Nat. Volatiles & Essent. Oils, 2021; 8(5): 10007-10010

NVEO Natural Volatiles & Essential Oils

Algorithm For Calculating Quality Indicators Waters of Geoinformation Systems

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Abstract

In this paper, water quality in the Tupalang river basin was analyzed using the Saint-Venant method. Based on the developed algorithm, water quality indicators were calculated for the Tupalang from the village Uzunskoe to Termiz under conditions corresponding to the period from April 21 to November 8, 1997 year.

Keywords: mathematical modeling, water quality, Saint-Venant method.

METHOD

To determine the water quality, it is built based on information modeling complexes (IMC), which implements a 1DH-model of water quality, reproducing the temporal and spatial distribution of the content of chemical components (pollutants) in the river and based on the following assumptions:

- point and distributed discharges are assumed to be specified;
- the flow in the rivers is assumed to be quasi-one-dimensional with restrictions that allow simulating the movement of water by the equations of Saint-Venant;
- chemical processes in rivers are modeled by equilibrium reactions;
- the processes in the river do not affect the processes occurring in the tributaries.

As a model water body for testing the BCI for calculating water quality indicators, a section of the r. Sariasiyansky from Uzun to Termez.

The mathematical formulation of the problem of calculating unsteady currents in an arbitrary system of river channels based on one-dimensional equations of the Saint-Venant type for each chemical component (pollutant) has the form:

$$\frac{\partial(\omega C_j)}{\partial t} + \frac{\partial(Q C_j)}{\partial x} = \omega \cdot H_j + G_j$$

where H_j is the term characterizing the non-conservatism of the considered j-th compound; C_j is the path load per unit length of the watercourse (specific lateral inflow of non-point sources of the j-th pollution).

The chemical components here are for the following values of j: 1 - BOD; 2 - deficiency of dissolved oxygen; 3 - suspended matter; 4 - COD; 5 - ammonium; 6 - nitrites; 7 - nitrates and 8 - phosphates, which are linked to each other in transformation reactions of chemical compounds:

$$H_j = K_j \cdot C_j \,, \qquad for\, j = 3, 4, 8$$

$$H_1 = -(K_1 + K_3) \cdot C_1 \,;$$

$$H_2 = -K_2 \cdot C_2 + K_1 \cdot C_1 + P_1 \cdot K_5 \cdot C_5 + P_2 \cdot K_6 \cdot C_6 + J \cdot \frac{B}{\omega}) \,,$$

where $K3$ is the sedimentation coefficient; $P1$ and $P2$ - conversion factors for oxygen losses during nitrification; J is the oxygen flux density due to absorption by bottom sediments and photosynthesis.

When calculating the transformation of nitrogen compounds ($j = 5 \div 7$), the following nitrification scheme is used:

$$H_5 = -K_5 \cdot C_5 + P_3 \cdot K_4 \cdot C_4;$$
$$H_6 = -K_6 \cdot C_5 + K_5 \cdot C_5;$$
$$H_7 = -K_7 \cdot C_7 + K_6 \cdot C_6;$$

where $P3$ is the conversion factor for the ammonification process.

The dependence of the transformation ratios on hydrological conditions is determined by parametrizing the mathematical model. The P_j values are estimated in accordance with real stoichiometric relationships. The value of G_j can be determined as follows:

$$G_j = C_{jb} \cdot q;$$

where C_{jb} is the concentration of the j-th compound in the tributaries, characterized by the lateral inflow rate q.

To solve the system of equations for calculating water quality indicators, a certain set of empirical information is required. The dependences of the cross-sectional area and bottom elevation $\omega = \omega(x)$, $\delta = \delta(x)$ are determined by processing cartographic information and directions. The roughness coefficient $n = n(x)$ in the bed of large rivers is taken equal to 0.025. In-situ determination of lateral flow is an extremely difficult task. In this case, it is estimated as the difference in flow rates in two adjacent water outlets, taking into account point sources (tributaries) and the distance between these water outlets.

The boundary conditions for the Saint-Venant equations can be obtained from the analysis of materials from hydrological yearbooks. The initial conditions are determined by finding a stationary solution to the original system of equations.

The empirical coefficients for the transport equations of chemical components K_j were obtained during the model calibration. The track load per unit length of the watercourse G_j was assumed to be zero. The water temperature was set by interpolation of data at the water points according to hydrological yearbooks. The initial and boundary conditions for the concentrations of the components, as well as the values of these concentrations in the tributaries, were taken to be equal to the MPC values for the pollutants under consideration.

RESULTS

Using the developed algorithm, water quality indicators were calculated for the Tupalang from the village Uzunskoe to Termiz under conditions corresponding to the period from April 21 to November 8, 1997.

The use of a system of quasi-one-dimensional equations allows, based on information from hydrological posts near the village Tupalang and on the river Shurchi to predict with acceptable accuracy the water surface levels in the area of Denau. Even those obtained on the basis of a relatively rough DEM built on the basis of a modern pilot map, the results of calculations using the 1DH-model show an error in determining the maximum water level in less than a day, and the error in calculating the level value is no more than 0.5 m. Application of a more accurate channel DEM and the floodplain of the river will certainly increase the accuracy of the problem.

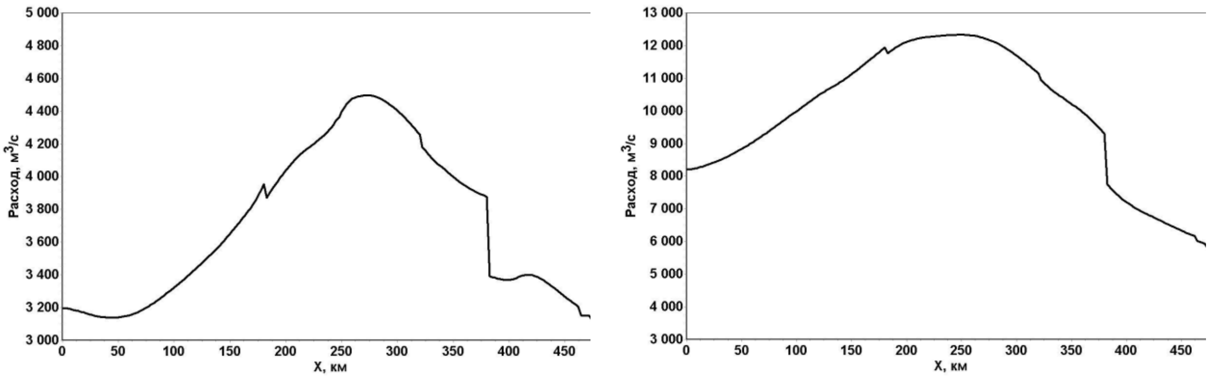

Figure: 1. Calculated distribution of discharge along the river bed. Tupalang at the time of the maximum water level near Sariasia according to 2017 (a) and 1997 data. (b). X coordinate values correspond to: 0 - Sariasia; 239 - Denau; 481 - village Shurchinskoe

One of the most important characteristics of water quality is the concentration of dissolved oxygen. In fig. 2 shows the change in its concentration near the city of Barnaul. It is seen that no oxygen deficiency is observed.

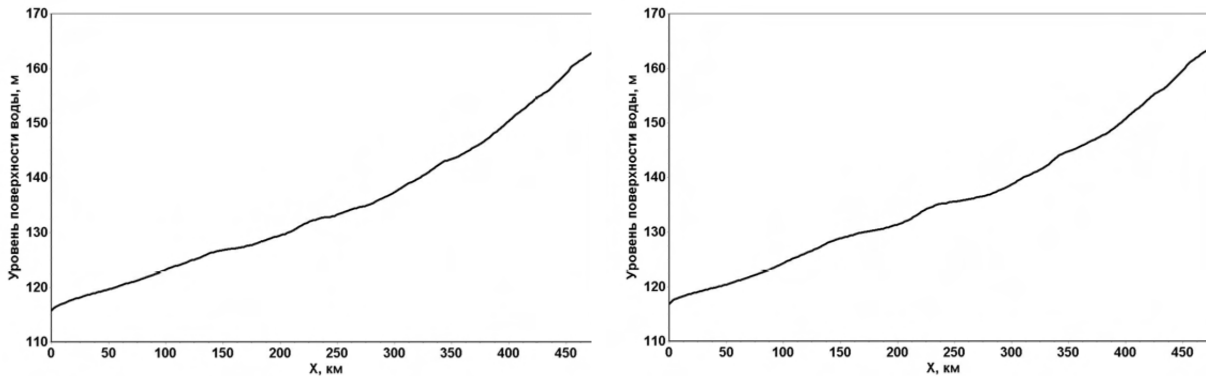

Fig. 2. The calculated distribution of the water surface level along the river. Tupalang at the time of the maximum water level near the city of Sariasia according to data from 2017 (a) and 1997. (b). X coordinate values correspond to: 0 - Sariasia; 239 - Denau; 481 - village Shurchinskoe.

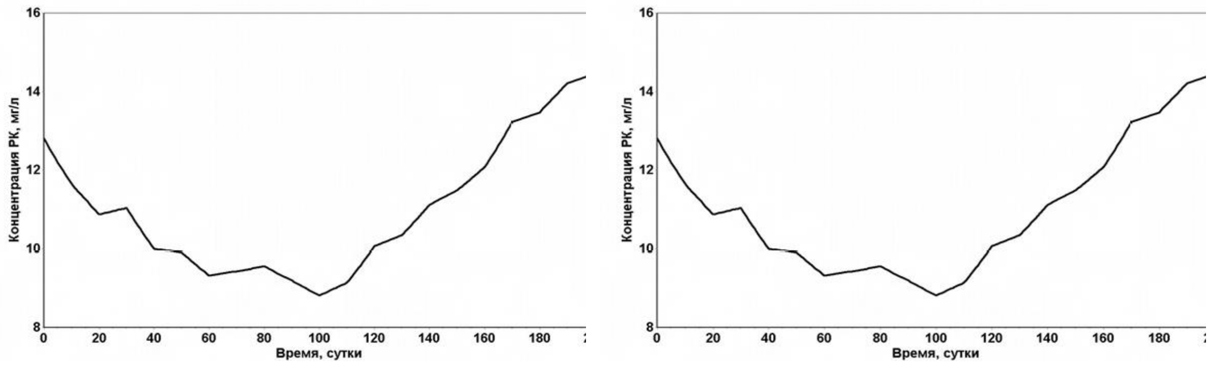

Figure: 3. The calculated distribution of the concentration of dissolved oxygen near the city of Sariasiya for the summer period of 2017 (a) and 1997. (b). The abscissa coordinate values 0 correspond to April 21 of the considered year.

CONCLUSION

The result obtained in this article shows that the developed algorithm 1HD model gives more accurate results than modern DEM data. It also shows that the selected river water quality is low in oxygen content. Another important feature is that the upstream BOD condition has usually improved. We hope that this article will be an important resource in determining water quality.

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