Current state of research on water quality of Prut River

GALINA MARUSIC[1], CALIN CIUFUDEAN[2]
[1]Applied Informatics Department, Technical University of Moldova, 168, Blvd Ştefan cel Mare şi Sfânt, Republic of MOLDOVA
[2] Computers, Electronics and Automation Department, Ştefan cel Mare University, 13, University Street, Suceava, ROMANIA
galinamarusic@yahoo.com http://www.utm.md

Abstract: - This paper presents a bibliography analysis on water quality of the River Prut. It deals with the concept of "water quality" in various aspects of water use. We discuss the need of developing mathematical models for determining and predicting water quality of "river-type" systems. It presents a case study for determining the pollutant dispersion for a section of the River Prut, Ungheni town, which was filled with polluted water with oil products from its tributary river Delia.

Key-Words: - water quality, Navier Stokes equations, continuity equation, the equation of transport pollutants, pollutant dispersion.

1 Introduction

Water quality problem was and is current for all areas of human activity since the formation of civilization. The concept of water quality is classified depending on the application and has several definitions:

- is a set of chemical, physical and biological properties of being able to use for a particular case [1];
- is a set of chemical concentrations and physical phenomena according to geochemists [2];
- ecologists refer to physico-chemical conditions of an aquatic system that could support a healthy community of aquatic biota in natural balance in local conditions;
- water quality refers to a specific location in terms of human health, including the risk of water borne diseases according to sanitary engineering;
- water management engineers define water quality, according to human uses such as drinking water, irrigation, industrial use, transportation or power generation [3];
- ecological condition very good, good, moderate, poor and bad according to the Water Framework Directive.

For human needs in most cases, water from rivers is used.

An important source of water supply for both, the Republic of Moldova and Romania, is Prut River, which marks the boundary between the two countries, and which is of great geographical and geopolitical importance [4].

2 Hydrological, geomorphological and biological research of Prut River basin

A hydrological summary of Prut River basin, which included hydrographic characteristics and spatio-temporal variation related to water resources was conducted by Florin Vartolomei. His work which presents the most important aspects of this field. It is noted that there is established a strict regime on water supply for people and livestock from the River Prut. The normative acts of both parts (Romania and Moldova) concerning water quality differ and need to be correlated [4].

Changing river geomorphology has many negative effects related to environmental and social fields, so the river beds shall be permanently to geomorphologists' attention. Riverbed deepening and cross-sectional geometry changes threaten engineering structures, losses of agricultural land happen, decreasing the number of individuals in ichtyofauna caused by inability of fish spawning, effects on the relationship between river and ground water, changing water quality parameters. Contemporary changes of the river Prut on the Romanian border were evaluated in [5].

An important role in determining water quality are biological factors. Water quality in the River Prut in Romania, Oroftiana was assessed based on biological indicators. The study is focused on the analysis of plankton, with special reference to phytoplankton. It was found that the Prut River water is poorly polluted, the processes of oxidation and mineralization have a lower intensity. CBO does not exceed normal values, dissolved oxygen concentration values are close to saturation and a high diversity of bacterioficeelor, cloroficeelor and euglenoficeelor is present [6].

3 Research on water quality modeling of Prut River

Lately, water quality, as a result of human activities is in continuous decline. Water pollution in rivers can be well defined and controlled via information systems for monitoring environmental pollution levels in time and space, a main component involved in this process is the modeling and forecasting conditions in the examined area.

To obtain a suitable model system it is necessary to know the real ecological systems and processes under modeling, based on which we can solve the following problems:

- developing the conceptual model of hydrodynamics and water quality of the river system studied;
- generating the numerical model for predicting water quality;
- the practical implementation of the mathematical and numerical model in water quality management.

A mathematical model of hydrodynamics and chemical pollutants dispersion for a sector of the River Prut in Costesti village was developed in [8]. The hydrodynamics of the studied sector was determined and the temporal and spatial evolution of nitrite N-NO2 and petroleum products was established. The Navier-Stokes equations in differential form as Reynolds, equation of continuity and equation of transport of pollutants were used for modeling:

$$h\frac{\partial u}{\partial t}+hu\frac{\partial u}{\partial x}+hv\frac{\partial u}{\partial y}-\frac{h}{\rho}\left(E_{xx}\frac{\partial^2 u}{\partial x^2}+E_{xy}\frac{\partial^2 u}{\partial y^2}\right)+gh\left(\frac{\partial H}{\partial x}+\frac{\partial h}{\partial x}\right)+$$
$$+\frac{gun^2}{\left(h^{1/6}\right)^2}\times\left(u^2+v^2\right)^{1/2}-\varsigma V_a^2\sin\psi+2h\omega v\sin\phi=0 \quad (1)$$

$$h\frac{\partial v}{\partial t}+hu\frac{\partial v}{\partial x}+hv\frac{\partial v}{\partial y}-\frac{h}{\rho}\left(E_{yx}\frac{\partial^2 v}{\partial x^2}+E_{yy}\frac{\partial^2 v}{\partial y^2}\right)+gh\left(\frac{\partial H}{\partial y}+\frac{\partial h}{\partial y}\right)+$$
$$+\frac{gvn^2}{\left(h^{1/6}\right)^2}\times\left(u^2+v^2\right)^{1/2}-\varsigma V_a^2\sin\omega+2h\omega v\sin\phi=0 \quad (2)$$

$$\frac{\partial h}{\partial t}+h\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+u\frac{\partial h}{\partial x}+v\frac{\partial h}{\partial y}=0 \quad (3)$$

where:

h - water depth (m); u - local velocity in the x direction (m/s); v - speed local in the y direction (m/s); t - time (s); ρ - density of water (kg/m^3); E - coefficient of turbulent viscosity (Pa.s or kg/m/s); g - acceleration of gravity (m/s^2); H - geodetic share of the riverbed (m); n - manning's roughness coefficient; ζ - empirical coefficient concerning the friction with the air; V_a - wind speed (m/s); ψ - wind direction; ω - angular velocity of the Earth rotation (rad/s); φ - latitude of the place [7].

$$h\left(\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}-\frac{\partial}{\partial x}D_x\frac{\partial c}{\partial x}-\frac{\partial}{\partial y}D_y\frac{\partial c}{\partial y}-\sigma+kc+\frac{R(c)}{h}\right)=0 \quad (4)$$

where:

h - is the water depth (m); c - concentration of pollutant (mg/l); t - time (s); u - velocity in x direction (m/); v - velocity in y direction (m/s);

D_x - turbulent diffusion coefficient in the x direction (m^2/s); D_y - turbulent diffusion coefficient in y direction (m^2/s); k - decay constant (s^{-1}); σ - term local source of pollutant (concentration unit/s); $R(c)$ - precipitation / evaporation (concentration unit × m/s) [8].

The developed model in [8] was used to determine the dispersion of copper products for a sector of the River Prut, Ungheni town. It was found that after 5 hours and 30 minutes the pollutant transport became stationary [9].

Iron water pollution has negative effects on human health. Numerical models for determining the iron concentration for a sector of Prut River is presented in [10].

The problem of mathematical modeling and numerical simulation of the process of fluoride dispersion in "river-type" systems are addressed in [11]. The results of numerical models for hydrodynamics and fluoride dispersion for a sector of Prut River, Ungheni town are presented.

4 Case Study - modeling dispersion of petroleum products for a sector of the River Prut

In November 2012 on an area of the Prut River, Ungheni town the maximum permissible concentration of petroleum products exceeded. To determine the temporal and spatial evolution of the pollutant it was proposed to simulate the process of oil products dispersion in the mentioned sector.

The mathematical model developed in the works [8-11] was used for modeling the studied sector.

The obtained numerical models were developed using the program Surface-water Modeling System (SMS) v.10.1.11, which was designed by experts from Aquaveo company [12]. The hydrodynamics of the studied sector, obtained using the SMS module named RMA2 [13], served as input for the RMA module 4, which determined the pollutant dispersion [14].

A concentration of 0.14 mg/L of petroleum product was used for modeling. This sample was taken by the Environmental Quality Monitoring State Hydrometeorological Service of the Republic of Moldova. The maximum permissible concentration of petroleum products is 0.05 mg/L. It was simulated a scenario of polluting Delia river with oil products, which is a tributary of the River Prut, and as well transportation and spreading the oil products on the River Prut.

The Prut River flow, as well as its tributary river flow Delia were taken into account for modeling. There were established the following boundary conditions: Delia River flow Q_1 = 50 m^3/s, Prut River flow Q_2 = 120 m^3/s and the geodesic share of the Prut River H = 4.6 m.

After simulation the hydrodynamics of the studied sector was determined. The resulting velocity field is shown in Figure 1.

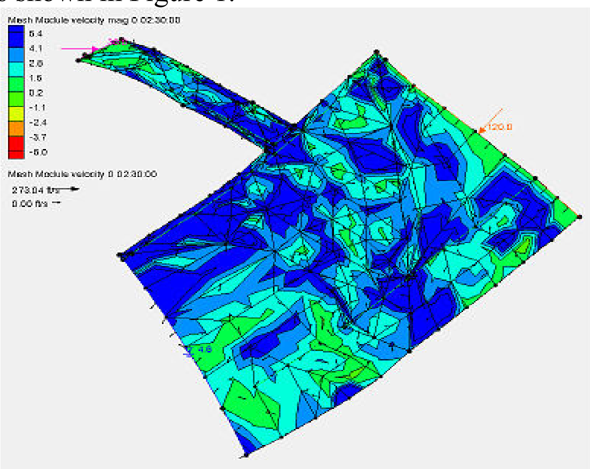

Fig 1. Resulting velocity field distribution.

Pollutant dispersion after 1 hour from water confluence is presented in Figure 2.

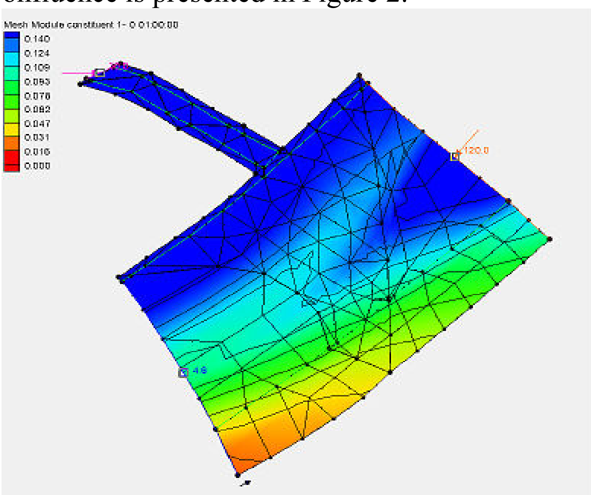

Fig.2. Pollutant dispersion after 1 hour from the water confluence.

It is noted that after 1 hour from water confluence with petroleum products, the tributary and the major part of the sudied sector of the Prut River were polluted.

Pollutant dispersion after 5 hours shown in Figure 3.

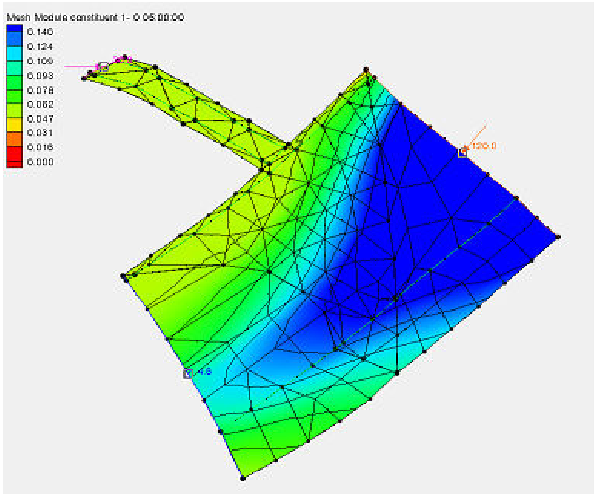

Fig.3. Field distribution of pollutant concentrations after 5 hours from the water confluence.

The transport and petroleum products dispersion after 9 hours and 11 hours are shown in Figures 4 and 5.

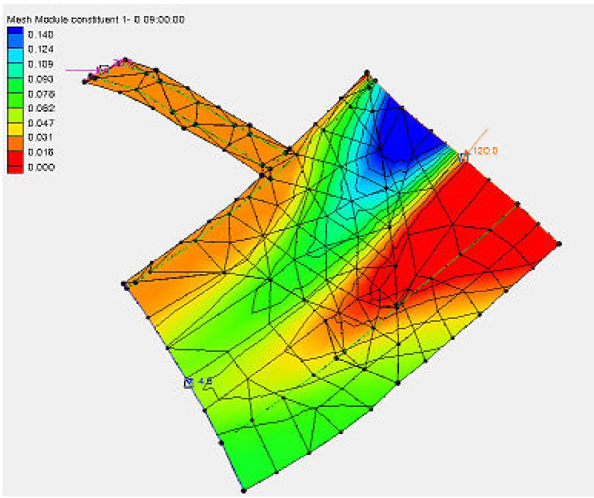

Fig.4. Field distribution of pollutant concentrations after 9 hours from the water confluence.

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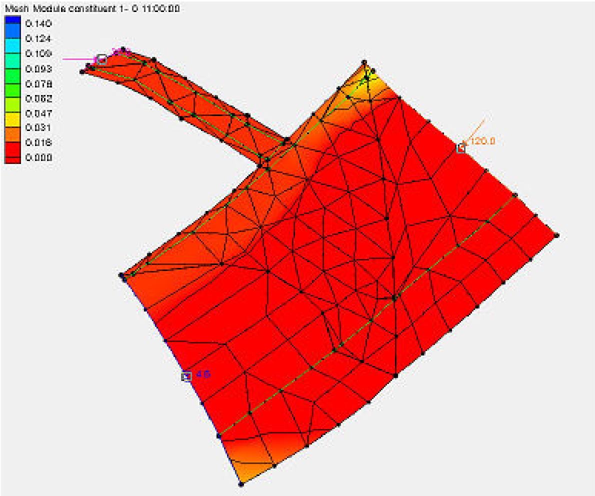

Fig.5. Field distribution of pollutant concentrations after 11 hours from the water confluence.

After 11 hours the concentration significantly decreased throughout the studied sector and became stationary.

5 CONCLUSION

As a result of bibliography analysis concerning the water quality from Prut River, it was found out that this area is less researched and requires further study. There are a small number of works related to the appearance of hydrological, geomorphological and biological control of this river, but are practically missing.

A scenario of pollutant dispersion was simulated after developing a mathematical model for a sector of the River Prut. The obtained numerical model of pollutant dispersion allows determining the spatio-temporal evolution of the pollutant, allowing correct determination of the water quality level.

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