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# Mathematical modeling of the discharged heat water effect on the aquatic environment from thermal power plant under various operational capacities

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ABSTRACT

The paper presents a mathematical model of the thermal load on the aquatic environment under various operational capacities of thermal power plant. It is solved by the Navier–Stokes and temperature equations for an incompressible fluid in a stratified medium based on the splitting method by physical parameters which approximated by the finite volume method. The numerical solution of the equation system is divided into four stages. At the first step it is assumed that the momentum transfer carried out only by convection and diffusion. Intermediate velocity field is solved by five-step Runge–Kutta method. At the second stage, the pressure field is solved by the found intermediate velocity field. Poisson equation for the pressure field is solved by Jacobi method. The third step assumes that the transfer is carried out only by pressure gradient. The fourth step of the temperature equation is also solved as motion equations, with five-step Runge–Kutta method. The algorithm is parallelized on high-performance computer. The obtained numerical results of three-dimensional stratified turbulent flow were compared with experimental data. What revealed qualitatively and quantitatively approximately the basic laws of hydrothermal processes occurring in the reservoir-cooler.



## 1. Introduction

Environment – the basis of human life, and the energy generated – is the basis of the modern world. However, the production of electricity adversely impact on our environment, worsening living conditions. Energy is the basis of different types of power plants. Electricity production in thermal power plants (TPP), hydropower plants (HPP) and nuclear power plants (NPP) is associated with adverse effects on the environment. Interaction energy and the environment has acquired new features, extending the influence of heat on the rivers and lakes. Previously, the impact of TPP or NPP on the environment was not considered, as the main purpose was to obtain the electricity. Electricity production technology in the power plant is connected with a lot of heat emission to the environment. The negative impact of energy on the environment is becoming an important issue, since the pollution increases each year.

Today it is important to find the best sources of electricity. One of such kind of source is the thermal power plants. Fuel, i.e. coal, gas or oil is burned in TPP. The generated heat converts water into steam, which drives turbines generators and electro

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generators. The water vapor is cooled and again converted into water, the water is heated again, and so on. In small TPP in addition of so-called fossil fuels, i.e. coal, natural gas or oil other fuels, such as straw or fast growing trees can be also used. TPP is divided into condensing power plant (CPP), intended only to generate electricity, and thermal power central (TPC), which produces electricity energy and heat in the form of hot water or steam. District large CPPs are called state district power plants (SDPP).

All power has a negative impact on the environment. The impact of TPP on the aquatic environment is manifested in these main points: plum liquid pollutants into water bodies; deposition on the surface of water bodies of the solid particles emissions into the atmosphere; thermal pollution of water bodies, etc. Local factors have some effect on the temperature of the water in the river sections. Due to the changes in water clarity, flow rate, presence or absence of aquatic vegetation, the presence of water surface's shading, the temperature in different parts of the river is different from the background values. The impacts of these factors are caused from the impact on the heat transfer of water mass and the atmosphere. For example, due to increased turbulent heat transfer the increased flow rate leads to an increase of heat exchange with the atmosphere. An aquatic vegetation slows the flow as a result, promotes the formation of dead zones where the water is warmed up. At low water transparency solar radiation is absorbed in the upper layer, 5–10 cm thick and will not penetrate deeper, resulting an increase in the temperature gradient over the depth of the river. The impact of these factors on the annual thermal regime is negligible. However, in studying the formation of the thermal regime of the river by depth, width and length, mentioned above things should be considered, as these spatial-temporal scales may be significant.

An important factor in the formation of the thermal regime and the status of watercourses in local areas of the rivers is anthropogenic influence. This term refers to a set of directed change of the heat flow. Thermal pollution varies according to the type and magnitude of the impact on the temperature pattern in the river. The most tangible impact on the thermal regime of rivers and streams have a thermal energetic, industrial and municipal water supply and regulation of water flow. Thermal energy alters the thermal regime of rivers as a consequence of discharged heated water to the channels. Other conditions being equal to the effect of thermal power facilities in the thermal regime is determined by the ratio of household expenditure in the river and the amount of water withdrawn for cooling and by the temperature difference between the river and the cooling water. Relatively cold water is taken from a water body for cooling condenser of TPP, SDPP and NPP. Direct-flow water system, which involves dumping heated water in the same water bodies from which the intake was produced in the rivers is the most commonly used. Temperature of discharged water of thermal power plant in this case exceeds the natural to $8-12\,^{\circ}\mathrm{C}$ , and sometimes more, depending on the time of the year. Area of heated water in large SDPP can be traced over an area of tens of square kilometers. Especially pronounced impact of discharged water from SDPP on the river could be clearly observed in the winter - in the area of power plant freeze-up will not be formed.

## 2. Background

The development of local circulation is directly dependent not only on the thermal contrast of the water surface and land. But also significant role is played by local orographic conditions. Probability of breezes' formation on the shores of large bodies of water depends on their geographical location. Changes in the wind direction at the reservoirs and on shore are connected not only with the local circulation. Differences in the roughness of the water surface and land lead to a rotation of the movement direction of the air mass to the right. When the air reaches especially high shore, it tends to move along it, because roughness of the land bigger than the waters. This gives the winds' rose the form of coastline. This effect is observed particularly clearly in narrow bays, at narrows of valley type reservoirs.

In general, however, we note that the tortuosity of the shoreline, difference between height and slope of the coastal incline determine the complicity of the picture of the wind direction. One of the most effective methods of hydrodynamics study of the lake is a method of mathematical modeling. In some cases this may be the only tool to predict changes in the hydrological regime and lake ecosystems. For example, when studying the changes that may occur in spatial redistribution of water, while constructing waterworks and other events are associated with the use of water objects.

Mathematical models can be classified according to the several criteria. It can be classified according to their model "dimension' [12–14]: one-dimensional (vertical or horizontal), two-dimensional (horizontal or vertical plane), three-dimensional model. The most simple - are one-dimensional models that commonly used for modeling of currents in rivers. Two-dimensional models are used to study wind and seiche flows, storm surges, etc. Lick [31] proposes to consider the following types of mathematical models of wind currents like: 1) integrated model (full flow), in which vertical integration over the flow is accounted but vertical profile of flows is not modeled, 2) stationary models of wind currents for constant and variable density of water 3) non-stationary model for barotropic and baroclinic lakes. To study the wind currents Sheng et al. [32] divided the models to: Ekman, integrated by vertical direction, multi-level and multi-layered. In addition to these models the dynamic method and a variety of three-dimensional thermohydrodynamic models are used for calculation of lakes' flows.

It is accepted to divide modeling into two classes - prognostic and diagnostic. In the first class the formation of interconnected flow fields, temperature, the atmosphere's and the lake's boundary layers are simulated. Solution of this problems class involve great difficulties of a numerical simulation of unsteady nonlinear partial differential equations. The use of data obtained from the observation of temperature and wind fields greatly simplifies the problems of circulation in lakes. This is the meaning of diagnostic solutions, which are widely used in the class of oceanographic problems, and subsequently for the study of flows in deep stratified lakes.