Process Optimization of Aeration in the Biological Treatment using Fine Bubble Diffusers

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Abstract— *The two most common types of aeration systems are diffused aerators and surface aerators. While each is highly effective, each has certain advantages and disadvantages that make them the appropriate choice based on their characteristics. The main functions of the aeration systems are summarised in this paper. In essence, it is to provide sufficient oxygen in order to satisfy the respiratory demand of the microbial biomass and to maintain this biomass in suspension. Aeration and mixing in the aeration tank is normally achieved by using either mechanical aeration, that is using surface aerators with either a vertical or horizontal shaft or by air diffusion.*

Keywords — *oxygen transfer, activated sludge process, diffusers, aeration systems, surface aerator.*

I. INTRODUCTION

In principle, an aeration tank can have a rectangular form, by case, from concrete or other materials, where the biological treatment takes place in the presence of a mixture of activated sludge and wastewater [1]. In order to ensure continuous mixing of the two components must be continuously mixing them with the air at the same time provide the necessary oxygen for aerobic bacteria from the activated sludge in the composition form of flocs [10].

Aeration tanks have a few of advantages [6]:

- ensure aeration and circulation of the wastewater;
- also is an ideal living conditions for aerobic bacteria
- aeration influence on flow conditions;
- design of the aeration tank;
- recirculation in the denitrification area and whole aeration tank.

Aeration equipment commonly employed in wastewater treatment is classified into three categories:

- air diffusion units;
- turbine aeration units;
- surface aeration units.

If comparing aeration devices or evaluating absorption of oxygen in various wastewaters, it is useful to consider the oxygen transfer efficiency, which is defined as:

$$\varepsilon = \frac{weight.of O_2 absorbed / unit.time}{weight.of O_2 \sup plied / unit.time} \cdot 100$$
(1)

In aerobic biological processes, aerators perform two basic functions:

- supply of the required oxygen transfer needed for oxidation of organic matter in wastewater;
- maintenance of an adequate level of agitation in the biological reactor.

The main characteristic of the pneumatic aeration is given by fine bubble aeration, due to the fact that these systems are obtained by blowing bubbles of air flow from a compressor.

In fine bubble diffusers, small orifice diffusion units as porous media, plates, or tubes are constructed of silicon dioxide (S_iO_2), or aluminum oxide (Al_2O_3) grains, held in a porous mass with a ceramic binder.

Small bubbles, having a high surface area per unit volume, provide good oxygen-liquid contact, leading to relatively high values of the oxygen transfer efficiency. Diameter of the bubbles released from these diffusers are 2,0-2,5 mm, the oxygen transfer efficiency depending on bubble size [11].

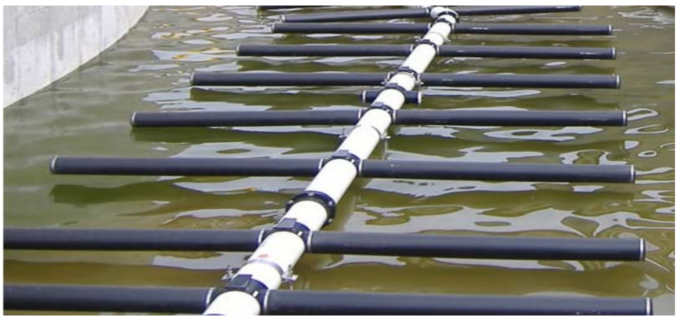

Fig. 1. Fine bubble air diffusion system consisting of a series of tube diffuser

In figure 1[5] is presented a fine bubble diffusion tube system.

A disadvantage of small orifice diffusion units is the high maintenance costs in some applications owing to orifice clogging. Air filters are commonly used to clean and eliminate dust particles that might clog the diffusers.

Dome diffusers (see fig. 2) [5].are circular discs constructed of aluminum compounds, commonly 3,8 cm high and 18 cm in diameter. They are mounted on base plates and factory connected to air piping. Aeration tank designs include total floor coverage or grid patterns installed at the base of the tank.

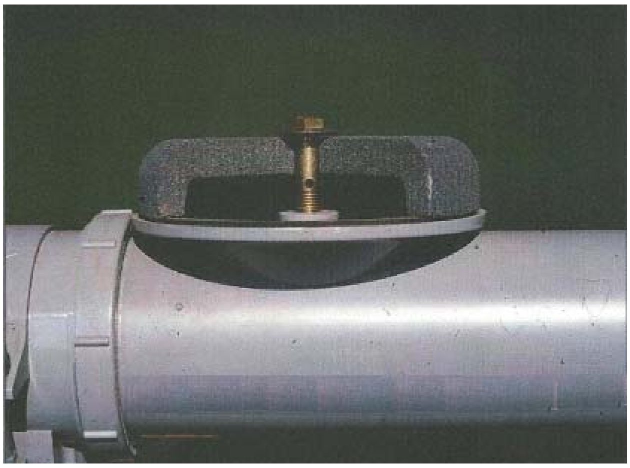

Fig. 2. Dome diffuser

In situation of dome diffusers made of porous, or ceramic materials, which indeed lead to efficiency, but it has problems in operation, because it is clogged very quickly. That's why requires a high air flow, which leads to higher energy to be able to retain dust, rust and others.

In the past combined aeration tanks were realized at pneumatic aeration through porous plates and to mechanical aeration through blades. Currently there are a few treatment plants using combined aeration due to high energy consumption.

Currently, the most effective type of pneumatic aeration is used in the rehabilitation of wastewater treatment plants and the construction of new wastewater treatment plants [3].

The aeration air is achieved by introducing air under pressure into the activated sludge tank and the oxygen reaches the water due to air bubbles and rise to the surface.

Surface aeration units are based on entertainment of oxygen from atmospheric air. Unlike air diffusion and turbine aerators there is no stream of air involved in this system.

Improved design of surface aerators has resulted improvement of oxygen transfer capacity.

The principle of operation of surface aerators is presented in figure 3 [13] liquid is drawn from underneath the unit and sprayed upward and outward by a propeller inside a vertical tube.

Most conventional surface aerators are fixed to piers mounted across the aerating tanks. Floating units are also available the whole unit being supported on a reinforced fiberglass float filled with plastic foam to make it unsinkable.

Fig. 3. Surface aerator

Oxygen transfer in surface aerators occurs according two mechanisms:

- transfer at the turbulent liquid surface
- transfer to droplets sprayed by the blades of the unit.

II. CASE STUDY

Generally, in practice, for circular aeration tanks fine bubbles diffusers are recommended because it can be easily mounted and provides a high degree of efficiency, for the oxygen requirement of the bacteria used, as well as a lower energy consumption.

For study was used a wastewater treatment plant from Gherla's city, which has two circular aeration tanks each of 4050 m^3 and a height of 5,75 m.

Fine bubble strip diffusers are available in both types "T" and Q". "T" types are available in 15 and 18 cm widths. The width of the "Q" type (see fig. 4) is 18 cm . Both types use the same micro-perforated polyurethane membrane secured to either a stainless steel. Both types have identical oxygen transfer performance characteristics.

Both models are available in 0,5 m incremental lengths up to 4,0 m. This means more active membrane area per diffuser for fewer diffusers and easier installation right on the tank floor. All of the membrane area of diffusers is in the horizontal plane.

The diffusers may be of different types as Q1, Q1,5, Q2, Q2,5, Q3, Q3,5, Q4,5 Q4 until they can have a length between 1000 and 4500 mm, and the area of the diffuser range can be from 0,175 to 0,787 m^2, with a weight of 2,7 to 10,9 kg, the maximum flow rate between 22 and 99 Nm^3/h.

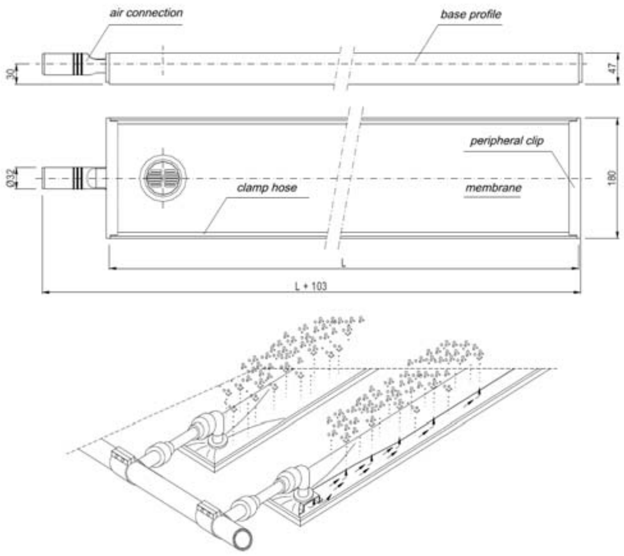

Fig. 4. Fine bubble strip diffuser

Membrane-plate-diffusers consist of a flat, heavily ribbed and fibre membrane.

The two part frame, which is made of fiber-glass-reinforced polypropylene, firmly holds the membrane on the base plate.

The membranes are provided with a special distribution of the slots which are formed so that's why the size and location is to achieve optimal supply of oxygen. Diffuser membrane plates are suitable for installation on steel and plastic pipes, and are suitable for high volume aeration tanks (see fig. 5.) [5].

Membrane plate aerators have a control range between 0 and 13 Nm^3/h or 0 and 20 Nm^3/h. Dimensions can be width 210 mm, length 1100 mm and height 21 mm. The free surface of the membrane is 0,2 m^2 for length 1070 mm and width 185 mm.

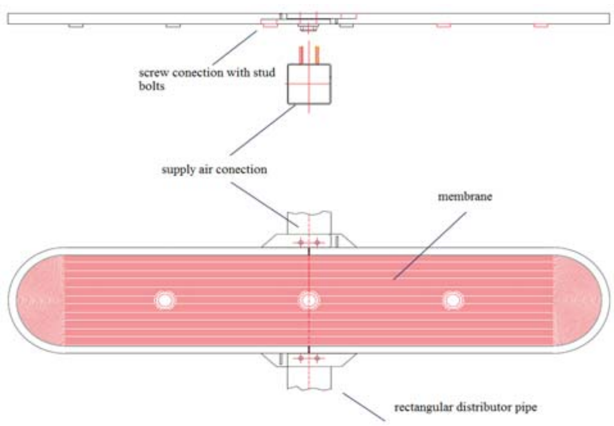

Fig. 5. Membrane plate diffuser

A disadvantage of this diffusers is also lead to the content of sludge in the diffusers, or the situation that enter sludge to the distributor piping system. Maintenance is at least once every year. In some cases there is a need for the addition of diluted acid dose in the compressed air.

Fig. 6. Evolution of membrane plate diffuser in time

As shown in figure 6 [5] the life of the plate diffusers is short because they are not resistant to oil-containing substances or solutions for dilution.

In sizing aerators for an aeration system, some basic factors are considered:

- the oxygen requirements of the process,
- the characteristics of wastewater and the anticipated field conditions,
- the requirements for solids suspension and mixing, the geometry of the tank and the oxygen transfer efficiencies of aerators.

Aerators selected must meet both requirements for oxygen transfer and turbulent mixing of the system.

In the activated sludge process (see fig. 7) [2] it is essential that an adequate circulation and turbulent mixing of the entire liquid contents be provided to keep the biological flocs in uniform suspension and an intimate contact with the incoming raw wastewater [7]. In wastewater treatment plants with activated sludge process, the power levels are determined by the requirement for oxygen transfer capacity and are generally greater than the requirement for solids mixing.

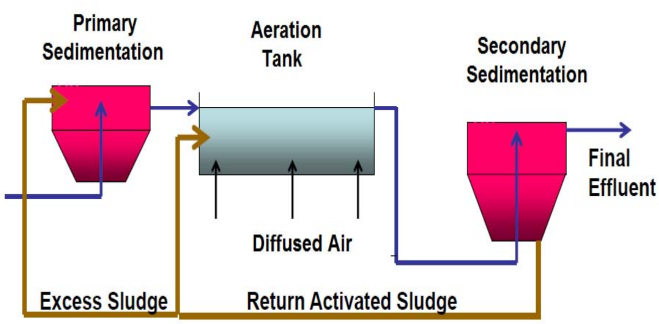

Fig. 7. Activated Sludge Process

A. *Techniques for surface aerator performance test. Unsteady-state aeration of deoxygenated clean water*

Oxygen transfer efficiency of a given aerator can be expressed by the value K_La the overall oxygen transfer coefficient. Because K_La is a function of the geometry of aeration tank, which varies from one installation to another, so a full-scale field performance test must be conducted to determine the actual oxygen transfer efficiency of an aerator installation [8].

Various techniques have been employed to evaluate the efficiency of aeration devices as follows [6]:

- unsteady-state aeration of deoxygenated clean water;
- steadystate aeration of activated sludge mixed liquor;
- steady-state aeration of a continuous flow system of deoxygenated clean water (by addition of a sulfite solution);
- unsteady-state aeration of deoxygenated activated sludge mixed liquor;
- deaeration of krypton-85 gaseous tracer added to clean water.

The first two of these methods are commonly applied in the field performance evaluation of aerator installations .

Performance testing of aerators with clean water in an aeration tank is based on equation as follows [4]:

$$\frac{dc}{dt} = K_L a \cdot (C_s - C) \tag{2}$$

The water under aeration is observed for the changes in dissolved oxygen concentration with aeration time, starting with a dissolved oxygen (DO) level close to zero to a level close to 90% of the saturation DO level, C_S, or higher, because the values of K_La and C represent the uniform or average values for the entire liquid contents, therefore a condition of complete mixing throughout the aeration tank is desirable.

B. Steady state aeration of activated sludge mixed liquor

In activated sludge mixed liquor under aeration, the rate of oxygen transfer can be estimated by using the following relationship [4].

$$\frac{dc}{dt} = K_L a \cdot (C_{sw} - C_t) - r_0 \tag{3}$$

where: C_{SW} is the oxygen saturation concentration of the wastewater;

r_0 is the oxygen uptake rate;

C is dissolved oxygen concentration of mixed liquor.

III. CONCLUSIONS

The results of the study showed that, both the depth of water and the extent of coverage area of diffuser, considering that tanks are circulars, nitrification and denitrification occurs in the same tank most efficient aeration systems are with fine bubble diffuser membranes. This diffusers are micro-perforated vertically using a preferred density of conical needles. The result is an optimum distribution of micropores with smooth walls. This allows the membrane to operate within a large flux range (0,3 – 7,0 m^2) while producing 1 mm bubbles. The pores close when air pressure below the membrane decreases below about 0,6 psi, allowing for intermittent operation.

Bubbles provide good oxygen-liquid contact, leading to relatively high values of the oxygen-transfer efficiency[9].

In this comparative study is concluded for this two fine bubble aeration systems with strip and plate diffusers, for circular aeration tanks the situation of strip diffusers is better because the depth of immersion is higher and the bubbles of oxygen introduced are smaller.

Acknowledgments

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