Modelling of biological purification process taking into account the temperature mode

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***Abstract* —** A mathematical model of the biological purification process is developed, taking into account the interaction of bacteria, organic and biologically non-oxidising substance in the conditions of diffusion, mass exchange disturbances and different temperature modes. An algorithm for solving the nonlinearly perturbed task "convection-diffusion-heat-mass-exchange" was elaborated. A computer experiment on the basis of the received algorithm was conducted. The influence of the concentration of oxygen and active sludge on the quality of the purification process as well as the mutual influence among heat and mass processes is shown. The possibility of automated control of the process for efficient purification of a biological filter taking into account the initial data of the wastewater is expected within the framework of this model

***Keywords* —** Mathematical model, asymptotics, singular perturbation, small parameter, biological purification, temperature mode

I. INTRODUCTION

DOMESTIC waste water contains mineral and organic pollutions, while industrial ones differ both by composition and concentration, depending on the region. Any type of waste water needs to be purified, because it contains pollutants that significantly exceed the permissible concentration levels. Filter systems that provide allowable concentrations of pollution are used to prevent the harmful effects of impurities on the environment [1-5].

A lot of research devoted to simulation and automation of biochemical wastewater treatment was conducted in recent years. These studies have considerably expanded the concept of water treatment, heat and mass transfer, the influence of variable parameters which are necessary for automatic control.

Wastewater purification is considered in some models as a technological process with details of mechanical constructions without taking into account the dynamic of changes of effective operation of the filter in time. In others interconnections of active sludge and impurities are considered without taking into account interacting parameters. In some studies a set of equations do not take into account the interplay among parameters which is clearly expressed in experiments and plays an important role [6-10].

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Moreover most of the existing works do not take into account the influence of the fluid temperature, which is one of the main factor influencing processes[11-15].

So the main purpose of this work is to develop a mathematical model of the purification process of wastewater, which takes into account the interaction of bacteria, active sludge and impurities, as well as temperature modes. The next step is to study this model with the help of computer simulation to get the optimal parameters of the technological process.

The proposed method and the algorithm allow to take into account the influence of various perturbations and temperature modes. This provides a possibility to carry out automated control of the process for effective precipitation of impurities in a biological filter depending on the initial data of the wastewater.

II. STATEMENT OF THE PROBLEM

Consider the process of liquids purification from organic pollutions by addition of the biological bacteria. According to literary sources [16-22] there are such stages of wastewater purification from pollution:

- decomposition of organic contamination by bacteria;
- growth and death of bacteria;
- production of "young" bacteria by an active sludge;
- transformation of impurities to a non-biologically non-oxidizing substance.

To describe the dynamics changes of pollution concentration, taking into account the influence of active sludge on the absorption of impurities, the following equation is used [20, 22]:

$$\frac{\partial C}{\partial t} = v_C \frac{\partial C}{\partial x} - \beta CB + w_C + D_C \frac{\partial^2 C}{\partial x^2}, \qquad (1)$$

where $\beta = \frac{Q \cdot (1+k_i)}{V}$ –a coefficient that takes into account the construction features of the filter and the flow rate of the liquid, C – concentration of pollution in water, V – volume of filter, k_i – coefficient of recirculation of active sludge, w_C – absorption rate of the substrate according to the adequacy of the model, v_C – velocity of substrate movement, D_C – diffusion coefficient ($D_C = d_C\varepsilon$).

Taking into account the bacteria move with the contaminated material in the porous environment, and also settle down in the lower part of the filter as an active sludge, we get the next equation for the growth, dying and transferring bacteria taking into account the biological requirement for oxygen:

$$\frac{\partial B}{\partial t} = v_B \frac{\partial B}{\partial x} + \beta BK \cdot K_B + w_B + D_B \frac{\partial^2 B}{\partial x^2}, \qquad (2)$$

where B – concentration of active sludge, K_B – absorption coefficient of oxygen and bacteria, w_B – the rate of accumulation of active sludge according to the adequacy of the model, v_B – velocity of active silt, D_B – diffusion coefficient ($D_B = d_B\varepsilon$)).

To improve the efficiency of the process and ensure optimal living conditions of bacteria additional oxygen submition is provided. The equation describing the dynamics of this process has the following form:

$$\frac{\partial K}{\partial t} = v_K \frac{\partial K}{\partial x} + \beta K + K_K \cdot C \cdot (K_0 - K) + w_K + D_K \frac{\partial^2 K}{\partial x^2}, \qquad (3)$$

where K – the oxygen concentration which is necessary to maintain the best bacterial absorption of contamination, K_K – coefficient of mass transfer of oxygen, K_0 – concentration of water saturation with oxygen at given temperatures and pressures, w_K – the rate of absorption of the oxygen substrate, v_K – oxygen flow rate, D_K – diffusion coefficient ($D_K = d_K\varepsilon$).

Since the processes occurring in the reactor release energy, we use equations for describing the changing of the temperature dynamics of the water environment:

$$\frac{\partial T}{\partial t} = D_T \frac{\partial^2 T}{\partial x^2} - v_T \frac{\partial T}{\partial x} + K_T CB; \qquad (4)$$

where K_T – coefficient of energy releasing from the purification process, v_T – heat transfer rate, D_T – diffusion coefficient ($D_T = d_T\varepsilon$)).

Where ε, K_B, K_B^0, K_K, K_K^0, K_T, d_c d_B, d_K, d_T – solid parameters (characterize the corresponding soft parameters $K_B(B)$, $K_K(B)$ etc.), are found in an experimental way, ε – small parameter (it characterizes the prevailing of some parts of the process over other, in particular, the phenomena of intercomponent interaction and diffusion of this process are small in comparison with others).

The set of differential equations (1), (2), (3) i (4) describes the changes of the concentrations of bacteria, pollution, oxygen and temperature in the biological filter. Various interactions between the characteristics of the environment and the process should be taken into account by introducing coefficients into the corresponding equations. This gives a possibility to analyze the processes taking place in the bio-reactor as a set of interconnected influences. There is always some delays caused by certain causes in real systems. In this case, the transfer of contaminated material requires a certain amount of time. Further we will assume that any change of external factors, for example, an increase of the pollution concentration or bacteria, occurs only after some time (time of delay $\tau > 0$). Proceeding from the above, we get the next model problem:

$$\begin{cases} \dfrac{\partial C}{\partial t} = D_C \dfrac{\partial^2 C}{\partial x^2} - v_C \dfrac{\partial C}{\partial x} - \beta TCB, \\ \dfrac{\partial B}{\partial t} = D_B \dfrac{\partial^2 B}{\partial x^2} - v_B \dfrac{\partial B}{\partial x} + K_B(B) TK, \\ \dfrac{\partial K}{\partial t} = D_K \dfrac{\partial^2 K}{\partial x^2} - v_K \dfrac{\partial K}{\partial x} + K_K(B) \cdot (K_H - K) - \gamma(T), \\ \dfrac{\partial T}{\partial t} = D_T \dfrac{\partial^2 T}{\partial x^2} - v_T \dfrac{\partial T}{\partial x} + K_T CB; \end{cases} \qquad (5)$$

$$C|_{x=0} = C_*^*(t),\ B|_{x=0} = B_*^*(t),\ K|_{x=0} = K_*^*(t),\ T|_{x=0} = T_*^*(t),$$
$$\left.\frac{\partial C}{\partial x}\right|_{x=l} = 0, \left.\frac{\partial B}{\partial x}\right|_{x=l} = 0, \left.\frac{\partial K}{\partial x}\right|_{x=l} = 0, \left.\frac{\partial T}{\partial x}\right|_{x=l} = 0; \qquad (6)$$
$$C|_{t=0} = C^*(x),\ B|_{t=0} = B^*(x), K|_{t=0} = K^*(x),\ T|_{t=0} = T^*(x),$$

where l – the length of the bio-reactor, $C_*^*(t)$, $B_*^*(t)$, $K_*^*(t)$, $T_*^*(t)$, $C^*(x)$, $B^*(x)$, $K^*(x)$, $T^*(x)$ –a differentiable function is given a sufficient number of times, coordinated in the angular points of the area $G = \{(x,t) : 0 < x < l, 0 < t < t_* < \infty\}$.

III. Methods.

Methods of mathematical physics and hydrodynamics were used to build mathematical models of processes of water treatment in which some components dominate others - numerical-asymptotic methods; refinement methodology known classical models by going to the appropriate "perturbed" problems, thus preserving the classic form of laws that describe the processes of fluid flow in porous media, and the construction of their solutions without starting "first" supplement known "unperturbed" solution by various amendments.

IV. Asymptotic behavior of the solution

Solution of the problem (5)-(6) with accuracy $O(\varepsilon^{n+1})$ are sought in the form of asymptotic series by the power of a small parameter ε:

$$C(x,t) = C_0(x,t) + \sum_{i=1}^{n} \varepsilon^i C_i(x,t) + \sum_{i=0}^{n+1} \varepsilon^i \tilde{C}_i(\tilde{\xi},t) + R_C(x,t,\varepsilon), \qquad (7)$$

$$B(x,t) = B_0(x,t) + \sum_{i=1}^{n} \varepsilon^i B_i(x,t) + \sum_{i=0}^{n+1} \varepsilon^i \tilde{B}_i(\tilde{\xi},t) + R_B(x,t,\varepsilon), \qquad (8)$$

$$K(x,t) = K_0(x,t) + \sum_{i=1}^{n} \varepsilon^i K_i(x,t) + \sum_{i=0}^{n+1} \varepsilon^i \tilde{K}_i(\tilde{\xi},t) + R_K(x,t,\varepsilon), \qquad (9)$$

$$T(x,t) = T_0(x,t) + \sum_{i=1}^{n} \varepsilon^i T_i(x,t) + \sum_{i=0}^{n+1} \varepsilon^i \tilde{T}_i(\tilde{\xi},t) + R_T(x,t,\varepsilon), \qquad (10)$$

where R_B, R_K, R_C, R_T – reminders, $C_i(x,t)$, $B_i(x,t)$, $K_i(x,t)$, $T_i(x,t)$ ($i = \overline{0,n}$) – regular part of the asymptotics, $\tilde{C}_i(\tilde{\xi},t)$, $\tilde{B}_i(\tilde{\xi},t)$, $\tilde{K}_i(\tilde{\xi},t)$, $\tilde{T}_i(\tilde{\xi},t)$ ($i = \overline{0,n+1}$) – function of the borderline type (correspondingly amendments at the output of purified substance), $\tilde{\xi} = (L - x) \cdot \varepsilon^{-1}$ – corresponding transformations.

As a result of substitution (7)-(10) into the system (5)-(6) and using of the standard "equalization procedure" we'll get such tasks for definition of function $C_i(x,t)$, $B_i(x,t)$, $K_i(x,t)$, $T_i(x,t)$ ($i=\overline{0,n}$):

$$\begin{cases} \frac{\partial C_0}{\partial t} = -v_C\frac{\partial C_0}{\partial x} - \beta T_0 C_0 B_0, \\ \frac{\partial B_0}{\partial t} = -v_B\frac{\partial B_0}{\partial x} + \beta K_B T_0 K_0, \\ \frac{\partial K_0}{\partial t} = -v_K\frac{\partial K_0}{\partial x} + \beta K_K\cdot(K_H - K_0), \\ \frac{\partial T_0}{\partial t} = -v_C\frac{\partial T_0}{\partial x}; \\ C_0\big|_{x=0} = C_*^*(t),\ B_0\big|_{x=0} = B_*^*(t),\ K_0\big|_{x=0} = K_*^*(t), T_0\big|_{x=0} = T_*^*(t), \\ \frac{\partial C_0}{\partial x}\Big|_{x=l} = 0, \frac{\partial B_0}{\partial x}\Big|_{x=l} = 0, \frac{\partial K_0}{\partial x}\Big|_{x=l} = 0, \frac{\partial T_0}{\partial x}\Big|_{x=l} = 0, \\ C_0\big|_{t=0} = C^*(x),\ B_0\big|_{t=0} = B^*(x), K_0\big|_{t=0} = K^*(x),\ T_0\big|_{t=0} = T^*(x); \end{cases}$$

$$\begin{cases} \frac{\partial C_i}{\partial t} = d_C\frac{\partial^2 C_{i-1}}{\partial x^2} - v_C\frac{\partial C_i}{\partial x} - \beta T_i C_i B_i, \\ \frac{\partial B_i}{\partial t} = d_B\frac{\partial^2 B_{i-1}}{\partial x^2} - v_B\frac{\partial B_i}{\partial x} - K_B^0 B_{i-1}K_i + \beta K_B K_i, \\ \frac{\partial K_i}{\partial t} = d_K\frac{\partial^2 K_{i-1}}{\partial x^2} - v_K\frac{\partial K_i}{\partial x} - K_i\left(\beta K_K + \beta K_K^0 B_{i-1}\right) + \beta K_K K_H + \beta K_K^0 B_{i-1}K_H - \gamma(T_i), \\ \frac{\partial T_i}{\partial t} = d_T\frac{\partial^2 T_{i-1}}{\partial x^2} - v_T\frac{\partial T_i}{\partial x} + K_T C_{i-1}B_{i-1}; \\ C_i\big|_{x=0} = 0,\ B_i\big|_{x=0} = 0,\ K_i\big|_{x=0} = 0, T_i\big|_{x=0} = 0, C_i\big|_{t=0} = 0,\ B_i\big|_{t=0} = 0, K_i\big|_{t=0} = 0, T_i\big|_{t=0} = 0. \end{cases}$$

As a result of it's solution we got:

$$T_0(x,t) = \begin{cases} T_*^*\left(t - \frac{x}{v_T}\right),\ t > \frac{x}{v_T}, \\ T^*(x - v_T t),\ t \le \frac{x}{v_T}, \end{cases}$$

$$K_0(x,t) = \begin{cases} \frac{\beta K_K K_H}{v_K} e^{\frac{\beta K_K x}{v_K}}\cdot\int_0^x e^{-e^{\frac{\beta K_K \tilde{x}}{v_k}}}\tilde{x}d\tilde{x} + K_*^*\left(t - \frac{x}{v_K}\right),\ t > \frac{x}{v_K}, \\ \beta K_K K_H e^{\beta K_K t}\cdot\int_0^t e^{-e^{\beta K_K \tilde{t}}}\tilde{t}d\tilde{t} + K^*(x - v_K t),\ t \le \frac{x}{v_K}, \end{cases}$$

$$B_0(x,t) = \begin{cases} \frac{\beta K_B}{v_B}\int_0^x K_0\left(\tilde{x}, \frac{1}{v_B}(\tilde{x} - x + v_B t)\right)d\tilde{x} + B_*^*\left(t - \frac{x}{v_B}\right),\ t > \frac{x}{v_B}, \\ \beta K_B\int_0^t K_0\left(x - v_B(t - \tilde{t}), \tilde{t}\right)d\tilde{t} + B^*(x - v_B t),\ t \le \frac{x}{v_B}, \end{cases}$$

$$C_0(x,t) = \begin{cases} C_*^*\left(t - \frac{x}{v_C}\right)\cdot e^{-\frac{\beta\int_0^x B_0\left(\tilde{x}, \frac{1}{v_C}(\tilde{x} - x + v_C t)\right)d\tilde{x}}{v_C}},\ t \ge \frac{x}{v_C}, \\ C^*(x - v_C t)\cdot e^{-\beta\int_0^x B_0\left(x - v_C(t-\tilde{t}), \tilde{t}\right)d\tilde{t}},\ t < \frac{x}{v_C}, \end{cases}$$

$$T_i(x,t) = \begin{cases} \frac{1}{v_T}e^{\frac{\int_0^x \tilde{\tilde{T}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_T}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_T}}\cdot\int_0^x e^{-\frac{\int_0^x \tilde{\tilde{T}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_T}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_T}}\tilde{T}_i\left(\tilde{x}, t + \frac{1}{v_T}(\tilde{x} - x)\right)d\tilde{x},\ t > \frac{x}{v_T}, \\ e^{\int_0^t \tilde{\tilde{T}}_i\left(v_T(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\cdot\int_0^t e^{-\int_0^{\tilde{t}} \tilde{\tilde{T}}_i\left(v_T(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\tilde{T}_i\left(v_T(\tilde{t} - t) + x, \tilde{t}\right)d\tilde{t}, t \le \frac{x}{v_T}, \end{cases}$$

$$K_i(x,t) = \begin{cases} \frac{1}{v_K}e^{\frac{\int_0^x \tilde{\tilde{K}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_K}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_K}}\cdot\int_0^x e^{\frac{\int_0^{\tilde{x}} \tilde{\tilde{K}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_K}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_K}}\tilde{K}_i\left(\tilde{x}, t + \frac{1}{v_K}(\tilde{x} - x)\right)d\tilde{x},\ t > \frac{x}{v_K}, \\ e^{\int_0^t \tilde{\tilde{K}}_i\left(v_K(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\cdot\int_0^t e^{-\int_0^{\tilde{t}} \tilde{\tilde{K}}_i\left(v_K(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\tilde{K}_i\left(v_K(\tilde{t} - t) + x, \tilde{t}\right)d\tilde{t}, t \le \frac{x}{v_K}, \end{cases}$$

$$B_i(x,t) = \begin{cases} \frac{1}{v_B}\int_0^x \tilde{B}_i\left(\tilde{x}, \frac{1}{v_B}(\tilde{x} - x + v_B t)\right)d\tilde{x},\ t > \frac{x}{v_B}, \\ \int_0^t \tilde{B}_i\left(x - v_B(t - \tilde{t}), \tilde{t}\right)d\tilde{t},\ t \le \frac{x}{v_B}, \end{cases}$$

$$C_i(x,t) = \begin{cases} \frac{1}{v_C}e^{\frac{\int_0^x \tilde{\tilde{C}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_C}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_C}}\cdot\int_0^x e^{\frac{\int_0^{\tilde{x}} \tilde{\tilde{C}}_i\left(\tilde{\tilde{x}}, t + \frac{1}{v_C}(\tilde{\tilde{x}} - x)\right)d\tilde{\tilde{x}}}{v_C}}\tilde{C}_i\left(\tilde{x}, t + \frac{1}{v_C}(\tilde{x} - x)\right)d\tilde{x},\ t > \frac{x}{v_C}, \\ e^{\int_0^t \tilde{\tilde{C}}_i\left(v_C(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\cdot\int_0^t e^{-\int_0^{\tilde{t}} \tilde{\tilde{C}}_i\left(v_C(\tilde{\tilde{t}} - t) + x, \tilde{\tilde{t}}\right)d\tilde{\tilde{t}}}\tilde{C}_i\left(v_C(\tilde{t} - t) + x, \tilde{t}\right)d\tilde{t}, t \le \frac{x}{v_C}, \end{cases}$$

where $\tilde{\tilde{T}}_i = K_T C_{i-1}B_{i-1}$, $\tilde{\tilde{K}}_i = \beta K_K + \beta K_K^0 B_{i-1}$, $\tilde{\tilde{C}}_i = \beta T_i B_i$, $\tilde{T}_i = d_T\frac{\partial^2 T_{i-1}}{\partial x^2}$, $\tilde{C}_i = d_C\frac{\partial^2 C_{i-1}}{\partial x^2}$, $\tilde{K}_i = d_K\frac{\partial^2 K_{i-1}}{\partial x^2} + \beta K_K K_H + \beta K_K^0 B_{i-1}K_H - \gamma(T_i)$, $\tilde{B}_i = d_B\frac{\partial^2 B_{i-1}}{\partial x^2} - K_B^0 B_{i-1}K_i + \beta K_B K_i$. Functions $\tilde{C} = \sum_{i=0}^{n+1}\tilde{C}_i\varepsilon^i$, $\tilde{B} = \sum_{i=0}^{n+1}\tilde{B}_i\varepsilon^i$, $\tilde{K} = \sum_{i=0}^{n+1}\tilde{K}_i\varepsilon^i$, $\tilde{T} = \sum_{i=0}^{n+1}\tilde{T}_i\varepsilon^i$ intended to eliminate "inconsistencies", which were brought with regular parts $C(x,t) = \sum_{i=0}^{n}C_i\varepsilon^i$, $B(x,t) = \sum_{i=0}^{n}B_i\varepsilon^i$, $K(x,t) = \sum_{i=0}^{n}K_i\varepsilon^i$, $T(x,t) = \sum_{i=0}^{n}T_i\varepsilon^i$ in the point neighborhood $x = L$ (output of filtration flow), that is, ensure fulfillment of the condition:

$$\frac{\partial}{\partial x}\left(C+\tilde{C}\right)=O\left(\varepsilon^{n+1}\right),\qquad \frac{\partial}{\partial x}\left(B+\tilde{B}\right)=O\left(\varepsilon^{n+1}\right),$$

$$\frac{\partial}{\partial x}\left(K+\tilde{K}\right)=O\left(\varepsilon^{n+1}\right),\ \frac{\partial}{\partial x}\left(T+\tilde{T}\right)=O\left(\varepsilon^{n+1}\right).$$

To find these functions, we have problems analogous to [16-20]. The residual members are estimated similarly to [20].

It is enough to take 3-4 members of each asymptotic series to obtain approximate solutions with the accuracy of up to 4 significant digits in the interval of the filtration cycle time as it was expected.

V. Results of Numerical Calculations

Here are the results of a numerical experiment with $C|_{t=0}=1\,mg/l$, $B|_{t=0}=35\mathrm{e}^{x}\ g/l$, $K|_{t=0}=0.1\,g/l$, $T|_{t=0}=0.1\,^{\circ}C$, $Q=7.2\,m^3/h$, $V=0.7\,m^3$, $k_i=0.5$, $K_C=0.001\,h^{-1}$, $K_X=100\,h^{-1}$, $K_B^0=K_K^0=1$, $C_0=6\,mg/l$, $v_C=1.26\,m/h$, $v_B=1.92\,m/h$, $v_K=1.26\,m/h$, $v_T=1.53\,m/h$, $d_C=0.721$, $d_B=d_K=d_T=10^{-3}$, $\varepsilon=0.01$ (fig.1 – fig.8).

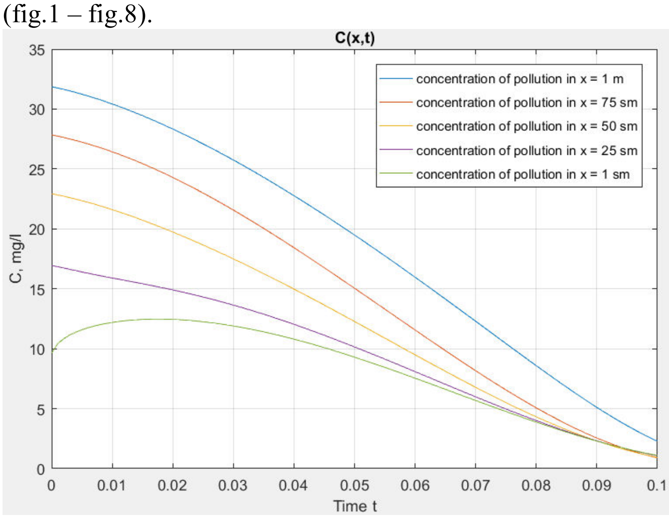

Fig. 1. Changes of the concentration of pollution by the time at different points of the filter

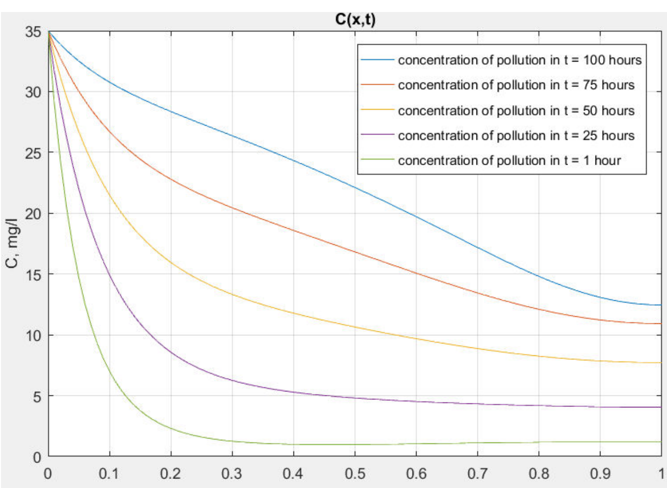

Fig. 2. Changes of the concentration of pollution by the length of the filter at different times

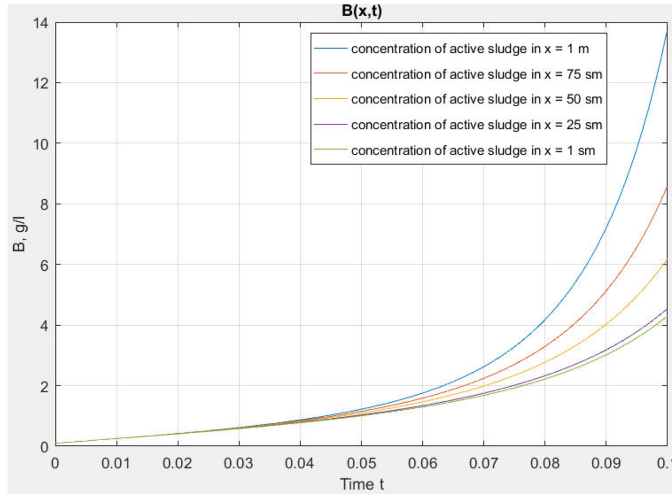

Fig 3. Changes of the concentration of active sludge by the time at different points of the filter

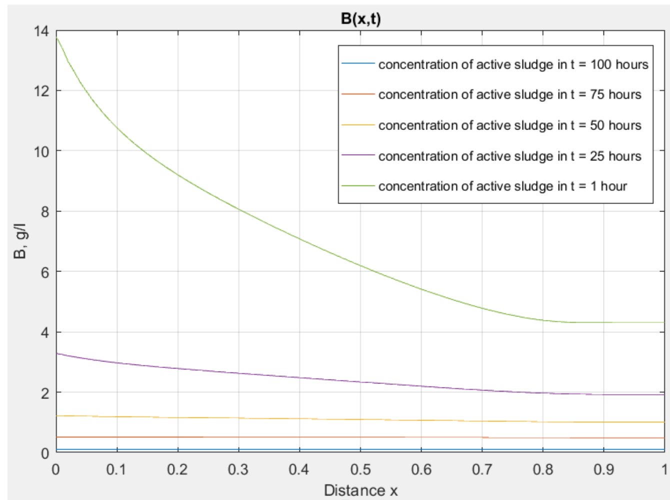

Fig 4. Changes of the concentration of active sludge by the length of the filter at different times

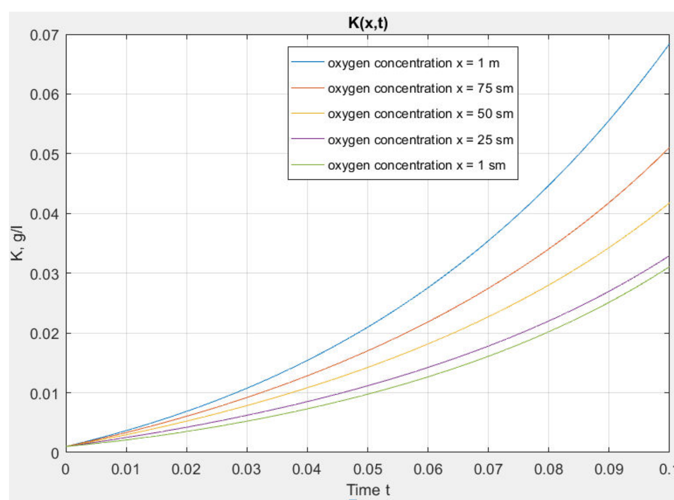

Fig 5. Changes of oxygen concentration by the length of the filter at different times

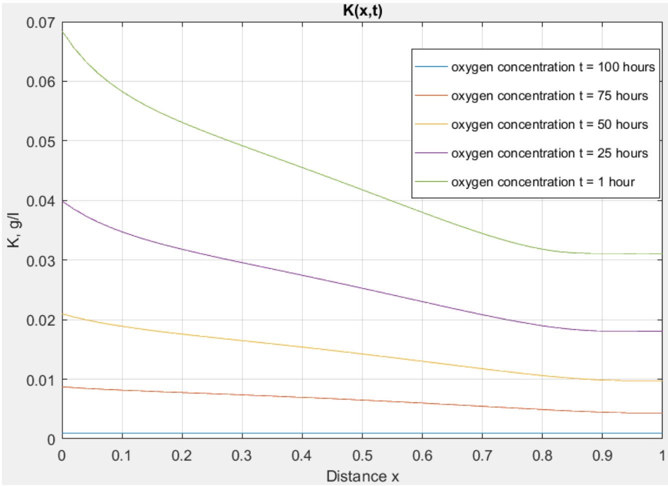

Fig 6. Changes of oxygen concentration by the length of the filter at different times

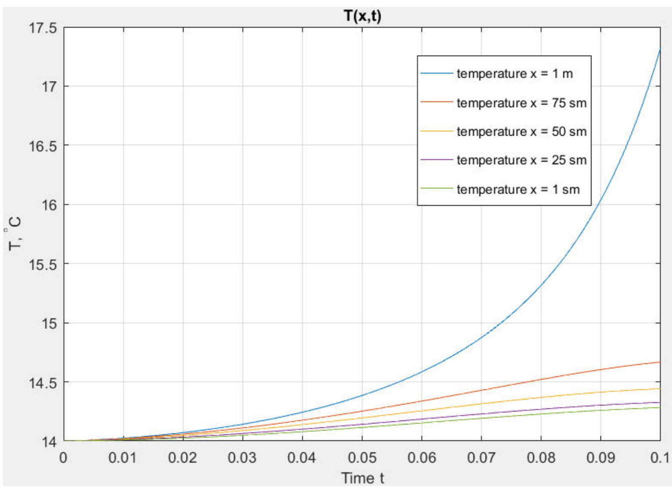

Fig 7. Dynamics of temperature of water environment by the length of the filter at different calculation points

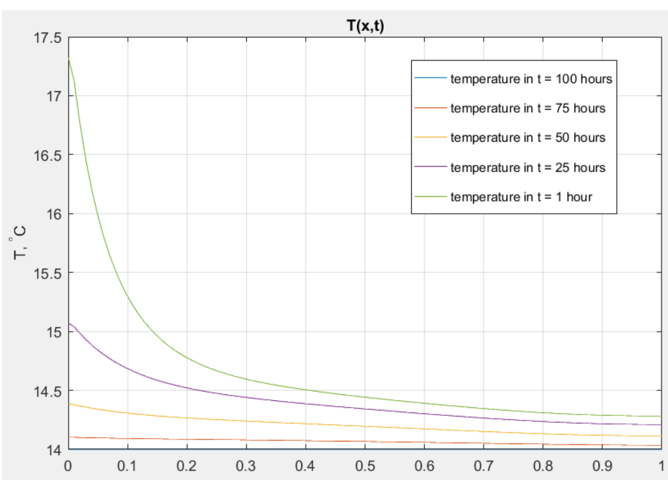

Fig 8. Dynamics of temperature of water environment by the length of the filter at different times

The results of the computer experiment reflect the character of the dynamics of functions by the time at the different points of the filter and by the length of the filter at different times. Fig. 1-2 demonstrate changes of the concentration of impurity particles by the time and in different points of the filter respectively. As shown in Fig. 3-4 the concentration of active sludge along the filter increases with time. This is due to the fact that favorable conditions for the reproduction of bacteria are created. These are: constant flow impurities and controlled supply of oxygen. Fig. 5-6 show change in the concentration of impurities, which eventually decreases. Fig. 7-8 demonstrate dynamics of temperature of wastewater by the length of the filter at different calculation points and times respectively. This confirms the effective operation of the filter. But at the early stage of purification at the outlet of the filter the required amount of bacteria and oxygen is not reached. This leads to an increase in the concentration of contamination. As expected, the rate of biochemical processes of wastewater purification depends to a large extent on the temperature of the environment.

VI. Conclusions

The new mathematical model and method of its solving for processes of aerobic wastewater purification was developed. It takes into account the interaction of bacteria, organic and biologically non-oxidant substances under the influence of the temperature modes in conditions of diffusion and mass exchange disturbances. The model provides a more profound predict of the technological processes. The proposed method and the algorithm allows to take into account various kinds of perturbations. It provides a possibility to take into account small inverse influence of the characteristics of the process on the environment by various kinds of corrections to the basic characteristics without starting the solution of the problem each time from the beginning. This gives a possibility to parallelize the computation. Based on this a computer experiment was conducted. As a result numerical characteristics of the influence of the concentration of oxygen and activated sludge on the quality of the purification process were obtained. Within the framework of this model, it is possible to develop automatic control system of the process for efficient purification of a biological filter taking into account the initial data of the wastewater.

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