Testing the efficiency of water aeration with the use of ATOL-OXY type air applicer

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Abstract. The purpose of this study was to determine the effectiveness of aeration with the use of an air applicer (a device for aeration of sludge protected by the patent application no P-416711) by determination of characteristics of its operation depending on the stream of water flowing through the device, the height of the outlet over the water table and multiplication factors of measuring water pumped through the applicer. On the basis of laboratory tests/measurements, a mathematical model of the increased concentration of oxygen dissolved in water has been developed. As a result of the research, a significant increase in oxygen concentration has been achieved only after the first water pumping through the applicer. The determined mathematical model can be used to calculate predicted increases of oxygen concentration dissolved in water in variants other than those investigated.

1 Introduction

The main problem in the design of sanitary sewage systems is the decreasing water consumption for social welfare purposes, which in consequence reduces the content of the input oxygen dissolved in wastewater while increasing the concentration of pollutants. This problem is particularly evident in rural and peripheral systems, where small wastewater flows in the ducts increase the stopping time in pumping stations and discharge pipelines. Too low a flow velocity (less than 0.8 m/s - considered self-cleaning velocity of the ducts) causes sedimentation, deposition, and decay of organic deposits at the bottom of the pipelines [1-8].

Introduction of general water consumption metering under the Act of 7 June 2001r. about collective water supply and collective waste water discharge (Journal of Laws of 2001, No. 72, item 747) [9] caused the population's water consumption to decrease markedly. In 1990, household water consumption was 192,300 m³, 136,000 m³ in 2000, and 119,600 m³ in 2014 [10]. Reduced water consumption by the residents results in reduced effluents with constant production of pollutants resulting from human metabolism, and consequently lower flow rates and velocities in sewage channels [11]. Smaller amounts of sewage in the sewage system (especially in very dispersed systems) result in long flow times, and in particular long drain times at local pumping stations. Recommended in the German standard [12], the time of sewage retention in the pumping station is 4 hours. After this time, the sewage rots, generating odors and is dangerous to health due to the hydrogen sulphide evolution [13-18].

An attempt to counteract the formation of oxygen deficits in sewage systems is the use of an air applicator type ATOL-OXY. The tests were aimed at checking the aeration efficiency of the device.

2 Materials and methods

ATOL-OXY air applicer is a device designed for water and sewage aeration. The operation principle of the device is to disperse a stream of liquid in the form of a cone in the air, which causes repeated air increase in contact with air. For lower flow values and higher unit heights above the water table, the cone surface is interrupted to form drops.

The research on content of oxygen soluble in water was conducted between July 21st and September 28th 2015. A total of 96 measurements of the oxygen concentration dissolved in water were performed. The concentration of dissolved oxygen was performed according to Water Quality PN-EN 25813. Determination of dissolved oxygen. The iodometric method [19] was performed in a laboratory of Sanitary Engineering Department of the Water Technology, Wastewater and Waste Department.

2.1. Description of the measuring station operation

The measuring station is shown on Fig. 1. In the A tank with the capacity of 1000 dm³ a pump was placed (1) responsible for the production of kinetic energy and circulation of measured water. Water was transported by a DN 50 steel pipe to a ball valve (2), with which the flow was stifled. By controlling the indicators on the water meter (3) the desired flow rate was set through the valve. The section from the valve to the water meter (2-3) was made of PN10 pipe with the diameter of
40x2.5 mm PE. Further sections from the water meter to the applier were made of PN10 pipe with the diameter of 50x3mm PE. Manometer (4) performed a control function. Next, water flowed through the applier and got into the B tank from which samples were taken in order to determine the amount of dissolved oxygen. Then, water returned to the A tank by a gravity duct.

To make sure that all water in the B tank is oxygenated, samples were taken at the end of each time water passed through the applier. During measurement the overpressure value on the manometer and the test water temperature was recorded, which averaged 21.16 ± 1.09°C.

Table 1. Water overflow time for the tested flow values.

| Flow [dm³/s] | Time one ribbon [s] | Time one ribbon [min] |
|--------------|---------------------|-----------------------|
| 1            | 800                 | 13:20                 |
| 1.5          | 533                 | 8:54                  |
| 2            | 400                 | 6:40                  |
| 2.5          | 320                 | 5:20                  |
| 3            | 267                 | 4:30                  |

4 Results and discussion

Basing on the measurement data, the operating characteristics of the device were determined in relation to the height above the water table, the flow rate and the multiplication of the water flow through the applier. In addition, a model of the increase of dissolved oxygen concentration after one-time water overflow was calculated as a function of two variables - height and flow.

Analyzing the increase in oxygen concentration dissolved in water after one-time overflow through the applier depending on the flow rate for the three tested heights: 0.3; 0.4 and 0.5 m of the applier above the water table, an upward trend in oxygen concentration was proven which was dependent on the flow and height of the applier over the water table (Fig. 2). It was observed that the highest increase in water soluble oxygen was at the height of 0.5 m and amounted to 5.05 mgO₂/dm³ (flow 1 dm³/s), and the lowest increase was at the height of 0.3 m - 2.75 mgO₂/dm³ (flow 1 dm³/s). In subsequent calculations of the mathematical model of operation after a measurement error was defined, the measurement result for the flow of 2.5 dm³/s at H = 0.4 m was rejected. As a result, regression equations were estimated and an approximate linear increase in dissolved oxygen concentration was observed at one time, depending on the flow rate (Fig. 3).

In further research, basing on the laboratory experiment, a mathematical model was developed. It described the concentration dependence of dissolved oxygen in water from the height and flow of water. To define a complete model of dissolved oxygen concentration increase, a linear regression was used as a function of two variables and the below function pattern was obtained:

\[ \Delta C = f(H, Q) = 8.01H + 0.842Q - 0.172 \]  \hspace{1cm} (1)

Description of equation:
\( \Delta C \) - increase in oxygen concentration, mg/dm³
H - outlet height of the applier over the water table, m
Q - water flow through the applier, dm³/s
Based on the mathematical model, the relation shown in Fig. 4 was developed.

According to this dependence, the increase in dissolved oxygen concentration increases linearly as a function of the height of the applier over the water table and the water flow through the applier. This model helped to generalize the three linear functions shown in Figure 3 into one plane of the increase in oxygen concentration. The model also allows to determine the increase in oxygen concentration in different height and flow variants and thus optimize the performance of the device and its full potential.

5 Conclusions

1. After the first injection of water through the applier, a significant increase in oxygen concentration was achieved. The increase in oxygen concentration after single extrusion ranged from 1.63 mg / dm³ (0.5 m height, 3 dm³/s flow) to 5.59 mg/dm³ (height 0.4 m, 3dm³/s flow).
2. After five times of water overflows, oxygen saturation exceeded 95% in twelve out of sixteen measurements.
3. The mathematical model allows calculation of predicted increases in dissolved oxygen concentration in water in variants other than those tested. In addition, the mathematical model can be used to optimize the operation of the pump-applier system, taking into account the conditions of pumping stations or expansion wells.
4. The use of the applier in existing sewage systems would contribute to the improvement of the aerobic condition of sewage. It would also help solve the problem of oxygen deficiency, the formation of toxic hydrogen sulphide and nuisance odors in both existing and planned sewage systems.

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