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CHANGE IN CONCENTRATION OF COLLECTOR WATERSALONG THE FLOW LENGTH TAKING INTO ACCOUNT THE DIFFERENCE IN DENSITIES

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Abstract: the change in water quality due to the mixing of river and collector waters is considered in the paper. Analytical formulas are given for the prediction of water quality based on individual substances that change the concentration of river water.
Keywords: waste collector waters, salinity, standards in irrigation, point source diffusion, concentration, interactions, constant density

Irrigation issue is one of the urgent problems in our region. The lack of irrigation water requires the use of waste collector waters. As it is known, collector waters have different concentrations. When mixing collector waters with irrigation water of the canal, the concentrations change. The use of such water in irrigation is assessed by different regulations, including normative standards inirrigation. At collector watersdisposal into open channels, a diffusion

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process occurs, i.e. the mixing of water flows of different densities takes place. In mathematical simulation, the process ofthe mixingof collector and open channel waterscan be considered as a diffusion process. For open flows with similar cross sections, the equation of uniform diffusion with account of the difference in densities of disposal water is [1,3]:

(1)

where ρ is the density of incoming flow.

Consider the stationary case of diffusion with regard to non-conservatism. Then equation (1) has the form:

$$u\frac{\partial(\rho C)}{\partial x}=\frac{\partial}{\partial x}\left[D_x\frac{\partial(\rho C)}{\partial x}\right]\pm kC \qquad (2)$$

At constant density, the mixing is caused only by turbulence initiated by external effect.

Consider the flow along the $x$axis in the range $0\le x\le l$, at $x=0$, then separate the fluid with a concentration of pollutants C_0 of density ρ from the fluid that does not contain any pollutants of density ρ_0.

Assume that the average flow rate u is constant and the turbulence is homogeneous, i.e.

$$D_x=D=const$$

This system is shown schematically in Figure 1. Based on the condition that $\rho=\rho_1$ at $x=0$ and $\rho=\rho_0$ at $x=l$ (where l is the distance from the beginning of discharge to the complete mixing range), for the function $\rho(x)$ the dependence[1] is taken as:

$$\rho(x)=\rho_0+(\rho_1-\rho_0)e^{-\beta x} \qquad (3)$$

To solve the problem, we accept the following boundary conditions:

$$\beta=\sqrt{\frac{u^2}{4D^2}+\frac{k}{D}}-\frac{u}{D}$$

To solve the problem, we accept the following boundary conditions:

$$\left.\begin{array}{lll} C=C_0 & at & x=0 \\ C=\left(\frac{100}{p\%}-1\right)C_0 & at & x=l \end{array}\right\} \qquad (4)$$

where $p\%$ is thepercentage ofmixing; C is the permissible concentration after $p\%$-th mixing. Substitutingthedependence (3) informula (2) weget:

$$u\frac{d}{dx}\left[\rho_0+(\rho_0-\rho_1)e^{-\beta x}\right]C=D\frac{d^2}{dx^2}\left[\rho_0+(\rho_1-\rho_0)e^{-\beta x}\right]C\pm k\left[\rho_0+(\rho_1-\rho_0)e^{-\beta x}\right]C=0 \qquad (5)$$

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$$\frac{\partial(\rho C)}{\partial t}+\vartheta\frac{\partial(\rho C)}{\partial x}=\frac{\partial}{\partial x}\left[D_x\frac{\partial(\rho C)}{\partial x}\right]$$

If toput the sub-differential functions depending on x, as in $F(x)$, then equation (5) transformsinto a homogeneous second-order differential equation with constant coefficients[4,5]:

$$\frac{d^2F}{dx^2}-\frac{u}{D}\frac{dF}{dx}-\frac{k}{D}F=0 \qquad (6)$$

Solution of this equation is:

$$F=a_1e^{\lambda_1 x}+a_2e^{\lambda_2 x} \qquad (7)$$

where a_1, a_2 aretheconstants of integration;

$$\lambda_{1,2}=\frac{u}{2D}\pm\sqrt{\frac{u^2}{4D^2}+\frac{k}{D}}-\frac{u}{D}$$

Sincethevalueof

$$\lambda_{1,2}=\frac{u}{2D}+\sqrt{\frac{u^2}{4D^2}+\frac{k}{D}}-\frac{u}{D}$$

violates the physics of the process, as the concentration along the flow should not increase, the second term of equation (7) is neglected. Taking

$$F(x)=\left[\rho_0+(\rho_1-\rho_0)e^{-\beta x}\right]C(x)$$

and considering the above, we get

$$C(x)=\frac{a_1e^{-\beta x}}{\rho_0+(\rho_1-\rho_0)e^{-\beta x}} \qquad (8)$$

Determining a_1 fromboundaryconditions (4), for $C(x)$ we get:

$$C(x)=\frac{\rho_1C_0e^{-\beta x}}{\rho_0+(\rho_1-\rho_0)e^{-\beta x}} \qquad (9)$$

Nowconsiderthecase when ρ depends on the concentration:

$$\rho(x)=\rho_0+(\rho_1-\rho_0)C(x) \qquad (10)$$

Substitutingformula (10) in equation (2) and denoting

$$[\rho_0+(\rho_1-\rho_0)C]C(x)=\psi(x)$$

we get the following differential equation

$$u\frac{d\psi}{dx}=D\frac{d^2\psi}{dx^2}-k\psi$$

Solving this equation we find

$$\psi(x)=a_1e^{-\beta x}$$

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Determining a_1 fromboundaryconditions (4) and for $C(x)$) we get the following expression:

$$C(x)=\sqrt{\left[\frac{\rho_0}{2(\rho_1-\rho_0)}\right]^2+\frac{[\rho_0+(\rho_1-\rho_0)C_0]C_0}{\rho_1-\rho_0}}-\frac{\rho_0}{2(\rho_1-\rho_0)} \qquad (11)$$

So, using formulas (9) and (11), we can find contamination concentrations at any distance from the beginning of the discharge, taking into account the difference in densities of river and waste waters.

Diffusion of salt water from the collector source into moving water of the channel. Consider the diffusion of a component A, injectedinto a solvent B,moving in the x direction at a constant rate w_0. Inthiscase, thefollowing equationshouldbesolved

$$w_0\frac{\partial C_A}{\partial z}=D\nabla^2 C_a \qquad (12)$$

Atboundaryconditions [2]: $C_a=0$ at $r\to\infty$

$$4\pi r^2 D\left(\frac{\partial C_a}{\partial r}\right)=Q_A \text{ at } r\to 0,$$

where r is the distance from the source ($r^2=x^2+y^2+z^2$); z is thedistance downstream the source; Q_A is the rate at which the component A enters the system. Thesolutionofequation (12) leadstothedependence:

$$C_a=\frac{Q_A}{4\pi r D_{AB}}e^{-\left(\frac{w_0}{2D_{ab}}\right)(r-z)} \qquad (13)$$

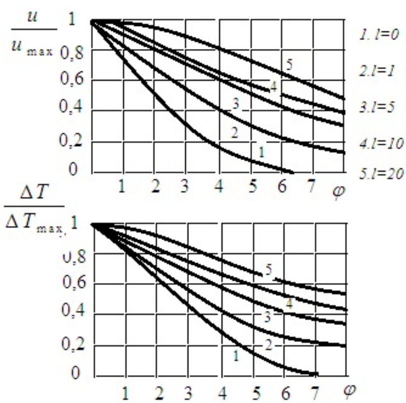

Fig. 1. Change in rate profile(a) and excess temperature (b)

Diffusion from a point source is used in analyzing the concentration profile and determining the eddy diffusion coefficients[2].

The experiments have been conducted in the laboratory of the "Hydrology" department. The experimental installation is a hydraulic chute of 11.7 m long and a cross section of 0.3x0.6 m. The water discharge changes up to 30 l/day. A jet of warm water is heated in a specially designed system, where the temperature is set and maintained automatically.

The water flow rate in the system is set using a glass plug valve, and at different discharge, different flow rates of the jet are reached at water outlet. Near the jet outlet,the TPEM-1 electric thermometer sensor is mounted with a division of 0.2°. The water temperature in the chute is measured with a conventional thermometer with a division of 0.3°. Todeterminethewaterflowby volumetricmethodanelectronictimer is used.

Conclusions

The formulas derived on the diffusion process can be used to find the concentration of pollution at any distance from the beginning of the discharge, taking into account the difference in density of river and collector waters.

Diffusion from a point source is used in analyzing the concentration profile and determining the eddy diffusion coefficients.

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