USD 628.35

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ABOUT THE OXYGEN INFLUENCE ON THE EFFICIENCY OF THE WASTEWATERS TREATMENT FROM ORGANIC POLLUTIONS IN BIOREACTORS

Introduction

In biological wastewater treatment reactors in particular in aerotanks the removal of organic contaminants (OC) occurs in aerobic conditions that is when oxygen is consumed for biooxidation of OC and self-oxidation of cell material and also used in other processes that may occur at this time. Therefore, the modeling and development of the aeration system consist in providing such an oxygen regime in the reactor in which the rate of the biological treatment process should not be limited by the amount of oxygen contained in the reactor. In such reactors the processes of dissolution and consumption of oxygen occur simultaneously and are interconnected and under normal conditions OC removal occurs only at the expense of suspended biocenosis (active sludge).

Main Part

In this paper the peculiarities that occur in the modeling of the oxygen regime at the aerobic biological treatment of the wastewaters in aerotanks with suspended and fixed biocenosis are considered.

The aim of the work is to develop the mathematical model for evaluation and analyze of the oxygen regime in aerotanks-mixers and aerotank-displasers under given conditions on the base of corresponding equations of the material balance recorded relative to the concentration of oxygen C.

To achive the goal the following prerequisites were taken into account:

- the limiting cases of aerotanks work in the system of biological wastewaters treatment were considered;
- at evaluation of the removal of the OC the linear kinetics of reactions of the first and the zero orders according to Monod were used

The removal of organic contaminants by suspended and fixed biocenosis in aerotanks must ensure uninterrupted supply of oxygen for growth and livelihoods of the microorganisms and control of its consumption in the amount necessary to maintain the kinetics of reactions with a high rate of utilization of OC in the given conditions of the aerobic process. The proposed models are as

- for aerotank - mixer

$$W_p \frac{\partial C_a}{\partial t} = Q_a (C_0 - C_a) + W_p \alpha K_C a (\beta C_p - C_a) - F_{\delta_l} N_c - R_{a_c} W_p, \tag{1}$$

- and for the aerotank – displacer

$$\varepsilon \frac{\partial C_a}{\partial t} = D_c \frac{\partial^2 C_a}{\partial x^2} - v \frac{\partial C_a}{\partial x} + \varepsilon \alpha K_C a (\beta C_p - C_a) - \frac{F_{\delta_l}}{W_p} N_c - R_{a_c}, \tag{2}$$

$$R_{a_c} = R_{c_a} + R_{c_c}.$$

In practical calculations it is enough to consider equations (1)-(2) in stationary conditions and to evaluate their members taking into account the known diffusion criterion of Peckle $Pe = \frac{vl}{D_c}$ according to [1,7,8,9,10].

In the above equations in the general case the value of the flow of oxygen entering into the biofilm through its surface is determined by the equation:

$$N_c = -D_c \frac{dC}{dz} = (1-\eta) K_C \left(C_a - C|_{z=0}\right) + \eta \alpha K_{Cn} \left(\beta C_p - C|_{z=0}\right), \tag{3}$$

where η – the ratio of the surface area of the biofilm when in contact with air bubbles to the total surface area of the biofilm.

In other words, the equation (3) takes into account the possible additional flow of oxygen into a biofilm both from the volume of liquid in the form of dissolved oxygen and as a result of the so-called inter-surface transfer (IST) directly from the bubbles adhered to the biofilm. In the case when $\eta = 0$ the flow of dissolved oxygen from the volume of liquid to the biofilm due to diffusion [1,2,5,6]:

$$N_C = -D_C \frac{dC}{dz} = K_C \left(C_a - C|_{z=0}\right). \tag{4}$$

Note that the determination of the flow of oxygen through the surface of the biofilm N_c is as a result of solving the following equation which characterize the consumption of oxygen in the removal of OC by a fixed biocenose (biofilm):

$$\frac{\partial C}{\partial t} = D_C \frac{\partial^2 C}{\partial z^2} - R_C \tag{5}$$

So, for practical calculations the solution of equation (5) is sufficient to solve for stationary conditions that occur fairly quickly that is when $\frac{\partial C}{\partial t} = 0$.

The solution of equation (5) is performed under the following boundary conditions, namely: N_c = 0 for $z = 0$, and $\frac{\partial C}{\partial z} = 0$ for z = δ which allows us to determine the change in the concentration of oxygen in the thickness of the biofilm l and in subsequent calculations for determination of the concentration on the surface of the biofilm $C|_{z=0} = C\delta$

In the above equations and dependencies C, C_δ, C_a, C_0 – are respectively the concentration of oxygen in the biofilm, on the surface of the biofilm, in the aerotank and in the wastewaters at the entrance to the aerotank; C_p – concentration of saturation (soluble) oxygen in the liquid; R_c, R_{a_c} – the rate of reactions of using oxygen in a biofilm and aerotanks, taking into account the oxidation velocity of the isolated substances during the death of microorganisms; W_a, w_p, W_δ – respectively the aerotanks working volume, the volume of the liquid in the aerotank, the volume of the elements of the established loading with the fixed biocenose; $F_{\delta l}$, F_δ – respectively the total surface area of the biofilm in the aerotank (reactor) and the surface area of the oxygen in the biofilm; $K_C a$, K_{cn}, K_C – respectively the volumetric mass transfer coefficient, the coefficient between the surface transfer of oxygen in biofilm, mass transfer coefficient of oxygen in liquid film [1,3,4,7,8].

Thus, the implementation of the proposed models allows with known geometric and other characteristics of biofilm to evaluate the influence of oxygen regime on the processes of treatment in aerotanks in different conditions of their operation and to substantiate an economical and efficient technological supply system with oxygen taking into account the features of extraction of OC in aerotanks with suspended and fixed biocenosis. In this case it is possible to substantiate the criteria in which the biochemical oxidation process will be adequately supplied with oxygen that is will not limit on the kinetics of biooxidation both suspended and fixed biocenosis [1,2,7,9,10,11].

Conclusions

In a result of conducted analysis, it is possible to make the conclusion that the removal of organic pollutions and others ones may be improved substantially in the different bioreactors by the arranging of the fixed biocenosis as a biofilm with the high microorganism’s concentration. For solution of the wastewater’s problems the bioreactors-mixers and bioreactors-displaser are used in many cases now in which the removal of organic pollutions is realized by the suspended biocenosis and using of the additionally biofilm technology allows to increase the efficiency of the exploitation of given types constructions at the wastewater’s treatment. Development of the calculative methodic of the parameters of the joint wastewaters treatment by biofilm will be most substantiated if it based on the general mathematical model’s realization. At creation of the such models it is necessary in first to take into account on the heterogeneous structure of biofilm, its dimensions, oxygen regime and correspond balance equations of kinetic reactions. During the valuation of the oxygen influence on the oxidation process ammonium to nitrate the relation O_2/ $N\text{-}NH_4$ is proposed. This parameter is the better alternative of the control at nitrification in the bioreactor in comparison with oxygen concentration. Oxygen is the main parameter which controls and limits nitrification in biofilm. If the values of given relation in the different points of biofilm is 0.05-0.1 then the conversion about 80% of ammonium to nitrite have a place. Using of the proposed relation at the practical calculations allows to regulate the wastewaters treatments processes and to improve the efficiency of bioreactors exploitation.

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