of COD fraction in the raw wastewater. The test object was open intercepting sewer of Zielona Góra. Methodology for determining the COD fraction was based on the guidelines ATV- A 131. The real concentration of fractions in raw wastewater and the percentage of each fraction in total COD are different from data reported in the literature. The processes occurring in an open interceptor are also influenced by external factors. The most important of them are the ambient temperature and the extent of solar exposure. The changing temperature influences solubility of oxygen and activity of micro-organisms. Open space and cascade arrangement of the interceptor decrease the probability of oxygen-free environment. In this case, the dominating significance in the decomposition of organic compounds is to be ascribed to oxygen processes.

Keywords: biochemical process, dissolved oxygen, COD fraction, open intercepting sewer, cascade

1. INTRODUCTION

The main function of a sewerage system is reception and channelling of sewage to a wastewater treatment plant (WWTP), or a receiver. Currently, more and more frequently, a sewerage systems is analysed in the context of biochemical processes which take place therein. A sewer which carries sewage to WWTP can be treated as a flow sewage receiver, and it can be assumed that this is where transformations the basis of which are self-purification processes, occurring in

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rivers, take place. Changes in the composition of sewerage in sewage system can significantly influence operation of treatment plants and receivers of treated sewage.

Hydrolysis of organic compounds, increase in biomass of microorganisms, alterations in fractions of organic substance, as well as sedimentation of suspended matters are processes which take place during transport of sewage through a sewage system, and which directly influence quality of the sewage incoming to the treatment plant. These processes occur in water environment, in deposits, bacterial jelly which form on the inside walls of a sewer, and their intensity depends, among other factors, on the type and length of the sewage system. The processes occurring in sewers are presented in Fig. 1 [1,4].

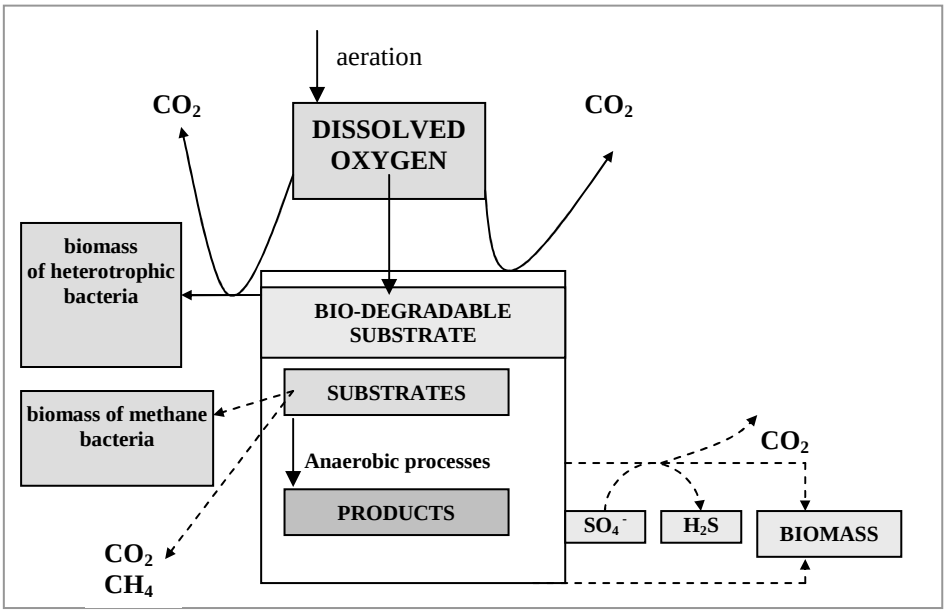

Fig. 1. Microbiological transformations of organic compounds in sewage system, in aerobic/anaerobic processes

Due to high concentration of pollutions, biochemical changes proceed slowly, and the result of treatment of sewage during its transport will be determined by intensifying interference of human. Decomposition of organic compounds occurs the most intensively in oxygen environment, between the layer of bottoms and the flowing sewage. These processes cause significant decrease in sewage contamination. Both at the cellular level, and at the ecosystem level, the processes of transforming organic substrates require hydrolysis of insoluble organic polymers into soluble forms, available for

microorganisms. Part of the pollutants undergo direct, biochemical oxidation into carbon dioxide and water, while the remaining fraction is assimilated in the form of increase in the living mass of the microorganisms [2,3].

Sewage transported via the sewage system contain various groups of microorganisms, the development of which depends on specific environmental conditions. Living organisms which dwell in the bottoms often manifest high metabolic activity, participating in the process of biodegradation of various organic contaminations contained not only in the deposits, but also in the sewage which flows through the system.

Chemical and biological processes in the intercepting sewers can significantly influence the composition of the sewage, particularly during rainless stretches. In an anaerobic processes, next to an increase in concentration of sulphur compounds, transformations of organic matter into easily-biodegradable substrates, which are a notable base of effective denitrification and biological dephosphatation, gain crucial importance. Whereas in oxygen processes, concentration of biodegradable fraction of organic biomass decreases, and heterotrophic biomass which can be effectively removed in the mechanical section of a treatment plant, increases [4].

The application of modern technologies requires thorough identification of the composition of substrates present in sewage, as compared to data obtained with conventional pollution indicators ($COD\text{-}_{Cr}$, BOD_5) [5,6]. One of the most significant achievements in sewage technology is COD fractioning, which makes it possible to isolate fractions depending on the size of molecules and their responsiveness to biochemical decomposition [7,8]. Determination of COD fractions furnishes a detailed characteristic of sewage composition, but primarily makes it possible to determine the amount of organic contaminants, both easily and poorly degradable [9].

Changes in the physical-chemical characteristics of sewage in a sewage system are presented on the basis of studying an open sewer which channels sewage from Zielona Gora (Poland) to a wastewater treatment plant in Lezyca.

2. MATERIAL AND METHODS

2.1. Open sewage channel to WWTP in Lezyca

Zielona Gora (Poland) has 118 221 inhabitants. Branches of the industrial sector typical for the city are: textile industry (wool, ornamental fabric, sheet flooring), production of means of transport (freight cars), food industry (distilling, winemaking, dairy, meat, brewery), precision industry, furniture industry.

The central sewage treatment plant for Zielona Gora is situated about 7km north of the city, and west of the Lezyca village.

The treatment plant of flow capacity $Q = 51.225\ m^3/d$ has been designed for mechanical-biological sewage treatment, with biological dephosphatation,

denitrification and nitrification, as well as chemical precipitation of the remaining phosphorus.

The sewage are channelled to the wastewater treatment plant via an open sewer. The course of the open sewer runs outside the city borders (Fig. 2).

Fig. 2. Plan of Zielona Gora, with marking of the open sewer which carries raw sewage to WWTP

The length of the open sewer is 4850 m. Due to significant altitude difference between the start and the end of the sewer, it has been partitioned with cascades, which form six sections: first - 700 m long, second - 258 m, third - 742 m, fourth - 500 m, fifth - 1000 m, sixth - 1650 m. The stilling basius constructions form five storage reservoirs, with total capacity of 84 000 m^3.

The average sewage flow rate for the entire sewer is 0,9 m/s (for rainless periods), whereas the average time of sewage flow through the open channel is 1,5h. During intensive rainfall, the rate increase to about 2,0 m/s.

2.2. Analytical methods

Analysis of physical-chemical composition of the sewage collected from the open sewer which channels sewage from Zielona Gora to treatment plant in Lezyca was carried out five times.

Sewage sampling was planned in a period preceded with several rainless days. The ambient temperature changed as follows:
Series 1 – ambient temperature 17 ^{o}C, sunny
Series 2 – ambient temperature 20 ^{o}C, heavy clouds
Series 3 – ambient temperature 10 ^{o}C, heavy clouds
Series 4 – ambient temperature 12 ^{o}C, partly cloudy
Series 5 – ambient temperature 16 ^{o}C, partly cloudy

In each series of the study, 7 samples of sewage were taken from the open sewer: first sample at the beginning of the open sewer, samples 2, 3, 4, 5, 6 directly after subsequent cascades, whereas the final sample 7 was taken at the end of the open sewer (Fig. 3).

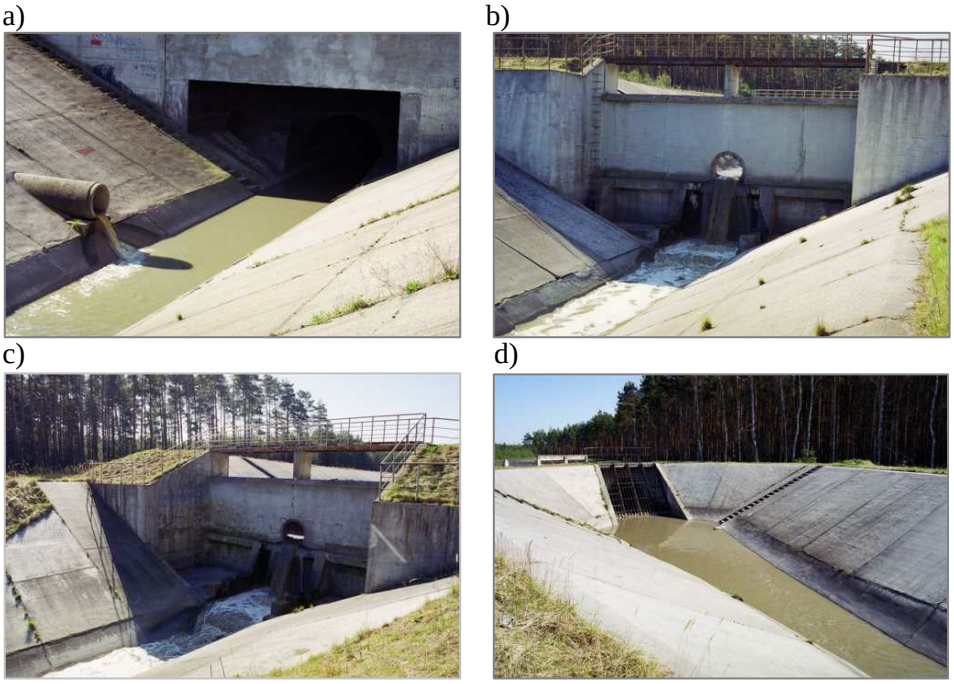

Fig. 3. View of the open sewer which channels sewage to WWTP in Lezyca
a) beginning of the open sewer - measuring point 1, b) measuring point 2,
c) measuring point 3, d) end of the open sewer - measuring point 7

The following parameters were marked in the sewage samples: concentration of dissolved oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_5). The analyses were made of the method applicable in Poland.

In every series, collection of sewage from the first measuring point was made at 09.00. The next samples were taken after a time which takes into account the speed of sewage in the channel. Concentration of dissolved oxygen, pH and sewage temperature were measured directly in the intercepting sewer.

On the basis of the designated values BOD_5 and COD, organic compounds were divided into suspension and dissolved fractions, as well as into easily and slowly biologically degradable. COD of the sewage, with division into fractions, can be calculated in a simplified manner in accordance with the following dependence [6]:

$$COD = S_S + S_I + X_S + X_I \quad (1)$$

S_S - COD of dissolved organically compounds, easily biodegradable,
S_S - COD of dissolved organically compounds, non-biodegradable,
X_S - COD of organic suspensions, slowly-degradable,
X_I - COD of organic suspensions, non-degradable.

The methodology of determining the COD fraction was developed on the basis of guidelines ATV-131 [Commentary on ATV - A131, 2000].
It should be stressed that assessment of the values of contamination indexes and COD fraction for samples of sewage taken directly from the intercepting sewer is a difficult and subjective assessment, depending on numerous external factors related to sampling, daytime, day of the week (unevenness of water consumption), and for complete orientation and comparison, it requires a lot of results from each point.

3. RESULTS

On the basis of the performed measurements of dissolved oxygen concentration (Fig. 4), directly past each cascade, it has been found that it gradually increases between the start of the open interceptor and the 4the (5^{th}) cascade.

In sewage transported through the sewer between the 5^{th} cascade to the 7^{th} measuring point (longest distances between cascades), concentration of DO is lower.

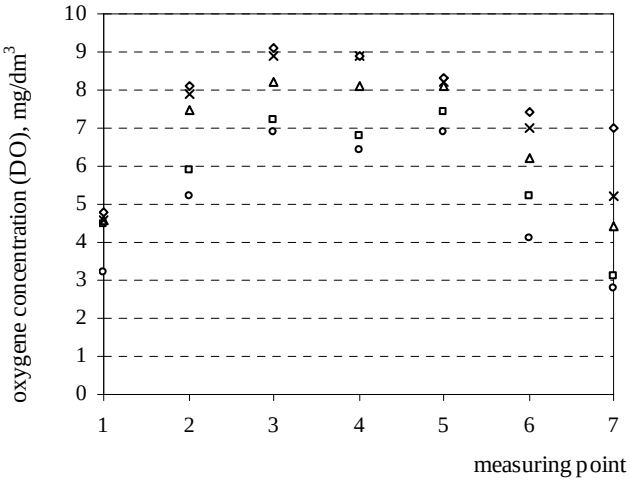

Fig. 4. Changes of DO in the sewage in 5 series

Changes of COD and BOD_5 in the sewage in open intercepting sewer are presented graphically in Fig. 5.

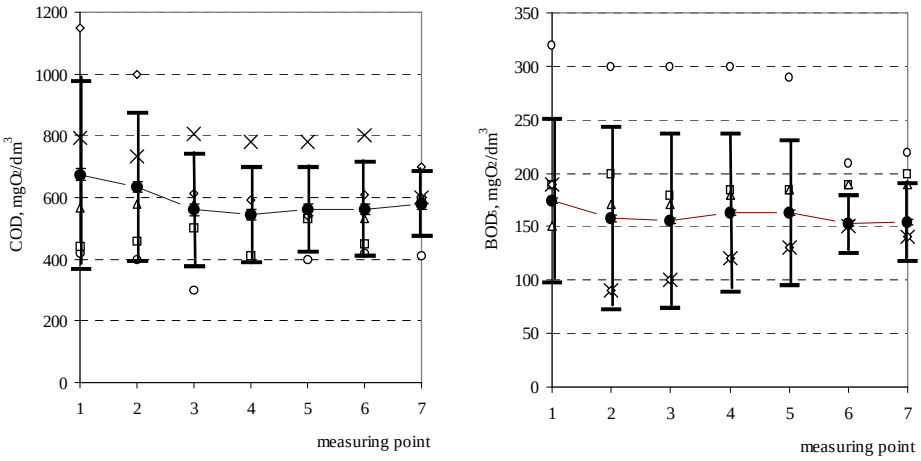

Fig. 5. Changes in COD and BOD_5 in the sewage at measuring points (5 series) and standard deviation of average values

The average (specified on the basis of 5 measurements) value of total COD in the sewage at sections of the open intercepting sewer (measured at points 1 to 7) changed from 674 to 544 mgO_2/dm^3 between point 1 and 6, to reach the value of 577 mgO_2/dm^3 at the end of the interceptor. The amount of

organic compounds in the sewage expressed as average BOD_5 ranged between 181 and 150 mgO_2/dm^3.

Average values of COD fraction in the sewage at subsequent measuring points is shown in Table 1. Share of the inert fraction COD ($X_I + S_I$) (Fig. 6.) changed from 13 to 20%, and biodegradable substance ($X_S + S_S$) in the sewage was between 80 and 87%.

The amount of dissolved biodegradable substance ranged from 30 to 35%. Share of dissolved fraction ($S_S + S_I$) in $COD_{tot.}$ varied from 31 to 39%, whereas the share of the suspension fraction ($X_S + X_I$) – from 64 to 71%.

Table 1. Average values of COD fraction in the sewage at subsequent measuring points

COD fraction, mgO_2/dm^3	measuring point						
	1	2	3	4	5	6	7
S_s	235	185	191	191	194	160	179
S_i	2	9	1	5	4	3	9
X_i	67	90	79	94	93	85	91
X_s	370	351	291	254	256	315	298
Sum	674	635	562	544	547	563	577

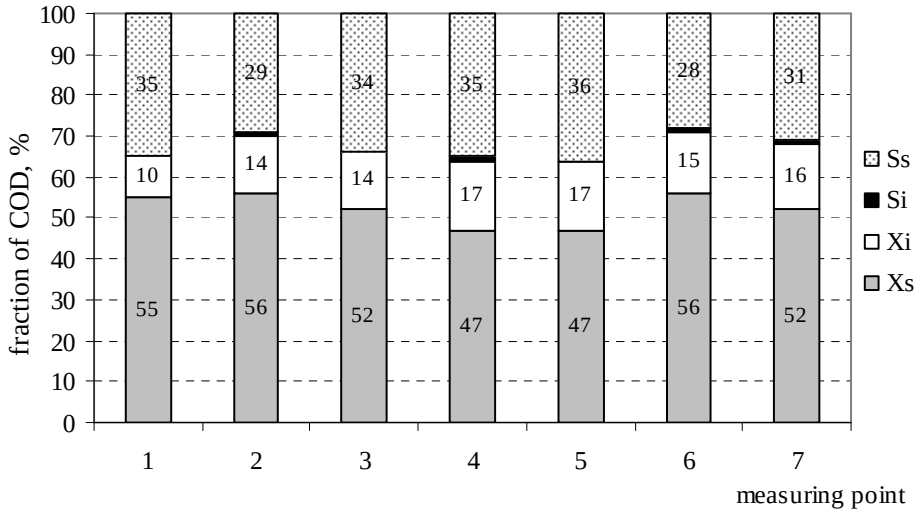

Fig. 6. Average values of COD fraction in the sewage at subsequent measuring points [divided into fractions in %]

Analysis of the obtained values of individual COD fractions, depending on the point of collecting the sample, demonstrated, that comparable results were achieved for all five series. It was also found that regardless of the COD and

BOD_5 values in raw sewage channelled via open sewer, distribution of individual COD fractions in all the series was very similar.

The presented research results demonstrate that during transportation of sewage through an open sewer, changes in the composition thereof take place. Significant differences were found for COD and BOD_5 of the sewage.
During the research period, the highest extent of decrease in the sewage COD value within the channel was 35%, and for BOD_5 – 33%.

4. CONCLUSION

The processes occurring in an open interceptor are influenced by internal and external factors. The most important are the ambient temperature and the extent of solar exposure. The changing temperature influences solubility of oxygen and activity of micro-organisms. Open space and cascade arrangement of the interceptor decrease the probability of oxygen-free environment. In this case, the dominating significance in the decomposition of organic compounds is to be ascribed to oxygen processes.

The sewage treatment processes begin already in the sewer and they can positively influence operation of the treatment plant. It should be remembered that the conditions of sewage flow are changeable, and modelling of changes as well as effective use of an open interceptor as a biological reactor require further, detailed research.

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PRZEMIANY ZWIĄZKÓW ORGANICZNYCH W OTWARTYM KANALE ŚCIEKOWYM

S t r e s z c z e n i e

Głównym zadaniem sieci kanalizacyjnych jest odbiór i odprowadzenie ścieków do oczyszczalni lub odbiornika. Obecnie coraz częściej sieć kanalizacyjna jest analizowana w aspekcie zachodzących w niej procesów biochemicznych. Kanał doprowadzający ścieki do oczyszczalni można potraktować jak przepływowy odbiornik ścieków i przyjąć, że zachodzą w nim przemiany, których podstawą są procesy samooczyszczania zachodzące w rzekach. Zmiany w składzie ścieków w kanalizacji mogą w istotny sposób wpływać na pracę oczyszczalni i odbiornik ścieków oczyszczonych.

W artykule przedstawiono wyniki badań zmian charakterystyki ścieków surowych dopływających do oczyszczalni ścieków kanałem otwartym. Ustalono, że na procesy zachodzące w kolektorze otwartym znaczący wpływ mają czynniki zewnętrzne. Najważniejszym z nich jest temperatura otoczenia i stopień nasłonecznienia. Temperatura ścieków wpływa na rozpuszczalność tlenu w ściekach i aktywność mikroorganizmów. System kaskadowego przepływu ścieków w kolektorze zmniejsza prawdopodobieństwo wystąpienia warunków beztlenowych.