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Numerical simulation of density stratification in the solution of the problem of selective water intake from reservoirs

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The paper deals with the development of hydrodynamic model of Chusovaya water intake, which supplies potable water to most part of the Perm city, including about one million inhabitants. This water intake is located in the vicinity of the confluence of two rivers, greatly different in hydrochemical regimes - Chusovaya and Sylva (the Sylva water is characterized by much higher hardness and mineralization than the Chusovaya water). Thus, for the improvement of water quality, it is important to organize selective water intake. However, the solution of this problem is complicated due to the fact that the hydrodynamic regime in the area under consideration is determined by a complex combination of hydrological regimes of Chusovaya and Sylva rivers, the water level in the Kama water reservoir and the regimes of the Kama Hydropower Station. It should also be taken into account that the hydrological regimes of two rivers are characterized by strong seasonal variability. All these factors, combined with the limited possibilities of water monitoring, makes urgent the development of numerical hydrodynamical models of the hydrological system. Optimization of the design of water intake on the basis of mathematical modeling can be an alternative to costly and time consuming manufacturing methods to reduce water hardness.

The difference in water mineralization leads to the difference in its density. Due to that, during the mixing, more dense Sylva water should move to the bottom and less dense Chusovaya water rise to the surface. Thus, the density inhomogeneities in depth for this problem is of fundamental importance and modeling in the framework of two-dimensional approach by averaging over depth is incorrect for the part of the hydrological system, where there is an active mixing of waters of two rivers. At the same time, the solution of the problem in three-dimensional formulation for the entire computational domain, given its large size and complex geometry requires the use of extremely large computational resources. In this connection, a combined approach is being used that combines two-dimensional and three-dimensional calculation schemes. Calculations in the immediate vicinity of the intake tip and bottom barriers were carried out within the three-dimensional model, and hydrodynamics of the rest of the computational domain was calculated on base of the two-dimensional model.

The results of two-dimensional calculations show that for typical regimes of Sylva and Chusovaya rivers, after the confluence, strong mixing in the horizontal direction is observed: the admixture concentration in the horizontal sections is nearly homogeneous. Three-dimensional calculations confirm this conclusion and demonstrate the formation of significant vertical inhomogeneity of the admixture concentration in depth: the mineralization of water near the bottom is several times larger than that on the surface. Thus, an organization of selective water take from the surface layers may significantly reduce the hardness of water taken for portable water purpose, without any additional costs for water treatment.

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