# SIMULATING THE PHENOMENON OF RIVER POLLUTION

## SIMULAREA FENOMENULUI DE POLUARE A RÂURILOR

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***Abstract****. The main factor in reducing the volume of drinking water in Romania is the phenomenon of pollution. Drinking, industrial and agricultural water consumption is not limiting because natural resources are recoverable, but the use of water sources becomes limited due to pollution. The forecast of water quality along a river, in case of accidental pollution, can be simulated by using modern software. The paper also proposes the development of new simulation models, more accessible as a way of working and with a shorter analysis time. The simulation carried out on the Moldova River in sections characterized by the existence of various sources of pollution in nature confirms the effectiveness of these models.*

**Key words**: concentration, diffusion, customized software, forecasting

***Rezumat.*** *Factorul principal în reducerea volumului de apă potabilă în România este fenomenul de poluare. Consumul de apă potabilă, industrială și agricolă nu este limitativ, deoarece resursele naturale sunt recuperabile, dar utilizarea surselor de apă devine limitată din cauza poluării. Prognoza calității apei în lungul unui râu, în cazul unor poluări accidentale, poate fi simulată prin prin utilizarea unor software moderne. Lucrarea propune și dezvoltarea unor modele noi de simulare, mai accesibile ca mod lucru și cu un timp de analiză mai scurt. Simularea efectuată pe râul Moldova în secțiuni caracteristice de existență a unor surse de poluare diverse ca natură confirmă eficiența acestor modele.*

**Cuvinte cheie**: concentrație, difuzie, prognoză, software particularizate

## INTRODUCTION

The surrounding environment is strongly affected by the industrialization process, developed excessively in the last hundred years, but also by human activity that has intensified a lot in densely populated areas. The combination of natural pollution and anthropogenic pollution has produced real ecological catastrophes in recent times. A component of the heavily polluted environment is water and especially drinking water sources.

Water is considered one of the basic needs for all living organisms, in which case it is necessary to protect and use it sustainably. In this period, the need for the quantitative and qualitative assessment of drinking water bodies is necessary as the world population increases, and the impact of natural pollution, but especially of anthropogenic pollution, decreases the volumes of available water (Alexandrescu *et al.*, 2012). All this leads to increased pressure for the permanent assessment of the

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quantity and quality of surface and underground water resources in Romania (Crețescu *et al.,* 2021, Mănescu, 2013).

In many countries around the globe, comprehensive environmental protection policies have not been developed to respond to the degradation of drinking water sources. Legal standards for environmental quality were often neglected (Ridzuan, 2017, Mănescu, 2013). The main element for a correct management of water sources is the creation of a water quality monitoring network, which also benefits from effective legislative support (Crețescu *et al*., 2021, Diaz-Cassallas *et al.,* 2019, Mănescu, 2013). At the same time, it is necessary to develop fast models for forecasting the degree of pollution and the characteristic parameters of the phenomenon.

The paper presents the results of research on the creation and use of simulation models of the degradation of river water quality parameters under the impact of natural and anthropogenic pollution.

## STUDY AREA AND RESEARCH METHOD

The research was carried out on the upper course of the Moldova River, where the correlation between natural and anthropogenic pollution is strongly felt. The effect of the pollution phenomenon leads to the temporal degradation of water quality in the sampling sections of the water volumes needed by the population.

Theoretical and experimental research was carried out in the following areas:

1. Studies and research on the evolution over time of the phenomenon of surface water pollution, highlighting the sources of pollution and their mode of action.
2. Selection of sections and sections for analysis of pollutant concentrations on the investigated river section.
3. Data collection to define the initial and boundary conditions required in the simulation program.
4. Defining scenarios for the analysis of the pollution phenomenon on the considered river sections and introducing them into the simulation program.

The primary data were processed using analysis and calculation programs (statistical, hydrological and hydraulic) applicable to the case study (Mănescu, 2013).

## RESULTS AND DISCUSSIONS

The objective of the research was to simulate the transport of pollutants on river sections in the Siret hydrographic basin. For this purpose, a calculation program was developed for the phenomenon of dispersion of pollutant concentration in time and space. The simulation program was based on the transport equation of a pollutant with concentration (C) (Hâncu et al., 2003):

$$\frac{\partial \rho_j}{\partial t} + div\left(\partial_j \cdot \vec{V}\right) = qD_j - div\vec{q}S_j\,, \qquad (1)$$

where $V$ is the average speed of the water (m/s); $E$ - longitudinal dispersion coefficient ($m^2/s$); φ (C) - general term of reaction of the pollutant with water; S - intake source.

The simulation model was made in the MATLAB v.7.12 programming environment. In order to carry out the simulation, it is necessary to define the hydraulic parameters and the concentration values of the chemical parameters determined from field measurements. In order to simulate the transport of pollutants with the developed program, the data collected from the field regarding the water quality parameters of the Siret hydrographic basin were used. Also, a series of data was taken based on the collaboration with the Siret Water Basin Administration (2021, Mănescu, 2013).

Over time, a series of areas with important sources of surface and underground water pollution have been created in the Moldova river basin (Ursu *et al.*, 2017). These sources have negatively influenced surface and groundwater quality over time. The efforts of the water management authority, but also the cessation, or as the case may be, the reduction of the activities of some polluting economic agents, had the effect of improving the water quality on some river sectors.

The pollution of the Moldova River in the upper sector is also influenced by the mining operations (Fundu Moldovei, Lesu Ursului, Ostra Quarry and other). Manganese, zinc and copper ore were extracted from the mine. The water quality of the Moldova River and its tributaries was variably affected depending on the duration of ore extraction and their processing (Mănescu *et al.*, 2014, Mănescu, 2013). In the last 30 years, a number of mining operations have been closed, but the effects of insufficiently treated mine waters are not completely eliminated. A particular impact on surface and underground water is presented by tailings dumps without stable conservation works. Closed underground and surface mines, decommissioned ore processing plants, and incompletely preserved and maintained tailings sites present residual pollution of watercourses.

In the conducted research program, a number of 22 control sections located on the rivers of the Siret hydrographic basin were analyzed and selected. Four control sections were located on the upper reaches of the Moldova River in the Baia, Campulung Moldovenesc, Fundu Moldovei and Gura Humorului sections.

The following water quality indicators were used in the research: biochemical oxygen demand (CBO5), chemical oxygen demand (CCO-Cr), CCO-Mn, ammonium nitrogen (NH4+-N), nitrogen nitrates (NO3--N ), nitrogen nitrites (NO2--N), N-NH4, P-PO4 total phosphorus (TP), Metals (Cu, Zn, Mg, Fe, Ni, Cd, Pb, Cr, Hg), Ca, Na, Cl , fixed residue, pH filterable residue (Mănescu A., 2013). The analysis of the pollutants in the considered sections was done by selecting them according to the intensity of their action according to the documentary data. The simulation of the dispersion of pollutants on the river sections considered in the research was carried out by selecting those with a greater permanence in time according to the documentary data.

A one-dimensional hydrodynamic pollutant transport model was used to simulate the dispersion of pollutants on the Fundul Moldovei-Prisaca Dornei section located on the Moldova River. The purpose of the case study was to analyze the change in the concentration values of the water quality parameters over time and along the

length of the research section, as well as the hydraulic parameters. Also, the developed calculation program and the conditions of use were tested.

On the investigated river section, nitrates and nitrates resulting from the discharge of household waste water from rural localities without treatment plants are mainly manifested. The input data for the simulation of the transport of the pollutant N-NO2 on the section of the Moldova river between the sections "Fundul Moldovei-Prisaca Dornei" were the maximum concentration of the pollutant ($C_{max}$) in mg/*l*, the injection time (t) in minutes and the coefficient of loss by chemical reaction (T).

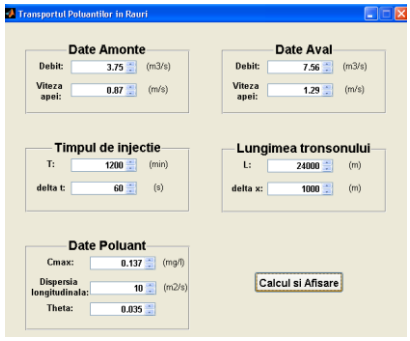
The initial data entered into the program were as follows (fig. 1):

- in the upstream section, for pollutant injection, the entered values were:

A - hydraulic parameters: flow rate, 3.75 $m^3/s$, average water speed, 0.87 m/s;

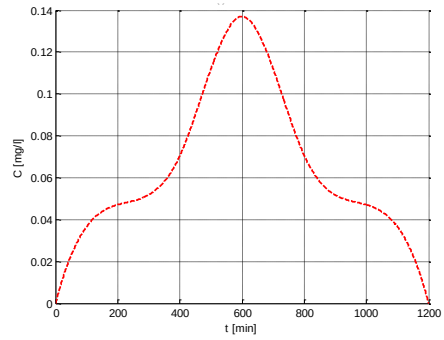
B - N-NO2 pollutant parameters: maximum concentration $C_{max}$ N-NO2= 0.137 mg/l, injection time t = 1200 minutes, dispersion coefficient Cd = 10.0 m2/s, the coefficient of loss by chemical reaction, T=0.35.

- in the downstream section, the values of the hydraulic parameters were entered: flow rate, 7.56 $m^3/s$ and average water speed, 1.29 m/s.




a

**Fig. 1**. Program interface for input data




b

**Fig. 2** Simulated variation of concentration over time of the N-NO2 pollutant in the initial section

As a result of running the simulation program, the values of the pollutant concentrations over time and along the simulated river section, as well as the hydraulic parameters that determine the transport, were obtained. The pollutant values were interpreted according to the rules in force (limit values allowed in the watercourses) to differentiate the pollution characteristics of the river sections on the analysis sector. The experimental results were processed and interpreted. As an example, the results obtained for the pollutant N-NO2, predominant in the area of the research section, are presented in figures 2 - 4. The concentration of nitrates in surface waters is normally low, but can reach high values in the case of agricultural wastewater discharges or contamination with leach ate from household waste, animal manure, human sewage, etc.

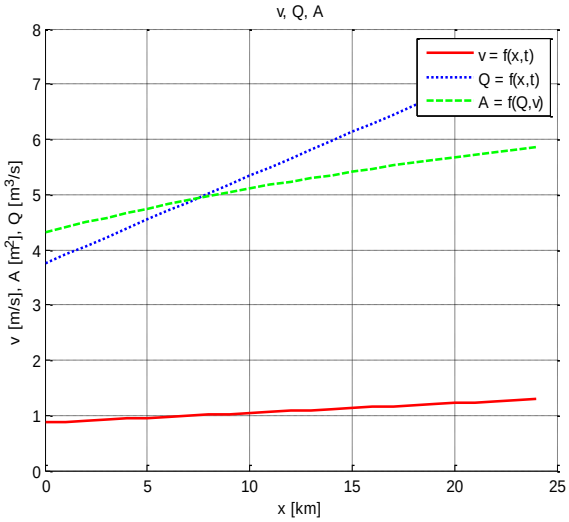



**Fig. 3** The simulated variation of the hydraulic parameters on the research section

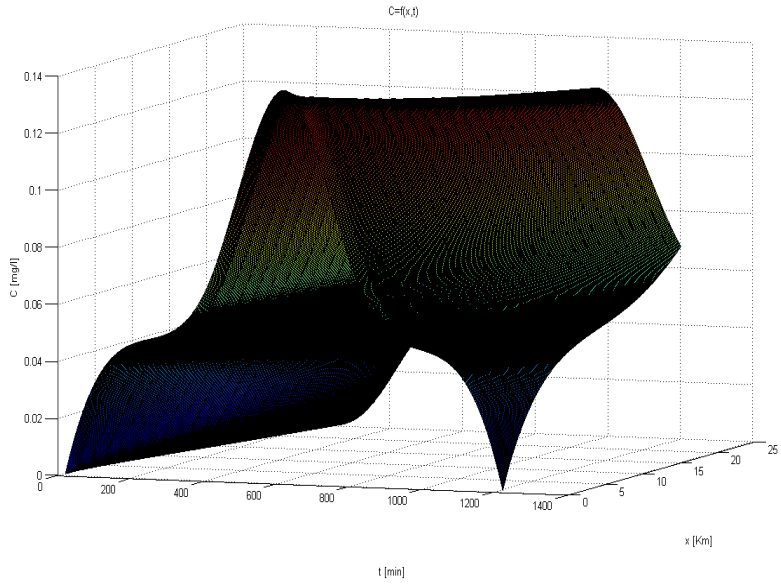



**Fig. 4** The simulated variation of the N-NO2 pollutant concentration along the length of the section of research Fundul Moldovei-Prisaca Dornei

On the research sector on the Moldova River and between the Fundul Moldovei and Prisaca Dornei control sections, the simulation resulted in a decrease in the concentration of the N-NO2 pollutant from 0.137 mg/*l* to 0.121 mg/*l*. The variation of the pollutant concentration occurred in a time interval of 1,200 minutes and over a length of 24.000 km. The result of the simulation shows that the dispersion of the N-NO2 pollutant on this river sector produces a decrease in concentration by about 12%

(Mănescu 2013). The N-NO2 indicator registers this section in the 2nd quality class according to the Water Framework Directive 2000/60/EC.

## CONCLUSIONS

1. The intensification of the degree of anthropogenic emissions pollution, especially those originating from untreated household wastewater, contributes to the accelerated degradation of drinking water sources on the territory of Romania.

2. The management of wastewater discharged by industrial, agricultural and human sources must be carried out according to national regulations, but also correlated with the provisions of European legislation in order to limit the negative impact on surface and underground waters.

3. The use of the simulation program of pollutant transport and dispersion on a river section is easier and requires a shorter time to analyze the parameters interested in monitoring the pollution process.

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