# The Construction of Systems for Air Dispersion in Wastewater

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***Abstract:*** *For an efficient aeration of wastewater, two options are proposed:*
*1) In the case of stagnant waters, the use of fine bubble generators; these fine bubble generators ensure accurate and uniform air dispersion;*
*2) In the case of the water flowing through the pipes, the aeration of the water will take place right inside the pipes, thus eliminating those huge aeration tanks used for water treatment.*
*The pipes carrying the wastewater can be placed horizontally or vertically; only horizontal pipes will be analysed in the paper.*

***Keywords:*** *Fine air bubble generator, water aeration.*

## 1. Introduction

Water aeration is a process of mass transfer of oxygen from atmospheric air to a volume of water; in this way the concentration of dissolved oxygen in the water will increase.
Water aeration systems determine certain energy consumption; by using the modern technologies of construction of these systems, a reduction of the energy consumption can be obtained.
In specialized papers [1], [2], [3] it is noted that the pneumatic aeration is clearly superior to the mechanical aeration systems.
The best performing aeration systems are those that produce fine air bubbles [4], [5]. The paper proposes the aeration achievement of the wastewaters by introducing the compressed air into the pipes that carry these wastewaters.
This constructive solution eliminates those aeration tanks with volumes of hundreds of $m^3$, thus reducing the investment and operating costs of wastewater treatment plants.
In a two-phase system the transfer of a component takes place between areas where there are different phases; for example, the transfer of a gas into a liquid (air-water) [6], [7], [8]. In this case the mass transfer is interfacial. Table 1 shows a classification of the mass transfer (diffusion) phenomena encountered in technical engineering.

**Table 1:** Classification of mass transfer processes

| Fluid in which diffusion takes place | Flow type | Flow regime | Mass transfer takes place through: |
|---|---|---|---|
| 1- Stagnant fluid (w = 0) | - | - | Molecular diffusion |
| 2- Fluid in flow (w ≠ 0) | Free flow | - | Convective natural diffusion |
| | | Laminar regime | Convective forced diffusion |
| | | Turbulent regime | Convective forced diffusion |

In biphasic systems, at low speeds of the system phases, molecular diffusion predominates, and at high speeds convective diffusion predominates.

## 2. Analysis of two-phase fluid flow through pipes

### 2.1 The purpose of the researches and initial data for the two-phase fluid flow process

The paper aims to present two water aeration systems:
- Option 1: Water aeration is performed with a fine bubble generator (FBG) placed in a tank with volume V = 0.125 $m^3$.
- Option 2: The aeration of the water is carried out on the flow by the installation in a pipe of an air dispersion device in the wastewater; the volume of water that will flow will be all V = 0.125 $m^3$.
Other common initial values for the two options are:

- Air flow in the water: $\dot{V}$ = 0.6 $m^3$/ h;
- The area of the air outlet section in water A = 1.2 $\cdot 10^{-6}$ $m^2$, orifices number = 17;
- Hydrostatic load 0.5 m;
- Water temperature: t = 24 °C;
- Initial dissolved oxygen concentration in water $C_0$ = 5.48 mg/$dm^3$;
- Experience duration: $\tau$ = 120 minutes;
- For t = 24 °C for water, a value of the dissolved oxygen concentration in water was obtained [9]: $C_s$ = 8.4 mg/$dm^3$.

### 2.2 Establishing the flow regime of the two-phase fluid

From previous experimental researches it is considered that the water volume to be aerated in time ($\tau$) of two hours is V = 0.125 $m^3$.
This volume will flow through a pipe with an internal diameter of 44 mm; consequently, the volumetric flow rate ($\dot{V}$) and the water velocity (w) in the pipe will be [10] [11]:

$$\dot{V} = \frac{V}{\tau} = \frac{0.125}{2 \cdot 3600} = 0.01736 \cdot 10^{-3}\, m^3/s \quad (1)$$

$$w = \frac{\dot{V}}{\frac{\pi}{4} d^2} = \frac{0.0173 \cdot 10^{-3}}{0.786 (0.044)^2} = 0.0115\, m/s \quad (2)$$

For water at 20°C, the kinematic viscosity is [12]: ν = 1 $\cdot 10^{-6}$ $m^2/s$, so the Reynolds number will be:

$$\mathrm{Re} = \frac{wd}{\nu} = \frac{0.0115 \cdot 0.044}{1 \cdot 10^{-6}} = 506 \quad (3)$$

So, the flow regime for water is laminar (Re <2320). The air flow rate in the water:

$$\dot{V}_{air} = \frac{0.6}{3600} = 0.0001666\, m^3/s \quad (4)$$

This value is very small, as a result, it does not change the flow regime previously established.

### 2.3 Structure of two-phase fluid flow (air + water)

It is considered that the air and water flow rates that are transported through the pipe remain constant i time, and the water and air temperature are approximately equal to the ambient temperature. In the case of two-phase fluid flow (water + air), there can be several types of flows that have a different architecture (Figures 1, 2, 3) as follows:

A) Bubble flow (figure 1). If the motion of the air bubbles is superimposed over the liquid flow, an image of the two-phase flow is obtained:

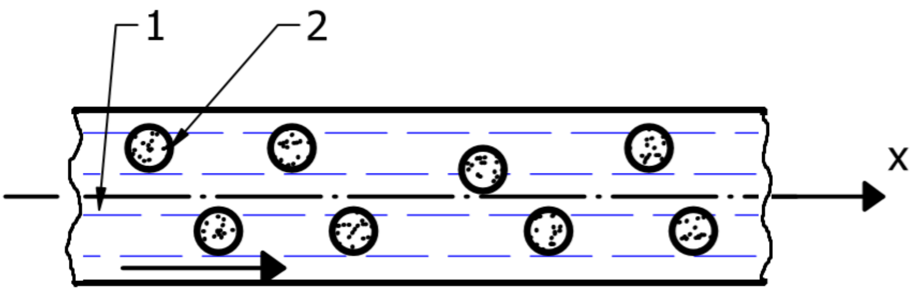


**Fig. 1.** Bubble flow

1- liquid (water); 2- air bubbles

The gas is dispersed as bubbles in the liquid; in their movement the air bubbles tend to rise at the top of the pipe. The study takes into account the horizontal pipe expected for the experimental installation that has Ø 50 x 3 mm, so an internal diameter of 44 mm.

B) Flow with gas plugs (figure 2).

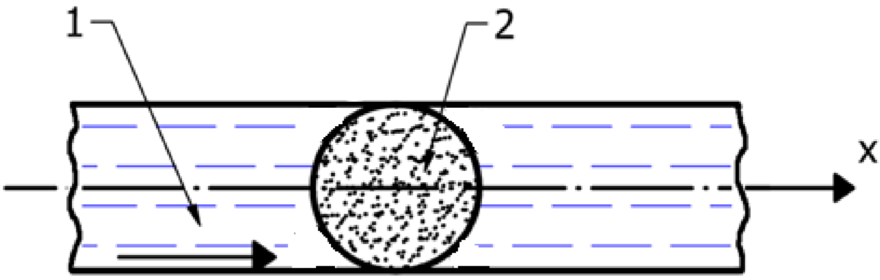


**Fig. 2.** Flow with gas plugs

1- liquid phase (water); 2- gas phase (air)

The gas bubbles unite and form plugs that move at a speed equal to that of water.

C) Layered flow (Figure 3).

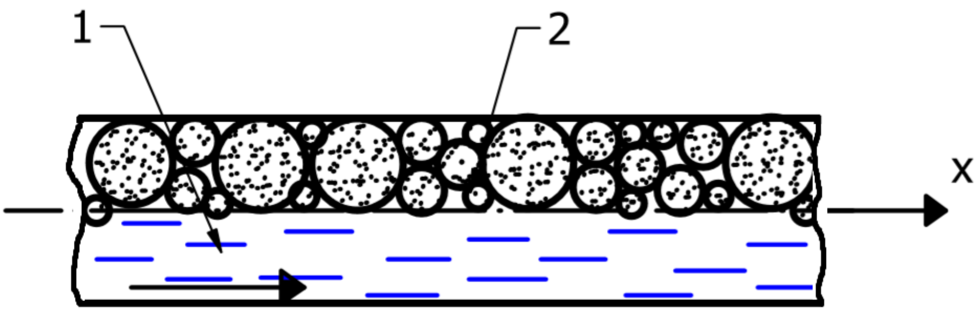


**Fig. 3.** Layered flow

1- liquid (water); 2- gas bubbles (air)

The flow has a separation surface between the liquid at the bottom of the pipe and the gas at the top ($\rho_{water} > \rho_{air}$).

## 3. Air dispersion devices in water

### 3.1 Aeration of stagnant water using the fine bubble generator (option 1)

Figure 4 shows an overview of a fine bubble generator.

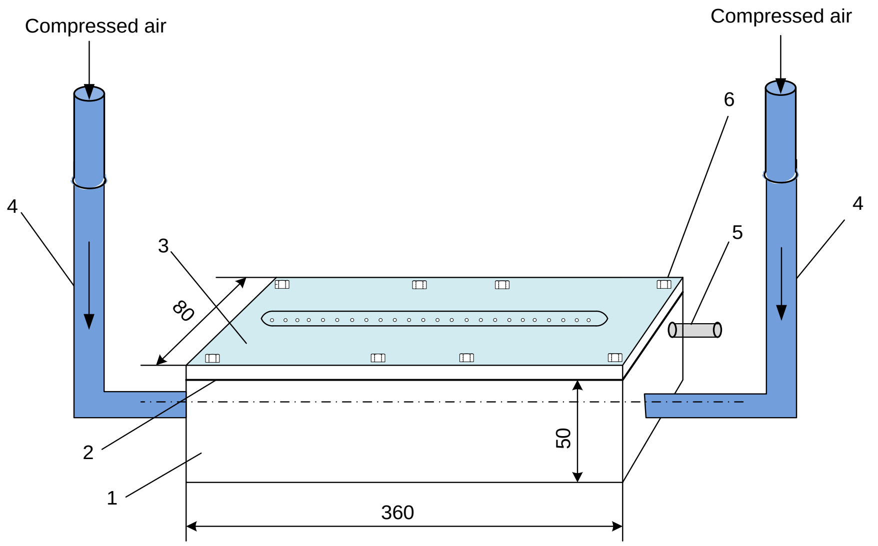


**Fig. 4.** Fine air bubble generator

1 - compressed air tank; 2 - sealing gasket; 3 - orifice plate; 4 - compressed air supply pipe of FBG ø 18 mm; 5 - compressed air pressure connection; 6 - screws for fixing the plate with orifices in the tank frame

Compressed air enters the tank through the FBG with a plate with orifices (Figure 5). The distance between the orifices is 6 mm and the thickness of the aluminium plate is 2 mm.

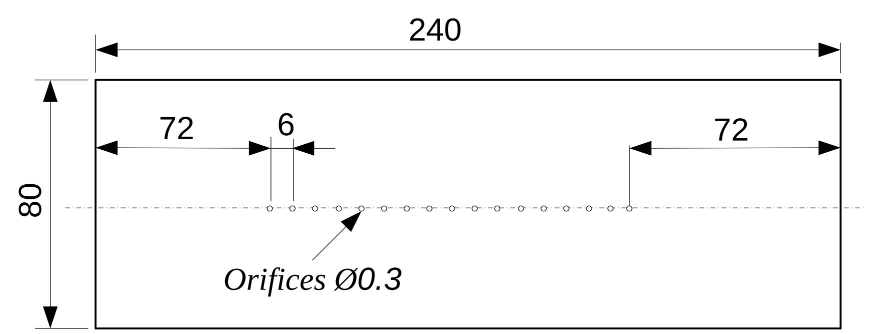


**Fig. 5.** Perforated plate with 17 orifices Ø 0.3 mm

In both options the location of the orifices must meet two conditions [4] [12]:

$$\frac{s}{d_0} > 3 \tag{5}$$

$$\frac{d}{d_0} > 8 \tag{6}$$

where:
s - the thickness of the metal wall;
$d_0$ - the diameter of the orifice through which the air exits into the water;
d - the distance between two successive orifices.

For the presented bubble generator: s = 2 mm, $d_0$ = 0.3 mm, d = 6 mm; one obtains:

$$\frac{s}{d_0} = \frac{2}{0.3} = 6.66 > 3 \qquad (7)$$

$$\frac{d}{d_0} = \frac{6}{0.3} = 20 > 8 \qquad (8)$$

From the constructive solutions achieved in previous researches [13] [14], a fine bubble generator with n = 17 orifices with a diameter of 0.3 mm was chosen.

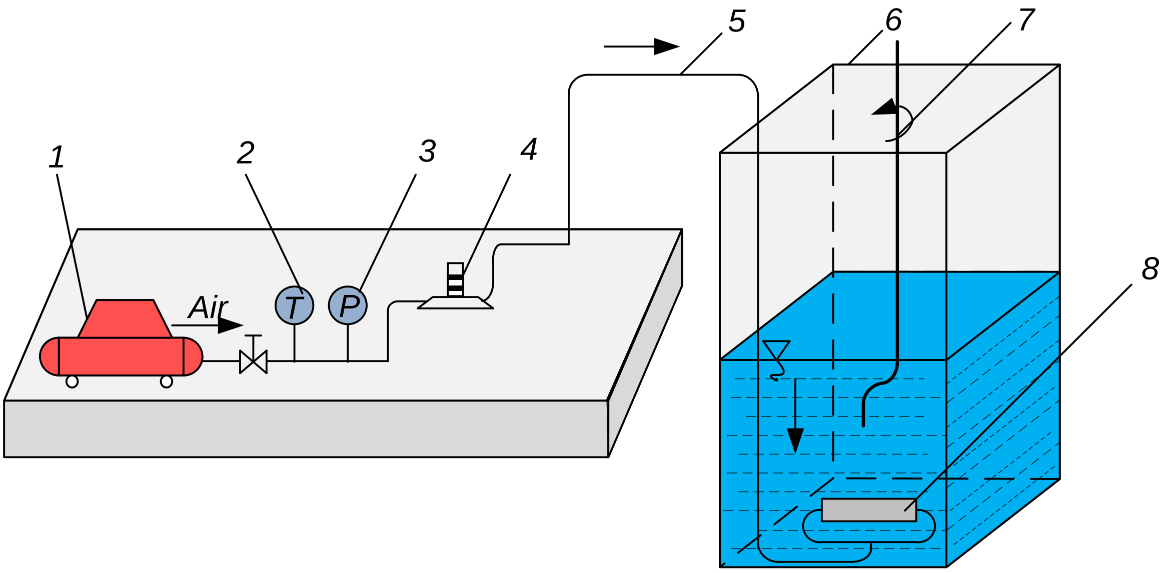


**Fig. 6.** Sketch of the experimental installation for the introduction of atmospheric air in water

1 - air compressor; 2 - thermometer; 3 - manometer; 4 - rotameter; 5 - compressed air supply line of the bubble generator; 6 - parallelepiped water tank; 7 - oxygen meter probe; 8 - of fine bubbles generator with 17 orifices

The device of dispersing the air in the water flowing through a pipe will have the same number of orifices.

### 3.2 Aeration of water flowing through pipes

In this option, for the uniform and controlled introduction of air into the water, a flat spiral has been designed and built which is mounted inside the pipe.
The spiral follows approximately the shape of three circles with diameters of 16 mm, 26 mm, 36 mm and lengths of 50.24 mm, 81.64 mm and 113.24 mm, their total length is L = 244.92 mm.
As a result, the distance between two orifices will be:

$$l = \frac{L}{n} = \frac{244.92}{17} = 14.4m \qquad (9)$$

A number of orifices will be placed on each circle:

$$n_1 = \frac{L_1}{l} = \frac{50.24}{14.4} \approx 3 orifices \qquad (10)$$

$$n_2 = \frac{L_2}{l} = \frac{81.64}{14.4} \approx 6 orifices \qquad (11)$$

$$n_3 = \frac{L_3}{l} = \frac{113.24}{14.4} \approx 8 orifices \qquad (12)$$

In total, there are 17 orifices of Ø 0.3 mm (figure 7).

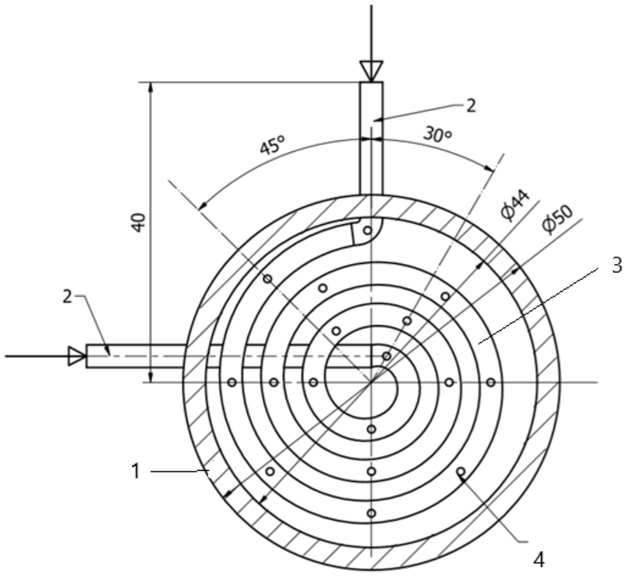


**Fig. 7.** Cross section through the pipe in the area where the spiral is located.
1- pipe Ø 50x3 mm; 2- compressed air inlet connections;
3- spiral; 4- orifices Ø 0.3 mm

The spiral is made of a capillary tube (figure 8) with an outer diameter of 3 mm and an inner diameter of 1 mm; the two conditions for placing the orifices presented above are verified:.

$$\frac{s}{d_0} = \frac{2}{0.3} = 6.66 > 3 \tag{13}$$

$$\frac{d}{d_0} = \frac{6}{0.3} = 20 > 8 \tag{14}$$

**Fig. 8.** Plan view of the spiral with 17 orifices Ø 0.3 mm

Figure 9 shows the experimental installation built for the purpose of measuring the dissolved oxygen concentration in water; the measurement is performed with the electrical or optical method [15].

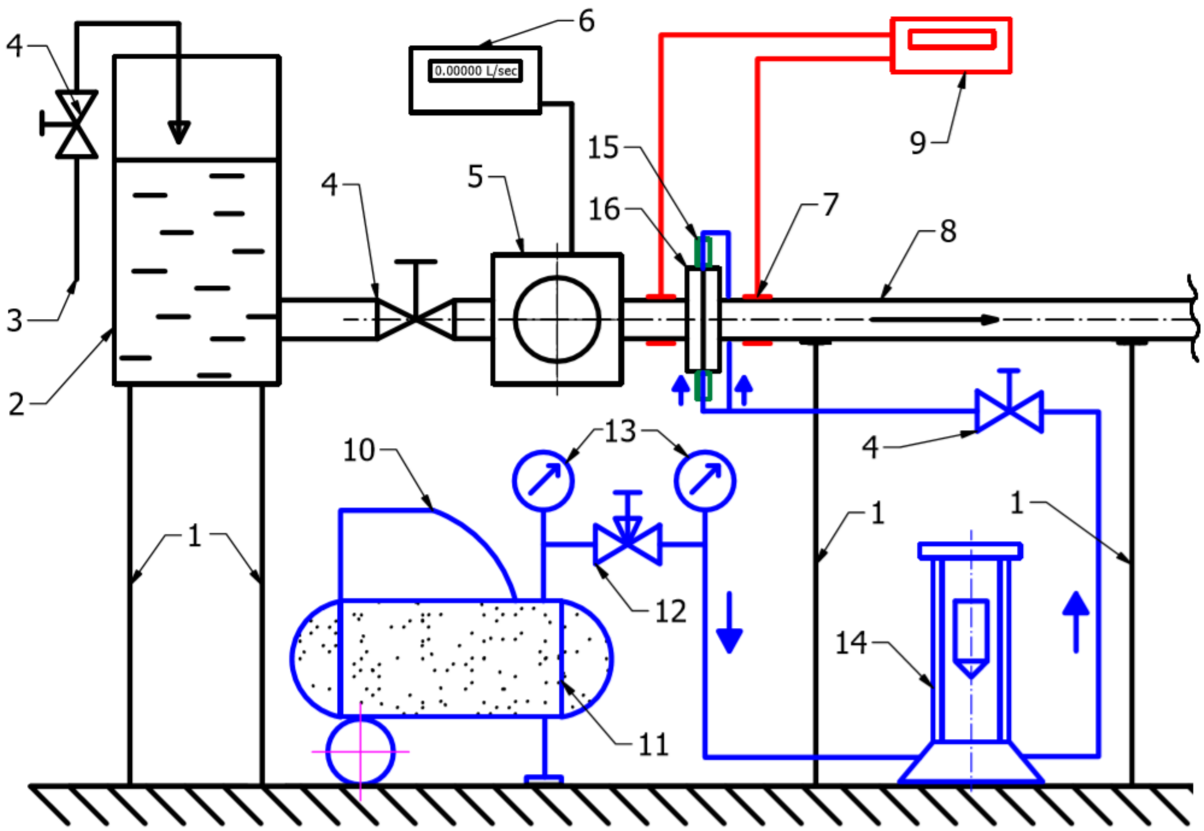


**Fig. 9.** Sketch of the experimental installation
1- supports; 2- water tank; 3- connection for mains water supply; 4- tap; 5- flow meter sensor; 6- flow meter with digital indication; 7- sensors for measuring the dissolved oxygen concentration in water; 8- transparent plexiglass pipe; 9- oxygenometer; 10- electro compressor; 11- compressed air tank; 12- pressure reducer; 13- manometers; 14- rotameter; 15- connection from the coil; 16- serpentine fixed between the flanges of the pipe.

For the flow rate measurement, a flow rate sensor with a Hall sensor was provided which sends 7.5 pulses at 1 $dm^3$ / min. The sensor sends a signal to an arduino microcontroller with a display; the controller shows the flow rate within an interval of one second and 5 seconds for greater accuracy.
Before and after the coil the dissolved oxygen concentration in water is measured using the oxygenometer.

## 4. Conclusions

1. The paper presents two constructive options of water aeration for stationary water and for water flowing through pipes.
2. Option 2 is more favourable because it removes the aeration tanks from the water treatment plants.
3. The experimental researches that will be presented in a paper published in 2020 will determine precisely which constructive solution is more favourable.

**Acknowledgments**

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