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Numerical Modeling of Thermal Pollution of Large Water Bodies from Thermal and Nuclear Power Plants

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Currently, the major manufacturers of electrical energy are the thermal and nuclear power plants including the cooling ponds in the processing chains. For a wide range of both environmental and technological problems, the evaluation of the temperature fields in the cooling ponds at certain critical values of hydrological and meteorological parameters is important.

The present paper deals with the evaluation of the thermal effect of one of the largest thermal power plant in Europe - Perm GRES - to its cooling pond which is the Kama Reservoir.

Since the area of the possible impact is rather large and the reservoir itself is characterized by a very complex morphometry, numerical modeling of thermal spot propagation in the Kama River due to the discharge of warm water by Perm GRES for the entire area in the 3D-formulation with the desired detail setting morphometric characteristics of the water body meets very serious difficulties. Because of that, to solve the problem, a combined scheme of calculations based on the combination of hydrodynamic models in 2D and 3D formulations was used.

At the first stage of the combined scheme implementation, 2D hydrodynamical model was developed for all possible area, using software SMS v.11.1. The boundary and initial conditions for this model were formulated on the basis of calculations made using 1D hydrodynamical model developed and applied for the entire Kama Reservoir.

Application of 2D hydrodynamical model for solving the problem under consideration was needed to obtain the necessary information for setting the boundary conditions for the 3D model. Software package ANSYS Fluent v.6.3 was used for the realization of 3D model. 3D modeling was performed for different wind speeds and directions and quantitative characteristics of the discharge of warm water.

To verify the models, the data of the detailed field measurements in the zones of thermal pollution of the Kama reservoir due to impact of the Perm GRES were used. A significant difficulties in performing these verification assessments were caused by variability of meteorological parameters such as wind speed and direction and air temperature in the surface layer.

Verification assessments taking into account the variability of wind speed and direction have shown good agreement between the calculated and observed values of the temperature, which justified the use of the developed models to estimate the temperature fields in different meteorological conditions in the area of warm water discharge.

The calculations have demonstrated the formation of a considerable heterogeneity in temperature with depth. It has been found that in the presence of wind in the direction opposite to the direction of flow in the river, a three-dimensional vortex is formed in several hours. The horizontal size of this vortex can be equal or even exceed the distance between the intake and discharge points of water and a vertical size equals to the depth of the river. The presence of this vortex results in the movement of warm water against the flow in the river. In this situation, less than in a day, warm water reaches the point of water intake of GRES cooling channel which is unfavorable from technological point of view.