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# CFD SIMULATION OF THE WATER PURIFICATION IN THE HORISONTAL SETTLER

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**Introduction**. The main operation in many wastewater treatment plants for the purification of industrial and domestic sewage is the activated sludge process in biological reactors or secondary settling tanks (SSTs). In practice the horizontal settlers are used for waste waters treatment at the different enterprises. Despite a century of usage and experience, the sedimentation process in the SST is still a challenge in modeling the full-scale operation of wastewater treatment plants (WWTPs). Most commercial simulators for the SST do not provide reliable simulation models in the sense that there is no guarantee that the simulation satisfy fundamental physical properties under under all conditions. From a practical point of view, current SST simulation models tend to be inaccurate.

**Literature review.** In Ukraine to calculate the process of the waste waters purification in settlers the empirical models are widely used. These models do not take into account the geometrical form of the settler and the peculiarities of the sedimentation process. [3,5,6]. Therefore, it is important to develop CFD models having more capabilities to simulate the process of the waste waters treatment in settlers [1,2] .

**The purpose**. The main objective of this paper is the development of the effective CFD model which is more effective than the employed in Ukraine models and which can be used for prediction of the horizontal settler efficiency.

Modeling equations. To simulate the process of the water purification in the horizontal settler the transport equation (1) is used [1, 2]:

$$\frac{\partial C}{\partial t}+\frac{\partial uC}{\partial x}+\frac{\partial (v-w)C}{\partial y}+\sigma C=\frac{\partial}{\partial x}\left(\mu_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_y\frac{\partial C}{\partial y}\right) \qquad (1)$$

where $C$ is the concentration; $u$, $v$, are the velocity components in $x$, $y$ direction respectively;

$w$ – is the speed of the gravity fallout;

$\sigma$ is the parameter taking into account the process of flocculation and decay;

$\mu_x$ , $\mu_y$ , are the coefficients of turbulent diffusion in x, y direction respectively;

$x_i$ , $y_i$ , are the Cartesian coordinates;

The transport equation is used with the following boundary conditions [1,2,4]:

– inlet boundary: $C|_{inlet}=C_E$ , where $C_E$ is the known concentration ( in the case study of this paper it is dimensionless and equal to $C_E$ =*100* );

– outlet boundary: in numerical model the condition $C(i+1,j)=C(i,j)$ is used. Here, C(i+1,j) is the concentration at the outlet boundary (this boundary condition means that we neglect the process of diffusion at this plane).

*Fluid Dynamic Model.* To simulate the flow in the horizontal settler the model of potential flow. In this case the governing equation is [7]

$$\frac{\partial^2 P}{\partial x^2}+\frac{\partial^2 P}{\partial y^2}=0$$

where P is the potential of flow. The components of the water flow inside the settler are calculated as follows [7]

$$u=\frac{\partial P}{\partial x}, v=\frac{\partial P}{\partial y}$$

The boundary conditions are discussed in [2].

Numerical integration of the equations. To develop the numerical model the following splitting of equation (1) is carried out [7]:

$$\frac{\partial c}{\partial t}+\frac{\partial u c}{\partial x}+\frac{\partial (v-w)c}{\partial x}+\sigma c=0$$

$$\frac{\partial c}{\partial t}=\frac{\partial}{\partial x}\left(\mu_x\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu_y\frac{\partial c}{\partial y}\right)$$

The following approximation of the first order derivatives is fulfilled [7]:

$$\frac{\partial C}{\partial t}\approx\frac{C_{ij}^{n+1}-C_{ij}^{n}}{\Delta t}\quad \frac{\partial uC}{\partial x}=\frac{\partial u^+C}{\partial x}+\frac{\partial u^-C}{\partial x}\quad \frac{\partial vC}{\partial y}=\frac{\partial v^+C}{\partial y}+\frac{\partial v^-C}{\partial y}$$

where: $$u^+=\frac{u+|u|}{2}\quad u^-=\frac{u-|u|}{2}\quad v^+=\frac{v+|v|}{2}\quad v^-=\frac{v-|v|}{2}$$

$$\frac{\partial u^+C}{\partial x}\approx\frac{u_{i+1,j}^{+}C_{ij}^{n+1}-u_{ij}^{+}C_{i-1,j}^{n+1}}{\Delta x}=L_x^+C^{n+1}$$

$$\frac{\partial u^-C}{\partial x}\approx\frac{u_{i+1,j}^{-}C_{i+1,j}^{n+1}-u_{ij}^{-}C_{ij}^{n+1}}{\Delta x}=L_x^-C^{n+1}$$

$$\frac{\partial v^+C}{\partial y}\approx\frac{v_{i,j+1}^{+}C_{ij}^{n+1}-v_{ij}^{+}C_{i,j-1}^{n+1}}{\Delta y}=L_y^+C^{n+1}$$

$$\frac{\partial v^-C}{\partial y}\approx\frac{v_{i,j+1}^{-}C_{i,j+1}^{n+1}-v_{ij}^{-}C_{ij}^{n+1}}{\Delta y}=L_y^-C^{n+1}$$

The second order deriveties are approximated as following:

$$\frac{\partial}{\partial x}\left(\mu_x\frac{\partial C}{\partial x}\right)\approx\mu_{x_1}\frac{C_{i+1,j}^{n+1}-C_{ij}^{n+1}}{\Delta x^2}-\mu_{x_2}\frac{C_{i,j}^{n+1}-C_{i-1,j}^{n+1}}{\Delta x^2}=M_{xx}^-C^{n+1}+M_{xx}^+C^{n+1}$$

$$\frac{\partial}{\partial y}\left(\mu_y\frac{\partial C}{\partial y}\right)\approx\mu_{y_1}\frac{C_{i,j+1}^{n+1}-C_{ij}^{n+1}}{\Delta y^2}-\mu_{y_2}\frac{C_{i,j}^{n+1}-C_{i,j-1}^{n+1}}{\Delta y^2}=M_{yy}^-C^{n+1}+M_{yy}^+C^{n+1}$$

Here we use notation v=v-w. In these formulas $L_x^+, L_x^-, L_y^+, L_y^-, L_z^+, L_y^-, M_{xx}^+, M_{xx}^-$, etc. are the notations of the difference operators.

After the approximation the solution of the difference equation is splitted in 4 steps [7]:

– at the first step $k=\frac{1}{4}$ ; $\frac{C_{ij}^{n+k}-C_{ij}^{n}}{\Delta t}+\frac{1}{2}\left(L_x^{+}C^{k}+L_y^{+}C^{k}\right)+\frac{\sigma}{2}C_{ij}^{n}=0$

– at the second step $k=n+\frac{1}{2}$ ; $c=n+\frac{1}{4}$

$$\frac{C_{ij}^{k}-C_{ij}^{c}}{\Delta t}+\frac{1}{2}\left(L_x^{-}C^{k}+L_y^{-}C^{k}\right)+\frac{\sigma}{2}C_{ij}^{k}=0$$

– at the third step $k=n+\frac{3}{4}$ ; $c=n+\frac{1}{2}$

$$\frac{C_{ij}^{k}-C_{ij}^{c}}{\Delta t}=\frac{1}{2}\left(M_{xx}^{-}C^{c}+M_{xx}^{+}C^{k}+M_{yy}^{-}C^{c}+M_{yy}^{+}C^{k}\right)$$

– at the fourth step $k=n+1$ ; $c=n+\frac{3}{4}$

$$\frac{C_{ij}^{k}-C_{ij}^{c}}{\Delta t}=\frac{1}{2}\left(M_{xx}^{-}C^{k}+M_{xx}^{+}C^{c}+M_{yy}^{-}C^{k}+M_{yy}^{+}C^{c}\right)$$

To solve the fluid dynamic equation of potential flow Samarskii A.A. implicit difference scheme is used. On the basis of the developed numerical model the code was created using FORTRAN language.

Results. The developed model was used to compute the process of the water treatment in the horizontal settler with one plate, two plates, with one plate and fin and with three plates. The initial data was as following: the speed of the flow at the inlet plane is 0.1m/s; w=0.01m/s; diffusive coefficients are equal to 1.7m2/s. Concentration at the inlet is equal to 100 (the concentration is dimensionless).

In Fig.5, 6, 7, 8 the dimensionless concentration field inside the settler is shown. These figures allow to see zones with different intensity of water purification.

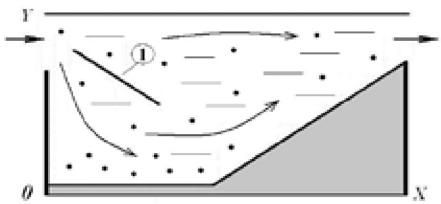


*Fig. 1. Sketch of the computational domain:*
*1 – plate*

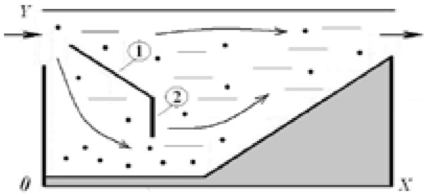


*Fig. 2. Sketch of the computational domain:*
*1 – plate; 2 – vertical plate*

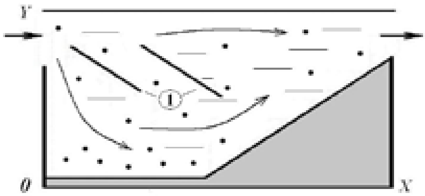


*Fig. 3. Sketch of the computational domain:*
*1 – plate*

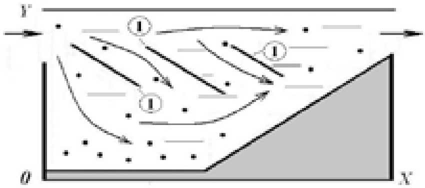


*Fig. 4. Sketch of the computational domain:*
*1 – plate*

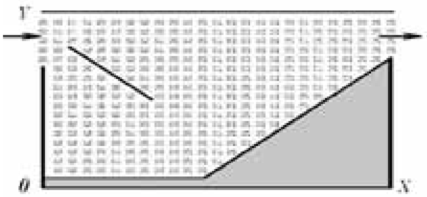


*Fig. 5. Concentration field*

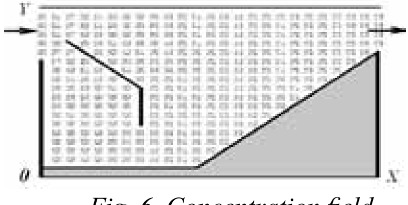


*Fig. 6. Concentration field*

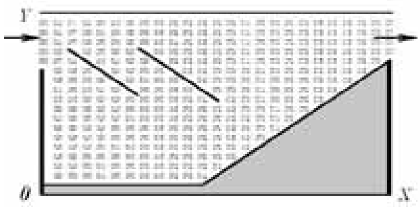


*Fig. 7. Concentration field*

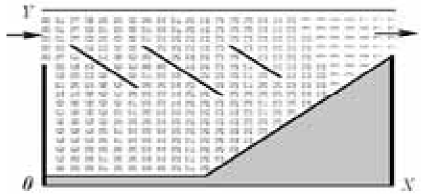


*Fig. 8. Concentration field*

The developed model allows to obtain the concentration at the outlet plane that is very important. The computational time to solve the problem was about 10 sec. So the developed model can be used to predict very quickly the concentration field in the settler.

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