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Experimental Researches on Electricity Consumption in the Process of Water Aeration

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Abstract: *The paper analyzes two versions of water aeration:*
1) Atmospheric air is introduced into stagnant water
2) A gaseous mixture of atmospheric air + ozone, supplied by an ozone generator, is introduced into the water.
The electricity consumption for the two versions and chooses the most economical version are highlighted.

Keywords: *Water aeration, oxygen meter, fine air bubble generator.*

1. Introduction

Manuscripts Water aeration is a fundamental process of thermodynamics, a process of transfer between water and air. The process is based on the transfer of oxygen from the air or the direct transfer of pure oxygen to a given volume of water [1] [2].
Aeration of water can be done mechanically or pneumatically [3] [4].
Pneumatic aeration has superior net performance compared to mechanical aeration systems.
The performance of the pneumatic aeration system is defined by two parameters: aeration efficiency and effectiveness [1] [2].
These parameters are determined by the efficiency of the compressed air production installation and the efficiency of air dispersing devices in the water.
The efficiency of pneumatic aeration systems is reduced with increasing water temperature because oxygen stability decreases when the water temperature rises.
Current scientific researches in the field of biochemistry ecology are concerned with the analysis of the possibilities of increasing the dissolved oxygen concentration in water.
This problem can be solved as follows:
a) By introducing atmospheric air into the water;
b) By introducing atmospheric air into water and oxygen from a cylinder;
c) By introducing low nitrogen (95% O_2 and 5% N_2) air supplied by oxygen concentrators;
d) By introducing a gaseous mixture consisting of air + ozone;
In the present paper only paragraphs a) and d) will be analyzed.
Ozone systems contain two elements:
- A compressor that introduces air into the ozonizer;
- An ozone generator producing 1.5 g/h ozone; on an industrial scale there are ozone generators producing 2 - 10 kg / h of ozone [5] [6].

These ozone generators are powered by atmospheric or oxygen air.
The introduction of atmospheric air or ozone-enriched air into the water requires compression of the air to overcome the hydrostatic load of water [7] [8].
Gas compression can be done with fans or compressors [9].
Performance fans can overcome a load of about 1 mH_2O, which is inefficient at the Olympic swimming pools where the water layer has 2-5 m.
The problem of air compression is solved by the use of piston or rotating compressors that provide an air pressure of 1-10 bars at their discharge.

2. Presentation of the versions analyzed in the paper

Two versions are analyzed:
- The version I: atmospheric air (21% O_2, 79% N_2) is introduced into the water (Figure 1);
- The version II: a gaseous mixture of air supplied by an electro compressor and ozone delivered by an ozone generator (Figure 3) is introduced into the water.
For each version, it is intended:
a) Changing the dissolved oxygen concentration in water in time: C = f (τ)

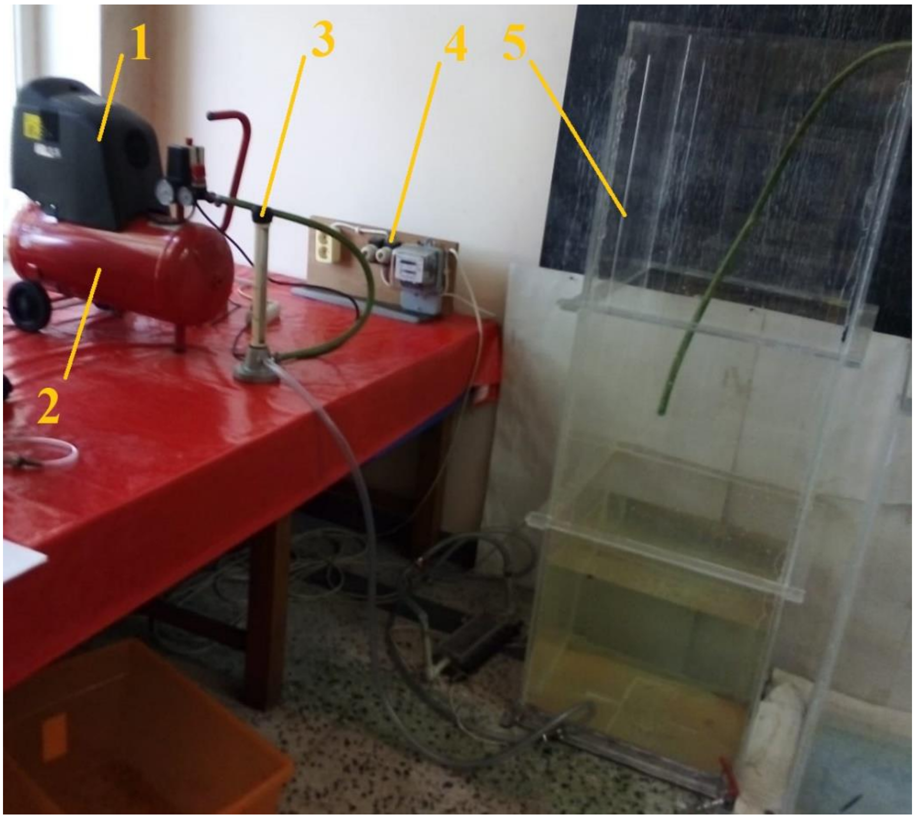

Fig. 1. Overview of the experimental installation for the version I
1 - electro compressor; 2 - compressed air tank; 3 - rotameter; 4 - electric meter;
5 - water tank

b) Measuring the electricity consumed until the initial concentration (C_0) of dissolved oxygen in water reaches the value of the saturation concentration (C_S). Item a) is presented in detail in the paper [10]. Figure 2 shows the graphical representation of the function C = f (τ) for the version I.

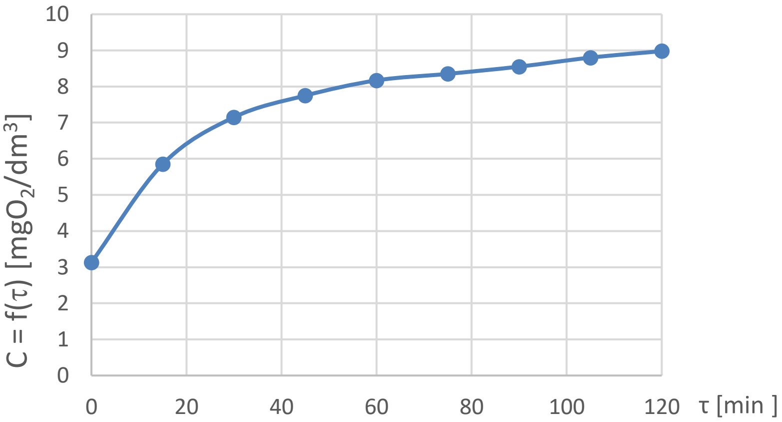

Fig. 2. The dependence of C = f (τ) in the version I

Figure 2 shows that the dissolved oxygen concentration in water increases from the initial concentration (C_0 = 3.13 mg / dm^3) to saturation value (C_s = 8.9 mg / dm^3) in 120 minutes.
Figure 3 shows an experimental installation containing, in addition to Figure 1, an ozone generator (3).

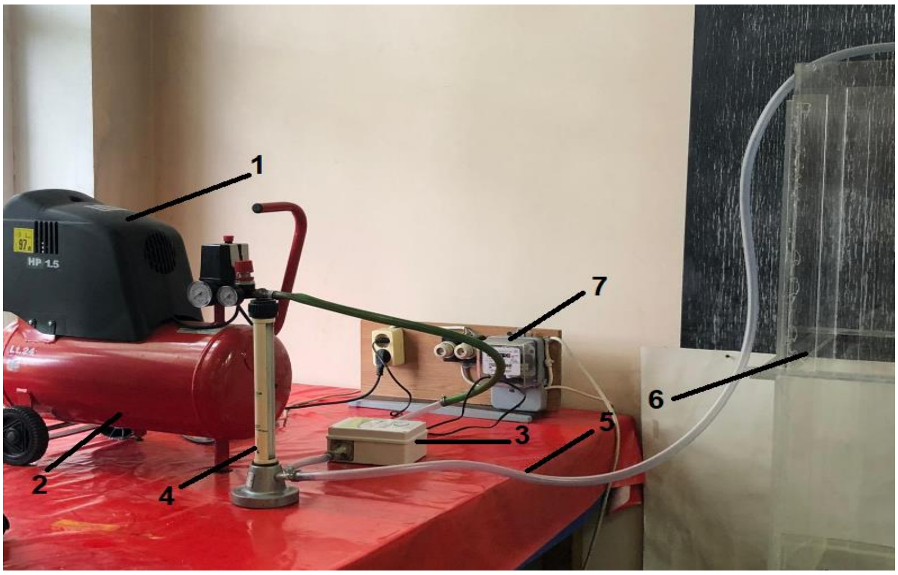

Fig. 3. Overview of the installation for water ozonation
1- electro compressor; 2 - compressed air tank; 3- ozone generator; 4- rotameter; 5- compressed air line to the fine bubble generator; 6- water tank; 7-electric counter

Figure 4 shows the function graph C = f (τ) for version II.

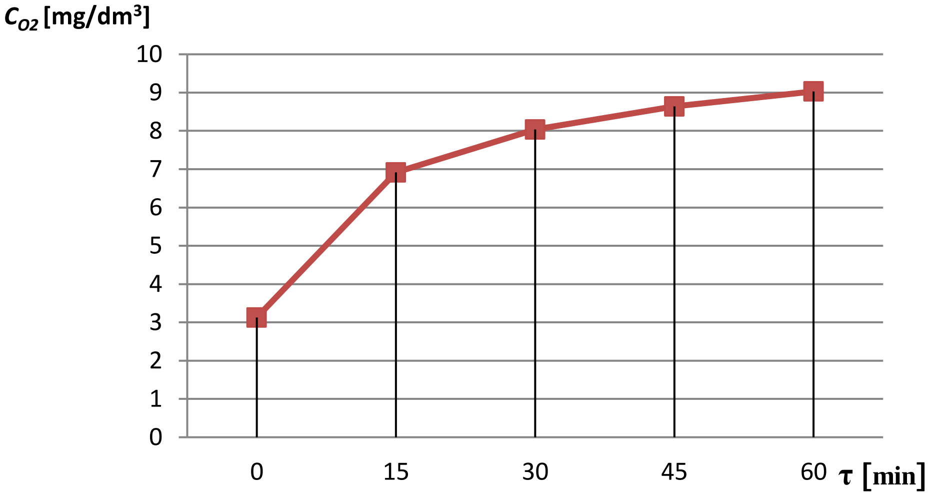

Fig. 4. Center The dependence of C = f (τ) in version II

Figure 4 shows that the saturation value of oxygen is reached in a shorter time than in version I.

3. Experimental researches

3.1 Scheme of the experimental installation

In the version I, when the fine bubble generator is supplied with atmospheric air, the experimental installation comprises (figure 5) the electro compressor, the rotameter, the water tank, and the devices panel.

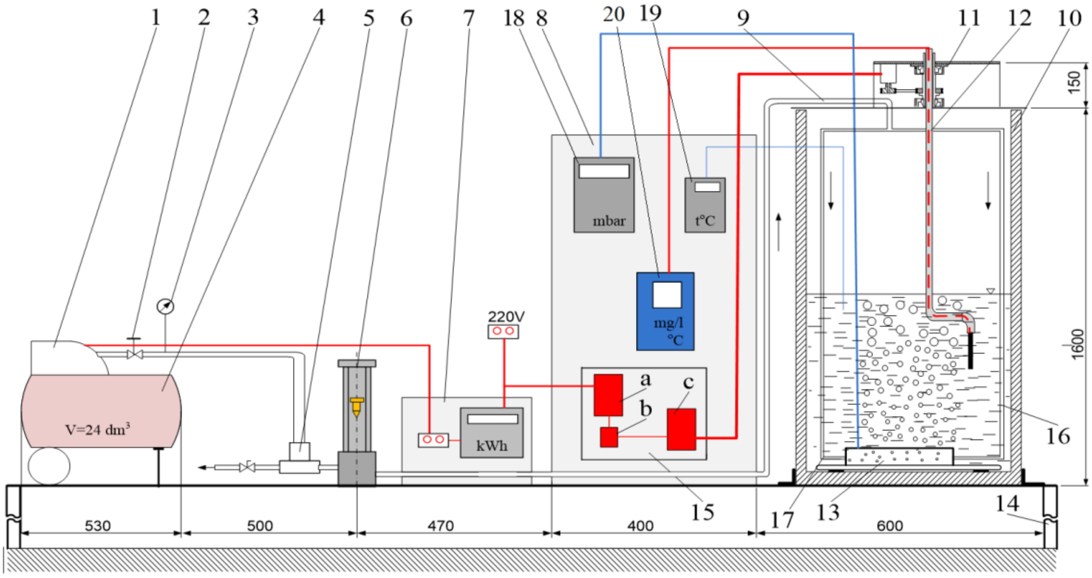

Fig. 5. Scheme of the experimental installation for researches on water oxygenation
1- electro compressor with air tank; 2- pressure reducer; 3-manometer; 4-compressed air tank V = 24 dm^3; 5- T-joint; 6- rotameter; 7- electric panel; 8-panel with measuring devices; 9-compressed air pipeline to the fine bubble generator; 10 - water tank; 11 - probe actuation mechanism; 12-oxygen probe; 13- fine bubble generator of rectangular shape; 14 - support for the installation; 15-command electronics: a - power supply, b - switch, c - control element; 16, 17- compressed air supply pipes; 18 - digital manometer; 19 - electronic thermometer; 20 - oxygen meter

The installation works as follows: compressed air from an electro compressor (1) 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 fine bubble generator (13). The fine bubble generator (FBG.) has the shape of a parallelepiped with 37 orifices Φ 0.5 mm. During an experiment, the volumetric air flow rate is kept constant, the pressure at the entrance to the fine bubble generator and hydrostatic load. The panel (15) with the control electronics provides, via the mechanism (11), the rotation of the oxygen sensor probe into the water tank at a rate of 0.3 m / s.
In version II when the fine bubble generator is fed with a gaseous mixture of air and ozone, the ozone generator (5) appears in the operating diagram (figure 6) in addition to figure 5.

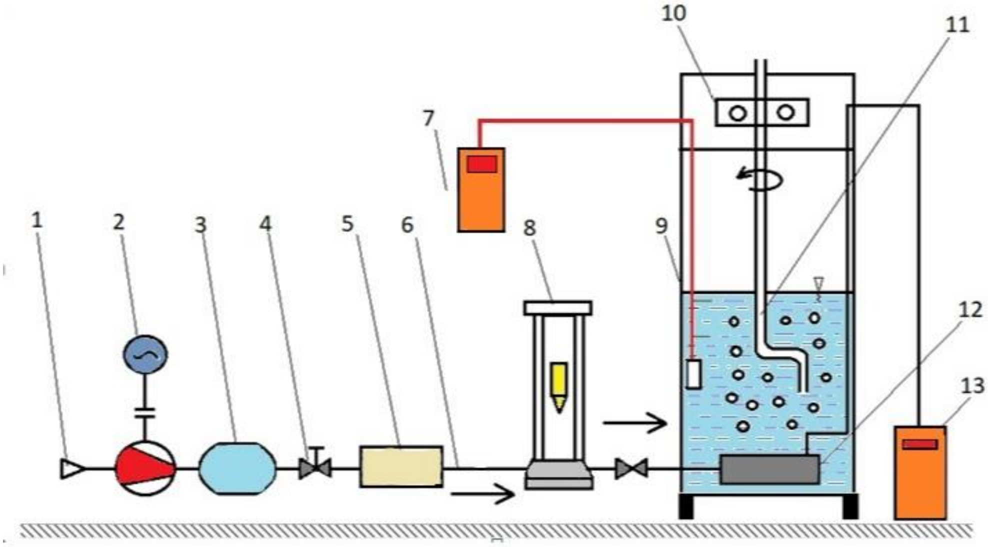

Fig. 6. Scheme of experimental installation for water ozonation
1-air filter; 2- electro compressor; 3 - compressed air tank; 4 pressure reducer; 5 - ozone generator; 6-pipe; 7- digital thermometer; 8-rotameter; 9- water tank; 10- mechanism for rotating the oxygen probe in water; 11 - oxygen meter probe; 12 - fine bubble generator; 13- digital manometer.

The experimental installation contains an ozone generator type FQM - P300 with the characteristics: power: 12W; ozone flow rate: 100-300 mg / h; voltage: 220 V / 50 Hz.

The experimental installation can be used in the case of various gases introduced into water to increase the dissolved oxygen concentration in water, such as [11]:

- Atmospheric air delivered by an electro compressor;
- Atmospheric air + oxygen from the cylinder;
- Atmospheric air + ozone provided by an ozone generator;
- Low nitrogen air supplied by oxygen concentrators.

The experimental installation is equipped with modern digital indication devices for measuring the flow rate, pressure, and temperature of the gas introduced into the water and the temperature of the water in the tank.

3.2 The methodology of measurements of the variation in dissolved oxygen concentration in water and of electricity consumption

For each measurement step the following phases are successively [12] [13] [14] [15]:

1. Perform the pressure test of the fine bubble generator;
2. Fill the tank up to H = 0.5 m with water;
3. Measure the initial concentration of dissolved oxygen in water C_0 (mg / dm^3);
4. Measure the water temperature in the tank and the air temperature;
5. Introduce the fine bubble generator and record the start time of the experiment;
6. The flow rate and compressed air pressure are measured and maintained constant by means of the control valves;
7. After 15 minutes the oxygenation of the water stops and the oxygen probe is introduced into the water;
8. Start the electro-actuator of the probe that provides a speed of 0.3 m / s; when the oxygen concentration value on the oxygen meter screen stabilizes, it means that the measurement has been completed;
9. Remove the oxygen sensor from the tank;
10. Restart the oxygenation system and note the time.

From the previous investigations [16] [17] [18] it was found that by introducing an airflow rate of 600 dm^3 / h into the water tank with hydrostatic load of H = 0.5 m in a water volume (0.5 x 0.5 x 0.5 = 0.125 m^3), the dissolved oxygen concentration in the water approaches the saturation concentration after a time τ = 2 h.

The concentration of dissolved oxygen in water was measured at equal time intervals: τ = 0 min; τ = 15 min; τ = 30 min; τ = 45 min; τ = 60 min; τ = 75 min; τ = 90 min; τ = 105 min; τ = 120 min. For the measurement of electricity consumption, a two-phase electric counter was used, indicating the meter reading at the start and end of the experiment, for each version.

4. Experimentally obtained results

* In the version I, only atmospheric air (21% O_2, 79% N_2) was introduced by means of the electro compressor; it was found that during one hour it consumed 1.041 KWh. During the two-hour experience (τ_F), the electricity consumed by the compressor was E_I=2.082kWh.

** In the version II a gaseous mixture (air + ozone) is introduced so that in the water the dissolved oxygen concentration increases from C_0 to C_5 it takes a duration of τ_{II} one hour; at this time, the power consumption of the compressor and the ozone generator was E_{II}=1.22KWh. Version II is more advantageous because $E_{II} < E_I$ and the time (τ) where C_0 increases to C_s is shorter for version II: $\tau_{II} < \tau_I$.

5. Conclusions

Experimental researches were carried out for the two versions considered:
I. Introduction of atmospheric air into the water tank;
II. Introduction of a gaseous mixture consisting of atmospheric air and ozone.
The following conclusions resulted:

• For the same initial data, when a gaseous mixture (air + ozone) is introduced into the water through the fine bubble generator, the period in which Cs is reached is reduced by half, which makes this process much more efficient.
• The power consumption (E) for version II is lower than the one in the version I: $E_{II} < E_I$, which leads to the saving of electricity.
• Ozone use is a new way to increase the dissolved oxygen concentration in water.
• Due to its properties, ozone can be a very viable alternative for air disinfection and especially for disinfection and treatment of polluted waters.
• Increasing the production capacity of the ozone generator leads to increased volumes of air or water that can be treated and also considerably reduces the time required for treatment.

Acknowledgments

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