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The design of a new oxygenation system for water flowing through a tube

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***Abstract*—Due to climate change, stagnant or flowing waters continue to warm, and the content of dissolved oxygen in water decreases, endangering aquatic ecosystems and anthropogenic activities. To improve the water quality, water oxygenation or water aeration are used. This paper presents a system that aims to increase the concentration of the O_2 dissolved in water flowing through tubes. The assembly of a helix with orifices through which air is introduced with pressure given by a compressor inside a tube is presented.**

***Keywords—** flowing waters, water oxygenation, dissolved oxygen in water*

I. Introduction

Water eutrophication, a difficult global environmental matter [1-5], is an essential situation faced by different stationary water sources. Water aeration is a necessity and plays a significant role in bringing back an optimal oxygen level of aquatic life as is specified in the EU Regulation and in the Council Parliament [6]. Also, aeration is carried out in the case of waters containing sulfur dioxide, carbon dioxide, iron, manganese, ferruginous waters lacking dissolved oxygen and in the deferrization process [7].

Through the process of photosynthesis, Cyanobacteria or blue-green algae can produce their own nutrients or use different nutrients from the environment. As a source of food, it can use chemical elements such as: K, N_2 or P. During the summer or when the temperatures are high, it contributes to the eutrophication of the waters due to the rapid growth from the end of the summer or the first part of the autumn.

The main morphological feature is that it has gaseous vesicles (pulsatile) with a role in buoyancy. Thus, it migrates under favorable conditions in the water mass. Decant hard or not at all. It forms large, macroscopic colonies on the water surface, as a dense, apparently green felt. If the water is stagnant or the flow rate is low, this felt prevents the exchange of gases, the oxygen concentration decreases, and the ecosystem is destroyed. Their most important structural feature is the fact that it produces toxins, called micro toxins, which mainly affect the liver and nervous system of fish and humans. Thus, in the process of water treatment, it must be removed and not destroyed.

When aging or in the absence of oxygen (it consumes at night what it produces during the day), blue algae die, rot very quickly, produce gases, have a swampy appearance and in this case, water aeration is a mandatory process.

The use of microbubble generators brings an additional advantage, namely, it produces water bubbling which leads to a magnification in the degree of water turbulence that does not allow the algae development. Aquaculture brought serious negative effects on the aquatic environment due to the need to store large quantities of fish, such as depletion of oxygen content and eutrophication [8-10]. Low oxygen in water can kill fishes and other organisms present in water [11]. Recently, in areas with limited resources, research has been conducted into the use of a solar aeration system for pond aquaculture [12][13]. Fishponds are usually located geographically away from power lines. Thus, it is possible to capitalize on the potential of each type of renewable energy, for example: solar energy. Researchers have already started a study generated by modified technology for development and testing of an economical alternative for improving the aeration system that will be of great importance in the operation of the fishpond [14]. Another sustainable hybrid energy system for aquaculture farms that uses photovoltaic system is presented in [15]. To support the electrical power requirement of a solar pond aeration system, a new system for determining the optimal size for the electrical power design is illustrated in [16].

The device proposed in this paper can introduce compressed air into the water in a controlled and uniform manner and can be used in any location. Moreover, the device can be used during periods of low oxygen content in any type of water aeration systems.

II. The chosen solution for air introduction in flowing water by a transparent plexiglass tube Ø - 50 x 3 mm

To be able to introduce compressed air in a water mass, a helix with a flat shape was made. The helix was constructed with Φ 1 mm (internal diameter) and Φ 3 mm (external diameter) from a copper capillary tube.

In the papers [17][18] it was demonstrated that the transfer of oxygen to water had a higher rate after aeration with very small bubbles that present larger surfaces for the transfer of O_2. The experimental research in [19] showed that the mass transfer coefficient is higher in aeration processes the smaller the diameter of the air bubbles.

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A number of n=17 orifices with a diameter of 0.3 mm were made in the helix to introduce compressed air into the water. This helix contains 3 circles (figure 1) with Ø 16 mm, Ø 26 mm, Ø 36 mm, with a total length of 244.92 mm.

To have symmetry, the distance between two holes is given by dividing the total length by the number of orifices, resulting: l = 14.4 mm.

Multiples orifice were created on each circle as follows [20][21]:

$$n_1 = \frac{L_1}{l} = \frac{50.24}{14.4} \approx 3 \qquad (1)$$

$$n_2 = \frac{L_2}{l} = \frac{81.64}{14.4} \approx 6 \qquad (2)$$

$$n_3 = \frac{L_3}{l} = \frac{113.24}{14.4} \approx 8 \qquad (3)$$

Exactly the 17 orifices. The used air flow rate is chosen: $\dot{V}_{air} = 600\, dm^3 / h = 0.0001666\, m^3 / s$.

A cross-section through the tube in which the helix is mounted is shown in figure 1.

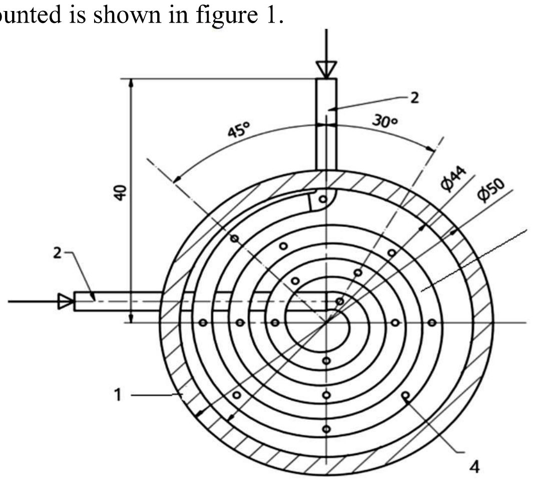

Fig. 1. Overview of the helix through which the air is dispersed in the water
1– tube; 2 – connections for the air inlet; 3 – helix; 4 – orifices.

Figure 2 shows the helix through which air is dispersed in the flowing water through a transparent Plexiglas tube.

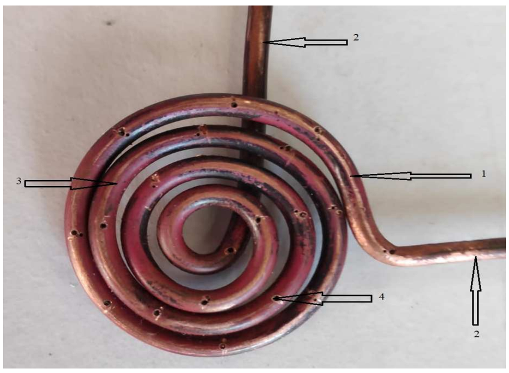

Fig. 2. Transversal view of the tube with the helix is location
1– tube; 2 – connections for the air inlet; 3 – helix; 4 – orifice.

The air dispersion system in a cross-section of a tube transporting a fluid subject to aeration is an effective and original solution.

If the tube through which the oxygenated fluid circulates is metallic, a short transparent Plexiglas tube can be mounted on its route, a fact that allows measuring the O_2 content in water in a noninvasive manner.

The installation scheme can be seen in figure 3.

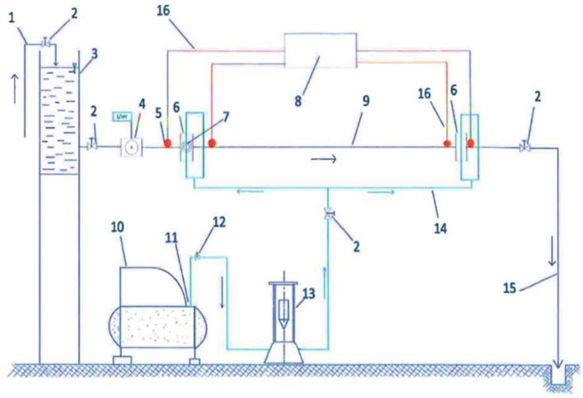

Fig. 3. Scheme of the experimental installation
1– tube for the water supply; 2 – valve; 3 – reservoir with water; 4 – flowmeter; 5 – spot light insulator; 6- flange; 7 – helix; 8 – oxygen meter; 9 –tube; 10 – electric compressor; 11 – air reservoir; 12 – pressure reducing; 13 – rota-meter; 14 – air tubes; 15 –discharge tube; 16 – optical fiber.

Through the method of injecting air into horizontal tube, in multiple consecutive points, till the saturation concentration is reached, it is possible to eliminate those huge reservoirs from the water treatment stations that could reduce the investments value.

The assembly of the helix (1) inside the transparent plexiglass tube is shown in Figure 4. The two connections (2) allow compressed air to enter the helix and then, through the 17 orifices made in it, it leaves and moves parallel to the water.

In the scheme in figure 3, two measurement points can be observed, points located successively on the pipe through which the fluid flows. Figure 4 shows the first measuring point as well as the location of the serpentine between the flanges.

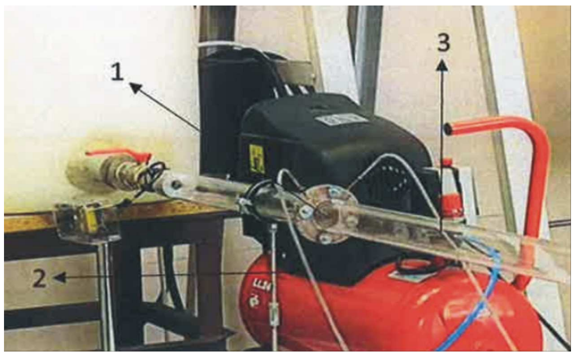

Fig. 4. Placement of helix between flanges
1– helix; 2 – air connections; 3 –tube

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Figure 5 shows in detail the inside of the transparent Plexiglas tube with the helix mounted in, while a general installation view can be seen in Figure 6.

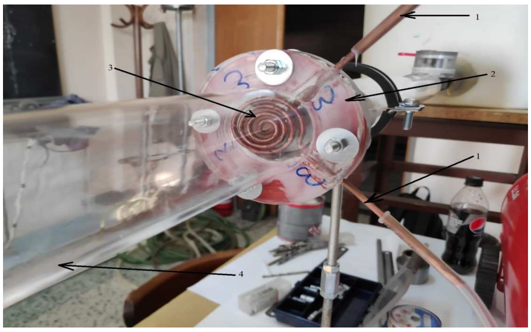

Fig. 5. Placement of the helix inside the tube
1 - connections for compressed air; 2 – flange; 3 – helix; 4 – transparent plexiglass tube.

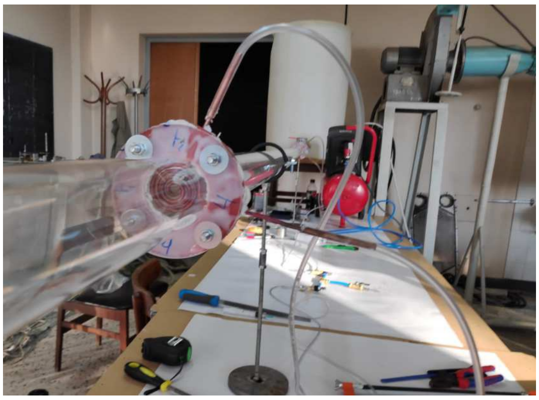

Fig. 6. Experimental installation - general view .

Determining the value of the O_2 content in water could be performed with the following methods: electrical, chemical, or optic [22][23].

The transparent plexiglass tube (3) makes it possible to determine the O_2 content in water by a non-invasive procedure, i.e., by the optical method.

III. Results and Discusstions

The multitude of laboratory or industrial applications for which a real-time monitoring of the O_2 content in fluids is required, allowed the determination of different measuring ways [24][25].

One of the latest measurement methods is the noninvasive method with appliance in feeding and drinking manufacture.

In these cases, in order to measure with high accuracy, the determinations are made with sensors mounted on transparent surfaces such as transparent plastic (Plexiglas) or glass materials.

Oxo-luminescence conception is the foundation of these measuring devices [26]. A signal emitted by the sensor is transmitted through the optical fiber to the oxygen meter.

As the main characteristics of these devices for measuring oxygen dissolved in fluids one can mention:

- the use of nondestructive and noninvasive methods to find out the value of the O_2 content.
- has great applicability: on liquid and gaseous environments.
- long-life sensors and simple maintenance or calibration operations.
- available both on research and on the industrial environment.
- simple, movable, multilateral.
- ensures the exact establishment of the O_2 content in the fluid.

Figure 7 shows a general view of the research setup.

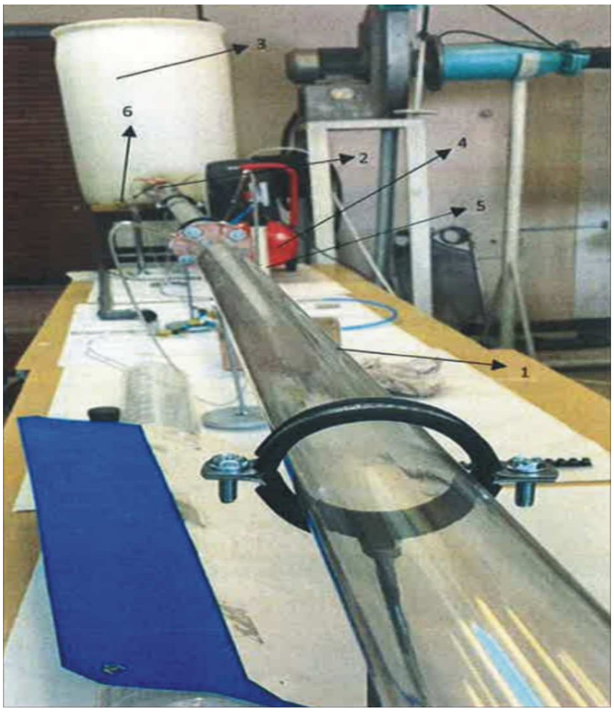

Fig. 7. Research setup general view

1– tube; 2 – helix; 3 – water reservoir; 4 – electric compressor; 5 – rota-meter; 6 – digital flowmeter.

Figure 8 presents the formation of bubbles inside the tube. The experimental installation was tested in order to establish its functionality.

Fig. 8. Bubbles formation inside the tube.

The problem of air dispersion in water flowing through a tube was solved as follows:

* A dispersion system of air in water flowing through a horizontal tube was preformed, a system containing an Archimedean helix that was sized accordingly.

* The tube being a transparent Plexiglas pipe (Ø 50 x 3 mm) allows measuring the O_2 content in water.

CONCLUSIONS

Water oxygenation is more efficient due to the degree of mixing achieved with the help of the helix presented in the paper, causing the growth of dissolved the O_2 content solubility. By using this tube water aeration system, the high structures needed to separate oxygen from the air and transport liquid oxygen cylinders to the places where water oxygenation is needed are eliminated.

In conclusion, the paper brings necessary facts to a foundation for the development of productive water oxygenation technologies with fine air microbubbles.

The solution proposed in this paper can be compared to the water oxygenation in vertical tubes. This idea is a new and original one, since research on the oxygenation of water flowing through a tube is minimal. Therefore, understanding the efficiency of oxygenation is essential to maintaining an optimal dissolved oxygen concentration in water.

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