POLLUTANTS IDENTIFICATION IN NATURAL AND ARTIFICIAL WATER STREAMS AND DISPERSION SPATIAL ANALYSIS

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La nivel naţional industrializarea şi urbanizarea au determinat evacuarea în diverse bazine hidrografice a unor cantităţi importante de substanţe poluante, care au modificat tabloul ecologic. Realizarea unui sistem integrat de modelare a proceselor de transport a poluanţilor în mediul acvatic, de evaluare a propagării agenţilor poluanţi şi estimare a impactului asupra mediului şi sănătăţii populaţiei, este imperios necesară.

At national level the industrialization and urbanization has determine the disposal of different pollutant substances in different hydrographical basins that modify the natural habit. Designing a new mathematical model system for pollutant transport in aquatic medium and the evaluation of pollutants agents flood routing and estimation the impact over the environment and human health are strongly recommended.

Keywords: pollutant, dispersion, mathematical model

1. Introduction

At international level exists a series of programmable software's, based on numerical simulation of experimental dates that can model the pollution effect. All this programs has been developed in bidirectional axes and they can not predict the site conditions when the pollutant wave must be watch in large hydrographical basins.

Principal problem of this programs is that they must be calibrated so the numerical setting up to be closely to environmental reality.

This can be achieved only by creating specific data bases, in a large scale. The improvements of these mathematical equations lead to the values of dispersion coefficients. Surface-active substances (detergents, proteins, microbial metabolites etc) from the water lead to modifying the superficial tension and have

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a final effect over diametric values of bubbles. Introducing the surface-active substances in the motion fluid minimized the frequency and vortexes amplitude from the surface. The surface-actives substances actions like a barrier for molecular diffusion and increased the water transfer resistance witch is proportional with surface-active substances concentration.

In dispersion processes the fluid turbulence has an important role through his major characteristics – components mixing. Dispersion has a final role in polyphasic fluids mixing and she ends when the pollutant concentration is uniform, the flow is hydraulically continuous in transversal section and is chemically stationary.

For mathematical modelling of pollutant propagation, event evolution prediction and environmental impact estimation are proposing the necessary instruments. Pollutants dispersion in fluid medium study has direct implications in environment rehabilitation.

Analysis and interpretation of experimental dates, mathematical model determination and processes numerical simulation are necessary for creating the control systems for hydrographical basins and water quality monitoring.

In this context it is imposed to create a national informational system for water quality monitoring used, also, in informational exchange in concordance with European directives.

The theoretical model will permit the numerical simulation of pollutant wave evolution in aquatic medium in receptor basin. After theoretic model calibration, this will be easily used in national Environment Agency, in lakes zone with piscicultural utility etc, especially for preventing the catastrophic situations.

Mathematical models are frequently used for quantitative description. These have multiple input and output equations and model characteristics description.

2. Experimental dates

The evolution of water parameters on Danube River in four water sampling points will be presented and discussed. The four points are: Bazias at 1075km from influx, upstream from Dr.Tr.Severin, downstream from Dr.Tr.Severin and Pristol at 833km from influx.

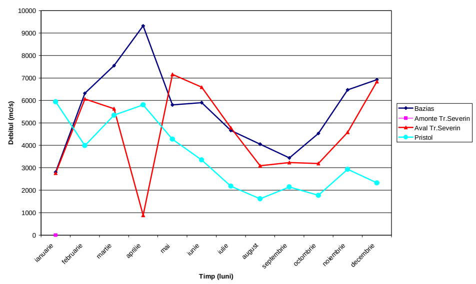

Fig. 1 Water flow rate variation

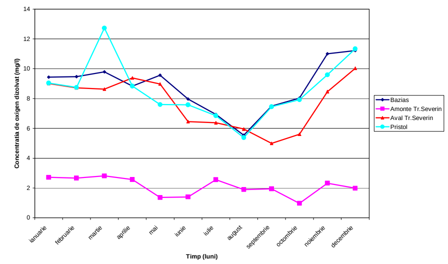

Fig. 2 Dissolved oxygen concentration variation

In figure 2 it is observed a smaller concentration for dissolved oxygen in upstream Dr.Tr.Severin measuring point due to the fact that in this zone there is an intense bacterial activity.

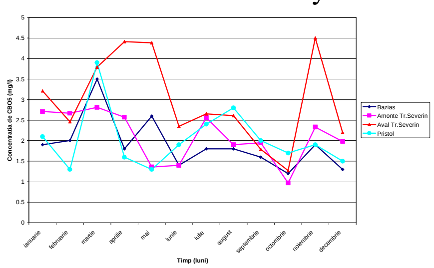

Fig. 3 CBO_5 concentration variation

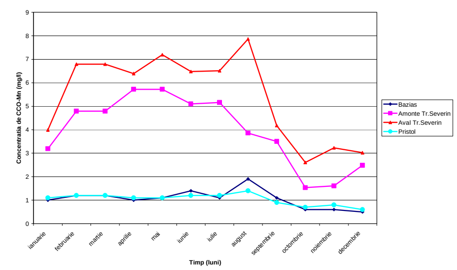

Fig. 4 CCO-Mn concentration variation

In figure 3 it is observed reduced concentrations for CCO-Mn in Bazias and Pristol measuring points. Around Dr.Tr.Severin there is an important increased of CCo-Mn concentration due to the municipal and industrial wastewater discharges with different organics load.

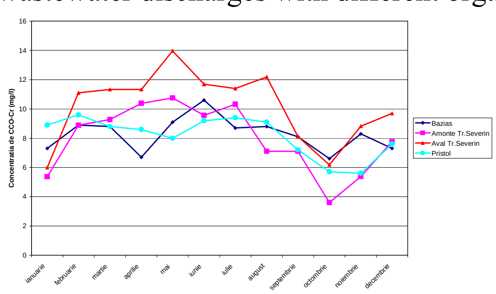

Fig. 5 CCO-Cr concentration variation

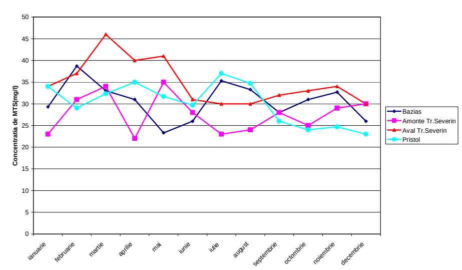

Fig. 6 MTS concentration variation

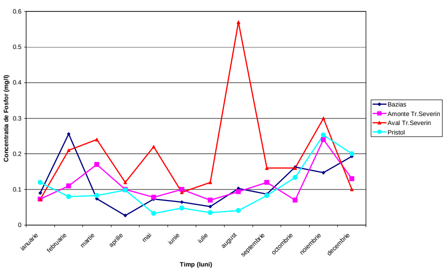

Fig. 7 Phosphor concentration variation

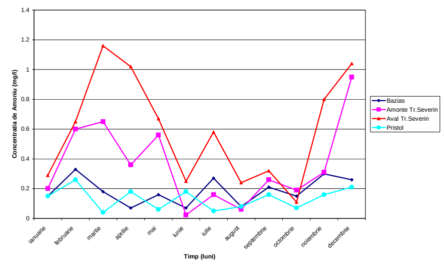

Fig. 8 Ammonium concentration variation

In figure 7 are high values for phosphor in august month in downstream Dr.Tr.Severin measuring point due to the fact of wastewater discharges in Danube river rich in nutrient substances. This will increase the river eutrophication phenomenon.

The comparisons for annual medium values in the four measurements points are showed in the next paragraph.

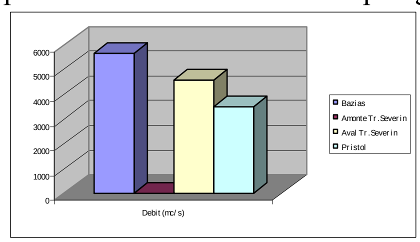

Fig. 9 Water flowrates comparison

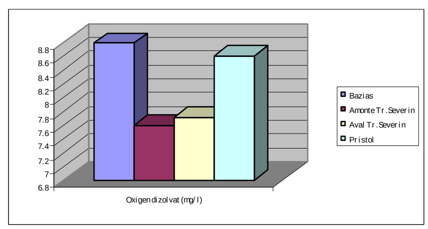

Fig. 10 Oxygen demand concentration comparison

In figure 10 the oxygen demand concentration in upstream and downstream Dr.Tr.Severin measuring points are smaller due to the fact of wastewater discharges from different utilities with important role at bacterial population increased in emissary.

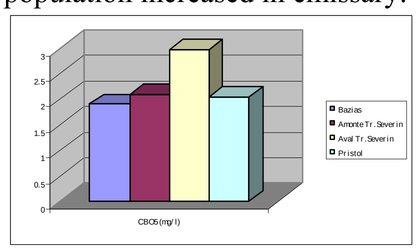

Fig. 11 CBO_5 concentration comparison

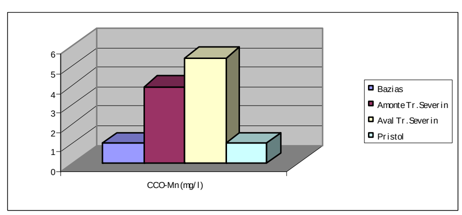

Fig. 12 CCO-Mn concentration comparison

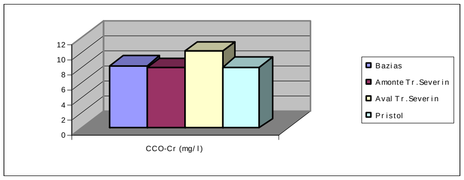

Fig. 13 CCO-Cr concentration comparison

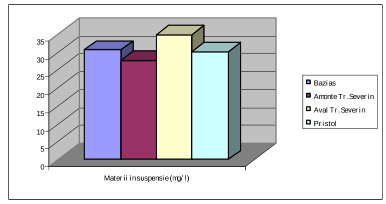

Fig. 14 MTS concentration comparison

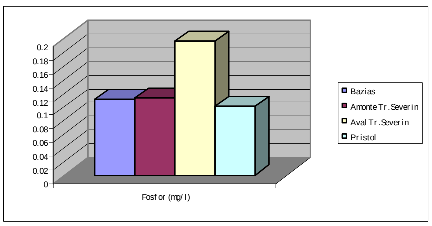

Fig. 15 Phosphor concentration comparison

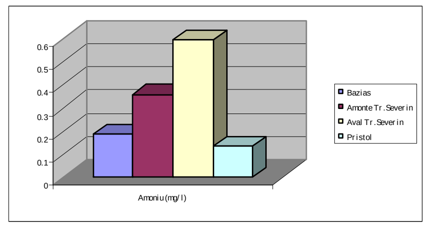

Fig. 16 Ammonium concentration comparison

In figures 15 and 16 in upstream and downstream Dr.Tr.Severin measuring points the phosphor and ammonium concentrations are larger than the are two that shown a wastewater discharge rich in nutrient substances.

Based on experimental dates it will be calculated the pollutants concentration discharge in emissary from a punctual source. The daily medium flow rate is $Q_{zi,med}$ = 2100m^{-3}/s, emissary water speed is v_{med}^{emisar} = 2.2 m/s. The distance from discharge section to the first utility measured in Danube axis is l = 4km, the distance from discharge section to the first utility measured in straight line is L = 5.9km.

Dilution at effluent discharge:

→ after complete mixing zone

$$d_1 = \frac{Q_{zi,med}}{Q_{zi,max}} = \frac{2100}{2.5} = 840 \quad (1)$$

$$d_2 = \frac{Q_{zi,med}}{Q_{orar,max}} = \frac{2100}{2,76} = 760.86 \quad (2)$$

→ inside complete mixing zone

$$d_1' = a\frac{Q_{zi,med}}{Q_{zi,max}} = 0,8\frac{2100}{2.5} = 672 \quad (3)$$

$$d_2' = a\frac{Q_{zi,med}}{Q_{orar,max}} = 0,8\frac{2100}{2.76} = 608.69 \quad (4)$$

In witch *a* is mixing coefficient.

Mixing coefficient:

$$a_1 = \frac{1-e^{-\alpha_1\sqrt[3]{L}}}{1+d_1 * e^{-\alpha_1\sqrt[3]{L}}} = \frac{1-e^{-1,46\sqrt[3]{5900}}}{1+840 * e^{-1,46\sqrt[3]{5900}}} \approx 1 \rightarrow complete\ mixing \quad (5)$$

$$a_2 = \frac{1-e^{-\alpha_2\sqrt[3]{L}}}{1+d_2 * e^{-\alpha_2\sqrt[3]{L}}} = \frac{1-e^{-1,4\sqrt[3]{5900}}}{1+760.86 * e^{-1,4\sqrt[3]{5900}}} \approx 1 \rightarrow complete\ mixing \quad (6)$$

In witch

$$\alpha_1 = \xi\varphi\sqrt[3]{\frac{D_T}{Q_{zi,max}}} = 3*1.475\sqrt[3]{\frac{0.0875}{2.5}} = 1.46 \quad (7)$$

when the discharge effluent flow rate is $Q_{zi,max} = 2.5m^3/s$

$$\alpha_2 = \xi\varphi\sqrt[3]{\frac{D_T}{Q_{orar,max}}} = 3*1.475\sqrt[3]{\frac{0.0875}{2.76}} = 1.4 \quad (8)$$

when the discharge effluent flow rate is $Q_{orar,max} = 2.76m^3/s$ – this is the most disadvantages situation from the point of view of emissary impact.

$\xi = 3$ → discharge through dispersion system

$$\varphi = \frac{L}{l} = \frac{5.9}{4} = 1.475 \text{ - Sinuosity coefficient} \quad (9)$$

$D_T = 0.0875 m^2/s$ - turbulent dispersion coefficient

Total mixing length:

$$L_1^{am.tot} = \left[2.3\frac{1}{\alpha_1}lg\frac{aQ_{zi,med}+Q_{zi,max}}{(1-a)Q_{zi,max}}\right]^3 = \left[2.3\frac{1}{1.46}lg\frac{0.8*2100+2.5}{(1-0.8)2.5}\right]^3 = 169.78m = 0.16km \quad (10)$$

$$L_2^{am.tot} = \left[2.3\frac{1}{\alpha_2}lg\frac{aQ_{zi,med}+Q_{orar,max}}{(1-a)Q_{orar,max}}\right]^3 = \left[2.3\frac{1}{1.4}lg\frac{0.8*2100+2.76}{(1-0.8)2.76}\right]^3 = 187.23m = 0.18km \quad (11)$$

CBO_5 concentration determination in emissary water:

→ upstream from complete mixing zone

$$C_{am}^1 = \frac{C_{pol}^{emisar} * Q + C_{pol}^{ap.uz} * q}{Q+q} = \frac{2.97*2100+4.6*2.5}{2100+2.5} = 2.971 mg/l \quad (12)$$

$$C_{am}^2 = \frac{C_{pol}^{emisar} * Q + C_{pol}^{ap.uz} * q}{Q+q} = \frac{2.97*2100+4.6*2.76}{2100+2.76} = 2.972 mg/l \quad (13)$$

In witch

C_{pol}^{emisar} - pollutant concentration in emissary water, [mg/l];

$C_{pol}^{ap.uz}$ - pollutant concentration discharge in emissary, [mg/l];

Q – emissary flow rate, [m³/s];

q – discharge effluent flow rate (maximum day flow rate, respectively maximum hour flow rate), [m³/s].

→ inside complete mixing zone (discharge section)

$$C_{am}^{3} = \frac{a * C_{pol}^{emisar} * Q + C_{pol}^{ap.uz} * q}{aQ + q} = \frac{0.8 * 2.97 * 2100 + 4.6 * 2.5}{0.8 * 2100 + 2.5} = 2.972 mg/l \quad (14)$$

$$C_{am}^{4} = \frac{a * C_{pol}^{emisar} * Q + C_{pol}^{ap.uz} * q}{aQ + q} = \frac{0.8 * 2.97 * 2100 + 4.6 * 2.76}{0.8 * 2100 + 2.76} = 2.972 mg/l \quad (15)$$

a is the mixing coefficient.

From CBO_5 concentrations analysis result that the effluent discharge from the punctual source has a negligible impact over the emissary environment.

3. Mathematical modeling dispersion of a pollutant into emissary

The fundamental dispersion equation is

$$\frac{\partial \overline{C}}{\partial t} + \frac{\partial}{\partial x}\left(\overline{uC}\right) + \frac{\partial}{\partial y}\left(\overline{vC}\right) + \frac{\partial}{\partial z}\left(\overline{wC}\right) = \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial \overline{C}}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial \overline{C}}{\partial y}\right) + \frac{\partial}{\partial z}\left(\varepsilon_z \frac{\partial \overline{C}}{\partial z}\right) + D_m\left(\frac{\partial^2 \overline{C}}{\partial x^2} + \frac{\partial^2 \overline{C}}{\partial y^2} + \frac{\partial^2 \overline{C}}{\partial z^2}\right) + S(x,y,z,t) \quad (16)$$

$\varepsilon_x, \varepsilon_y, \varepsilon_z$ – longitudinal, transversal and vertical dispersion coefficient.

A complete solution of this equation is completed with the movement and continuity equations. This are depended from flow regime, nature, form and dimensions of dissipated particles and physical properties of the environment.

For FlexPDE numerical simulation is used the following equation

$$\frac{\partial \overline{C}}{\partial t} + \frac{\partial}{\partial x}\left(\overline{uC}\right) + \frac{\partial}{\partial y}\left(\overline{vC}\right) = \frac{\partial}{\partial x}\left(\varepsilon_x \frac{\partial \overline{C}}{\partial x}\right) + \frac{\partial}{\partial y}\left(\varepsilon_y \frac{\partial \overline{C}}{\partial y}\right) + D\left(\frac{\partial^2 \overline{C}}{\partial x^2} + \frac{\partial^2 \overline{C}}{\partial y^2} + \frac{\partial^2 \overline{C}}{\partial z^2}\right) \quad (17)$$

In witch D=0.05m²/s molecular dispersion, u=0.5m/s fluid longitudinal speed, v=2.5m/s fluid vertical speed, ε_x=0.1 m²/s, ε_y=0.2 m²/s, a=500m length, h=20m height.

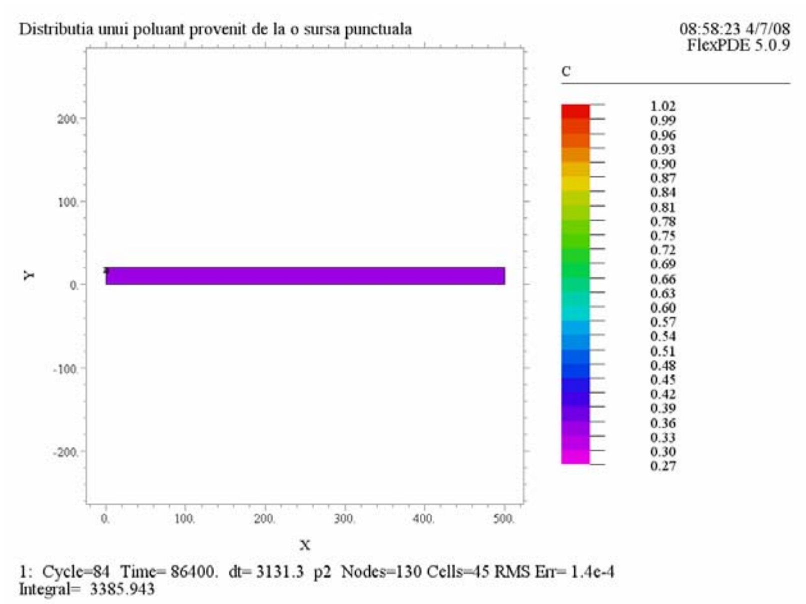

Fig. 17 Pollutant concentration variation

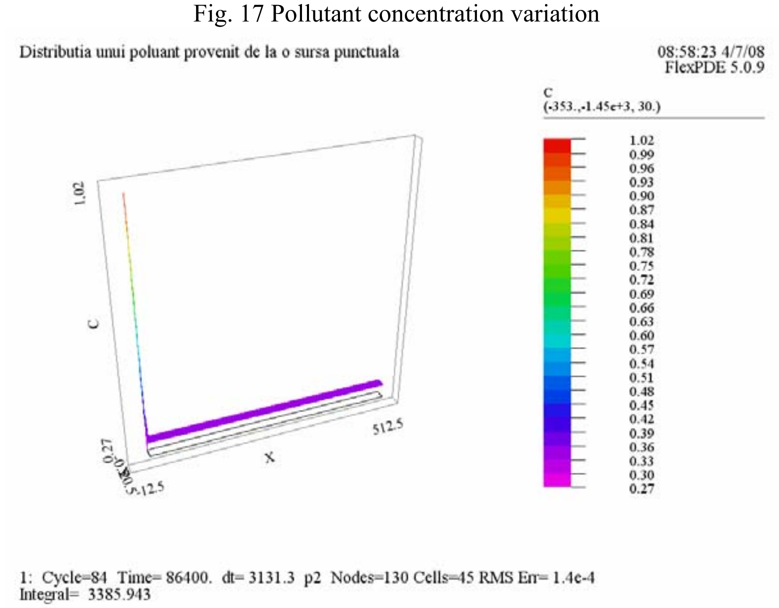

Fig. 18 Pollutant concentration variation, it is shown the injection point into the emissary

It is observed the reducing of pollutant concentration when this is dispersed through the emissary.

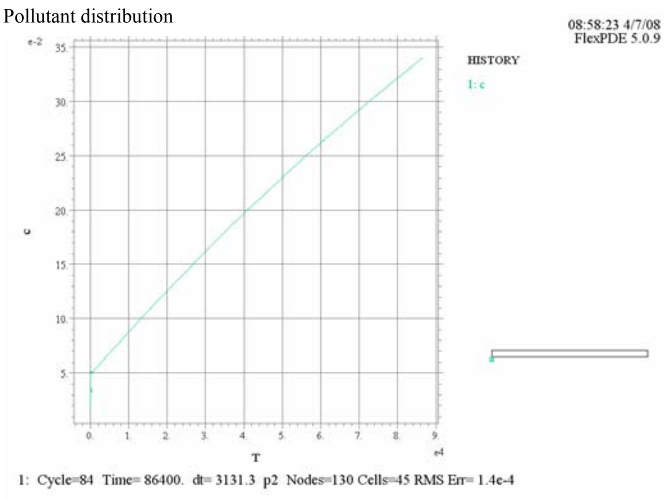

Fig. 19 Pollutant concentration variation in time

The numerical simulation shows the pollutant dispersion in emissary. This can be used like a prevention method for amplitude accidental pollutions with negative impact over the emissary ecosystem.

In the future it is intended to develop this phenomenon by taken in consideration multiple pollutant sources and the way in witch this influence the self-cleaning capacity of the emissary in function with chemical and bacteriological characteristics of discharge wastewaters.

4. Conclusions

Analysis and interpretation of experimental dates, mathematical model determination and processes numerical simulation are necessary for creating the control systems for hydrographical basins and water quality monitoring.

The final purpose is the improving the environmental instruments used in water quality parameters monitoring with positive impact from economical and social point of view.

In this context it is imposed to create a national informational system for water quality monitoring used, also, in informational exchange in concordance with European directives.

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