A study on the mathematical modeling of water quality in "river-type" aquatic systems

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Abstract: - This paper deals with the problem of pollution in "river-type" aquatic systems. We discuss prediction methods of pollution and water quality determination, and the concept of "water quality". It examines the main sources of pollution in the river. It presents an analysis of scientific work in the field of river pollution. It addresses the problem of mathematical modeling of hydrodynamics and pollutant dispersion in "river-type" systems. It summarizes the scientific work in the field of river water quality modeling.

Key-Words: - water quality, river, turbulent motion, punctate pollution, diffuse pollution, mathematical modeling, numerical model

1 Introduction

The economic activity of society brings negative changes in aquatic systems for example: changing the chemical composition of water and disrupting aquatic systems. Most human activities are carried out using water from rivers, which is lately steadily declining.

Water must meet quality standards in order to be used. The term "water quality" is defined in several ways:

- Depending on the intended use of the water - is a set of chemical, physical and biological characteristics, concerning its capacity for a particular case application [1].
- From the point of view of environmentalists - the state of an aquatic system referred to the physico-chemical conditions of this system, which could support a healthy community to the aquatic biota in balance in local conditions.
- According to sanitary engineering - water quality refers to a specific location in terms of human health, including diseases transmitted through water.

From the point of view of specialists in water management - water quality is defined by human uses, such as drinking water, irrigation, industrial or transportation use, power generation [2].

According to the Water Framework Directive 2000/60/EC (Amended by Directive 2008/32/EC) approved by the European Commission, till 2015 it is required to be insured status "very good" for all Water Bodies. The main objective of the Directive is to protect and improve the ecological status of aquatic ecosystems. This can be achieved through appropriate management of water systems and environmental quality standards on pollution management processes of water systems. Currently, water quality assessment in accordance with the requirements of the Water Framework Directive for several rivers in Europe showed a satisfactory or unsatisfactory environmental condition. In this connection, it is necessary to analyze the "river-type" water systems to rehabilitate and maintain them in a state "very good" [3, 4].

Problems of environmental pollution requires swift action to prevent lowering water quality. Choosing pollution control methods and determining quality is an important step in improving water quality.

An effective method of controlling and predicting water pollution is the use of information systems consisting of two main components: mathematical models and software, which are generated by numerical models [5].

2 Problem Formulation

Surface water pollution is an important issue in recent years. Reducing the pollution of aquatic systems is a primary global objective.

The behavior of contaminants in the aquatic environment depends on many factors: chemical, physical, hydrodynamic and biological. Pollution is a pressure that influence the state of aquatic ecosystems. Sources of pollution of aquatic systems are different (Fig. 1):

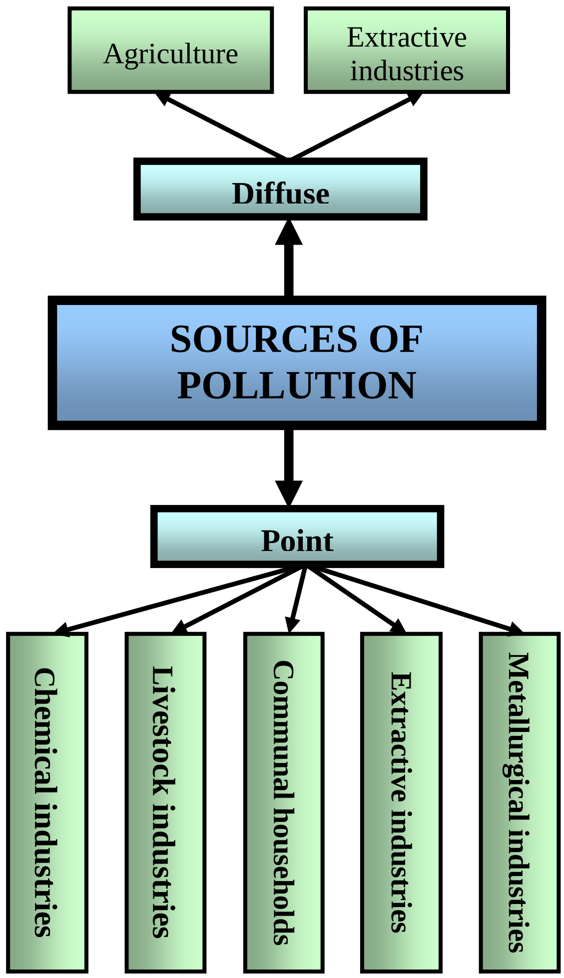

Fig 1. Sources of surface water pollution.

Surface waters often degrade after being used for agricultural fertilizers and pesticides and heavy metals presence in the water. The simultaneous existence of multiple sources of pollution leads to significant variations in the concentration of pollutants field. The chemical composition of water is greatly affected by agricultural and urban pollution management [6, 7, 8].

Such rivers from Romania as: Tur, Lapus, Aries, Cavnic, Arges, Tîrnava, Cibin, Dîmbovița, Vaslui, Jijia are strongly influenced by human activities through pronounced pollution. A dispersion model was developed on accidental pollution in natural streams, which allows predicting the evolution of pollutant in aquatic environment and impact assessment of the environment. Dispersion processes were simulated and spatial development of pollutant was monitored in the rivers Arges, Dîmbovița in different flow sectors. It was noted that in the river depth, the concentration of the pollutant is higher. At the confluence of the Dâmbovița and Arges, the concentration of the pollutant is totally dispersed. This is explained by the fact that the Arges river has a higher flow rate [9].

An analysis of the water quality of the river Arges, Romania, is presented in [10]. Arges basin provides water supply during the whole year in Bucharest. Key indicators affecting the chemical and biological quality of the river Arges river on Vidraru - Golesti: BOD5, NH4, NO2 and NO3, P_{total}, Phytoplankton were evaluated. For a more accurate assessment it was proposed to divide the river sector in segments, each segment being defined by potential changes. The pollution level was assessed taking into consideration the sampling mode, the number of parameters analyzed, frequency of measurements. It was established that the level of pollution can be reduced by eliminating, first, the sources of pollution. There were highlighted major sources of pollution: Curtea de Arges and Pitesti on Arges River, Campulung Muscel and Mioveni on Tirgului River [10].

An important issue, both, for human health and for fauna and flora, is the Aries river pollution from Romania. Sources of pollution of the river are multiple: mining, uncontrolled activity on the farm wastewater discharge in different tributaries of the river, and others. To determine the degree of pollution and water quality assessment of this river a research method was used that consists in knowing the intensity of enzymatic activity. Knowing the intensity of enzyme activity determines the degree of impurity of an aquatic ecosystem. The sediment samples were taken from the upstream or downstream in the main places which are crossed by the river. Five sampling points were described: Abrud, Baia de Aries, Sălcuia, Luncani and Turda. Ther were registered large variations in enzyme activity depending on the nature of the enzyme studied, the point of sampling, the main pollutants in the river, as well as the physical and chemical characteristics of the water [11].

To determine water quality, it is necessary to accurately assess the physico-chemical parameters. A case study is presented for Asmaki channel from Greece. The results of a study conducted over two years on specific water quality parameters are presented. The physico-chemical parameters (Na^+, K^+, Cl^-, Ca^{2+}, Mg^{2+}, electrical conductivity, SO_4^{2-}, total alkalinity, CO_3^{2-}, and HCO^{3-}) and the presence of heavy metals (Cr, Pd, Ni, Cu, and Cd) were evaluated, in order to monitor water quality and to assess the contribution of urban, agricultural and industrial activities [12].

The problem of water quality is actual for the Republic of Moldova. Groundwater and surface water quality in the country, in most cases, do not meet national, European and international standards (UNESCO, World Health Organization, etc..). Water quality management system is unbalanced and there is not a unique concept on the rational utilization of water resources. Surface water and groundwater are polluted from various sources:
- discharge of untreated water from the municipal system;
- inadequate waste management;
- deposits of pesticides etc.

An example of river pollution in Moldova may be exceeding the MAC (maximum allowable concentration) values of some pollutants in water samples taken from the largest rivers in Moldova, Prut and Nistru, in February 2013 recorded by the Hydrometeorological Service Moldovan state.

For the Prut river there were recorded exceedances of MAC for ammonium (N-NH4) and nitrite (N-NO2) in some regions [14], (Fig. 2):

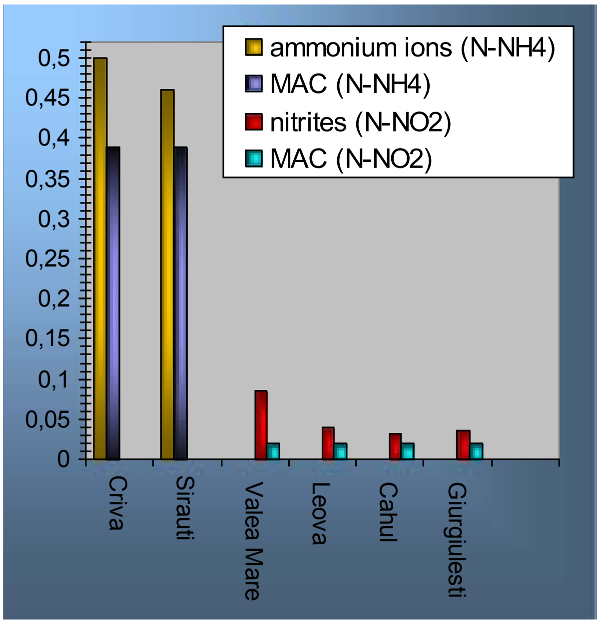

Fig. 2. The concentrations of N-NH4 and N-NO2, which exceeded MAC for the Prut river, the O*y*-axis - the concentration (mg / L), O*x* - name localities.

For the Nistru River there were recorded exceedances of MAC for ammonium (N-NH4) and phenols [14], (fig. 3):

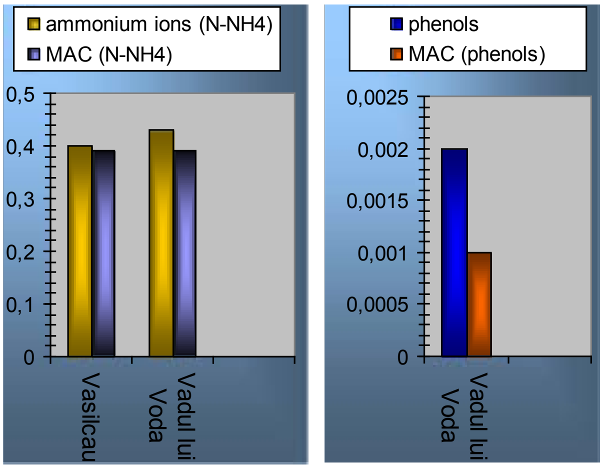

Fig. 3. The concentrations of N-NH4 and phenols, which exceeded the MAC for the Nistru River in those areas, the O*y*-axis - the concentration (mg / L), O*x* - name localities.

A danger to human health, primarily for children, is the nitrite water pollution. Using water polluted with nitrates affects long-term psychomotor development of children. With regard to an adult, the use of water contaminated with nitrates causes various forms of cancer. A particularly important issue and difficult to prevent represents water pollution with petroleum products, which has an adverse effect on the aquatic environment and human health. Exceeding the maximum allowable concentrations of nitrite N-NO2 and petroleum products was recorded in July 2011 for a sector of the Prut River Costesti, Moldova. It was determined the concentrations of pollutants field evolution using numerical models that have been generated from mathematical models. It was found that after 5 hours the pollutant transport became stationary [15].

High concentrations of copper in water has toxic effects on the human body as copper compounds poisoning is very fast. In August 2011 in a sector of the Prut River in the town Ungheni Moldova was registered about 16-fold excess of CMA for the concentration of copper compounds. This excess is linked with agricultural activities when vine plantations near the Prut River, were processed with copper sulphate. After heavy rains a quantity of copper sulphate reached the river. As a result, the concentration of copper compounds in the river significantly exceeded the maximum allowable concentration value. The pollutant dispersion was determined in time and space in dynamic simulation using numerical models [16].

Fluoride is an important chemical needed for proper development of teeth and skeletal bones. The problem of the fluoride influence on the human body is presented in [17]. It discusses aspects of fluoride content in drinking water, fluoride deficiency and excess in the body. General toxic action of fluoride on the body is proportional to its amount into the human body and does not depend on access roads. The concentration of fluoride ions in drinking water supplies in many regions of Moldova is increased, exceeding the MAC, which is 1 mg / L. In Nisporeni, Hâncesti, Calarasi, Ungheni Făleşti fluoride concentration in drinking water is above permissible concentrations 5-10 times [13]. Taking into consideration this fact, the problem of mathematical modeling of the fluoride dispersion was carried out in [17]. Fluoride concentration field development for the studied river was obtained. It was found that after 7 hours the pollutant transport became stationary [17].

Using iron polluted water has negative consequences for human health. This is discussed in [18]. It models a scenario for dispersing iron in a sector of the Prut River in the town Ungheni, Moldova. It was used iron sample value C = 0.02 mg / L, taken in July 2011, which exceeded the maximum allowable concentration. It was noted that after 6 hours the iron concentration values decreased substantially throughout the study. Since then, the pollutant transport has become stationary [18].

Taking into consideration the above, the problem of analyzing and studying the mathematical modeling process is being formulated in order to determine the level of water quality in the "river-type" systems and to predict and prevent pollution processes.

3 Problem Solution

River hydrodynamics is a complex process, which presents a turbulent flow. The problem of reducing pollution and improving water quality can be solved by using the appropriate mathematical models and their implementation in software.

In the list of current problems, which are solved by using mathematical modeling, environmental issues play a distinct role. The issue of water quality is a difficult problem because water is a complex physical, biochemical and ecological system. An effective solution for analyzing and solving various problems in water systems are methods based on mathematical modeling of such systems. Using mathematical modeling helps to predict the behavior of aquatic systems and to determine the results of actions of different processes on aquatic systems. The basic steps of mathematical modeling are: observation, hypothesis formulation, modeling itself, experimenting with pattern and pattern completion [19].

Marvin Minsky wrote: “A model (M) for a system (S) and an experiment (E) is anything to which E can be applied in order to answer questions about S” [20].

A model always requires a system and an experiment. Cellier divides models into 2 types: well-defined, with which proceed to system design, and ill-defined. In environmental systems partial differential equations and ordinary differential equations are used to calculate various processes [21].

Environment mathematical modeling began in the 1900s with the works of Streeter and Phelps on dissolved oxygen. Modeling of environmental systems is a complex and difficult problem. For solving these problems different mathematical models are used (Fig. 4):

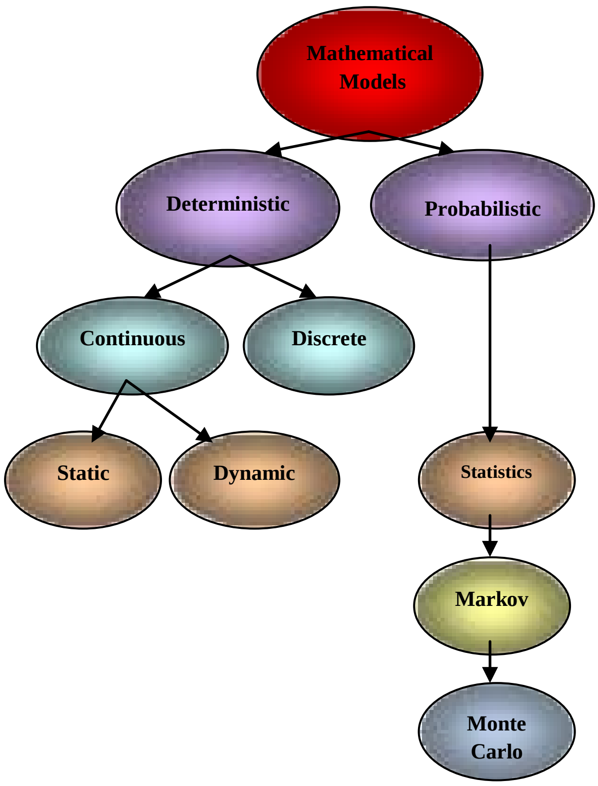

Fig. 4. Mathematical models for environmental modeling

The choice of model depends on the nature of the variables, mathematical approaches used and the behavior of the real system.

During the modeling process, algebraic equations, systems of algebraic equations, Ordinary differential equations, Partial differential equations, which can be Linear and Nonlinear, are used. These equations are solved by Analytical and Numerical methods.

For modeling processes through probabilistic models, the method of Monte Carlo is used.

In surface waters area the mathematical models are used for solving wastewater treatment, industrial pollution, agricultural pollution, protection of potable water sources and others. The models are used in dispersion the transport of pollutants, control and analysis of the processes [19].

Mathematical models of various processes of the river-type systems are based on modeling the homogeneous fluid flow. Lately, the two-dimensional models have been used for modelling the processes in river-type systems. One-dimensional models use average flow velocity in the cross section and describe the processes with reduced exactity. Analytical methods are used when solving equations. At the same time, using one-dimensional model has not to be neglected because the solutions obtained can be used to test numerical models and quick evaluation of characteristic parameters for the problem. A one-dimensional model was developed in [22]. The basic equations of the model are:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+g\frac{\partial H}{\partial x}=g\frac{dh_0}{dx} \quad (1)$$

$$\frac{\partial A}{\partial t}+\frac{\partial}{\partial x}\left[A(x,t)u\right]=0 \quad (2)$$

Where $u(x,t)$ - the average speed of the water flow, $A(x,t)$- cross-sectional area of the flow, $H(x,t)$ - full depth of the basin, $h_0(x)$ - undisturbed value, g – acceleration of free fall, x – coordinate in the direction of the river flow, t – time.

This system is not closed and the connection equation between A and H is given by the geometry of the water flow in a vertical plane. For this it is necessary to know the river bed profile $z(y;x,t)$ at each and every cross section along the river. Cross sectional area of flow is calculated as follows:

$$A(x,t)=\int z(y;x,t)dy \quad (3)$$

Analytical solutions have been obtained, which describe the transformation of a steady flow in a channel with variable parameters. The results enable performing hydrological analysis for small rivers [22].

When modeling, it is necessary to reduce the gap between simulation and real system. In general, this reduction is complicated because of the inevitable uncertainties in the modeling process. Analyzing and assessing the impact of uncertainty on the model performance can provide useful information for obtaining a better mathematical model. A methodology for analysing the model uncertainty of river water quality was developed in [23], aiming to assess the ecological status of small rivers. The methodology was applied to Oreto river in Italy. It was used a mathematical model developed by Thomann and Mueller in 1987 and Chapra in 1997, based on the advection-dispersion equation for one-dimensional flow:

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}=D_L\frac{\partial^2 C}{\partial t^2}-f(C) \quad (4)$$

Where C – concentration of a generic pollutant, t – time, x – longitudinal displacement, u – velocity, D_L – diffusion coefficient, $f(C)$ – a generic term for reactions involving the pollutant C.

In order to generate a large number of parameters for the model, the Monte Carlo method was applied. Simulations were performed for each parameter set in order to compare with measured data (BOD, DO, NH4, and NO3). The effectiveness of this approach was evaluated with reference to the interpretation of data collected from the field [23].

A mathematical model based on the system of equations of Sen - Venan is developed in [24]. A river discharge of Ural and Samara river basins in Russia was modeled. It was used the one-dimensional continuity equation and the equation of motion for river channels, with lateral inflows:

$$\omega\frac{\partial V}{\partial x}+V\frac{\partial \omega}{\partial x}+\frac{\partial \omega}{\partial t}=q \quad (5)$$

Where Q – water consumption (m^3/s), ω – cross-sectional area (m^2), V – the average flow velocity (m/s), q – side flow per unit of length (m^2/s), x-spatial coordinate (m), t - coordinated time (s).

$$\frac{\partial V}{\partial t}+V\frac{\partial V}{\partial x}+\frac{g}{\omega}.\frac{\partial\left(\overline{H}\omega\right)}{\partial x}+\frac{V.q}{\omega}=g\left(I-I_T\right) \quad (6)$$

Where g - acceleration of free fall, I - river bed slope (m / m), I_T - Hydraulic gradient (m / m), H - the distance between the water surface and the center of gravity of the cross section.

It was developed a parallel algorithm that determines the solutions for each sector that have constant hydrological characteristics [24].

A discrete mathematical model of the hydrodynamics is developed in [25]. In developing the discrete model, the main source of error is approximation of limit conditions. It is important that all input data to be of the same order of approximation. It was developed a three-dimensional model of hydrodynamics based on the equations of Navier-Stokes and continuity equation for incompressible fluids:

$$u_t' + uu_x' + vu_y' + wu_z' = -\frac{1}{\rho}P_x' + \left(\mu u_x'\right)_x' + \left(\mu u_y'\right)_y' + \left(vu_z'\right)_z' + 2\Omega\left(v\sin\theta - w\cos\theta\right) \quad (7)$$

$$v_t' + uv_x' + vv_y' + wv_z' = -\frac{1}{\rho}P_y' + \left(\mu v_x'\right)_x' + \left(\mu v_y'\right)_y' + \left(vv_z'\right)_z' - 2\Omega u\sin\theta \quad (8)$$

$$w_t' + uw_x' + vw_y' + ww_z' = -\frac{1}{\rho}P_z' + \left(\mu w_x'\right)_x' + \left(\mu w_y'\right)_y' + \left(vw_z'\right)_z' + 2\Omega u\cos\theta + g \quad (9)$$

$$u_x' + v_y' + w_z' = 0 \quad (10)$$

Where $V = \{u,v,w\}$ - the velocity vector components, p – hydrodynamic pressure, ρ - density, Ω - angular speed of the earth rotation, θ - angle of angular and vertical velocity, μ, v - horizontal and vertical components of the coefficient of turbulence.

A discrete mathematical model was obtained where border nodes have the same order of approximation as the interior [25].

A deterministic mathematical model was developed to determine the dispersion of petroleum products for a sector of Prut River from Costesti in the Republic of Moldova. The hydrodynamic of the studied sector has been shaped by means of the system of Navier-Stokes equations in the form of Reynolds (11) and (12) in conjunction with the continuity equation (13):

$$h\frac{\partial u}{\partial t} + hu\frac{\partial u}{\partial x} + hv\frac{\partial u}{\partial y} - \frac{h}{\rho}\left(E_{xx}\frac{\partial^2 u}{\partial x^2} + E_{xy}\frac{\partial^2 u}{\partial y^2}\right) + gh\left(\frac{\partial H}{\partial x} + \frac{\partial h}{\partial x}\right) + \frac{gun^2}{\left(h^{1/6}\right)^2}\times\left(u^2+v^2\right)^{1/2} - \varsigma V_a^2\sin\psi + 2h\omega v\sin\phi = 0 \quad (11)$$

$$h\frac{\partial v}{\partial t} + hu\frac{\partial v}{\partial x} + hv\frac{\partial v}{\partial y} - \frac{h}{\rho}\left(E_{yx}\frac{\partial^2 v}{\partial x^2} + E_{yy}\frac{\partial^2 v}{\partial y^2}\right) + gh\left(\frac{\partial H}{\partial y} + \frac{\partial h}{\partial y}\right) + \frac{gvn^2}{\left(h^{1/6}\right)^2}\times\left(u^2+v^2\right)^{1/2} - \varsigma V_a^2\sin\omega + 2h\omega v\sin\phi = 0 \quad (12)$$

$$\frac{\partial h}{\partial t} + h\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + u\frac{\partial h}{\partial x} + v\frac{\partial h}{\partial y} = 0 \quad (13)$$

Where h – water depth (m), u - The local velocity in the x (m/s), v - the local velocity in the y direction (m/s), t - time (s), ρ – water density (kg/m^3), E - turbulent viscosity coefficient (Pa.s sau kg/m/s), g - acceleration of gravity (m/s^2), H - geodetic elevation of the riverbed (m), n - Manning roughness coefficient, ζ - empirical coefficient of friction with the air, Va – wind velocity (m/s), ψ – wind direction, ω - angular speed of earth rotation (rad/s), φ - the latitude [15, 26, 27].

To determine the dispersion of petroleum products it was used the basic two-dimensional advection-dispersion equation applied to turbulent flow regime [28, 29]:

$$h\left(\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} - \frac{\partial}{\partial x}D_x\frac{\partial c}{\partial x} - \frac{\partial}{\partial y}D_y\frac{\partial c}{\partial y} - \sigma + kc + \frac{R(c)}{h}\right) = 0 \quad (14)$$

Where h - is water depth (m), c - the concentration of the pollutant (mg /L), t - time (s), U - velocity in the x (m/s), v - speed of the S (m/s),

D_x - turbulent diffusion coefficient in the x direction(m^2/s),

D_y - turbulent diffusion coefficient in the y direction(m^2/s),

k - decay constant (s^{-1}), σ - local pollutant source term (the measure of the concentration/s), $R(c)$ - precipitation / evaporation (concentration unit x m/ s).

Local variation of the concentration is represented by I the term of the equation, II is an advection term in the x direction; III - advection term in the y direction.

The phenomenon of dispersion in the x direction is represented by the IV term, and in the direction y – by the V term;

VI term represents the local source of pollutant;

VII models exponential degradation of the pollutant;

VIII takes into account the effect of precipitation / evaporation.

To determine the turbulent diffusion coefficients were used empirical formula:

$$D_x = 5{,}93 h u_* \qquad (15)$$

where h is the water depth,

$$u_* = \sqrt{\frac{\tau_0}{\rho}} \quad \text{- friction velocity} \qquad (16)$$

τ_0 - average tangential effort to the wall,

ρ - water density.

$$D_y = \alpha h u_* \qquad (17)$$

Where α – a coefficient (after Fischer, 1979, α = 0,6;after Elder, 1959, α = 0,2).

The following boundary conditions were established: flow rate Q = 135 m^3/s and H = 3 m geodetic rate.

When solving mathematical models, numerical methods were used. Pollutant concentration values determined from the left bank at different intervals are shown in Figure 5:

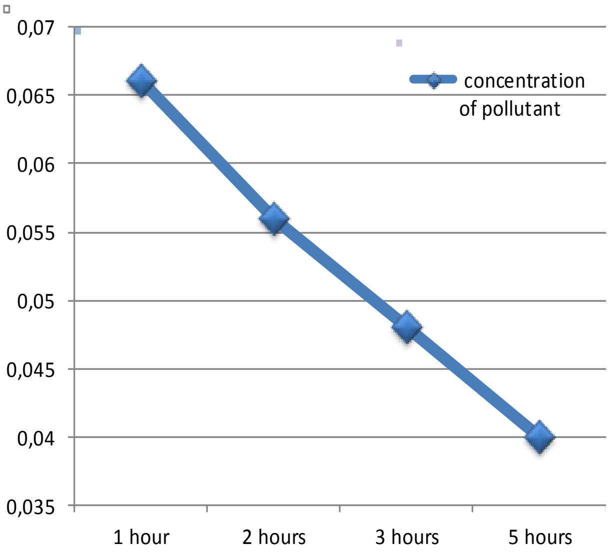

Fig. 5. Changes in the concentration of the pollutant in the left bank: O*y* - concentration (mg / L), O*x* - time (hours).

The obtained numerical models allowed the determination of hydrodynamics and pollutant dispersion in time and space [15].

The developed model in [15] was used to determine the evolution of the field concentration of copper compounds on a sector of the Prut River in the town Ungheni. The following boundary conditions were established: flow rate Q = 56 m^3/s and H = 6 m geodetic rate. It was determined the hydrodynamics and the field concentration of the pollutant in any finite element of the considered sector. Reducing pollutant concentration value recorded at the left bank depending on the time is shown in Figure 6:

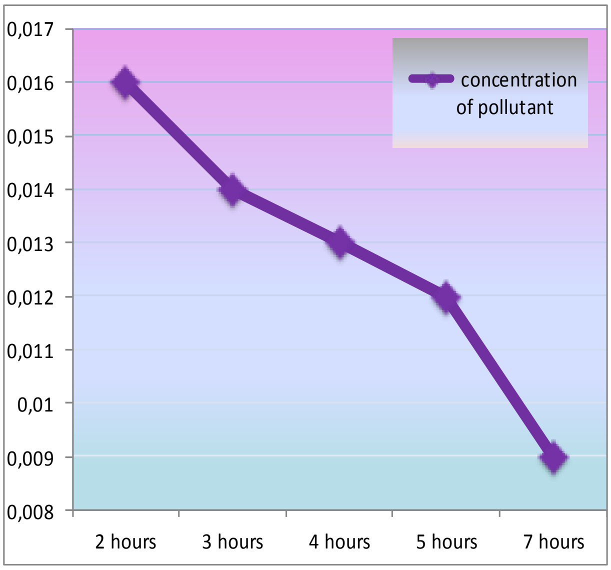

Fig. 6. The evolution of copper compounds concentration on the left bank: O*y* - concentration (mg/L), O*x* - time (hours).

It was established that after 7 hours the pollutant concentration became stationary [30].

A danger to the human body is iron water pollution. Long-term use of water with increasing iron concentration may result in causing many diseases and may even be poisonous. In rivers, iron occurs by natural and artificial sources. In July 2011 in a section of the river Prut in the town Ungheni was detected a significantly exceeded maximum allowable concentration (MAC) of iron. The mathematical model developed in [15] was used to determine the evolution of the pollutant concentration field. The following boundary conditions were established: Q = 54,3 m^3/s - the constant flowrate (was assigned for the arc group at the inflow (top) cross sections), H = 4,6 m – the constant geodetic rate (was assigned for the arc group at the outflow cross sections). The obtained numerical models allowed the determination of the of hydrodynamics and pollutant concentrations field of all finite elements of studied sector. Temporal evolution of the pollutant from the left bank is shown in Figure 7:

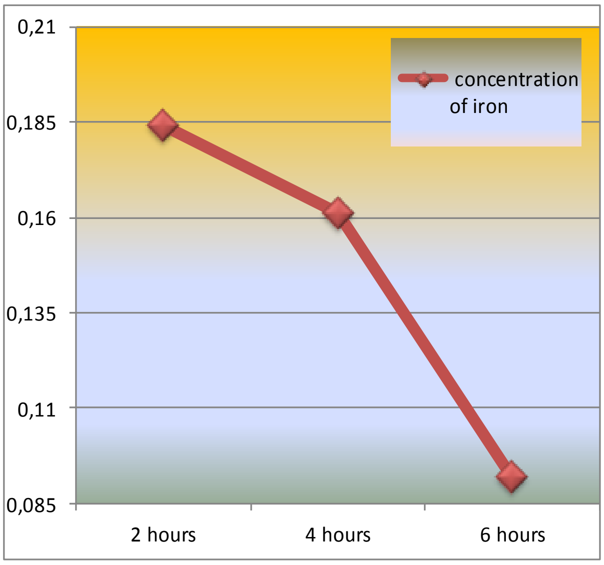

Fig. 7. Temporal evolution of the iron concentration on the left bank.

A reduction of iron concentration value was registered after 6 hours of water confluence [18].

More and more frequently, river pollution with oil products has been recorded. An exceedance of the maximum allowable concentration for petroleum products was recorded for Delia river, which is a tributary of the River Prut. As a result, some of pollutant was transported and spread on the river Prut. To determine the pollutant dispersion, a scenario of Delia and Prut river pollution was simulated. 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. From the obtained numerical models was found that after 10 hours and 30 min. The value of pollutant concentration decreased significantly throughout the studied sector (Fig. 8):

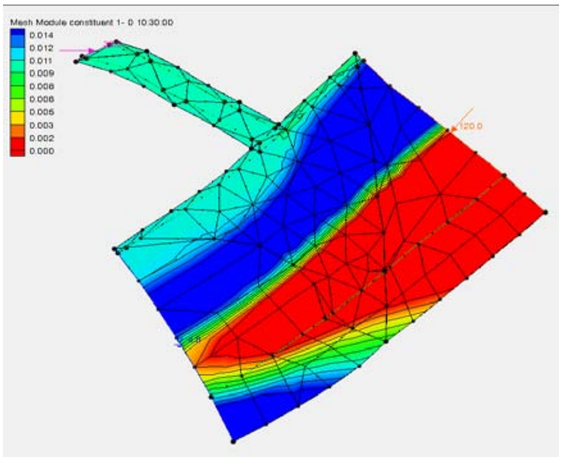

Fig. 8. Field distribution of pollutant concentrations after 10 hours and 30 minutes.

Temporal evolution of the pollutant from the left bank is shown in Figure 9:

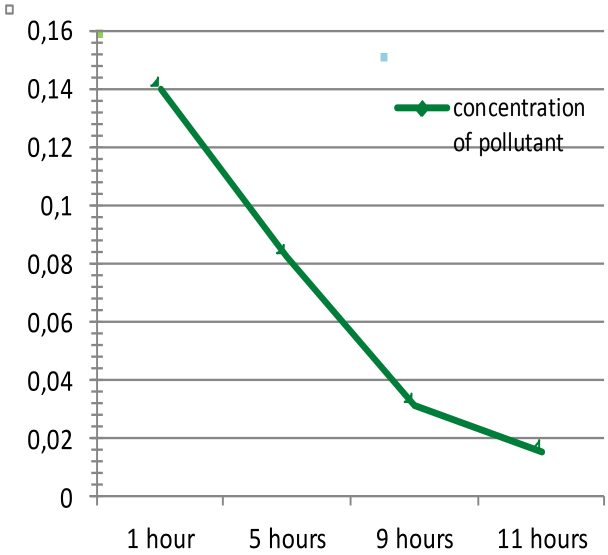

Fig. 9. Temporal evolution of the pollutant concentration on the left bank.

After 11 hours the concentration value decreased significantly throughout the studied sector and the pollutant transport became stationary [31, 32, 33].

A mathematical model based on Spline analysis of physico-chemical parameters for the River Suceava, Romania is presented in [36]. The need for modeling this river is given by the fact that currently there are few studies on the Suceava river water quality. An approximation function known as Spline function is obtained:

$$S(x)=S(x_k)=s_{k0}+s_{k1}(x-x_k)+s_{k2}(x-x_k)^2+s_{k3}(x-x_k)^3$$

$$x\in[x_k, x_{k+1}], \qquad k=\overline{0,n-1} \qquad (18)$$

Using Spline function was modeled physico-chemical evolution following indicators: dissolved oxygen, CBO5, N-NO3. In several sections the analyzed was determined aquatic ecological status high and good.

Function obtained can be used to approximates the evolution of concentration in sections monitored and solve different interpolation and approximation problems [34, 35, 36].

4 Conclusion

The issue of water quality is a key to sustainable human development. This issue is complex and therefore its solution is necessary to involve experts from all fields: physics, chemistry, mathematics, etc. The water must meet quality standards depending on the use, placing an emphasis on drinking water quality. Using polluted water causes many diseases in children and adults, which is very difficult to treat and in some cases impossible to treat.

Achieving the objectives Water Framework Directive should be a primary issue for all the countries on Earth globe. Only in this case will meet all water quality standards.

Proceeding from the analysis of scientific papers on pollution of "river-type" systems and mathematical modeling of processes in these systems, it was found that deterministic mathematical models are a powerful and useful tool for the pollution control and prevention in the systems mentioned above.

The type of mathematical model can be chosen depending on the flow regime of the river and the studied processes. It is necessary to note that the mathematical models are very sensitive to changes in parameters and requires careful coefficients selection for specific aquatic system model.

To obtain results with high accuracy, two-dimensional and three-dimensional models are used. Numerical methods are used to solve them. But for a better understanding of the behavior of the real system one-dimensional models can be used, and these models can be solved by analytical methods. Analytical solutions obtained can be used to model complex processes in"river-type" systems.

The study shows that the water quality modeling process involves researchers from different countries: Romania, Greece, Russia, Moldova, etc. To get the best results it is necessary that all produced and developed models to be implemented in practice. This would bring great benefits for the environment and emergencies prevention.

The next step of this study will be software packages analysis that are used in the implementation of mathematical models in numerical models, highlighting the best software packages.

References:

[1] C. Park, *Dictionary of Environment and Conservation*, Oxford University Press, 2007.

[2] D. Cuff, A. S. Goudie, *Encyclopedia of Global Change*, Oxford University Press, 2005.

[3] V. Vasilache, C. Filote, Monica A. Cretu, I. Sandu, V. Coisin, T. Vasilache, C. Maxim, Groundwater Quality for Nitrate and Nitrite Pollutants in some Vulnerable areas in Botosani Country, *Environmental Engineering and Management Journal*, Vol. 11, No. 2, 2012, pp. 471-481.

[4] Gh. Bătrinescu, E. Birsan, G. Vasile, B. Stanescu, E. Stanescu, I. Paun, M. Petrescu, C. Filote, Identification of the Aquatic Ecosystems Integrating Variables in Suceava Hydrographic Basin and their Correlations, *Journal of Environmental Protection and Ecology*, Vol. 12, No. 4, 2011, pp. 1627-1643.

[5] R. Găgescu, M. Tertişco, P. Junie, C. Eremia, Ensuring sustainable use of water on Earth by computerized environmental monitoring, *Romanian Journal of Information and Automation*, vol. 21, No. 3, 2011, pp. 5-12.

[6] M. Dassenakis, M. Scoullos, E. Foufa, s.a., Effects of multiple source pollution on a small Mediterranean river, *Journal of Applied Geochemistry*, vol. 13, No. 2, 1998, pp. 197-211.

[7] K. Fytianos, A. Siumka, G. Zachariadis, S. Beltsios, Assesment of the quality characteristics of Pinios River, Greece. *Journal of Water, Air and Soil Pollution*, vol. 136, No. 1- 4, 2002, pp. 317-329.

[8] D. Bellos, T. Sawidis, I. Tsekos, Nutrient chemistry of river Pinios (Thessalia, Greece), *Journal of Environment International*, vol. 30, No. 1, 2004, pp. 105-115.

[9] C. Mocanu, D. Fodor, Numerical simulation of pollutant dispersion in the natural course, *Ecoterra*, No. 28, 2011, pp. 119-125.

[10] M. Diaconu, Water quality in the upper basin of the Arges river upstream Golesti, *IWM 2008 Conference*, pp. 27-32.

[11] A. Bodoczi, M. Drăgan-Bularda, Enzymology quantitative analysis of river sediments upstream Aries at various points downstream, *Analele SNBC*, vol. 13, 2008, pp. 287-291.

[12] Nikos E. Mastorakis, New Method for Designing 2-D IIR Comb Filters, WSEAS Transactions on Systems, Issue 1, Vol. 10, January 2011, pp. 1–6

[13] Z. Jiang, J. Huang, The Mathematical Structure of a Bias-Minimized Assessment Algorithm, WSEAS Transactions on Systems, Issue 11, Vol. 10, November 2011, pp.387 – 397

[14] V. Prepelita, Adjoints 2D Hybrid Boundary Value Systems over Spaces of Regulated Functions, WSEAS Transactions on Systems, Issue 1, Vol. 9, Jan. 2010, pp.82– 93

[15] Gh. Duca, Water management in Moldova. Expertise of A.Ş.M., *Akademos*, No. 2 (17), 2010, pp. 26 - 27.

[16] ***http://www.meteo.md/mold/anulcurent.htm.

[17] V. Besliu, C. Cufudean, C. Filote, G. Marusic, V. Moraru, B. Ştefănescu, Mathematical modeling of hydrodynamics and chemical

pollutant dispersion in rivers, *Proceedings of the 7th International Conference on Microelectronics and Computer Science ICMCS – 2011*, Technical University of Moldova, Chişinău, vol.1, September 22-24, 2011, pp. 160 -165.

[18] G. Marusic, V. Moraru, Mathematical modeling of pollutant transport for a sector of the Prut River. *Proceedings of the 3th International Conference "Mathematical modeling, optimization and information technology"*, Academy of Transport, Information and Communications of Moldova, Chişinău, March 19-23, 2012, pp. 86-98.

[19] C. Ciufudean, C. Filote, D. Amarandei, Model-based Diagnosis of Controllers for Data Risk Overflow, 10th WSEAS International Conference on AUTOMATIC CONTROL, MODELLING And SIMULATION (ACMOS '08) Istanbul, Turkey, May 27-30, 2008, pp.422-426,.

[20] G. Marusic, C. Filote, C. Ciufudean, The Spatial - Temporal Evolution of Iron Dispersion in "River-type" Systems, *Proceedings of the 17th WSEAS International Conference on APPLIED MATHEMATICS (AMATH '12)*, Montreux, Switzerland, December 29-31, 2012, pp. 95 – 98.

[21] N. Nirmala Khandan et al., *Modeling Tools for Environmental Engineers and Scientists*, CRC Press, 2001.

[22] M. Minsky, “Models, Minds, Machines”, *Proceedings IFIP*, 1965, pp. 45-49.

[23] F. E. Cellier, *Continuous System Modeling*, Springer - Verlag, New York, 1991.

[24] N. C. Petruhin, E. N. Pelinovschii, Modeling of water flow in the one-dimensional shallow water equations. Proceedings of Nizhny Novgorod Technical University, № 4(91), pp. 60-69.

[25] G. Mannina, Uncertainty Assessment of a Water-Quality Model for Ephemeral Rivers Using GLUE Analysis, *Journal of Environmental Engineering*, vol. 137, No. 3, 2011, pp. 177 – 186.

[26] V. V. Vlatschii, Modeling of river flow using GIS_Tehnology, *Bulletin of the Orenburg State University*, Russia, No. 9, 2010, pp. 104 – 109.

[27] A. E. Cisteacov, Approximation of boundary conditions of three-dimensional model of movement of water environment, *Proceedings of the Southern Federal University*, Russia, No. 6, 2010, pp. 66 – 77.

[28] *** „SMS Tutorials”, SMS v.10.1.11, AquaVeo, 2011.

[29] Surface Water Modeling System - RMA2, US Army Engineer Research and Development Center, AquaVeo, 2011.

[30] S. A. Socolofsky, G. H. Jirka, *Special Topics in Mixing and Transport Processes in the Environment* (5th Ed.), A&M University, College Station, Texas, 2005.

[31] *** Surface Water Modeling System - RMA4, US Army Engineer Research and Development Center, AquaVeo, 2011.

[32] G. Marusic, I. Sandu, V. Moraru, V. Vasilache, A. Cretu, C. Filote, C. Ciufudean, Software for modeling spatial and temporal evolution of river-type systems. *Proceedings of the 11th International Conference on Development and Application Systems*, Suceava, Romania, May 17-19, 2012, pp. 162-165.

[33] G. Marusic, C. Ciufudean, Current state of research on water quality of Prut River, *Proceedings of the 11th WSEAS International Conference on Environment, Ecosystems and Development (EED13*), Brasov, Romania, June 1-3, 2013.

[34] F. Neri, Cooperative evolutive concept learning: an empirical study, WSEAS Transaction on Information Science and Applications,WSEAS Press (Wisconsin, USA), issue 5, vol. 2, 2005, pp. 559-563.

[35] P. Vieru, The quality of Prut River in the Oroftiana sector, judged by biological indicators, *Journal “Dimitrie Cantemir” Geographic Seminar*, No. 25, 2005, pp. 203–2011.

[36] D. Wang, A. Duquennoi, A. Ern, *Mathematical Methods for Surface and Subsurface Hydrosystems*, Series in Contemporaray Applied Mathematics, CAM7, Higher Education Press, 2006. 230 p.

[37] C. Filote, C. Ciufudean, S. Alaci, G. Marusic, A. Cozgarea, The Spline analysis of parameters and pollutants dispersion in river surface water, Advances in Mathematical and Computational Methods, *Proceedings of the 14th WSEAS International Conference on Mathematical and Computational Methods in Science and Engineering (MACMESE '12)*, Sliema, Malta September 7-9, 2012, pp. 243 – 246.

[38] Gh. Bătrinescu, E. Birsan, G. Vasile, B. Stanescu, E. Stanescu, I. Paun, M. Petrescu, C. Filote, Identification of the Aquatic Ecosystems Integrating Variables in Suceava Hydrographic Basin and their Correlations, *Journal of Environmental Protection and Ecology*, Vol. 12, No. 4, pp. 1627-1643, 2011.