Researches on the Operation of a Fine Bubble Generator and Oxygen Concentrators

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Abstract: *Two water treatment procedures are presented in the paper:*
- a process for aerating the water with the help of a fine bubble generator;
- a process for waters oxygenation by means of oxygen concentrators.
In both processes, the flow rate of the conveyed gas is the same: 600 dm³ / h.

Keywords: *Fine bubbles generators, waters oxygenation, oxygen concentrators.*

1. Introduction

Considering the multitude of types and forms of gas bubble generators that are introduced into the water, there is a need for theoretical and experimental researches to treat the entire water aeration system unitarily. The literature [1] [2] [3] uses the term aeration or oxygenation; it is proposed to make the following distinction:
• Water aeration means the introduction of atmospheric air into the water (21% O_2 + 79% N_2);
• Water oxygenation means introducing a gaseous mixture as follows:
- Atmospheric air + oxygen from a cylinder in volumetric ratio (25%, 50%, 75%, 100%),
- Air with low nitrogen content (r_{O2} = 95%; r_{N2} = 5%) supplied by oxygen concentrators.
Fine bubble aeration is more efficient than the one made with coarse bubbles because the interfacial specific area between the two fluid systems (air-water) is higher. The interfacial specific area (a) is defined as the ratio between the gas particle area and volume V; a = A / V [5] [6].
In order to intensify the oxygen mass transfer phenomenon from air to the water it is necessary to achieve a maximum interphase contact surface, therefore a smaller diameter of the gas bubble.
➢ Water aeration is carried out in the following fields [7] [8]:
• In sewage treatment plants;
• In water treatment processes, removal of dissolved inorganic substances or chemical elements such as iron, manganese, etc., by oxidation and formation of sedimentable compounds or which can be retained by boiling;
• On biological treatment of waste water, either through the activated sludge process or with bio filters;
• In disinfection processes, by ozonisation of raw water captured from a source in the purpose of its drinking;
• In separating and collecting emulsified fats from wastewater.
Water oxygenation is a mass transfer process with wide application in water treatment. Oxygenation equipment's are based on the dispersion of one phase into the other, for example gas in the liquid, energy consuming process.
➢ Water oxygenation is carried out in the following fields [9] [10]:
• Maintaining an oxygen concentration in aquariums;
• The operation of swimming pools;
• In the medical field in the supply of oxygen to some lung patients.

2. Presentation of the fine bubble generator

Figures 1, 2, 3 show constructive details of the fine bubble generator (FBG).

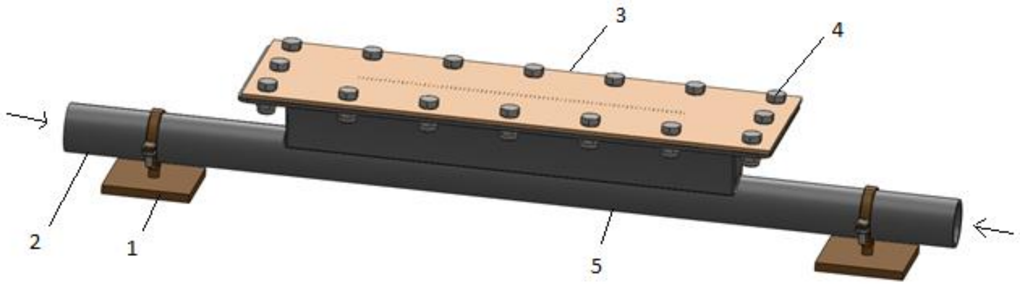

Fig. 1. Rectangular shaped fine bubble generator
1 - support, 2 - compressed air supply pipe, 3 - orifice plate, 4 - FBG body fixing screws, 5 - the body of the fine bubble generator

The 37 Φ 0.5 mm nozzles were disposed on a sole row, so that the bubble columns create a bubble curtain similar to the one formed by a planar jet with a rectangular shape transversal section [11][12]. The repartition of the Φ 0.5mm nozzles can be noticed in Figure 2.

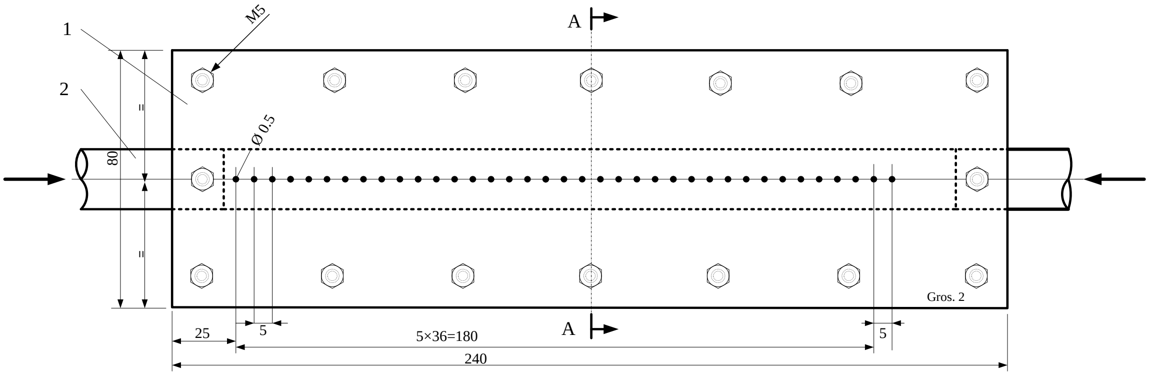

Fig. 2. Sketch of the rectangular shaped fine bubble generator perforated plate
1- orifice plate; 2- compressed air feed pipe.

A cross section through FBG it is seen in Figure 3, where the gas bubbles exit the orifices formed in a rectangular shaped plate.

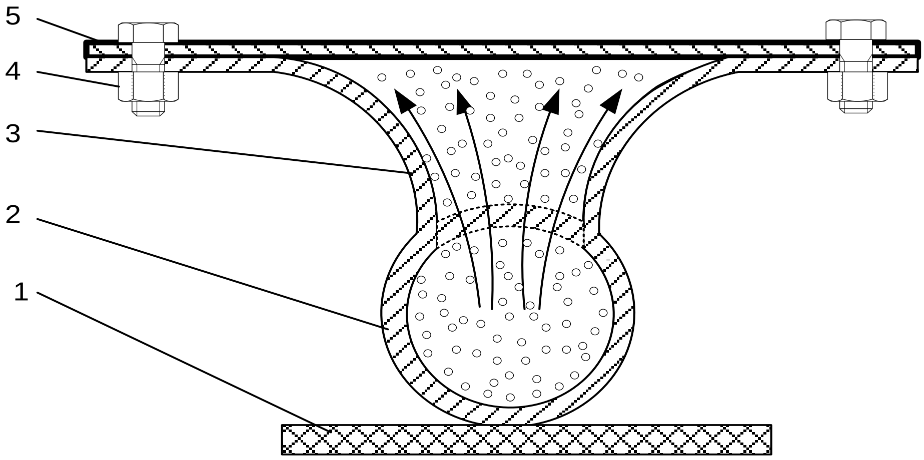

Fig. 3. Section from the rectangular shaped FBG.
1 – support; 2 – compressed air feed pipe; 3 – FBG body; 4 – screws for fastening the plate on the body; 5 – orifice plate.

This type of fine gas bubble generator will be used in experimental researches.

3. Experimental installation provided with a single fine bubble generator

The FBG is fed by its two ends, namely through the pipes 16 and 17.

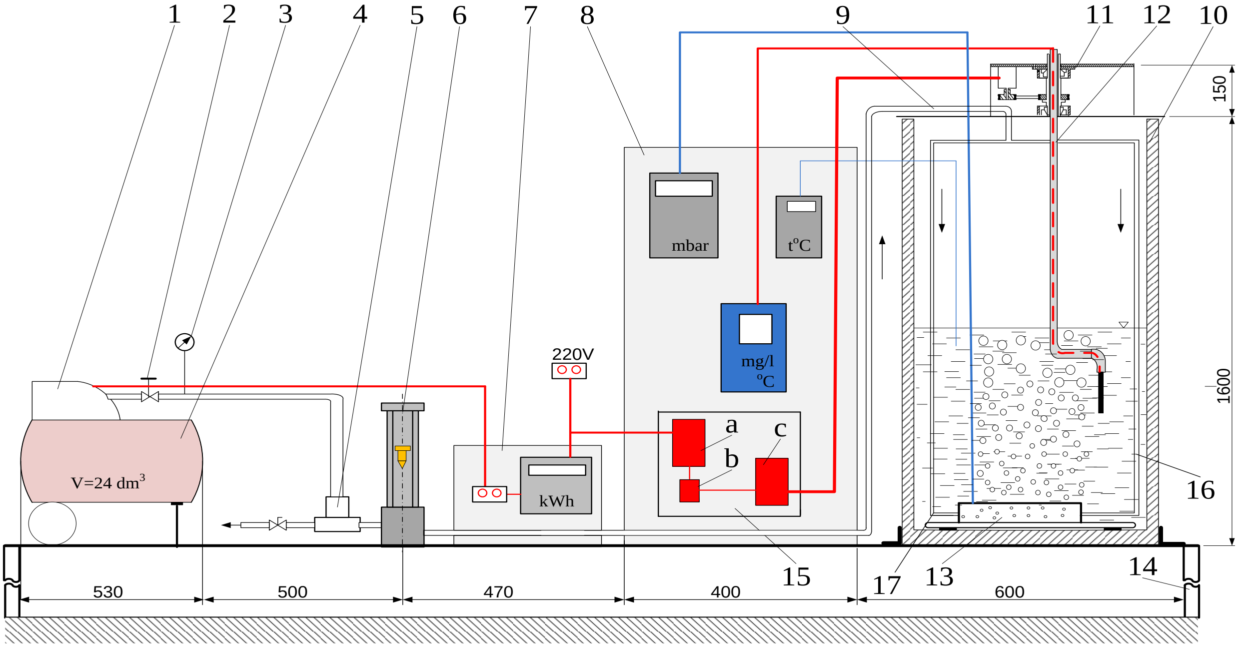

Fig. 4. Sketch of the experimental installation for researches regarding water oxygenation
1- electro compressor with air tank; 2- pressure reducer; 3-manometer; 4-compressed air tank V = 24 dm^3; 5-T joint; 6- rotameter; 7- electric panel; 8-panel with measuring devices; 9-compressed air pipeline to FBG; 10 - water tank; 11 - probe actuation mechanism; 12 - Oxygen probe; 13- rectangular shaped FBG; 14 - support for the installation; 15- electronics command: a - power supply, b - switch, c - control element; 16, 17 - compressed air supply pipes to FBG

Figure 5 shows the air bubble column emitted by the fine bubble generator.

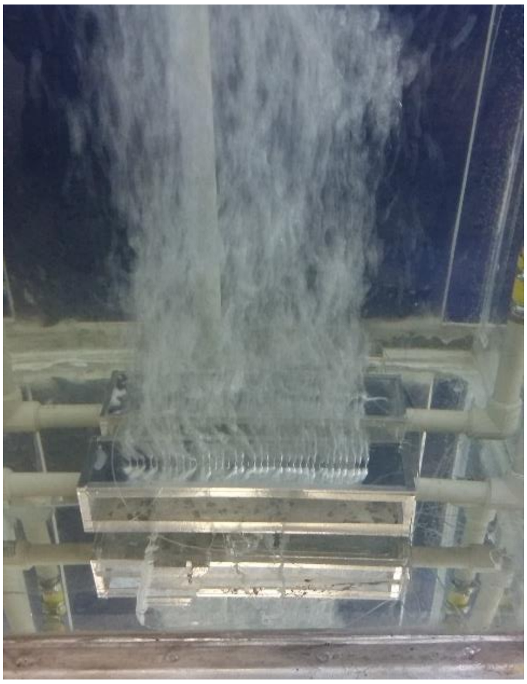

Fig. 5. Water oxygenation installation with one FBG in operation

Referring to the experimental installation of Figure 4, it is stated:
- It is possible to measure the flow rate and the pressure of the gas that ensure the oxygenation of

the water:
- atmospheric air;
- atmospheric air with low nitrogen content.

- Hydrostatic load can be changed in range of 0.5; 1.0; 1.5 m;
- It can be precisely measured with digital indicating devices: pressure, temperature and flow rate of gas introduced into the water tank;
- One can measure the instantaneous change of dissolved oxygen concentration in water or at time Δt with the oxygenometer whose probe is actuated by an electric mechanism.

For the installation operation electric current is needed to operate the electro compressor and for the mechanism of rotation of the oxygen sensor probe in the water tank.

The installation works as follows: compressed air from an electro compressor 1 (figure 4) accumulates at p = 1.5-2 bar in a 24 dm^3 tank. Subsequently, the air passes through the reducer 2 through the manometer 3 and reaches the FBG.

During an experiment, the volumetric air flow rate ($\dot{V}$), the pressure at the entrance at the FBG (p_{FBG}) and hydrostatic load (H) are kept constant.

The panel 15 with the control electronics provides, through the mechanism 11, the rotation of the oxygen sensor probe in the water tank at a speed of 0.3 m / s.

3.1 List of measuring devices provided on the installation scheme

For measuring the pressure and temperature of the air and the dissolved oxygen concentration in the water, there are provided digital indicating devices located on the panel (8) of Figure 4, namely:

a) A flow meter with a scale of 0 ÷ 2200 dm^3 / h for air was provided for the measurement of the flow rate.

b) A manometer with a digital indication in the range 0 ÷ 190 mbar was provided for the pressure measurement.

c) Measurement of temperature was performed with a digital thermometer with a scale of 50÷150ºC.

d) The dissolved oxygen concentration in water was measured using the electric method [13] [14] using a polarographic probe oxygen sensor.

For the measurements, the oxygen sensor is rotated in the water tank with 2 rot / s; for its rotation an electro-mechanical mechanism was designed in the Department of Thermotechnics, Engines, Heat and Refrigeration Equipment’s.

4. Experimental researches on the operation of a fine bubble generator

The fine bubble generator has 37 orifices Ø 0.5 mm; the air flow rate was 600 dm^3/h and the duration of the experiments was two hours.

The results of the measurements are shown in Table 1.

Table 1: Experimental data obtained for one FBG

No.	0	1	2	3	4	5	6	7	8
τ [min]	0	15	30	45	60	75	90	105	120
t_{H2O}[ºC]	23	23	23	23	23	23	23	23	23
t_{air}[ºC]	25	25	25	25	25	25	25	25	25
OD[mg/dm^3]	3.65	5.75	6.90	7.55	7.97	8.11	8.21	8.45	8.58

Based on the data in Table 1, function C= f (τ) was plotted (Figure 6).

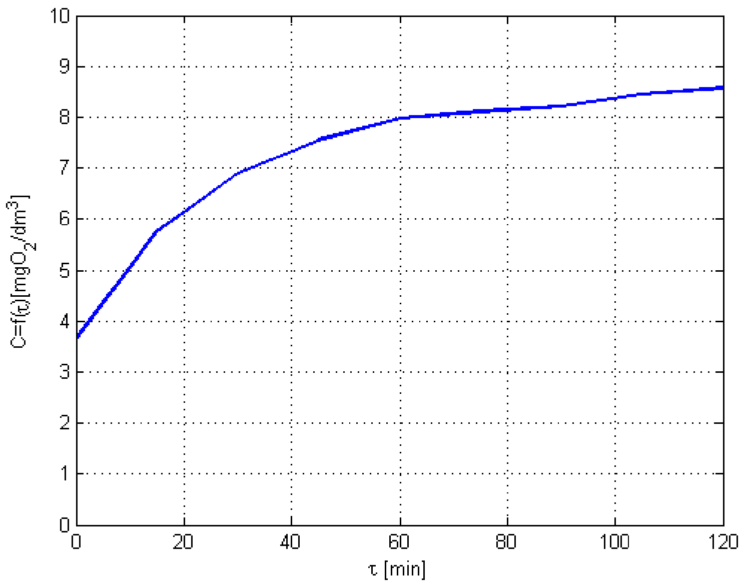

Fig. 6. The dependence C = f (τ) at the operation of a single FBG.

For a water temperature of 23 °C the value of C_s = 8.60 mg / dm^3.

5. Oxygen Concentrators

Two oxygen concentrators were used in the experimental installation each delivering a flow rate of 300 dm^3 / h.
Figure 7 shows the DeVilbis oxygen concentrator.

Fig. 7. Components of the DeVilbis oxygen concentrator

The technical data of this concentrator are shown in Table 2.

Table 2: DeVilbiss Concentrator technical data

DEVILBISS 5-LITER COMPAC T Concentrator		
Catalog Number	**525DS**	**525KS**
Delivery Rate	1 to 5 LPM	
Maximum Recommended Flow	5 LPM	
Outlet Pressure	58.6 kPa	
Electrical Rating	115V~, 60 Hz 3.3 A	220-230 V~, 50 Hz, 1.55 A 230 V~, 60 Hz 1.9 A
Operating Voltage Range	97-127 V~, 60 Hz	187-255 V~, 50 Hz 195-255 V~, 60 Hz
Oxygen Percentage	1-5 LPM = 93% ± 3%	

6. Experimental installation for the oxygen concentrators testing

Figure 8 shows the scheme of the experimental installation.
Oxygen concentrators (1) deliver 5 dm^3 / min ie 300 dm^3 / h each, so the installation delivers a flow rate of 600 dm^3 / h at $p > p_{atm}$.
This gas passes through the rotameter (4) and enters in the fine bubble generator on the position (12) located on the bottom of the water tank (10).
The air (5) (6) and water 8 (b + c) pressure and temperature are measured. For the operation of the air compressors within the oxygen generators 220V electric current is needed. Also, for the movement of the oxygen probe in the water tank it is necessary to operate a mechanism for rotating the probe in the water tank.

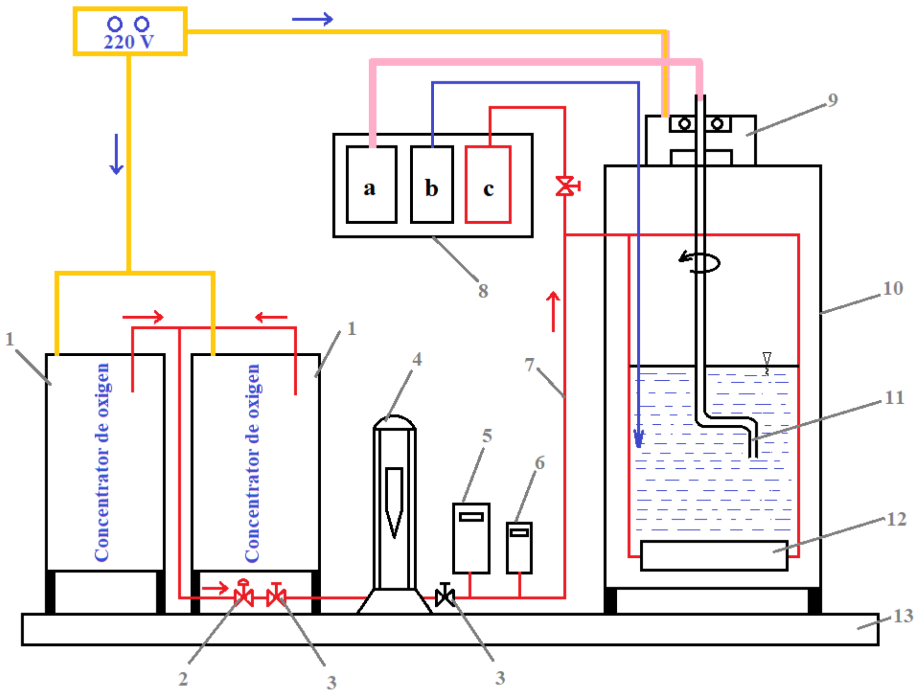

Fig. 8. Scheme of the experimental installation for researches on water oxygenation with oxygen concentrators
1 - oxygen concentrators; 2 - pressure regulator; 3 - valves; 4 - rotameter; 5- manometer with digital indication; 6 - digital thermometer; 7 - compressed air duct; 8 - panel with devices; a-oxygen meter; b - thermometer; c-manometer; 9 - electromechanical mechanism for probe oxygen sensor actuation; 10- water tank; 11 - oxygen probe; 12 - fine bubble generator; 13 - experimental installation support plate.

Figure 9 shows a general view of the two oxygen concentrators supplying a immersed FBG into the water tank.

Fig. 9. Overview of the experimental installation with two oxygen concentrators

Figure 10 shows the water tank with:
- digital indicating thermometer;
- oxygen measuring probe removed from the water.

Fig. 10. Details of the oxygen sensor probe removed from the water tank

7. Experimental researches on the operation of two oxygen concentrators

For the gas mixture the value of C_s is calculated with the relation:

$$C_s = C\frac{k\%}{21\%} \quad (1)$$

where k represents the volumetric ratio of oxygen that diffuses in water.
The results of the measurements for the operation of two parallel-bound oxygen concentrators are given in Table 3.

Table 3: The values of C measured by τ

τ [min]	0	30	60	90	120
C [mg/dm^3]	2.57	23.97	31.98	36.59	38.10

The measurements were made on 29.01.2019 and the results are:
- Volumetric gas flow rate: $\dot{V}$ = 600 dm^3 / h;
- The gas pressure at the entrance at FBG: p = 583 mmH_2O;
- Water temperature: t_{H2O} = 18 ℃.

For t_{H2O} = 18 ℃ from [4] results C_0 = 2.57 mg / dm^3.
If k = 0.93 ±3% is taken as a k = 0.9, the value of C_s is changed as follows:

$$C_s = 9.28\frac{0.9}{0.21} = 39.77 \approx 40\frac{mg}{dm^3} \quad (2)$$

So the function C_s = f (τ) will be framed in a rectangle:
- on the abscissa τ = 0 ÷ 120 [min];
- on the ordinate C = 0 ÷ 40 [mg / dm^3].

Based on the data in Table 3 the function C = f (τ) is graphically represented in Figure 11.

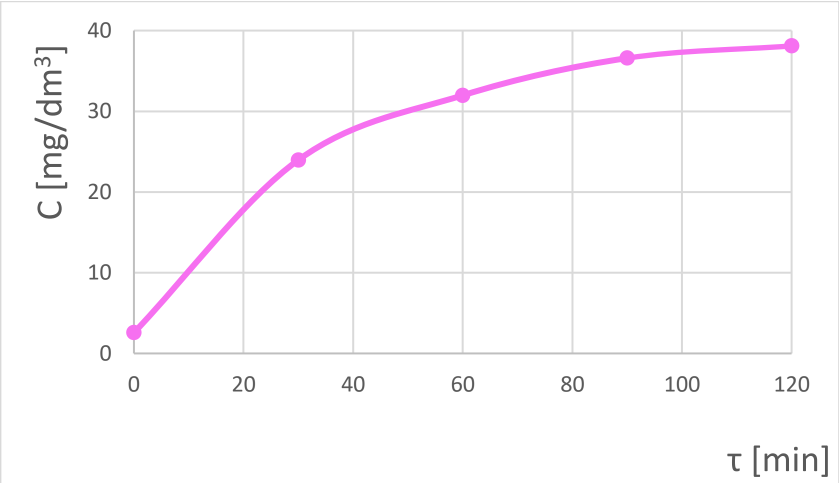

Fig. 11. The graphical representation of the function C = f (τ)

The experimental obtained data is similar to other scientific researches.
Figure 12 overlaps the two graphical representations for C= f (τ) in the cases:
- of the operation of a FBG (curve 1);
- of the operation of two oxygen concentrators (curve 2).

In both cases, the gas flow rate was 600 dm^3 / h.
On the ordinate, the right scale refers to Curve 2.
Figure 12 shows the following:
After 20 minutes from the beginning of the FBG experience, the C value reaches 6 mg / dm^3, and for the two oxygen concentrators C reaches 20 mg / dm^3. As a result, the operation of oxygen concentrators is more efficient.

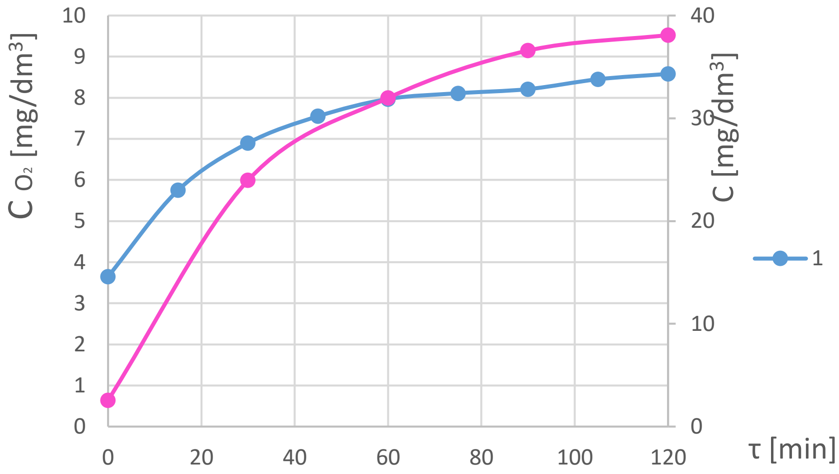

Fig. 12. The graphical representation of the function C= f (τ) for:
1 - fine bubble generator; 2 - two oxygen concentrators.

8. Conclusions

- Increasing the dissolved oxygen concentration in water is faster in the case of oxygenation with oxygen concentrators.
- It is necessary to analyse the consumption of electricity in the two versions.

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