

MODELLING AND SIMULATION CONCERNING THE PROCESS FROM THE AERATION TANKS WITH ACTIVATED SLUDGE

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Modelele matematice ale nămolui activ cunoscute în prezent descriu în amănunt dinamica proceselor de epurare biologică, dar neglijează influența factorilor hidrodinamici deși mediul în care au loc reacțiile biochimice este mediul apos. În această lucrare se prezintă modelarea și simularea evoluției dinamice a procesului de transfer de masă și dispersie a oxigenului din aer în apă în prezența consumului datorat degradării materiilor organice din apa uzată în procesele biologice din bazinele de aerare cu nămol activ ale stațiilor de epurare a apei uzate.

Mathematical models of the activated sludge which are known at present give a detailed description about the dynamics of biological treatment, but neglect the hydrodynamic factor influence although the medium in which these biochemical reactions take place is an aqueous medium. This paper presents modelling and simulation of the dynamic evolution related to mass transfer process and to oxygen dispersion from air to water in the presence of the demand due to organic matter damage from the wastewater, in biological processes from the aeration tanks with activated sludge belonging to wastewater treatment plants.

Keywords: modelling, dissolved oxygen, activated sludge, wastewater

1. Introduction

Mathematical simulation of the biological treatment in tanks with activated sludge has in view, based on material balance, kinetics of substrate demand and micro organisms mass increase, to set up relations which help the technological sizing of biological treatment equipment as well as control and optimization of their working [1].

Physical, chemical and biological processes which take place in aeration tanks with activated sludge, from wastewater treatment plants are complex processes and their mathematical simulation is difficult to be made.

There are certain models which describe the wastewater biological treatment process, but the most used and general accepted as a base of the biological modelling with activated sludge is the structural model ASM 1 -

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Activated Sludge Model no.1, proposed by a group of mathematical simulation from International Water Association (IWA) [2,3,4].

The differences between these models consist in kinetic expressions used to express the organic matter demand and activated sludge increase in order to select the equipment elements to achieve the mass balance and the manner in which the flow from the aeration tank is achieved, but the hydrodynamic factor influence is neglected, although the medium in which these biochemical reactions take place, is the aqueous medium. The hydrodynamic factors have an important role in the development of phenomena and processes which take place in the aeration tanks with activated sludge and they also have an important and direct influence on life conditions and metabolism of active cellular mass.

A methodology which consists in determination of variables implied in the system, identification of individual processes which contain the selected variables, production of equation systems which describe the relations between process and selected variables, calibration and validation of the results obtained from the integration of equation systems is necessary to draw up a certain model of the processes which take place in a system with activated sludge [1,3].

2. Contents

One of the most important control parameters of the treatment system with activated sludge is the dissolved oxygen. Oxygen requirement control is significant for the treatment plant operational costs lowering. Certain aeration methods may be tested by mathematical models and computer simulations.

Oxygen dispersion process transferred to aqueous medium by the interface of both phases, liquid and gaseous, is expressed by the following equation [1]:

$$\begin{aligned} \frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x}(\bar{u}\bar{C}) + \frac{\partial}{\partial y}(\bar{v}\bar{C}) + \frac{\partial}{\partial z}(\bar{w}\bar{C}) = \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial \bar{C}}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial \bar{C}}{\partial y}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial \bar{C}}{\partial z}\right) \\ + D_m \left(\frac{\partial^2 \bar{C}}{\partial x^2} + \frac{\partial^2 \bar{C}}{\partial y^2} + \frac{\partial^2 \bar{C}}{\partial z^2} \right) + S(x, y, z, t) \end{aligned} \quad (1)$$

where: x, y, z , are the coordinates of the point selected from the aeration tank;
 $C(x,y,z,t)$ is oxygen concentration from the aqueous medium; D_m – constant of oxygen diffusion from air into water having values depending on temperature ($D_m = 0,203 \text{ m}^2/\text{s}$ la 20°C , $D_m = 0,155 \text{ m}^2/\text{s}$ at 10° and $D_m = 0,18 \text{ m}^2/\text{s}$ la 15°C); $\varepsilon_x, \varepsilon_y, \varepsilon_z$ are longitudinal, transversal dispersion coefficients and on the vertical line of fluid flow, respectively; u, v, w speed vector components; $S(x,y,z,t)$ is the source or demand.

The term $S(x,y,z,t)$ is that which includes the influence of oxidization chemical reactions, as well as of biochemical damage reactions of organic matter, in the presence of oxygen supplied by aeration equipment, by means of a forced convection.

A complete solution of this equation, at which equations of movement and continuity have to be attached, is impossible to be obtained, due to the dependence of dispersion coefficients on flow condition, on the nature, form and size of the dispersed particles, as well as on physical properties of the media. We use simplified methods for this reason.

The turbulence contributes to sludge metabolic activity increase, together with the concentration of oxygen dissolved in the wastewater from the aeration tank. This turbulence maintains the active suspended sludge in the environment and has an important role - by mixing - for the contact between food, oxygen and micro organisms.

The equation of oxygen dispersion in water mass may be written in a form in which we introduce the expression of Nusselt number for Ox axis and Oy respectively^[5]:

$$\frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x}(\bar{u}\bar{C}) + \frac{\partial}{\partial y}(\bar{v}\bar{C}) = D_m Nux \frac{\partial^2 \bar{C}}{\partial x^2} + D_m Nuy \frac{\partial^2 \bar{C}}{\partial y^2} + S(x, y, t) \quad (2)$$

The use of Nusselt number allows the dimensionless process of terms, which considers the influence of turbulence intensity on transfer process.

The equation of oxygen dispersion in the aeration tank from the wastewater treatment plant is modified by considering the process of oxygen demand from mass water by micro organisms. The term which represents oxygen demand due to complex biological processes of nitrification and removal of organic matters is considered to be the following:

$$\mu_{mH} \frac{1-Y_H}{Y_H} \frac{S}{S+K_S} X_{BH} + \left(4,57-Y_A\right) \frac{\mu_{mA} X_{BA}}{Y_A} \frac{S_{NH}}{K_{NH} + S_{NH}} \quad (3)$$

where: 4,57 is oxygen requirement for the damage of a nitrous compound unit; μ_{mH} – maximum speed specific for heterotrophic increase; μ_{mA} – maximum speed specific for autotrophic increase; X_{BH} – active heterotrophic biomass; X_{BA} – active autotrophic biomass; K_S – saturation constant; S – substrate concentration; S_{NH} – biodegradable ammonia cal nitrogen; K_{NH} – saturation autotrophic coefficient of ammonium
Dispersion equation becomes:

$$\frac{\partial \bar{C}}{\partial t} + \frac{\partial}{\partial x}(\bar{u}\bar{C}) + \frac{\partial}{\partial y}(\bar{v}\bar{C}) = D_m Nux \frac{\partial^2 \bar{C}}{\partial x^2} + D_m Nuy \frac{\partial^2 \bar{C}}{\partial y^2} - \mu_{mH} \frac{I - Y_H}{Y_H} \frac{S}{S + K_s} X_{BH} \frac{C}{C_s} - \left(4.57 - Y_A\right) \frac{\mu_{mA} X_{BA}}{Y_A} \frac{S_{NH}}{K_{NH} + S_{NH}} \frac{C}{C_s} \quad (4)$$

Introducing the term of oxygen demand as a result of microbial activity – in the dispersion equation represents a novelty of modelling and simulation of organic matters damage process. In modelling this complex process we take into account the following: physical phenomenon of molecular transfer and a turbulent process of mass, dispersion of the gas diffused in the liquid medium, as well as aspects related to oxygen demand from the aqueous medium within the cellular metabolism. This model becomes near to the reality of the process which takes place in the aero-tank from the treatment phase.

Figures 1 and 2 show cases of equation numerical integration (4) by using the program FlexPDE, for an aeration tank with standard dimensions: length – L = 20 m and a height of 4 m.

Case A: Integrating equation (4), for the following parameters: $u=0.3$; $v=0.6$; $Nux=10$; $Nuy=100$; $Dm=0.203$; $S=1000$; $Ks=20$; $\mu_{mH}=0.6$; $\mu_{mA}=0.8$; $Y_H=0.67$; $Y_A=0.24$; $K_S=20$; $X_{BH}=2000$; $X_{BA}=1000$; $K_{NH}=1$; $S_{NH}=100$; $C_s=10$

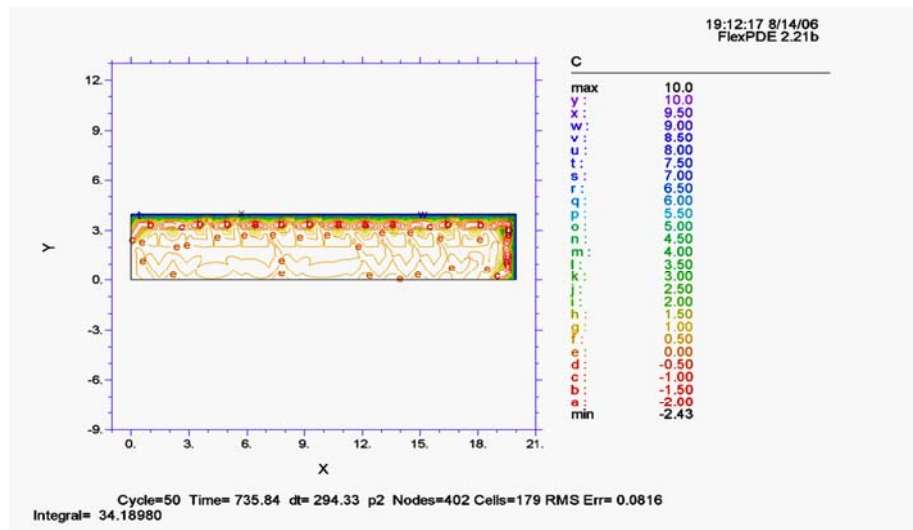


Fig. 1. In this case, oxygen demand is fast even at high values. This demand leads to concentration maintenance around zero in the aqueous medium from the aeration tank.

Case B: Integrating equation (4), for the following parameters: $u=0.2$; $v=0.8$; $N_{ux}=10$; $N_{uy}=1200$; $D_m=0.203$; $S=8000$; $K_s=20$; $\mu_{mH}=0.6$; $\mu_{mA}=0.8$; $Y_H=0.67$; $Y_A=0.24$; $K_S=20$; $X_{BH}=3000$; $X_{BA}=3000$; $K_{NH}=1$; $S_{NH}=100$; $C_S=10$

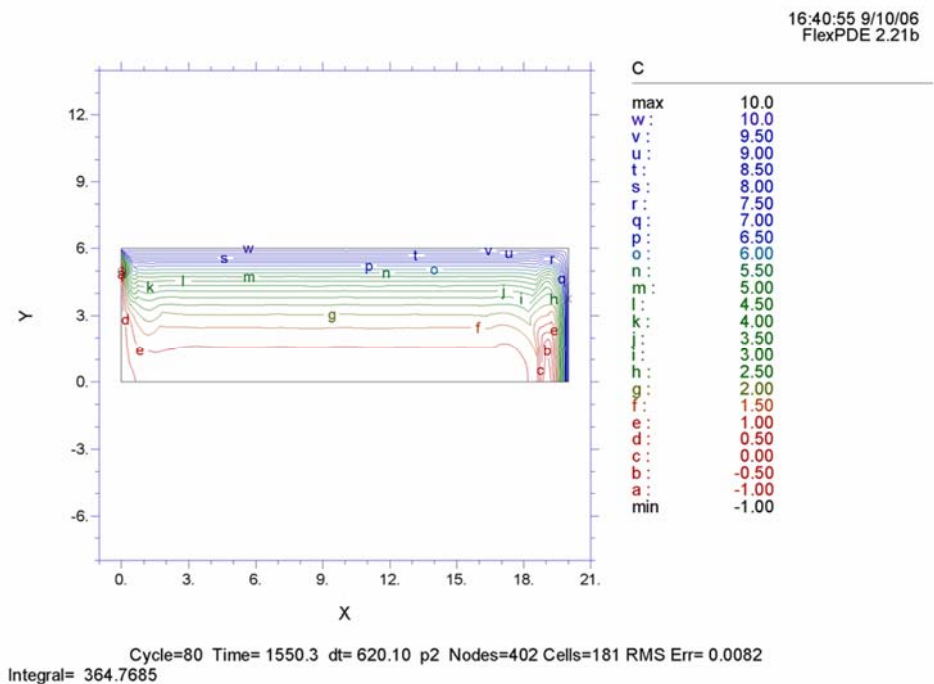


Fig. 2. The aeration equipment running is in accordance with the requirements and there is a correlation between geometrical parameters and physical and biochemical ones. A concentration of $0.5 \text{ mgO}_2/\text{l}$ of oxygen is present in the bottom region, but it is not a hazard for life and biological activity of the activated sludge.

3. Conclusions

Modelling and simulation of biological processes related to organic matters damage may be achieved and this paper presents the results obtained by numerical integration of equations specific for this process. They may be used for the automatic control and direction of these processes which rely directly upon physical, chemical and biochemical factor correlations.

The following aspects have the most important effect on the simulation of the dynamical evolution of transfer and dispersion process of oxygen from air into water in the presence of the demand due to organic matters:

- turbulence intensity generated by the ascent movement of air bubbles through the water mass which leads to higher dispersion coefficients and higher values of Nusselt number;

- oxygen demand due to metabolism reactions of aerobe bacteria from the activated sludge – this term represents the final part of the dispersion equations;

- aeration intensity, simulated by means of values imposed to the condition at limit on the grating of the rectangular aeration tank;

The above-mentioned models represent the author's contribution and they were drawn up in order to predict values related to the biochemical treatment of wastewater.

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