WATER AERATION RESEARCHES

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Abstract - The paper examines the possibility of increasing the dissolved oxygen content in the water by introducing compressed air into the waste water transport pipeline. A computation program is developed for the numerical integration of the equation of the oxygen transfer rate to water and the distance at which the saturated concentration of dissolved oxygen in water is reached is determined

Keywords: Water Aeration, Oxygen Dissolved in Water, Waste Water.

1. Introduction

By the aeration of water is meant the transfer of oxygen from the atmospheric air into the water, which is, in fact, a phenomenon of transfer of a gas into a liquid [1][2].

The most common method of removing organic impurities under the action of aerobic biomass is the introduction of oxygen gas into the wastewater.

Oxygen comes most commonly from atmospheric air, in this case the process bearing the name of water aeration (fig. 1).

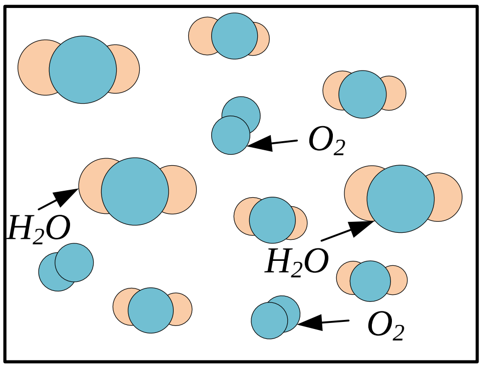

Figure 1: View of the molecular structure: dissolved oxygen [3].

From the above figure one can seen that each water molecule consists of an oxygen molecule connected to two hydrogen molecules (the blue sphere coupled to two pink spheres). The oxygen molecules (blue spheres) that constitute dissolved oxygen can be found among water molecules. The maximum amount of oxygen that can be dissolved in water depends on a number of physical and chemical parameters, such as: atmospheric pressure, water temperature, water salinity, degree of water turbulence [4][5][6].

Water temperature is an important factor, so the warmer the water, the lower the dissolved oxygen concentration. Therefore [7][8]:

- at t = 10ºC, in fresh, clean water, an amount of 11.3 mgO_2 / dm^3 can be absorbed;
- at t = 25ºC, in clean water, only 8.3 mgO_2 / dm^3 can be absorbed.

Water aeration leads to an increase in the dissolved oxygen concentration in the water.

Aeration is necessary to improve water quality, to avoid the occurrence of oxygen deficiency in systems where there is biochemical oxygen consumption above the water self-aeration capacity, to eliminate the toxic gases that can be found in water and in the process of wastewater purification [9] [10].

The main purpose of water aeration, regardless of the industry and the reason for its use, is to increase or maintain an optimal level of dissolved oxygen in a mass of water.

The oxygen needed for the aeration process is taken from the atmospheric air and introduced into the water. In order for this aeration to be effective, a uniform dispersion of air must be ensured throughout the water body in a tank or basin; the air must be spread evenly to provide oxygen.

A distinction must be made between the term "aeration" and "oxygenation" of the wings:

- Water aeration refers to the introduction of atmospheric air into the water;
- Water oxygenation refers to the introduction of a gas mixture:

  > atmospheric air + oxygen from a cylinder [10];

  > low nitrogen air delivered by oxygen concentrators [10] [11].

2. Analysis of Two-phase Fluid Flow Through a Horizontal Pipe

An air bubble emitted in the water has a certain space available to rise vertically [12]. This space is the inside diameter of the pipe (figure 2).

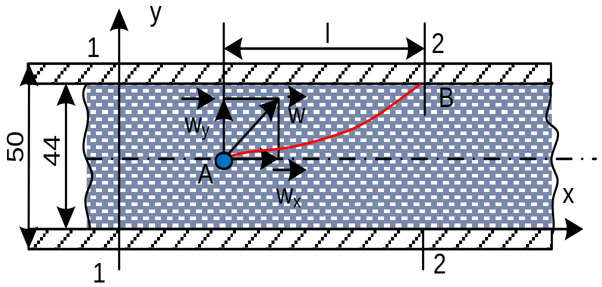

Figure 2: The trajectory of an air bubble in the case of water flow through horizontal pipes

During the flow the air bubble speed has two components:

w_x - speed on the ox axis;

w_y - speed on the oy axis

Due to the water and air speed, the air bubble will travel a curvilinear trajectory.

The problem formulation.

1) At what distance (l) (figure 2) will the air bubble come out of the water?

2) At the distance "l" was the concentration of dissolved oxygen reached in water from C_0 to C_s? (see section 1-1 and 2-2 performed on the horizontal pipe).

3. Numerical Integration of the Oxygen Speed Transfer Equation to Water

The equation of the rate of oxygen transfer in water is:

$$\frac{\mathrm{d}C}{\mathrm{d}\tau} = a \cdot k_L \left(C_s - C\right) \quad (1)$$

where:

- C - concentration of dissolved oxygen at time τ;
- ak_L - the volumetric mass transfer coefficient;
- C_s - oxygen concentration in water, at saturation.

The values of ak_L and C_s are constant in time.

If the boundary conditions $C = C_0$ for $\tau = 0$ are imposed, equation (1) can be integrated [14][15]:

$$\frac{\mathrm{d}C}{C_s - C} = a \cdot k_L \, \mathrm{d}\tau \quad (2)$$

In the case of C <Cs, after integration, results:

$$-\ln\left(C_s - C\right) = a \cdot k_L \cdot \tau + ct \quad (3)$$

Constanta is obtained from the boundary condition:

$$C = C_0 \qquad \text{for } \tau = 0 \quad (4)$$

and it has the value

$$ct = -\ln\left(C_s - C_0\right) \quad (5)$$

Introducing (5) into (3):

$$-\ln\left(C_s - C\right) = a \cdot k_L \cdot \tau - \ln\left(C_s - C_0\right) \quad (6)$$

$$\ln\left(C_s - C\right) = \ln\left(C_s - C_0\right) - a \cdot k_L \cdot \tau \quad (7)$$

$$\ln\left(C_s - C\right) = \ln\left(C_s - C_0\right) + \ln e^{-a \cdot k_L \cdot \tau} \quad (8)$$

$$\ln\left(C_s - C\right) = \ln\left(\left(C_s - C_0\right) \cdot e^{-a \cdot k_L \cdot \tau}\right)$$

$$C_s - C = \left(C_s - C_0\right) \cdot e^{-a \cdot k_L \cdot \tau}$$

$$C = C_s - \left(C_s - C_0\right) \cdot e^{-a \cdot k_L \cdot \tau} \quad (9)$$

initially $\tau = 0$, so $C = C_0$

The equation is repeated in the form [16] [17]:

$$C_{i+1} = C_s - \left(C_s - C_i\right) \cdot e^{-a \cdot k_L \cdot \tau_i} \quad (10)$$

$$\frac{C_{i+1} - C_s}{C_s - C_i} = -\frac{1}{e^{a \cdot k_L \cdot \tau_i}} \quad (11)$$

It is considered that the two-phase mixture (water-air) moves along the ox axis with w = ct, so:

$$\tau_i = \frac{\Delta x_i}{w} \quad (12)$$

$$\frac{C_s - C_{i+1}}{C_s - C_i} = \frac{1}{e^{a \cdot k_L \cdot \frac{\Delta x_i}{w}}} \quad (13)$$

$$e^{a \cdot k_L \cdot \frac{\Delta x_i}{w}} = \frac{C_s - C_i}{C_s - C_{i+1}} \quad (14)$$

From previous research [9], $ak_L = 0.042 \ s^{-1}$ and one can obtain:

$$\frac{a \cdot k_L}{w} = \frac{0.042}{0.0115} = 0.35 \quad (15)$$

$$e^{0.35 \Delta x_i} = \frac{C_s - C_i}{C_s - C_{i+1}} \quad (16)$$

$$\ln e^{0.35 \Delta x_i} = \ln \frac{C_s - C_i}{C_s - C_{i+1}} \quad (17)$$

$$\Delta x_i = \frac{\ln \dfrac{C_s - C_i}{C_s - C_{i+1}}}{0.35} \quad (18)$$

The relation (18) will be used in the calculation program in paragraph 4.

4. Elaboration of a Calculation Program to Determine the Modification of the Dissolved Oxygen Concentration in Water According to the Distance Completed by the Two-Phase Mixture

The logical scheme of the program has the following steps [18] [19] [20]:

1) The entry data is specified:

For water at t = 24 °C from [9] one can obtain:

- initial value of dissolved oxygen concentration in water: C_0 = 5.84 mg/ dm³ = 0.00584 kg /m³
- value of dissolved oxygen concentration in water, at saturation: Cs = 8.4 mg/dm³ =0.0084 kg/m³
- water speed: w =0.0115 m / s
- the ratio ak_L / w = 0.35 (see relation 15)

2) It is successively calculated:

$$\Delta x_i = \frac{\ln \dfrac{C_s - C_i}{C_s - C_{i+1}}}{0.35} \qquad (19)$$

3) Determine Δx_i after "n" intervals (distances) at which the concentration C_{i+1} reaches the threshold of dissolved oxygen concentration in water, at saturation, i.e. C_s.

4) At this moment, there is the distance completed by the two-phase mixture such that $C_0 \rightarrow C_s$; this distance specifies the length of the pipe at which $C_0 \rightarrow C_s$ is obtained.

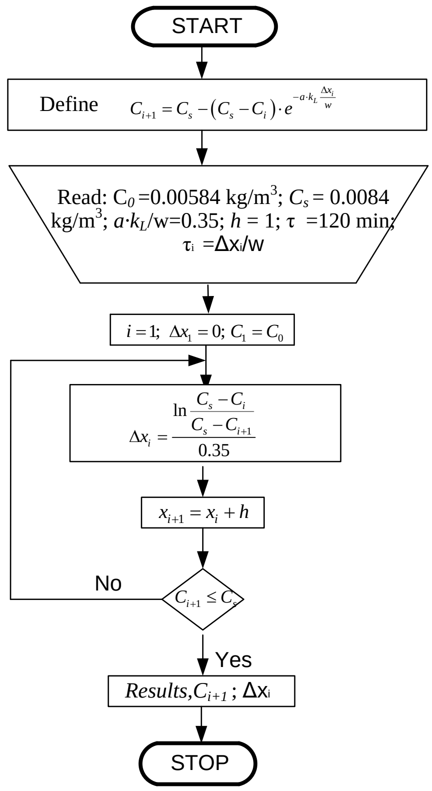

Figure 3: Logical calculation scheme of the program for calculating the variation of the dissolved oxygen concentration in the water according to the length of the distance until $C_{i+1} = C_s$

Table 1. Calculation results

i	C_i	C_{i+1}	Δx_i
1	0,00584	0,00594	0,113845
2	0,00594	0,00604	0,118571
3	0,00604	0,00614	0,123705
4	0,00614	0,00624	0,129305
5	0,00624	0,00634	0,135435
6	0,00634	0,00644	0,142176
7	0,00644	0,00654	0,149623
8	0,00654	0,00664	0,157893
9	0,00664	0,00674	0,167132
10	0,00674	0,00684	0,177519
11	0,00684	0,00694	0,189284
12	0,00694	0,00704	0,202719
13	0,00704	0,00714	0,218209
14	0,00714	0,00724	0,236262
15	0,00724	0,00734	0,257575
16	0,00734	0,00744	0,283117
17	0,00744	0,00754	0,314288
18	0,00754	0,00764	0,353183
19	0,00764	0,00774	0,403082
20	0,00774	0,00784	0,469437
21	0,00784	0,00794	0,562029
22	0,00794	0,00804	0,70035
23	0,00804	0,00814	0,929778
24	0,00814	0,00824	1,387165
25	0,00824	0,00834	2,802369

Based on the data in table 1, the graph in figure 4 was drawn.

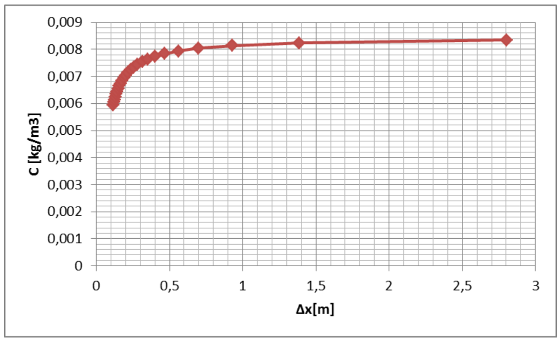

Figure 4: Graphical representation of the function $C_{O2} = f(x)$

From figure 5 one can observe that the value of the dissolved oxygen concentration in water rapidly increases over a distance (pipe length) of 1 m, and subsequently reach the value of the saturation concentration (C_s) over a distance of about 2 m. The allure of the curve C_{O2} = f (x) and the obtained values are similar to the data from other specialized papers [18][19][20]. The theoretical results obtained above will be validated by experimental researches that will be carried out in the immediately following period in the laboratories of the University Politechnica of Bucharest.

5. Conclusions

The paper aims to implement a reliable and economical solution for water aeration.

The proposed solution, i.e. aeration of fluids flowing through pipes is more advantageous compared to the existing procedures in practice because:

- eliminates those large aeration basins from the water treatment plants, thus reducing the investment cost.
- the electricity consumption for the water aeration is reduced.
- the operating and maintenance costs of the water treatment station are reduced..
- the quality control of the fluid subjected to the aeration process is easy to perform with the help of digital oxygenometer that use a non-invasive measurement method.

Acknowledgements

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