THEORETICAL AND EXPERIMENTAL RESEARCHES REGARDING THE INFLUENCE OF AN INDUSTRIAL POLLUTANT ON AN ARTIFICIAL LAKE

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The present paper tries to offer a solution for the complex problems regarding the pollutant dispersions in an aqueous environment with direct application of its evolution in large volume of water – Brădişor artificial lake. Brădişor Lake is an artificial accumulation formed by the realization of a dam. The main objective of this paper is to determine the spatial dispersion area of the pollutant discharges in the aqueous medium.

Keywords: mathematical modeling, numerical simulations, pollutant dispersion.

1. Introduction

Pollutants dispersion processes are often encountered where a quantity of water is discharged into the natural environment, in controlled or uncontrolled regime. By introducing a pollutant in an aqueous medium, its polyphase constituents are dispersed through the whole volume of water. The discharged constituents enhance the aqueous environment with nutrients and organic substances, which are decaying and will change the natural characteristics of the environment and make it unsuitable for any use.

In Romania were built artificial accumulation of water in order to supply the water demand to several villages. Artificial lakes formed by impoundment of the rivers, are an important reservoir of water and cover the water needs of many localities. In this way the artificial accumulation occurred on Bistrita, Moldova, Olt River, etc.

The present paper offers a solution for the complex problems regarding the pollutant dispersions in an aqueous environment with direct application for Brădişor artificial lake, which is an artificial accumulation formed by the realization of a dam. It is a part of comprehensive appliance of Lotru River. Its main scope is to feed with water the towns and small communities situated along the Olt valley - Brezoi, Călimăneşti, Râmnicul Vâlcea up to Drăgăşani. Near the dam, at Stan Valley, is situated a water treatment plant.

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In the middle of Brădişor lake is situated a facility for trout raising, which produces about 100 tone of fish every year. This construction contributes to the water quality degradation by pollutant discharges.

To ensure the water needs in the localities mentioned above is absolutely necessary to keep the water clean inside the Brădişor Lake. This fact is desired because the Brădişor Lake (Figure 1) is the main source of drinking water for the city Râmnicul Valcea. Taking into account the fact that the annual average lake phosphorus values are 0.0492 mgP/l, phytoplankton biomass is 4.706 mg/l and chlorophyll "a" is 3. 59 ug/l results that the water quality can be classified in class IV. Water captation is achieved through an outlet located in the dam area.

Fig. 1. Satellite view of the lake with trout facility

The volume of water in the lake is 39.7 million cubic meters. Distance from the trout facility to the dam is 1091 m. The lake, at the trout facility has a wide area of 667 m and the construction is located at 222 m from the left bank and 445 m from the right.

This construction contributes to the water quality degradation by: food abundance, which goes directly into the lake water; increasing the organic compounds because of the fish excrements; increasing the compound based on phosphorous and nitrogen; pollutant discharges of people who work in the facility. Trout facility from Brădişor produces around 100 tonnes of fish every year. The main goal is to obtain fish for population consumption, but also for restocking mountain waters with trout - 200,000 seedlings per year.

The main objective of this paper is to determine the spatial dispersion area of the pollutant discharges in the aqueous medium. It is necessary to be determined the manner and the degree of pollutant dispersions inside the lake, especially if these pollutants reach the dam and the captation area of water at alimentation point of Stan Valley treatment station.

2. Pollutants dispersion

The problem rising in the present study is to demonstrate the negative environmental impact of the trout facility situated in the middle of the lake. The paper establishes the pollutant dispersion inside the Bradisor Lake. It is obvious that the problem is complex because the water movement in the lake is generated by the power/velocity of river/water current and by the discharging area existing near the dam.

To build the mathematical model is considered the general equation of dispersion [2, 4, 5]:

$$\frac{\partial \overline{C}}{\partial t}+\frac{\partial}{\partial x}\left(\overline{u}\overline{C}\right)+\frac{\partial}{\partial y}\left(\overline{v}\overline{C}\right)+\frac{\partial}{\partial z}\left(\overline{w}\overline{C}\right)=\frac{\partial}{\partial x}\left(\varepsilon_x\frac{\partial \overline{C}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon_y\frac{\partial \overline{C}}{\partial y}\right)+\frac{\partial}{\partial z}\left(\varepsilon_z\frac{\partial \overline{C}}{\partial z}\right)+$$
$$+D_m\left(\frac{\partial^2 \overline{C}}{\partial x^2}+\frac{\partial^2 \overline{C}}{\partial y^2}+\frac{\partial^2 \overline{C}}{\partial z^2}\right)+S\left(x,y,z,t\right), \tag{1}$$

where ε_x, ε_y, ε_z are the longitudinal, transversal and vertical dispersion coefficients. A complete solution of this equation where must be attached the equations of motion and continuity, it is impossible to obtain because of the dependence of dispersion coefficients to the flow regime, the nature, form and size of dispersed particles. Because of this, it was applied a simplified model.

To simplify the equation is considered the orthogonal Cartesian system Oxy and the dispersion equation becomes [1, 5]:

$$\frac{\partial \overline{C}}{\partial t}+\frac{\partial}{\partial x}\left(\overline{u}\overline{C}\right)+\frac{\partial}{\partial y}\left(\overline{v}\overline{C}\right)=\frac{\partial}{\partial x}\left(\varepsilon_x\frac{\partial \overline{C}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\varepsilon_y\frac{\partial \overline{C}}{\partial y}\right) \tag{2}$$

where quantities are averaged over a period of time.

It builds the image of the lake in Cartesian coordinate system. It is similar with the one identified by the satellite. It is a very delicate matter that requires attention, because the contour of the lake is drawn from short polygonal lines that lead to the irregular shape of the banks.

The restriction is to not have exchange between aqueous medium and lake banks. It is used a Neumann type condition, which is expressed by $\frac{dC}{dn}=0$ [1; 3].

Then it comes to plotting the contour for the trout facility, which consists of regular rectangular - region 2 of the simulation program. The trout facility is positioned in the second half of the Lake, a little closer to the left bank. Across the contour, which obviously comes in contact with aqueous environment, is provided the pollutant concentration *value C = a* (constant). This is a Dirichlet condition and the value for *C* was determined following several experimental measurements on quality indicators of water. So *C* is considered to be *COD* and the determined values are situated between 20 and 24 mg/l. The trout facility contributes to an increased pollutant in aqueous medium.

Pollutant released by the trout facility, will disperse in the aqueous environment due to the fluid movement. Inside the lake appears a general flow from downstream up to the dam. The overall flow will contribute to the dispersion of pollutants in the lake.

Depending on the values of horizontal and vertical velocities and the coefficients of dispersion will result different responses to the degree of dispersion and how it is distributed in the area of water accumulation.

To determine the vertical pollutant dispersion was constructed a vertical section of the lake, including the trout facility.

3. Mathematical modelling and numerical simulations

The method used to determine the dispersion area is based on mathematical and numerical simulations. The simulations have been realized using FlexPDE5 program and the general equation of dispersion (simplified form) has been utilized. It has been studied the pollutant dispersion inside the lake. The simplified equation for dispersion was introduced in program FlexPDE5, and were obtained the results were presented below. Changes that occur in the distribution of concentration in the horizontal and vertical plan depend on the values that are adopted for flow velocities and for the dispersion coefficients.

Horizontal flow velocities to the dam were taken in the range u = 0.01 ... 0.10 m/s, while those in the vertical plane have the values situated in range v = 0.001 ... 0.005 m/s [5] - values which are considered normal inside the lake Brădişor.

Dispersion coefficient values varied in the range $\varepsilon_x = 0.05 \ldots 1\ m^2/s$, $\varepsilon_y = 0.01 \ldots 0.1\ m^2/s$ [2; 3]. It is considered that these values are normal for the movement of water inside the accumulation (compared with the constant value of oxygen diffusion from air into water $D_m = 0.13 \ldots 0.2\ m^2/s$ depending on temperature).

For the simulations represented in Figure 2 were considered the following values of velocity u = 0.01, w = 0.001 and dispersion coefficients are $\varepsilon_x = 0.2$, $\varepsilon_y = 0.1$. Pollutant dispersion can be observed in both sections (horizontal and vertical) of the Brădişor Lake.

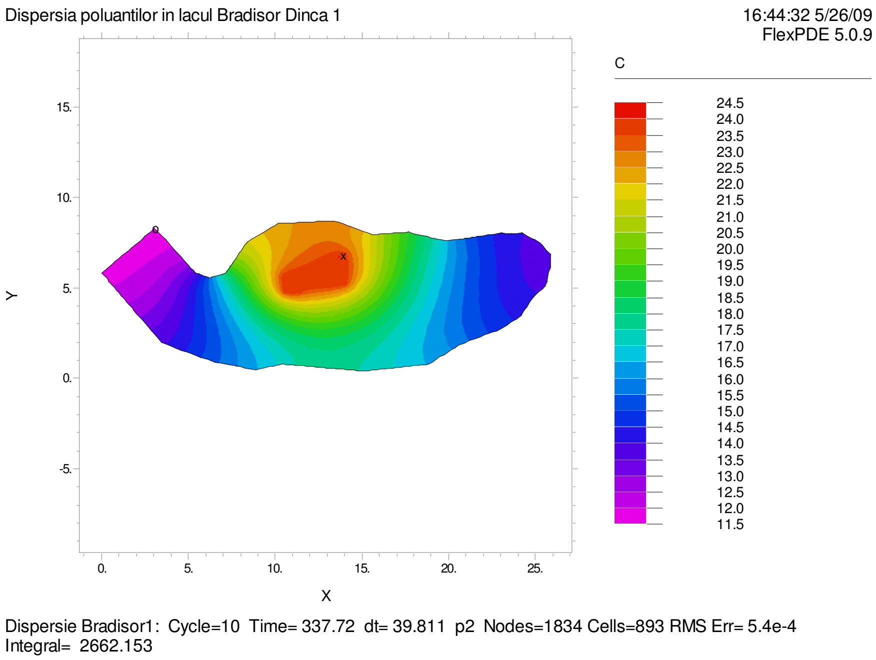

Fig. 2,a. Concentration of the pollutant

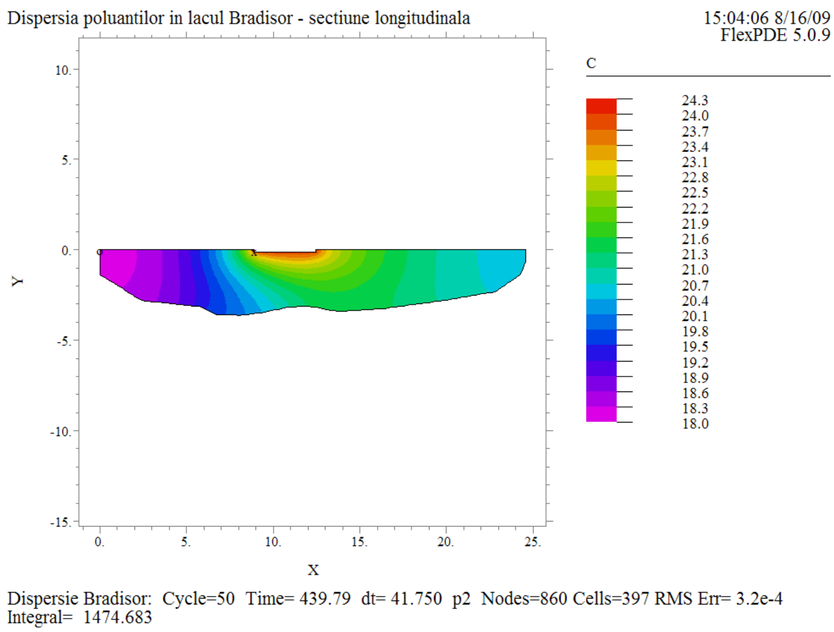

Fig. 2,b. Concentration of the pollutant – vertical view

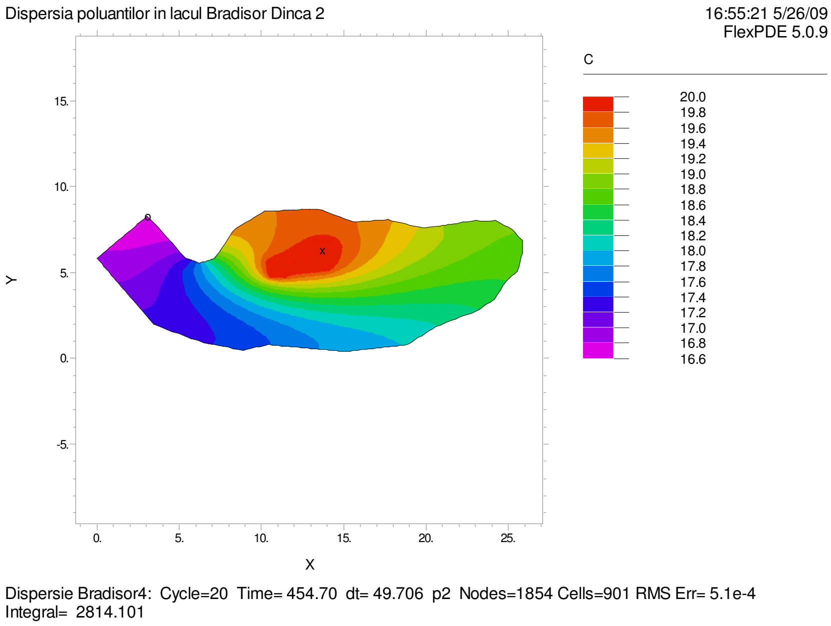

Fig. 3,a. Concentration of the pollutant

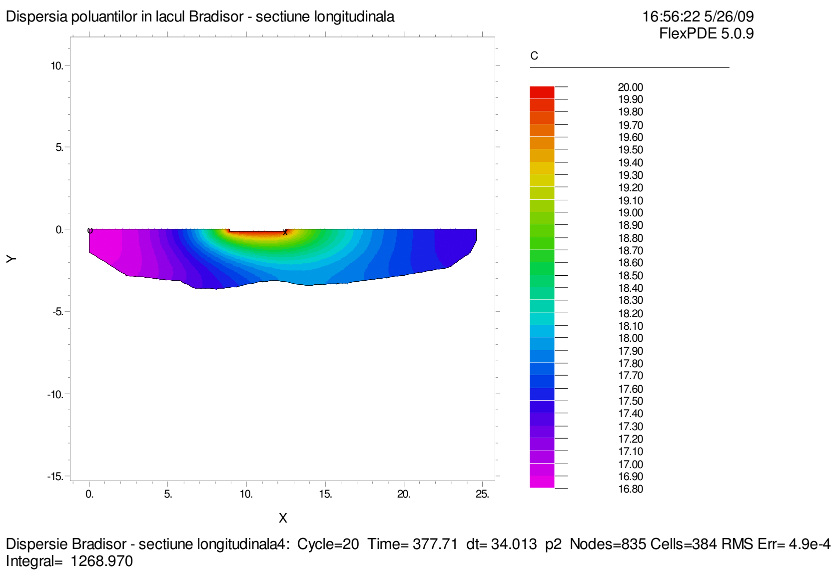

Fig. 3,b. Concentration of the pollutant – vertical view

Compared to the previous case it was considered that inside the lake, the flow velocities are higher u = 0.05 and w = 0005. Pollutant dispersion increases in intensity by the tail of the lake, near the dam. Thus, the water quality at the catchment area will be significantly lower compared to the previous case. It is noted that in this case the pollutant reaches higher depths at the tail of the lake.

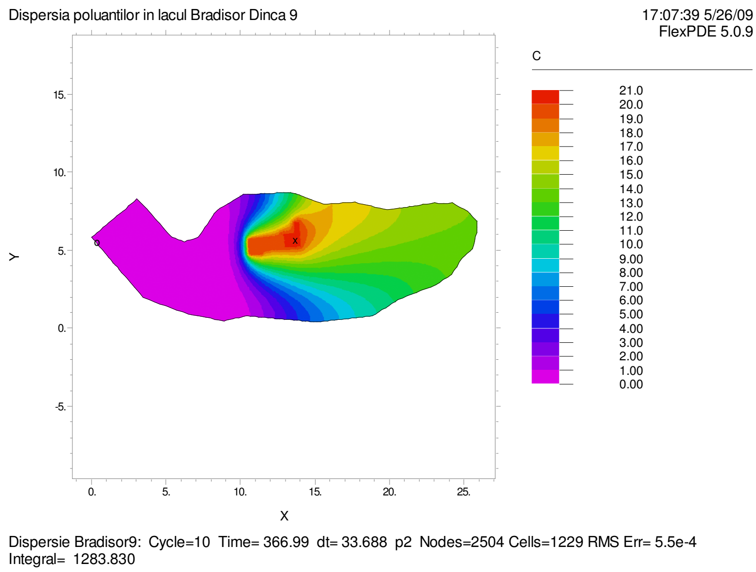

Fig. 4,a. Concentration of the pollutant

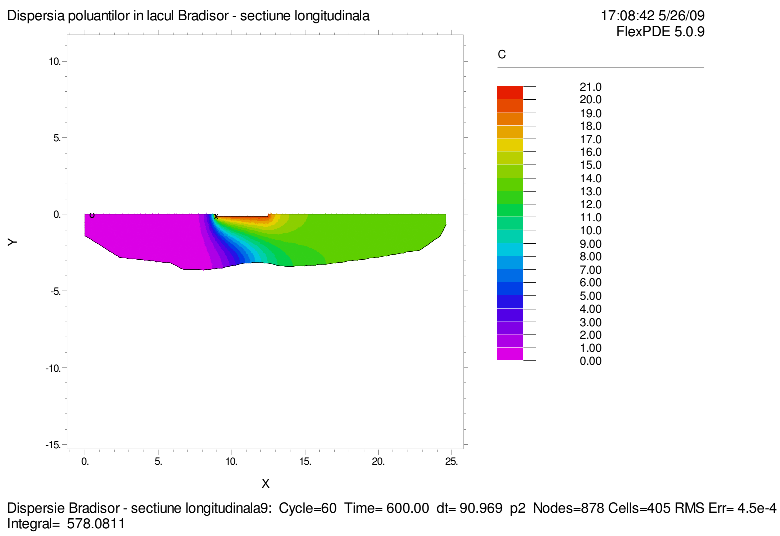

Fig. 4,b. Concentration of the pollutant – vertical view

Compared to the previous case flow velocities were also increased (Fig. 4). Due to dam water movement, it is noted that the influence of the trout facility is perceptible only in the second half of the lake. In this case can be noticed the influence of the facility to the bottom of the lake.

4. Conclusions

There are situations in which water accumulates in the lake and speeds are low, and others - in times of high water (flood) - the speeds inside the lake are high due to the discharge of water from dam. If the horizontal velocity *u* increases the pollutant reaches the dam where water captation is made. Also by increasing the horizontal velocity is remarkable the reduction in the influence upstream of the facility position.

In concordance with the results obtained during simulations, can be specified the optimal position of the raising trout facility referring to captation area of water for the treatment plant.

Theoretical researches have been followed by water quality measurements. In this way has been showed that the model was correctly calibrated and it can be used, respecting simulation value limits, to evaluate water quality from Bradişor Lake.

It has been demonstrated that the influence of the trout rising is perceptible in the area situated between this facility and the left shore of the lake. It is an effect of speed decreasing in this area; the liquid prefers to flow on the direct path (the minimum distance up to dam). The increasing of water velocity on a vertical plan from 1 mm/s up to 5 mm/s contributes to the enlargement of the area influenced by the pollutants. In this case the pollutants reaches up to the dam and it is captured a water with non-adequate quality. This polluted water will raise the investment costs of the treatment plant.

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