New method for wastewater pre-treatment in the sewage system

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Abstract: - The paper presents a new method, currently unused, for the practical application of the sewage network as a wastewater pre-treatment stage. This can be achieved by using alternative aeration systems along the sewage system, which lead to alternative aerobic and anaerobic areas and allow the development of the biological processes. The microorganisms that occurred partially decompose the organic pollutants from the wastewater in the sewage system. Besides the rationally and efficiently used of the sewage system for facilitating the operation of the wastewater treatment plant, another important advantage is the modified gaseous medium that lead to quickly and safety interventions of the operators in the sewage network, without danger. In this paper the mathematical model and numerically simulations are presented, which were done to obtain the optimum horizontally distribution of aeration equipment in aerobic zones and the optimum length of aerobic and anaerobic zones. It was found that the removing of the organic substances was around 15 – 17% using this method on 10 kilometers of the sewage system.

Key-Words: - aeration, wastewater, pre-treatment, modeling, oxygen dispersion, sewage systems

1 Introduction
Currently the sewage system is used to assure the wastewater gravitationally flow to the wastewater treatment plant.
The length of the sewage system depends on the relative position of the wastewater treatment plant from the locality and it is around 5 to 15 kilometers. It is necessary several hours for wastewater covers this distance. During this time the organic substances are anaerobically decomposed, eliminating toxic gasses (CH₄, CO₂, H₂S) and unpleasant smells through the apertures of the sewage system, with major implications for the safety of the maintenance personnel.
A new wastewater pre-treatment method is proposed for rationally and efficiently use of the length of the sewage system, [1]. This method consists of the alternation of the aerobic and anaerobic areas into the sewage, using aeration systems, which allow the development of the biological processes. The grown bacteria partially degrade the organic substances from the sewer system.
By aerating the wastewater from the sewer the gaseous medium is modified and this lead on quickly and safety interventions in the sewer system, without dangers for the operators.
The aeration systems assure the oxygen needed in the aerobic areas for the decomposition of the organic pollutants, for the metabolism of the microorganisms and for the multiphase fluid mixing. In this way the microorganisms are in continuous contact with the dissolved organic substances.
To improve the efficiency of the biological process, in the upstream of the sewage excess activated sludge from wastewater treatment plant could be injected. On the sewage walls a biological film occurred after a period of time that biochemical decomposes the organic matter. Due to the biomass fixed on the sewage walls the pipes corrosion will be prevented.
The cases presented in this paper consider the oxygen dispersion in the sewer at different flow conditions. The mathematical model and numerically simulations are compared with the experimental data.

2 Mathematical model
The purpose of mathematical modeling and numerical simulation is to identify the best position of the aeration equipment to have the optimum oxygen concentration in aerobic zones of wastewater, around 2 mg/l. Also, it is necessary to provide anaerobic zones, for denitrification.
The optimization of pre-treatment method is needed
for reducing the maintenance and operation costs, for energetic optimization of treatment equipments and to obtain maximum performances in wastewater purification [2].

The aeration process depends on hydraulic flow regime through the sewage, [3]. Hydraulically permanent motion and unidirectional horizontal motion are considered. The air is dispersed into the water using pneumatic equipment put on the bottom of the sewer and connected to a blower.

The mathematical model is based on the dispersion equation of dissolved oxygen in wastewater, considering complete mixing in the sewer:

\[ \frac{dC}{dt} + u \frac{dC}{dx} + w \frac{dC}{dy} = \varepsilon_x \frac{dC}{dx} + \varepsilon_y \frac{dC}{dy} - k \cdot C^3 \]  (1)

where: C-oxygen concentration, u–horizontally water velocity; w-lift velocity because of gas bubbles (gas bubbles flow along Oy – from now on standing for the vertical axis instead of Oz); \( \varepsilon_x \) – the axial dispersion coefficient; \( \varepsilon_y \)–the vertical dispersion coefficient; k-oxygen consumption factor.

The transversal turbulent dispersion coefficient is neglected because it has very small values against similar phenomena on Ox and Oy.

3. Numerically simulation

For the numerically integration of equation (1) FlexPDE software is used, [4]. This is a scripted finite element model builder and numerical solver. From a script written by the user, FlexPDE performs the operations necessary to turn a description of a partial differential equations system into a finite element model, solve the system, and present graphical and tabular output of the results. It allows the user to describe the mathematics of his partial differential equations system, the geometry of his problem domain and specify the boundaries conditions, [5].

A customized program is written to obtain oxygen profiles in wastewater, [5]. In the dispersion equation is introduced a term for oxygen consumption that considers oxygen demand for cellular metabolism and for mineralization of organic matters. For this term it was considered different expressions until the concentration profiles fit the real process, [6]. The constants in the equation (1) are: \( u=0.8 \) m/s, \( w=0.3 \) m/s, \( \varepsilon_x=0.3 \) m²/s, \( \varepsilon_y=2 \) m²/s, an \( k = 0.3 \) s⁻¹. Initially the dissolved oxygen concentration in the liquid is zero. A portion of the sewer pipe of 0.8 m diameter and 80.5 m length is considered. The first and the last 10 m are aerated. The length of oxygenation equipment is 0.5 m.

First, numerically simulations are performed in order to determine the optimum horizontally distribution of the aeration equipment in the aerated zones, so that the concentration of dissolved oxygen to be around 2-3 mg/l on the transversal section of the sewage pipe. The most significant results are presented below in fig. 1 and 2.

![Fig.1 Oxygen concentration profiles for distance between two consecutive aeration equipment 0.5 m (zoom view)](image1)

![Fig.2 Oxygen concentration profiles for distance between two consecutive aeration equipment 1 m (zoom view)](image2)

Oxygen concentration profiles show high values near the aeration equipments and lower at the top of the sewer pipe. In figures 1 and 2 the numerically simulations of equation (1) are made in the same condition, the only difference is horizontally distribution of the aeration equipment.

The optimum distance between the aeration equipment is 1 m. If the distance is shorter there is high dissolved oxygen concentration values into the wastewater and if the distance is longer the concentration of oxygen between two consecutive aeration equipment is below 2 mg/l.
Other simulations are performed to determine the concentration of oxygen in the sewerage pipe in aerobic and anaerobic zones. The results are presented in figure 3, 4, 5, 6 and 7.

From the figures 3 and 7 one can observe that the concentration of oxygen after the aerobic zone of 10 m length, decreases at zero values after another 20 m. Between 30 and 70 m there is not oxygen in wastewater.

Figures 4, 5 and 6 shows the distribution of oxygen in different zones of the sewerage pipe.

3 Experimental research
The experimental researches were made on an installation fitted into a municipal sewage system. The experiments realized for different configurations shown the following characteristics of organic loading (BOD₅) at the entrance of wastewater into the wastewater treatment plant, [6].

Tabel 1 shows the BOD₅ determination in three cases: the first case the aeration system is off, case 2 the aeration system is horizontally distributed as in Figure 1 and case 3 the aeration system horizontally...
distributed as in Figure 2. Figure 8 presents the graphical representation of the values indicated in Table 1.

Based on experimental research one can observe that the third case is the most appropriate to be used as a pre-treatment method. The system needs a longer distance between aeration systems so that the organic substances consume the oxygen supplied by aeration equipment.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Organic loading evolution in the sewage network in different aeration conditions</th>
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<tbody>
<tr>
<td>day</td>
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<tr>
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</tr>
<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>15</td>
<td>99.67</td>
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![Fig.8 Organic loading evolution in the sewage network in different aeration conditions](image)

4 Conclusion

The results of theoretical researches (mathematical modeling and numerical simulation with FlexPDE) and experimental researches realized for the pre-treatment of wastewater in the sewage systems show that the application of this method decrease the organic loadings in influent of wastewater treatment plant. As a consequence, wastewater treatment plant energy costs are smaller and the wastewater treatment plant efficiency increased.

The theoretical and experimental researches show that the alternation between the aerobic and anaerobic areas should be around 60 m. In these intervals the organic substances are decomposed.

References:


