Geophysical Research Abstracts
Vol. 14, EGU2012-9441, 2012
EGU General Assembly 2012

Mixing in three-dimensional turbulent flow near the river confluence

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Main source of potable water for Perm city having about one million inhabitants is Chusovaya water intake located in the immediate vicinity of the confluence of Chusovaya and Sylva rivers. These rivers are similar in water content but significantly different in hydrochemical regime: the water of Sylva river is characterized by high hardness and the hardness of Chusovaya river is much lower. Since the hardness is an important indicator of water quality, there arises the goal to organize the water intake in such a way that water was characterized by minimal hardness. The solution to this problem in the discussed case is complicated due to the fact that the water intake is located in the zone of hydraulic backwater of the Kama hydroelectric power station and the hydrodynamic regime in this zone depends not only on the cumulative effect of hydrological regimes of Chusovaya and Sylva rivers but also on the filling level of the Kama water reservoir and on the reset mode on the Kama hydroelectric power station.

From the viewpoint of ensuring the standard water quality, the dynamics of water hardness in the considered rivers and its dependence on the water flow rates is of the fundamental importance. This is especially significant for low flow rates typical for winter seasons. For large flow velocities and small differences in mineralization, one could expect sufficient homogeneity of water composition in depth due to intense vertical mixing. And in winter season, at low flow velocities and significant differences in mineralization, considerable vertical inhomogeneity of water composition may arise. Experimental measurements show that, in winter low flow season, specific electric conductivity and, consequently, mineralization and hardness of the water near the bottom several times larger than their values near the surface.

To study the formation of vertical stratification in different conditions, numerical simulation of mixing in three-dimensional turbulent flows for the configuration discussed above was carried out using commercial package Fluent 6.3.2. The calculations confirm formation of vertical stratification of water composition in the considered area, especially strong in winter low flow season. Additionally, the calculations show that vertical stratification arises not only in the vicinity of water intake, below the confluence of Chusovaya and Sylva rivers, but also before their confluence, upstream of the rivers. Analysis of three-dimensional velocity and concentration fields obtained in the calculations shows that the formation of vertical stratification in those areas occurs due to "leaking" of more dense water of Sylva river under less dense water of Chusovaya river and vice versa. These predictions are confirmed by the measurements of the specific electric conductivity.

Thus, based on the comprehensive study including numerical simulation of mixing in three-dimensional turbulent flows and the detailed analysis of hydrological and hydrochemical regimes, the effect of mutual penetration and propagation of the water upstream is discovered for the confluence of two rivers with different densities of water located in the zone of hydraulic backwater of hydroelectric power station.