CORMIX APPLICATION ON THE THERMAL POLLUTION OF LARGE RIVERS ASSESSMENT

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Introduction

The hydrosphere, like the atmosphere is of exceptional importance for the humanity. They both transport and disseminate basic components which guarantee the life in the planet. Nowadays, more and more pollutants enter the hydrological cycle. Because of this impact, the adequate modeling of the processes in water basins in case of polluted influents is necessary.

There are a number of mathematical models for solving different tasks related to pollutant transport in natural river flows.

This paper considers modeling of the thermal impact of the heated water from Kozloduy NPP on the Danube River through the decision support system "CORMIX", developed at the Cornell University, USA, which is a typical "length scales"-based model.

The investigation aim to assess the transboundary effect of the thermal water pollution as well, i.e. whether the heated waters from the NPP can increase the river temperature near to the opposite, the Romanian, bank.

The outcomes are adapted for the Bulgarian section of the Danube River at Kozloduy NPP, and the simulation models are compared to experimental investigations.

Basic principles of CORMIX use

„CORMIX" was developed mainly for analysis of river flows pollution in the advection zone but it may assist in solving problems, related to investigations in a remote mixing zone.

The length scales assess the dominating role played by the hydraulic flow parameters (water discharge, discharge flux quantity, buoyancy and velocity) in the pollutant transport. The following specific length scales are being used in the analysis of the mixing processes"
- Length scale of the water discharge, comparing the discharge with the discharge flux quantity, initiated by the source of pollution;
- the length scale "jet-plume" registers the dominating role of the initial discharge quantity or the one of the buoyancy;
-the length scale "jet – hydrodynamic force of flow" determines the dominating role of the hydrodynamic force of flow or the one of the discharge quantity of the pollution source;
-length scale "plume – hydrodynamic force of flow" registers the effect of buoyancy over the main flow.

Certain combinations of these basic length scales are obtained from the widely used dimensionless numbers – the densimetric Froude number, indicating the difference in the densities of the ambience of the receiver and the pollutant (Fr0) and the dimensionless ratio of the velocities of the main flow and the source of pollution (R).

Following a dimensional analysis and a number of laboratory and field investigations, the conclusion is that the impact of a point source of pollution on the ambience of the receiver may be divided into three basic regimes: free jet, bank-attached jet, and jet.

Again, through joint application of the dimensional analysis (for derivation of the basic relationships) and data from the field measurements (for determination of empirical coefficients to the basic relationships), expressions are obtained which describe the trajectory of the jet's axis and the concentration of the pollutant along this axis. The distribution of the concentration in a direction which is transversal to the motion of the jet is expressed through the normal (Gaussian) distribution.

The effluence of the heated-by-the-NPP water is a typical example for pollution of a river flow by a point source. This is caused by the so called "warm canal" of the Plant, which is situated axially at 65º of the river axis, and has a trapezoidal cross section.

Data from field investigations of the batimetry and water temperature, conducted by a team of Hydraulics and Hydrology Dept. in the autumn of 1991 and autumn of 1992 have been used for adjustment of the model.

The measurements in 1991 have been conducted on 14 November. The following parameters were measured: water volume in the Danube at the warm canal – Qam = 4600 m3/s; depth of the river up to 300 m from the Bulgarian bank between km 687 and km 678; average water temperature of the Danube – Tam = 7ºC; water discharge in the warm canal – Qdisch = 130 m3/s; depth of water in the warm canal at the outfall – Hch = 7.5 m; average water temperature in the water canal – Tdisch = 15.4ºC.

The measurements in 1991 have been used for calibration of CORMIX and these in 1992 – for its validation. The calibration was an approximation of the geometrical and hydraulical parameters of the river section in sense to be achieved equivalent parameters on the natural such.

The measurements in 1992 have been conducted on 9 September. The following parameters were measured: water volume in the Danube at the warm canal – Qam = 2800 m3/s; depth of the river up to 300 m from the Bulgarian bank between km 687 and km 678; average water temperature of the Danube – Tam = 19.9ºC; water discharge in the warm canal – Qdisch = 75 m3/s; depth of water in the warm canal at the outfall – Hch = 5.3 m; average water temperature in the water canal – Tdisch = 28.5ºC.

The modeling performed for Scenario 1 (based on data from the field measurements on 14 Nov 1991) and Scenario 2 (based on data from the field measurements on 9 Sept 1992) indicated that the impact of the warm canal water on the river water may be classified by CORMIX as "PL2", which corresponds to a plume without availability of intrusion against the flow. The plume "PL2" is a result of the high degree of buoyancy of the heated water, low values of the discharge flux quantity, and low values of the densimetric Froude numbers Frch (with respect to the warm canal) and Fro (with respect to the river flow). The axis of the plume (the line with the highest values of temperature longitudinally) follows the shoreline. The results of modeling are systematized in Figures 1 and 2.

The comparison between the results of the field measurements and the ones of modeling with CORMIX indicates a good coincidence within the boundaries of the thermal plume, while Scenario 1 exhibits some discrepancies at the beginning of the thermal plume. These discrepancies are due to the fluctuations of the geometric and hydraulic parameters of the river which can not be represented adequately with CORMIX. It is necessary to remind that the system is modeling precisely the mixing processes for a rectangular bed. Since at the outfall of the warm canal the river bottom has been dragged in order for more intensive mixing to be realized, the isolines "enter" almost perpendicularly the flow. Besides, slight discrepancies are observed also within the boundaries of the plume: in the field measurements the isolines fluctuate due to flow turbulence, while the system indicates that the boundary of the plume is almost a straight line downstream of km 684.00.

In Scenario 2, CORMIX calculates more precisely the boundaries of the thermal plume, which is mainly due to the fact that the water discharge from the warm canal is twice less than the one in Scenario 1, and the main part of the heated water is spread only to 100 m from the shore. Only the last isotherm (20°C) reaches a distance of 250 m from the Bulgarian shore.

Fig. 2 exhibits the comparison between the change of the temperature variance in the river and the warm canal along the plume axis. As it was already mentioned, this axis goes along the shoreline at the side of the warm canal.

Conclusion

The modeling conducted by the authors indicates that CORMIX decision support system forecasts relatively precisely both the thermal plume boundaries, and the temperature distribution along the plume axis, the constrains being mainly related to the impossibility to simulate fluctuations of geometrical and hydraulic nature.

It is visible (from the carried out investigation) that the cooling water discharge has only a local influence and can not cause a transboundary effect in means of thermal pollution.

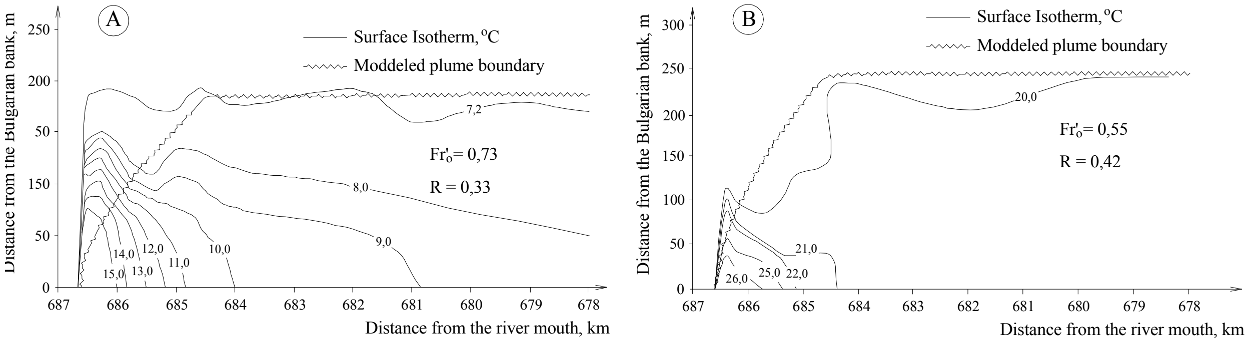

Fig. 1. Comparison between the results of the field measurements conducted on 14 Nov 1991 -„A" and on 9 Sept 1992 – „B", and the results of the simulation through "CORMIX"

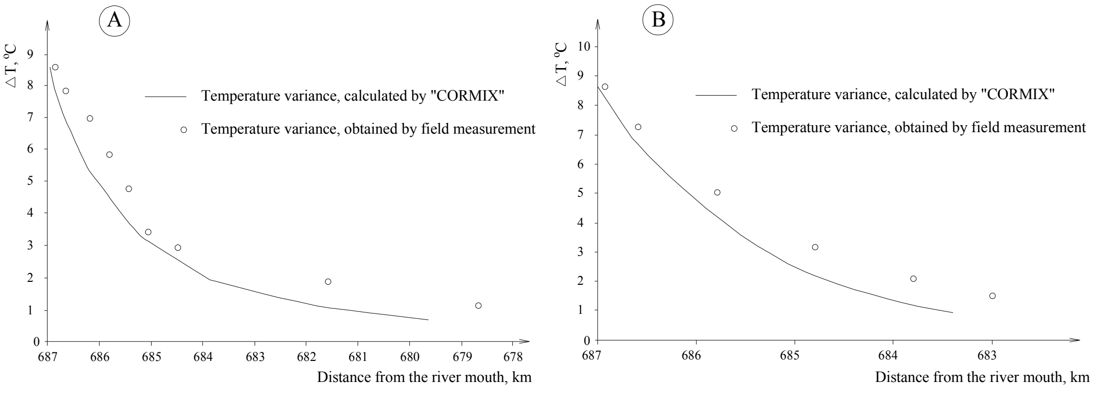

Fig. 2. Comparison between the temperature variance along the axis of the thermal plume from the field measurements, conducted on 14 Nov 1991 – "A" and on 9 Sept 1992 – „B", and the results of the simulation through "CORMIX"

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