E3S Web of Conferences **286**, 01001 (2021) https://doi.org/10.1051/e3sconf/202128601001
TE-RE-RD 2021

Researches on increasing the dissolved oxygen concentration in stationary waters

Marilena Monica Boltinescu (Roza)[1], *Nicolae Vlad* Sima[1], *Dorina Nicoleta* Albu[1], *Mihaela* Petroşel (Bănică)[1] and *Mihaela* Constantin[1,*]

[1]University Politehnica of Bucharest, Faculty of Mechanical and Mechatronics Engineering, Splaiul Independenței, no. 313, Bucharest, Romania

Abstract. This paper presents a way to solve the transfer rate equation of oxygen in water. After running a calculation program, the graph of the function that indicates the increase of the dissolved oxygen concentration in the water as a function of time is plotted. Constructed in an original manner, the experimental installation allows the measurement of the increase of the dissolved oxygen concentration in water. The experimental obtained results are compared with the theoretically obtained data.

1Introduction

The oxygen quantity that is dissolved in wateris a function depending on salinity, the temperature and the pressure [1].

Hot water has less O_2than cold water, salt watercontains less O_2than fresh water, and lower-pressure waterhas less oxygen than high-pressure water. Recommended dissolvedO_2degreefor fishes is from 5.0 mg / dm^{3}to 9.0 mg / dm^3. In the case that thedissolved O_2degree is under 3.0 mg / dm^3, due to lack of oxygen, the fishes can die. If the dissolved oxygen level is over 9.0 mg/dm^3, it can also be deadly to fishes.

Figure 1 shows thatO_2 can be:

- O_2 bound to H_2
- free oxygen, namely: oxygen dissolved in water.

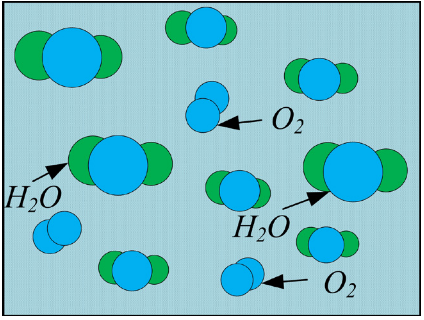

Fig. 1. The O_2 molecules dissolved in water.

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[*] Corresponding author: i.mihaelaconstantin@gmail.com

The oxygen solubility in wateris a function depending on the atmospheric pressure, the temperature, water turbulenceandthe magnitude of the air-water area.

Each water type source has its own biological and physicochemical specific featuresand differ from one area to anotheraccording to the composition of the mineralsin the covered region, the contact duration, the temperatureand the climatic regime.

The method of oxygenation of water is made on the basis of the transfer between air and water;from the air, oxygen is transferred through various methods. The air bubbles emitted by a system that forms it are placed in a water tank. Water oxygenation systems that generate very fine air bubblesare the most effective. From the literature [2] [3], it is known that the rate of O_2transfer to water is higher as the diameter of the air bubbles decreases; the diameter of the air bubble depends on the diameter of the orifice in the perforated plate of a FBG.

The air bubbles can be arranged in as follows (Figure 2):

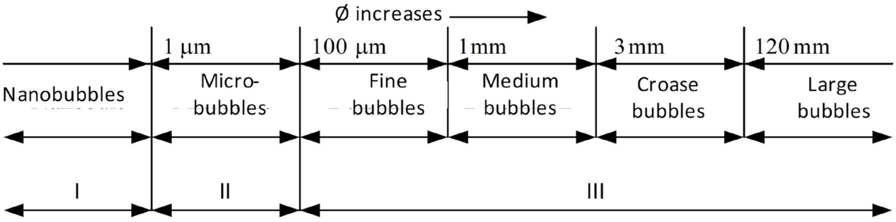

Fig. 2. Gas bubbles classification infunction of Ø:
I - the region where the air bubblescan be seen under a microscope;
II - the region where the air bubblesare difficult to see;
III - the region where the air bubblescan be seen with the naked eye.

Theperformance of awater oxygenation system is specified by the following two parameters[4][5]:

- the water oxygenation efficiency;
- the water oxygenation efficiency.

Themethodof aeration (oxygenation) of water is a fundamental field of Technical Thermodynamics, a discipline materialized by teaching the following courses: Mass and heat transfer, Gas Dynamics, Technical Thermodynamics.

2 Solving the oxygen transfer rate equation

In water oxygenationmethod, the temperature influences both the oxygen conditions, the dissolved O_2saturation concentration and the mass transfer coefficient. The saturation concentration values are directly influenced by the water temperature [6].

The dissolved O_2transfer rate in waterdepending on the temperature is given by the relation [7]:

$$\frac{dC}{d\tau} = \left(a \cdot k_L\right)_{20^0} \cdot \left(C_s - C\right) \ [kg / m^3 s] \quad (1)$$

where:

- ak_L–the transfer coefficient of the oxygen [s^{-1}];
- Cs –the mass oxygen concentration at saturation[kg / m^3];
- C –the current mass concentrationof the O_2[kg / m^3].

After integrating relation 1 applying the limit condition $C = C_0$ for $\tau = 0$, it results [6], [7]:

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

In the hypothesis that C <C_s, after preforming the integration, it results:

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

From the limit condition, the constant C is obtained:

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

resulting:

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

Introducing5 in 3 one can obtain:

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

From relation (6) one can obtain:

$$C = C_s - (C_s - C_0) \cdot e^{-a \cdot k_L \cdot \tau} \quad (7)$$

In equation (7), the following must be known: C_0, C_s, ak_L.

For the determination ofthevalues of $C = f(\tau)$, a computation program [8], [9] was elaborated, presented in figure 3.

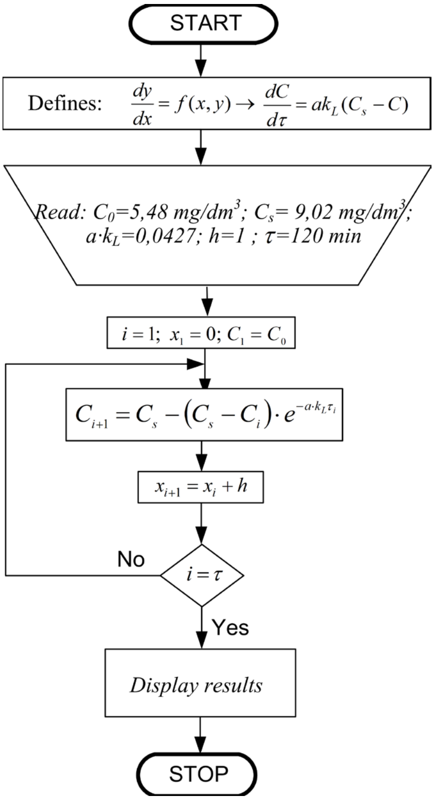

Fig. 3. Logical computation scheme for determining the change of the dissolvedO_2concentration.

After executing a calculation program(fig. 3), numerical values were obtained based on which, the curve in figure 4 was drawn.

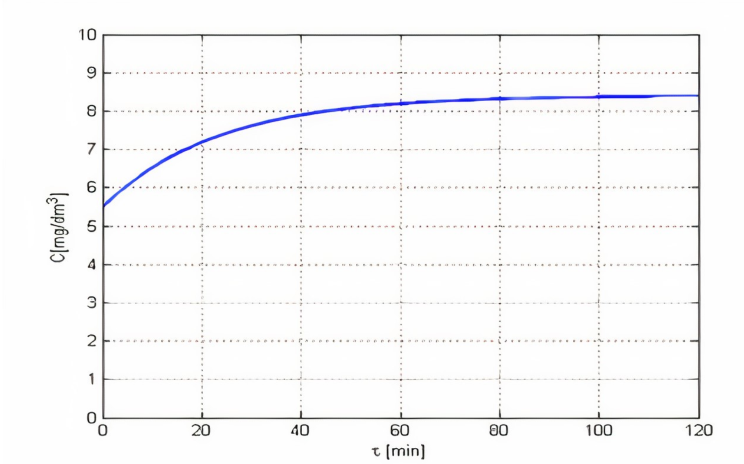

Fig. 4. The variationof thedissolved O_2concentration.

The main data that are maintained in the case of experimental researches are:

- the air flowrate: $\dot{V}$ = 600 dm^3/h; the inlet air pressure in the fine bubble generator: p = 573 mmH_2O; hydrostatic load: H = 500 mmH_2O; duration of the experience: τ = 120 min; C_0 = 5.84 mg / dm^3; t_{H2O} = 23.7°C → C_s = 9.02 mg / dm^3.

3 The presentation of the experimental installation

In figure 5 one can see the sketch of the experimental installationfor measuring theconcentration of the dissolved O_2in water, in time.

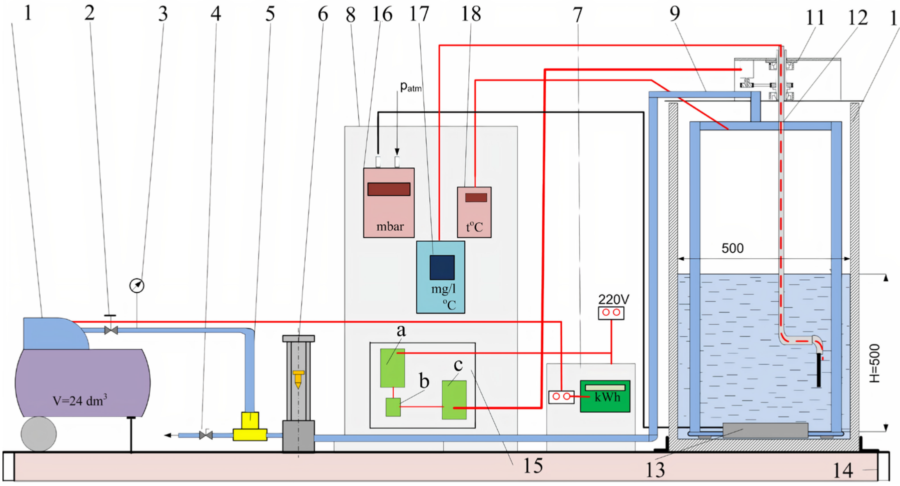

Fig. 5. Scheme of the experimental stand for researches related to water oxygenation

1 - electrocompressor with air reservoir; 2 - pressure reducer; 3 - pressure gauge; 4 - connection for evacuating air outside; 5 –T-bend; 6 - flowmeter; 7 - electrical instrument panel; 8 - gauge board; 9 - piping for transporting compressed air to the fine bubble generator; 10 - water tank;11 - machineryof actuation of the probe; 12 - oxygenometer probe;13 - fine bubble generator with orifices Ø 0.1mm; 14 - installation support; 15 - indicator: a - main inlet,b-interruptor, c - pilot cell, 16 - digital pressure gauge; 17 - oxygenometer 18 - digital thermometer.

The air compressed by the electrocompressor (1), traversethe flowmeter (6) and subsequently goes inthe FBG (13).

During the experiment, the following were measured: air flow rate, air pressure and the concentration of the dissolved oxygen in water.

The experimental installation (figure 5)comprises a series of devices mounted on the panel (8):

- digital thermometer withhigh accuracy, with thermistor sensor;
- differential pressure gauge, supplied with a piezoresistive transducer;
-oxygenometer with polarographic probe and microprocessor with digital board.

The electromechanical machineryfor actuating the oxygenometer probe (11), (12), is supplied with a pecker motor; this machineryadmitsthe cycle of the oxygenometer probe in the water mass, with a speed of 0.38 m /s [10][11].

Figure 6 shows an overview of the experimental stand, designed and constructed in theLaboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment's.

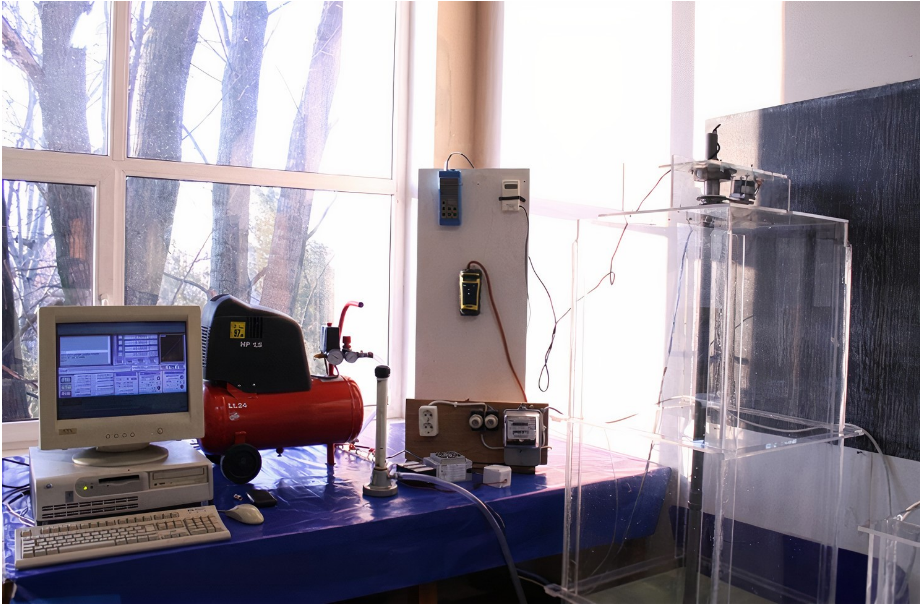

Fig.6. Overview of the experimental standfor studying the increase of the dissolved O_2concentration.

One can observe that on the leftwards of the image (figure 6), there is a computer that controls the actuation machineryof the oxygenometer probe; next to the computer is an electro-compressor with a compressed air tank and the devices panel. To the right of the image, is the water tank, made of clear plexiglass.

4 Experimental researches, obtained results

The steps to be followed in experimental researches are the following:

1. Introduce compressed air into the fine bubble generator and observe if the 152 orifices with Ø 0.1mm are not blocked;

2. The tank is filled with water (H = 500 mmH_2O) and measure t_{H2O}, C_0, t_{air};

3. The FBG (fine bubble generator)is introduced in water and the time at which the experienceis measured;

4. Introduce compressed air into the FBG and after 15 minutes pull out the FBG from the tank and insert the oxygenometer probe. This operation is performed every 15 minutes, until $\tau = 120$ minutes is reached;

5. From previous researches [12][13][14], it was found that after a time of $\tau = 120$ minutes, the value of C_0 tends to C_s;

6. Finally, clean the oxygenometer probe and drain the water.

Following the measurements, the data in table 1 were obtained.

Table 1. The values of dissolved O_2concentration in water,in time.

$\tau\ [min]$	0	15	30	45	60	75	90	105	120
$\dot{V}_{air}\ [dm^3/h]$	600	600	600	600	600	600	600	600	600
$\dot{V}_{IO_2} = 126\ [dm^3/h]$	126	126	126	126	126	126	126	126	126
$\dot{V}_{O_2}$ from other sources	0	0	0	0	0	0	0	0	0
$t_{H_2O}\left[{}^oC\right]$	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7	23.7
$t_{air}\left[{}^oC\right]$	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1
$C_0\ \left[mg/dm^3\right]$	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84	5.84
$C_s\ \left[mg/dm^3\right]$	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
$C\left[mg/dm^3\right]$	5.84	6.89	7.65	8.01	8.10	8.26	8.31	8.35	8.39

In conformity with the data in table 1, the curveform figure 7 was drawn.

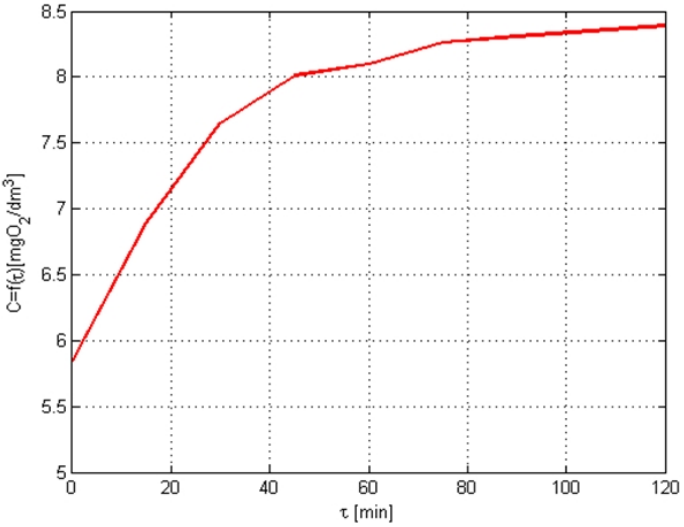

Fig. 7. The $C = f(\tau)$function.

From figure 7, one can observe that, with the passage of time the value of C_0 tends to C_s.

Figure 8 compares the modification of the dissolved O_2 concentration in water in the two cases:

1- graph plottedaccording to the theoretical data;
2- graph plottedaccording to theexperimental data.

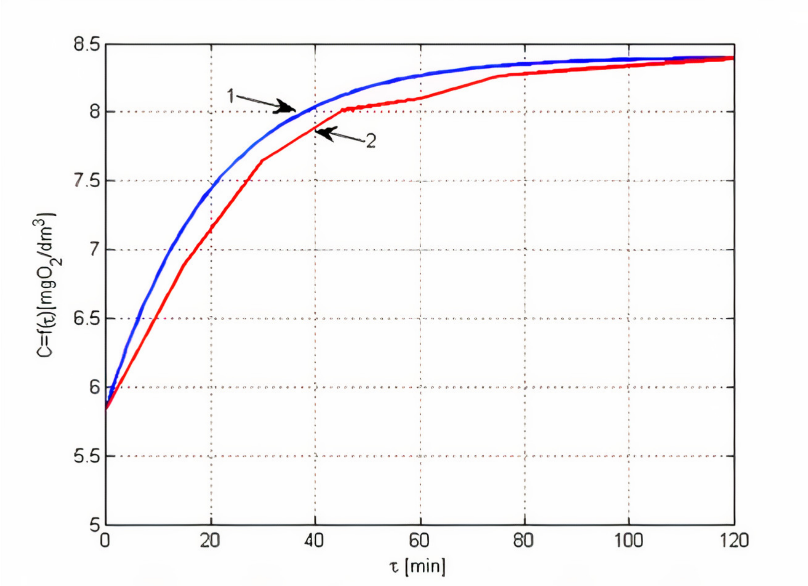

Fig. 8. The modification of the dissolved O_2concentration.

Figure 8 shows a good coincidence of the two graphs, which demonstrates the accuracy and rigor of theoretical and experimental researches.

5Conclusions

1. In the paper, the differential equation of the oxygen transfer rate in waterwas solved, by numerical integration.

2. A computation program was performed and the curve C = f(τ) was drawn; the theoretical results are similar to those obtained in other papers on the field of study.

3. The paper presents an original installation, designed and built-intosee the change in the dissolved O_2concentration in water.

4. Experimental researches has demonstrated the accuracy of theoretical calculations; for the graphs C = f (τ), the difference between theoretical and experimental values is small.

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