

NUMERICAL SIMULATIONS OF WASTEWATER TREATMENT AERATION PROCESSES

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În lucrare autorii prezintă necesitatea retehnologizării instalațiilor de aerare cu care este dotat reactorul biologic aerob din stațiile de epurare a apelor uzate. Asigurarea necesarului de oxigen în procesul biochimic de degradare a materiilor organice și menținerea în stare de suspensie a flocoanelor de nămol activ sunt cerințe de bază ale funcționării corecte a reactorului. Transferul de masă al oxigenului din aer în apă, realizat în funcționarea instalațiilor de oxigenare, este cel care necesită un consum ridicat de energie electrică. În lucrare se prezintă un studiu comparativ asupra proceselor de aerare în reactoarele biologice din Stația de Epurare a Apelor Uzate din Municipiul Târgoviște înainte și după retehnologizare, pentru a se sublinia necesitatea introducerii de echipamente moderne și performante pentru epurarea apelor uzate.

In this paper, the authors present the need to modernize the aeration equipments used in biological reactors of wastewater treatment plant (WWTP). The basic requirements for the correct operation of the biological reactor are to provide enough oxygen for the biochemical degradation of the organic matter and maintaining the state of activated sludge suspension flocs. The oxygen mass transfer from air to water is essential in biological processes due to high energy consumption of the aeration equipments. In the present paper the authors present a comparative study over the aeration processes in the biological reactors before and after refurbishment of Targoviste City WWTP in order to highlight the necessity to use modern and high-performance equipments for the wastewater treatment.

Keywords: aeration processes, numerical simulation, refurbishment

1. Introduction

Studies and researches from the last two decades have shown that the intensification of transfer can be accomplished by reducing the bubble mean diameter and to ensure a turbulent flow regime allowing continuous renewable contact water – air surface. Providing and maintaining the turbulent regime favours the suspensions of activated sludge flocs. To achieve increased turbulences in the biological reactor requires high energy consumption.

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In the paper the authors will show the difference between two aeration systems used for wastewater biological treatment. The first system is composed by perforated steel pipes and the air is supplied by a ventilator. The second system is composed by fine bubble air diffusers and the air is supplied by a high speed turbo blower.

2. Numerical simulation of oxygen transfer from the air bubble in water mass

For proper implementation of the air dispersion systems in the biological reactors of wastewater treatment plant the numerical simulation is an important preliminary step in order to determine the optimum hydrodynamics conditions for achieving the maximum treatment efficiency.

The basic equation describing the rate at which oxygen is absorbed by water is

$$\frac{dC}{dt} = K_L a (C_{st} - C_t) \quad (1)$$

where:

$\frac{dC}{dt}$ is the transfer rate of oxygen to the water (mg/l);

$K_L a = K_L \frac{A}{V}$ is the apparent volumetric oxygen mass transfer coefficient in clean water, (hr^{-1});

V is the water volume in the tank, (m^3);

A is the interfacial area of mass transfer, (m^2);

a is the interfacial area per unit volume, (m^2/m^3);

C_{st} is the saturation, or equilibrium, concentration of oxygen in water with respect to air in bubble at mean depth, (mg/l);

C_t is concentration of oxygen in the water at time t , (mg/l);

t is the aeration time.

2.1 Aeration processes through perforated steel pipes

For the numerical simulation in CFD software the equation (1) is introduced in the ANSYS code, in order to visualize the oxygen transfer rate in the biological tank.

The numerical simulation was done for the existing configuration of the aeration basin. The basin geometry has 50m length, 3m width and 3m depth. The air injection pipes have 25mm in diameter and the perforated diameter hole is 1.5mm. 25 pipes are arranged at a distance of 2 meters apart.

The following remarks were considered for numerical simulation:

- Water is considered the continuous fluid
- Air is considered the dispersed fluid
- Bubble diameter is 1.5 mm
- Reference pressure is 1 atm
- An additional variable *oxygen concentration* has been introduced, the values for the a coefficient result from the aeration tank geometry. In the work domain, the additional variable will be subject to transport equations.
- C_t is the injection oxygen concentration, the 10kg/m^3 value is imposed at the initial time;
- C_{st} saturation concentration, for which the imposed value is 12kg/m^3
- Water speed into the biological reactor 0.5 m/s

In Figs. 1 – 3 are presented the obtained results.

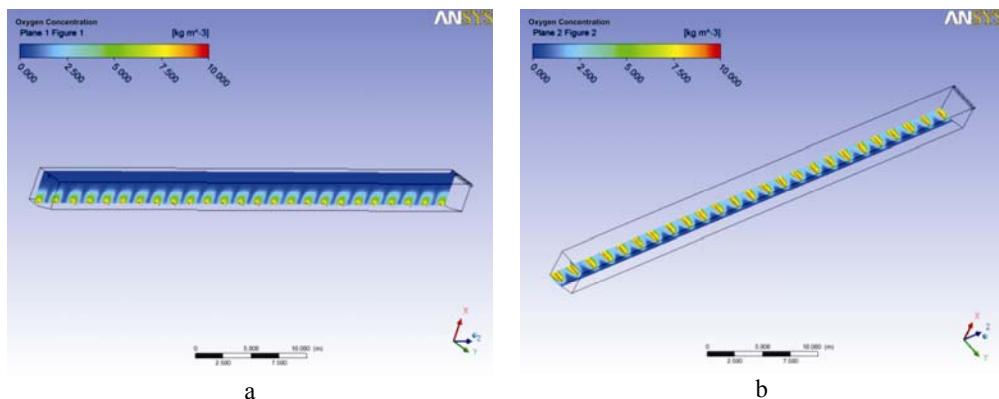


Fig. 1. Oxygen transfer in the biological reactor
(a) transversal view (b) horizontal view

In Fig. 1 one can observe the oxygen dispersion into the biological reactor. Because the perforated pipes are clogged, the air transfer into the water mass is present only on a 1.5m depth. At the surface, the oxygen concentration is 0kg/m^3 . This should be avoided in the operation of aeration tanks.

Fig. 2 shows the oxygen transfer evolution at three depths, first at the pipe injection level, 1m depth and at the biological reactor surface. Also, in Fig. 2 one can observe the transitory evolution due to the fact that the injection pipe is distributed at 2m distance. Between two injection pipes the oxygen is consumed by the organic matter.

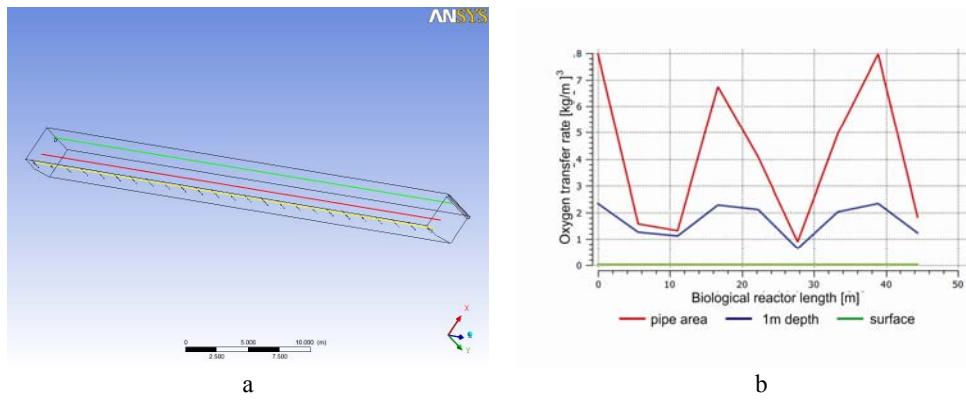


Fig. 2. Evolution of oxygen transfer rate along the biological reactor

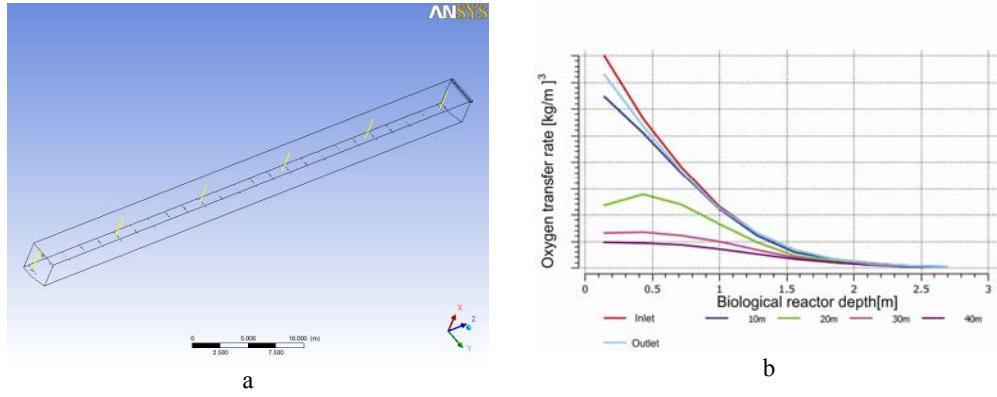


Fig. 3. Oxygen transfer rate on depth in different points of biological reactor

In Fig. 3 the lines corresponding to 20m, 30m and 40m lengths the dissolved oxygen transfer rate is lower because they are between two injection pipes.

2.2 Aeration processes through fine bubbles diffusers

The aeration network has 3 diffusers per width and 48 diffusers per length, disposed asymmetrically on the biological reactor foundation. The distance between two diffusers is 0.5m. Because of the asymmetrical disposal an area without air bubbles is created, higher at the base and lower to the surface because of the upward movement the air bubbles more away from each other and increase their diameter. This generates circular water currents (figure 4) with predominant vertical arrangement, buoyancy in the network and lower dispersion in the reactor foundation.

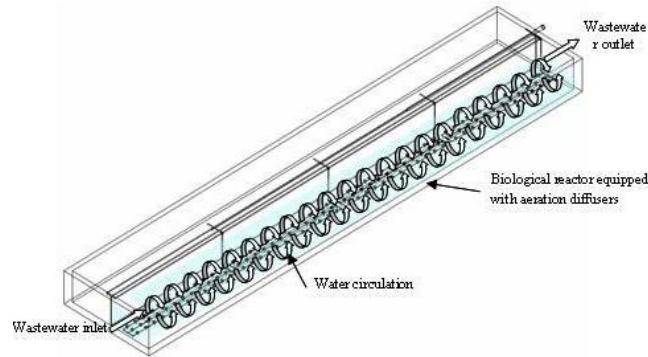


Fig. 4. Circular water currents formation in the biological reactor

The numerical simulations were realized in ANSYS software in the same condition has in the case of air injection through perforated pipes.

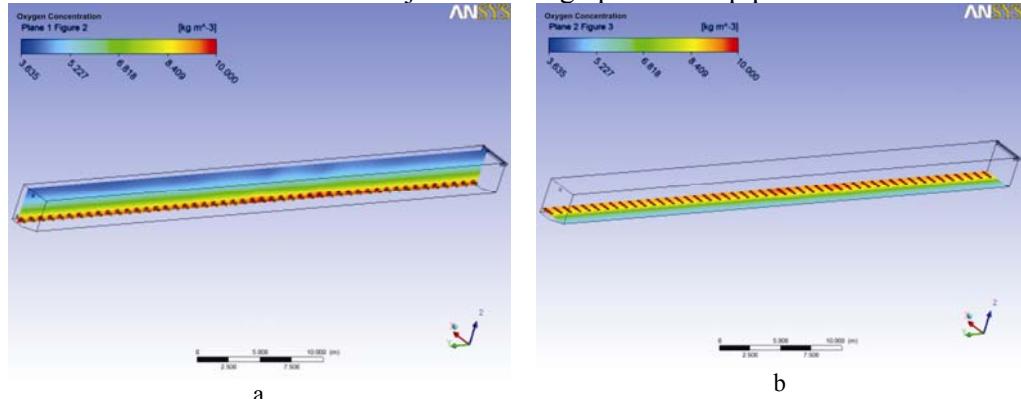


Fig. 5. Evolution of oxygen transfer in the biological reactor
(a) transversal view (b) horizontal view

In figure 5 the oxygen evolution through the biological reactor can be observed. One can notice the large difference between this case and the previous one. At the surface the oxygen concentration has around $3 - 4 \text{ kg/m}^3$ as shown in figure 6.

In Fig. 6 it can be noted that the oxygen transfer decreases along the depth of the reactor, but remains in normal operating conditions.

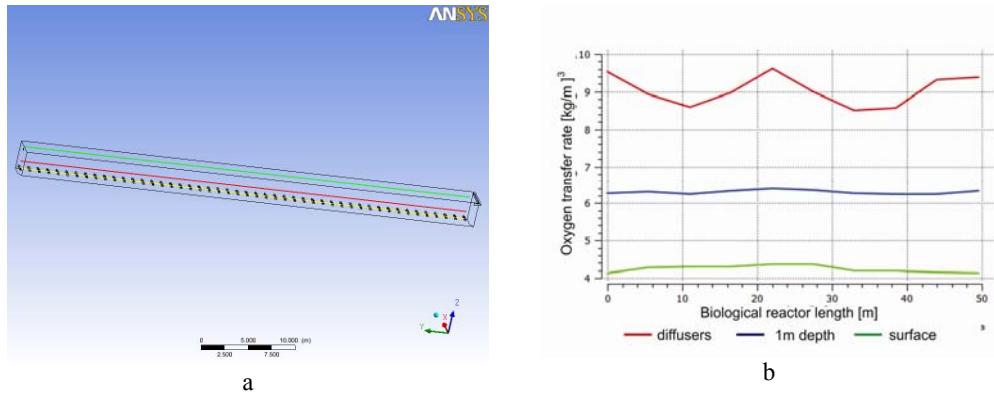


Fig. 6. Evolution of oxygen transfer rate along the biological reactor

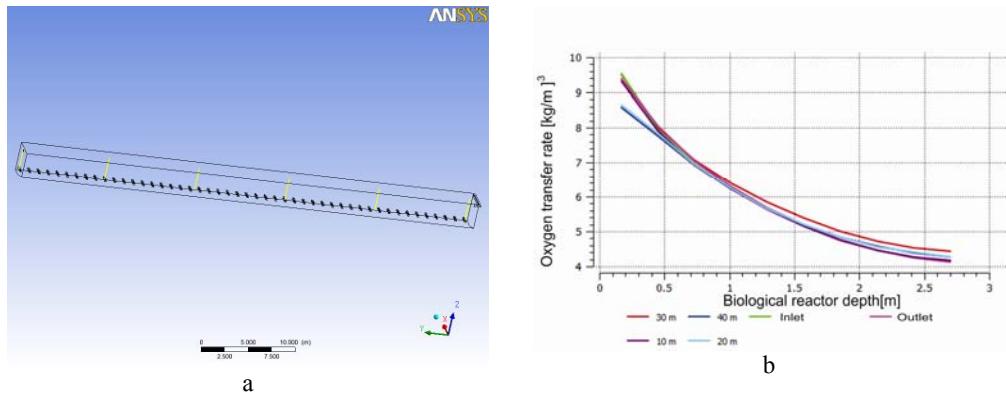


Fig. 7. Oxygen transfer rate on depth in different points of biological reactor

In Fig. 7 it can be observed a constant evolution of oxygen concentration with the basin depth. This is desirable in a real facility for proper disposal of organic matter.

In Fig. 8 the difference between the two simulated aeration systems, the air injection through perforated pipes (right side) and the air injection through fine diffusers (left side), is shown in normal operating conditions in Targoviste Wastewater Treatment Plant. One can observe that, at the same air flow, the perforated pipes don't assure the necessary biological conditions for the treatment process.



Fig. 8. Aeration in the biological reactor of Targoviste WWTP

3. Conclusions

In most wastewater treatment plants from Romania the existing equipments are old and inefficient and they need to be updated with new and advanced technologies.

In the paper the authors have presented the comparison between two aeration systems. The air injection into the biological basin through perforated pipes shows that in time these systems lose there efficiency due to the orifices clogging with the organic matter from the basin. In exploitation the air supplying equipment must give enough pressure for the air to penetrate through the clogged orifices, this means an increase of energy consumption.

Using the new and high-performance aeration system, the fine air diffusers, higher oxygen transfer efficiency can be observed in the same simulation conditions as in the case of the perforated pipes. When the air supply is stopped the diffuser has the capacity to close tightly, so the clogging is prevented and the air supply equipment will work efficiently and with minimum energy consumption.

Due to the higher aeration performances and lower energy consumption the use of the fine bubble diffusers is the most adequate solution for the refurbishment of the biological reactor from the Romanian wastewater treatment plants.

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