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**MODELING THE DISTRIBUTION
OF DISSOLVED OXYGEN CONCENTRATION IN BIOREACTORS
OF A LEACHATE TREATMENT PLANT**

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ABSTRACT

A necessary condition for proper functioning of the economically optimal biological reactor is the correlation between the flow rates of introduced oxygen with the consumed in the metabolic degradation of organic materials. Modeling of physical, chemical and biological processes of aeration tanks in leachate treatment plants is difficult because they are very complex. In the aerobic biological reactor, the oxygen consumption varies over time and space due to

the unevenness of the influent load of biodegradable organic substances or change the kinetic relationship between the growth rates of biomass and elimination rates of the substrate.

Biological reactors for the treatment of leachate considered, provided with two types of air dispersion devices placed at the bottom of the basin (perforated pipe in the first bioreactor and porous diffusers in second bioreactor), was created using Flex PDE, two models.

Modeling the dissolved oxygen concentration in the leachate, was aimed to optimize the process of mass transfer of oxygen from air into water, having an important role in minimizing the operating costs of facilities, energetic optimization of aeration systems and an improving on performances for leachate treatment.

The models were designed for a two-dimensional domain, and to appreciate the distribution of oxygen concentration for both bioreactors equipped with different lenses (perforated pipes and porous diffusers). Numerical integration of the dispersion equation for the analyzed case was adapted by running a program written by the user using Flex PDE software package. The phenomenon of mass transfer at the interface was found by a continuous flow conditions required in the surface pores through which compressed air is blown.

The results shows that the use of air insufflation made from porous diffusers is more efficient, compared to the system made from perforated pipes, the required value of the concentration of dissolved oxygen reached in a time period much lower, similar to that encountered in practice.

Keywords: modeling, dispersion, dissolved oxygen.

1. INTRODUCTION

A necessary condition under optimal conditions from the economic point of view, the biological reactor is the correlation between the flow rate of introduced oxygen consumed in the metabolic degradation of organic materials. Modeling of physical, chemical and biological processes occurring the aeration basins in leachate treatment plants is difficult because they are extremely complex. In the aerobic biological reactor, the oxygen consumption varies over time and space due to the unevenness of the influent load of biodegradable organic substances or change the kinetic relationship between the growth rates of biomass and elimination rates of the substrate [1]. Under real and normal operating it sets a dynamic equilibrium between the rate of oxygen transfer and consumption by organic matter mineralization reactions, leading to the achievement of a steady state of operation.

Testing the oxygen equipments under standard operating mainly aims to determine the oxygen concentration variation in time and space $C(x, z, y, t)$. There are many methods to test most commonly used is that of water remove with sodium sulfite in the presence of a catalyst [2]. After a full removal of the liquid in the tank is follow the development of the oxygen concentration over

time for various points in the tank under operating conditions of the aeration equipment. For this case it is necessary to develop a mathematical model in a non-stationary regime. This model have to describes the continuous increase in the concentration of dissolved oxygen in water mass, in terms of forced convection generated and induced by gas-lift effect, from zero to the saturation value and his dispersion in the liquid phase. The aeration equipment is considered to be a contributing source to forcibly introducing the gas into the water, ensuring the mixing and homogenisation of the aqueous medium. In the ascending movement, the air bubbles will lead the mass of liquid through the free surface of leachate in the tank and contribute to the process intensification by increasing the dispersion coefficient. Thus, if it is considered a main phenomenon the diffusion and the dispersion of the oxygen from the introduced air into the turbulent water table then the general equation of motion takes the form [3]:

$$\frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x} (\bar{u}\bar{C}) + \frac{\partial}{\partial y} (\bar{v}\bar{C}) + \frac{\partial}{\partial z} (\bar{w}\bar{C}) = \frac{\partial}{\partial x} (\epsilon_x \frac{\partial \bar{C}}{\partial x}) + \frac{\partial}{\partial y} (\epsilon_y \frac{\partial \bar{C}}{\partial y}) + \frac{\partial}{\partial z} (\epsilon_z \frac{\partial \bar{C}}{\partial z}) + D_m \left(\frac{\partial^2 \bar{C}}{\partial x^2} + \frac{\partial^2 \bar{C}}{\partial y^2} + \frac{\partial^2 \bar{C}}{\partial z^2} \right) + S(x, y, z, t) \quad (1)$$

where x, y, z are the coordinates of the considered point in the aeration tank; u, v, w - velocities in the three directions; C (x, y, z, t) is the concentration of oxygen in the aqueous medium; ϵ_x , ϵ_y , ϵ_z is the longitudinal dispersion coefficients, transverse and respectively on vertical fluid flow; D_m -molecular diffusion coefficient of oxygen from the air into water, S (x, y, z, t) - the time source.

The mediation size is a relative over time, because the regime flow is turbulent with changes of the sizes in time. A complete solution of this equation to which must attach the equations of motion and continuity is impossible to achieve because the dispersion coefficient values depend on the turbulent motion of the liquid medium, on its nature, shape and size of dispersed bubbles gets its physical properties of the environments. For this reason it is necessary to build a simplified model. For biological reactor, equipped with two types of air dispersion devices placed at the bottom of the basin (perforated pipe in the first bioreactor, and porous diffusers second bioreactor), the movement is reproduced identically to all parallel planes with a vertical plane for base. This assumption is justified because the released jets emitted by diffusers involve a large amount of liquid by gas lift effect that will return to the bottom.

The oxygen dispersion will be in the transversal direction as a result of turbulence and pulsation motion of the velocity vector, and caused by the movement bubbles in liquid medium on the ascending direction. It is noted that this process will be neglected because it is less intense in relation to the similar phenomena in vertical and longitudinal directions. It is neglected the proper term on molecular diffusion in transverse direction because it is insignificant compared to the turbulent convection. The developed model takes into account

the complete mixing assumption justified by horizontal transport movement combined with vertical displacements of environmental polyphase stages trained by gas bubbles. Under these conditions, the dispersion equation (1) becomes;

$$\frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x}(\bar{u}\bar{C}) + \frac{\partial}{\partial z}(\bar{w}\bar{C}) = \frac{\partial}{\partial x}\left(\epsilon_x \frac{\partial \bar{C}}{\partial x}\right) + \frac{\partial}{\partial z}\left(\epsilon_z \frac{\partial \bar{C}}{\partial z}\right) + D_m \left(\frac{\partial^2 \bar{C}}{\partial x^2} + \frac{\partial^2 \bar{C}}{\partial z^2}\right) + S(x, y, z, t) \quad (2)$$

For parameters that intervene in the equation (2) has been used the values obtained according to the literature [2; 3].

2. MODELING AND SIMULATION OF THE OXYGEN CONCENTRATION

Considering previously justified assumptions, Equation 2 can be integrated numerically by writing a program using Flex PDE software package. This program is intended to solve by finite element method of partial differential equations based on a large number of modules that allow a complete resolution of the problem [4]. The first module of this program is the editing by using the specific language for the program, the user can define their own equation system of partial differential equations and computational geometry field. The program has no predetermined equations and geometry, their selection and the definition of initial and boundary conditions depending on the user. The second module of the program is the equation analyzer that explains and develops parameters and relationships defined. The triangular finite element mesh on an arbitrary two-dimensional domain is performed automatically by the program [4]. Flex PDE has an estimation error procedure by which the mesh is refined where the error is large, it iterates the fine mesh to achieve the user-defined error tolerance. Results are shown in graphical form and can be exported. Solving the equation from which can be determined the concentration distribution of oxygen in bioreactors using this software involved writing a program.

Models consider as a main source of oxygen, compressed air blowing systems in the basin. Source term is independent of time because experimental measurements will be carried out under flow and pressure conditions. Its influence is seen in the program by continuous flow conditions (Neumann) imposed on the surface of porous diffuser and perforated pipe holes. The value of this flow can not be determined by theoretical way, so that in the process of modeling are considerate different sizes of it.

Defined geometry complies plant sizes of the transport laboratory polyphase fluid and pollution and allows estimating the influence of both types of dispersion systems.

2.1. The evolution of the dissolved oxygen concentration in the first bioreactor

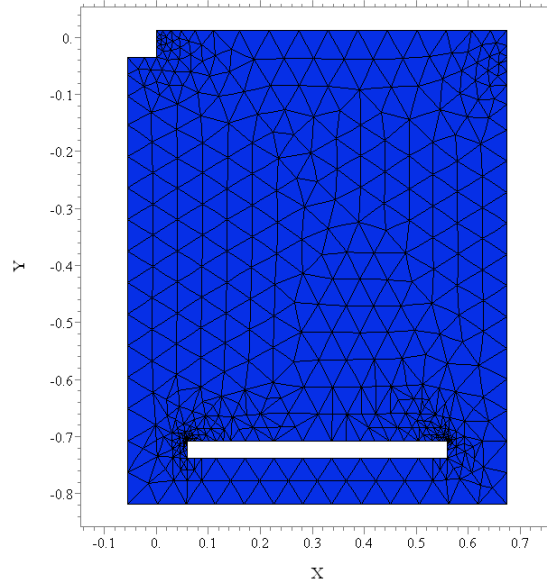


Figure 1. Calculation mesh for dimensional model for the first bioreactor

The figure 1 is the calculation mesh for the first bioreactor built automatically by the program, there is a higher density of network nodes in the air dispersion system for which were considered boundary conditions Neumann type.

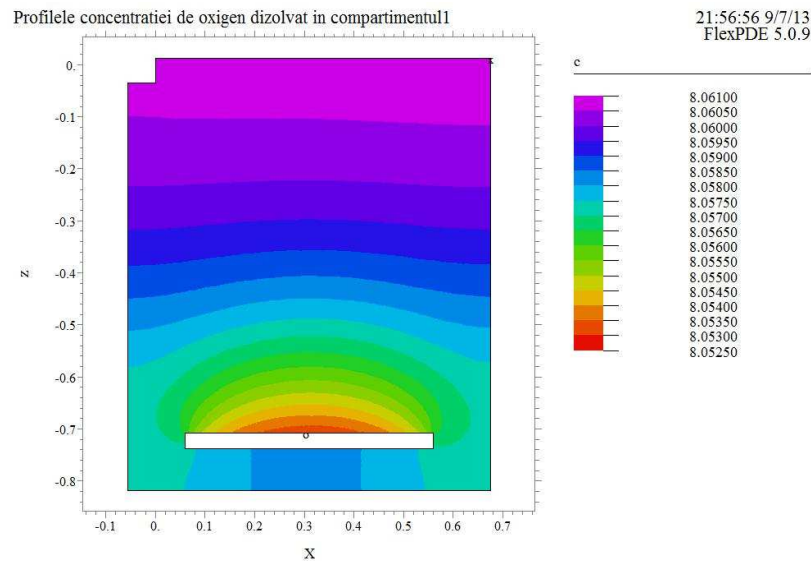


Figure 2. Modeling results of the concentration of dissolved oxygen to the first bioreactor

The figure 2 presents the results of numerical integration of equation 2 for the first bioreactor situation. It is noted that the existence of area of maximum concentration at the bottom of the tank, a situation that can be encountered in practice. As they ascend toward for the free surface, the bubbles gives oxygen

to liquid environment, resulting through air-lift effect amounts of liquid returning to the bottom with an enrichment oxygen concentration. The increased concentration of dissolved oxygen is significant a justification for a high oxygen deficit can be compared to saturation a factor that influences the speed transfer.

2.2. The evolution of the dissolved oxygen concentration in the second bioreactor

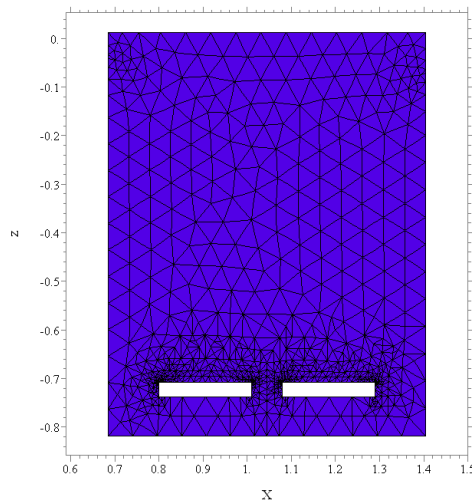


Figure 3. The calculation mesh for bidimensional model in second bioreactor

Porous diffusers are formed by the two rectangles with a length of 0.21 m positioned near the slab bioreactor, their influence is considered through boundary conditions continuous flow type imposed to the upper surface of the two rectangles.

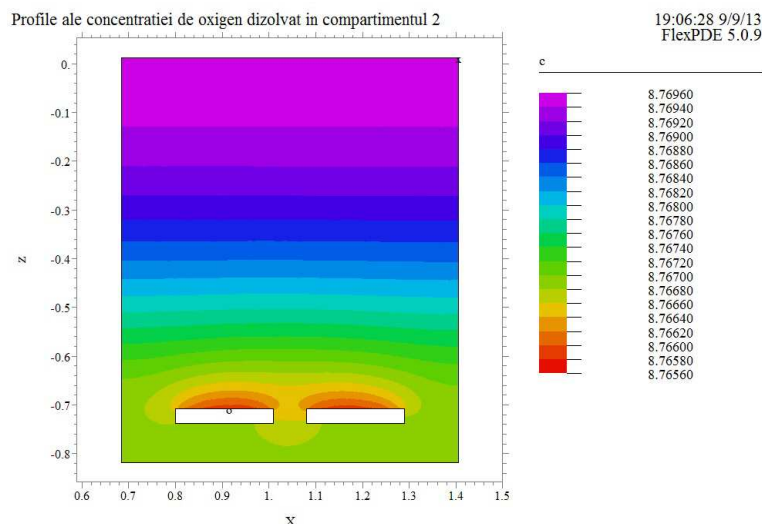


Figure 4. The results of modeling concentration of dissolved oxygen in the second bioreactor

Figure 4 presents the results of numerical integration of the equation 2 for the second bioreactor fitted with porous diffusers. It is noted the existence of maximum concentration area at the bottom of the tank, a situation that can be

encountered in practice. As they ascend to the free surface, the bubbles give oxygen to the liquid environment, resulting through air-lift effect amounts of liquid returning to the bottom with an enrichment oxygen concentration. Increasing the concentration of dissolved oxygen is significantly and faster, about 10 minutes, compared to the first bioreactor where to reach an equal value it requires a longer time about 14 minutes, a justification for this phenomenon is due to the influence of the dispersion system type used.

3. CONCLUSIONS

Modeling of the dissolved oxygen concentration in leachate was primarily aimed the optimization of mass transfer of oxygen from air into water, having an important role in minimizing the operating costs of facilities, energy optimization of aeration systems and on improving the performance of treatment leachate.

Mathematical models have been studied from the specialty literature and found that most are based on the mass transfer at the water - air. For a best possible comparison of the two aeration systems were developed two mathematical models for determining the concentration of dissolved oxygen in both aerobic biological reactors, the models considering both mass transfer and dispersion in the liquid phase. The models were designed for a two-dimensional domain, and are designed to appreciate the distribution of oxygen concentration for the two bioreactors equipped with different lenses (perforated pipes and hollow radial diffusers). Numerical integration of the dispersion equation adapted to the analysed case was performed by running a program written by user using Flex PDE software package. The phenomenon of mass transfer at the interface was considered by a continuous flow conditions required in the pores surface through which compressed air is blown.

The results show that the use of air blowing system formed by radial porous diffusers is more efficient in comparison with the system formed of perforated pipes, the required value of the concentration of dissolved oxygen reaching in a much lower period, similar to that seen also in practice.

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BIBLIOGRAPHY

- [1] *H. Chanson*, Air bubble entrainment in free-surface turbulent shear flows, Academic Press, ISBN 0-12-1681110-6, p 274-277, 1996;
- [2] *S. Stoianovici, D. Robescu, D. Stamatoiu*, Calculul si constructia echipamentelor de oxigenare a apelor, Editura Ceres, Bucuresti, 1985;
- [3] *D. N. Robescu, D. Robescu, S. Lanyi, A. Verstoy*, Modelarea si simularea proceselor de epurare, Editura Tehnica, Bucuresti, 2004;
- [4] [www. Pdesolutions.com](http://www.Pdesolutions.com)