Scientific Bulletin of Politehnica University of Timişoara

Transactions on HYDROTECHNICS

Volume 63(77), Issue 1, 2018

MODELLING THE EVOLUTION OF CRASNA RIVER WATER QUALITY

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Abstract: The water quality is determined by the sum of the chemical, physical, biological, and radiological characteristics of water. Water quality characteristics are a measure of the condition of water relative to any human need or purpose and or to the requirements of one or more biotic species. These characteristics determine the procedures and costs of water treatment to meet the quality requirements of the users, and the measures necessary for the protection / improvement of the water quality. An important aspect of the activity of water specialists is to monitor, analyze and forecast the evolution of water quality. In this paper is realized the modeling of the evolution of the water quality of the Crasna River, situated in the north-west part of Romania. The evolution of Crasna River water quality is important because it is a cross-border river and is subject to the Romania - Hungary bilateral conventions and EU directives.
Keywords: water quality, hydrodynamic modelling, ecological modelling.

1. INTRODUCTION

The water quality is determined by the sum of the chemical, physical, biological, and radiological characteristics of water. Water quality characteristics are a measure of the condition of water relative to any human need or purpose and or to the requirements of one or more biotic species. These characteristics determine the procedures and costs of water treatment to meet the quality requirements of the users, and the measures necessary for the protection / improvement of the water quality.

Water quality is measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), the amount of suspended material in the water (turbidity), the concentration of different chemical substances (ammonium, phosphorus, heavy metals etc.). In some bodies of water, the concentration of microscopic algae and quantities of pesticides, herbicides, and other contaminants may also be measured to determine water quality. [1]

The hydrologic cycle moves water from the air to the earth and back again. Water is a natural solvent that dissolves everything it touches.

The ways of changing the water quality/ pollution of water are presented schematically in Figure 1. [2]

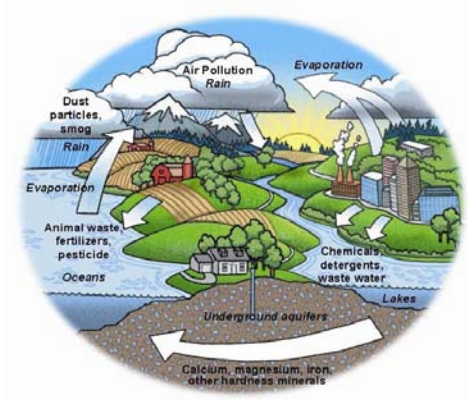

Figure 1. The ways of changing the water quality/ pollution of water

Water quality management is an important component of integrated water resources management. Most users of water depend on adequate levels of water quality.

An important aspect of the activity of water specialists is to monitor, analyze and forecast the evolution of water quality. An appropriate method for water quality forecasting is mathematical modeling. Water quality modeling involves the prediction of water pollution using mathematical simulation techniques. A typical water quality model consists of a collection of formulations representing physical mechanisms that determine position and momentum of chemical substances/pollutants in a water body.

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2. MIKE11 HYDRODYNAMIC MODULE AND ECOLAB MODULE

MIKE11 is a one dimensional hydrodynamic simulation program was utilized to model stream flow transport and water quality processing in the river system. It was developed by DHI Water • Environment • Health, Denmark. MIKE11 is an advanced hydroinformatic tool, known and applied worldwide.

Typical MIKE 11 applications:

• Flood analysis and flood alleviation design studies
• Real time flood forecasting
• Dam break analysis
• Optimisation of reservoir and channel gate / structure operations
• Ecological and water quality assessments in rivers and wetlands
• Sediment transport and river morphology studies
• Salinity intrusion in rivers and estuaries
• Wetland restoration studies.

The following hydraulic and hydrological simulation engines of MIKE 11 were used for water quality evolution modelling:

HD – Hydrodynamics: DHI's classic 1D hydrodynamic engine for rivers and open channels. Hydrodynamic Module uses an implicit, finite difference solver, was applied to calculate water level and flow for the river. Unsurpassed in flexibility, robustness and features, including:

• Fully dynamic solution to the complete nonlinear Saint - Venant 1D equations for open-channel flow
• Muskingum and Muskingum-Cunge routing method options for simplified channel routing
• Automatic adaptation to subcritical and supercritical flow
• A large suite of standard hydraulic structures such as weirs, culverts, bridges, pumps, energy loss and tabulated structures
• Choice of fixed, tabulated or adaptive simulation time step.

ECO Lab - Ecological Modelling: is a numerical laboratory for ecological and water quality modeling.
Typical applications of ECO Lab include:

• Water quality and ecological studies related to rivers, wetlands, lakes, reservoirs, estuaries, coastal waters and the sea
• Spatial predictions of any ecosystem response
• Simple and complex water quality studies
• Impact and remediation studies
• Planning and permitting studies
• Water quality forecasts.

One of the preconditions of ecological modeling is an accurate flow model for the area of interest. ECO Lab integrates seamlessly with the MIKE by DHI suite of flow simulation models covering all aspects - ranging from 1D to 3D modeling. [3] [4] [5]

3. CASE STUDY

To modelling of water quality evolution with MIKE11 and ECOLab models was considered a sector of Crasna River, located in north-western Romania, part of Somes –Tisa hydrographical space. (Figure 2, Figure 3 and Figure 4). Crasna River catchment is represented in Figure 4.

Figure 2. Crasna River catchment (source Bocoi, L.F, 2009)

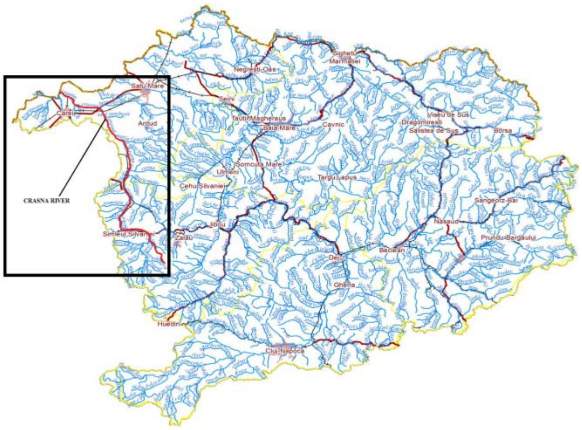

Figure 3. Somes –Tisa hydrographical space (source Administratia Nationala "Apele Romane")

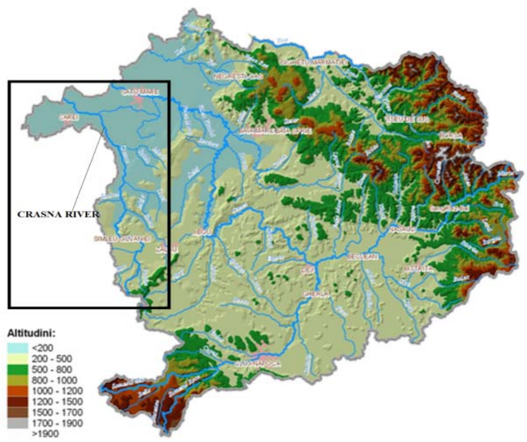

Figure 4. Somes –Tisa hydrographical space relief (source Administratia Nationala "Apele Romane")

Data necessary for model construction have been raised by the Romanian Waters, Somes-Tisa Basin Water Administration. [6]

The evolution of Crasna River water quality is important because it is a cross-border river and is subject to the Romania - Hungary bilateral conventions and EU directives.

Crasna River at hm 252, at the Varsolt cross-section, was in the year 2016 in the A2 quality category, corresponding to the level of normal physical, chemical and disinfection treatment. [7]

The most important sources of water pollution in the Crasna River catchment (mainly from the perspective of the volumes of processed water) are companies that have as their object the supply of water to the population and the collection of domestic waste water.

Human agglomerations with 10,000 - 100,000 e.p. generate 90% of the total volume of wastewater discharged in the Crasna River catchment in the year 2016. Of the total volume of water discharged into the Crasna River catchment, 7.721.280 m^3 - representing 96.57% - requires purge. 85.94% of the total volume being properly purged (Figure 5). [7]

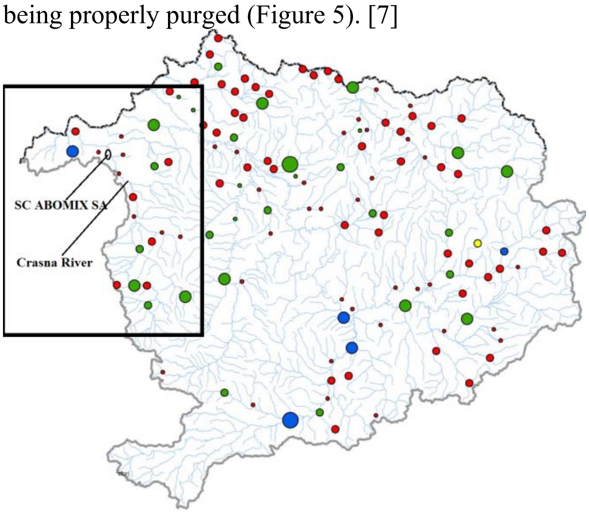

Figure 5. Pollution sources. Human agglomerations (> 2000 e.p.) with wastewater treatment plant in the Someş-Tisa hydrographical space. (source Administratia Nationala "Apele Romane")

Another possible source of pollution is S.C. ABOMIX S.A. Satu Mare - Moftin pig farm, having the activity of raising and fattening pigs with a capacity of max. 38 000 heads. Waste water resulting from technological processes is discharged into the Crasna River after a pre-treatment of the mechano-chemical and biological treatment through the wastewater treatment plant. Following the monitoring of priority hazardous substances, it was found that the values obtained were below the limit of detection and that allowed by the norms in force.

In 2016 in the Crasna River hydrographic basin were monitored a number of 44 wastewater treatment plants, of which 14 plants were functioning properly, representing 32%; 23 plants operated inadequately, representing 52%; and 7 plants representing 16% transiting non-requiring waste waters purge. [7]

In the Crasna River catchment was evacuated in 2016 a volume of approx. 7995 thousand cubic meters of wastewater from the following fields of activity (thousand cubic meters) [7]:

Table 1

Other activities	38.503902
Water prelevation and treatment for supply	7,200.557597
Trade and services for the population	14.414353
Construction	16.9529
Electrical and thermal energy	31.74849
Food industry	31.031
Extractive industry	2.452032
Metallurgical industry	17.276112
Metallurgical + machinery industry	281.86252
Wood processing industry	0.901152
Chemical processing	241.98049
Transport	12.508128
Zootechnics	104.996355

The source of diffuse pollution is represented by agriculture. Agricultural lands are predominant in the Crasna River catchment area (72.1%), forests occupy only 18.2%.

For the water body "Crasna - polder Moftin - HU border" following the water quality analyzes in 2016 resulted the following:

- the condition of the zoobenthos was very good
- the phytoplankton status was very good
- the condition of the phyobenthos was very good

The general physical and chemical parameters monitored indicate a very good condition after the specific "Thermal Conditions" and "Acidified Condition" groups, a good condition after the "Salinity conditions" indicator group and a moderate state after the "Oxygenation Conditions" (O_2=5.51mg/l, CBO_5=7.12mg/l, CCOCr=53.51mg/l) and "Nutrients" (NH_4=2.2954 mg/l, NO_2= 0.1271mg/l, N_{tot}=5.9649mg/l, PO_4= 0.3337 mg/l, P_{tot}= 0.5521mg/l), these determine the state of the body of water.

Assessing the state by general physico-chemical elements determines the moderate water body.

The ecological state of the water body recorded in 2016 is moderate, being determined by the values obtained for the physical and chemical support elements recorded during the year.

In order to assess the chemical status, analyzes were carried out for hazardous and priority hazardous substances of synthetic (microporous) and non-synthetic type (metals), showing compliance with the quality standards for both the average values and the maximum values recorded. The body of water was in good chemical state. [7]

Considered sector have a length of 64 km, representative cross-sections are considered in the right of localities Supuru de Jos, Craidorolt, Domanesti and Berveni, the state border with Hungary, the rest of the cross sections were built by interpolation.

For water quality evolution modelling were used MIKE11 software, HD and ECOLab modules (template MIKE11 WQ Level 1). Input data are (year 2017, October):

- river network and cross-sections (Figure 6 and 7)
- boundary conditions:

1. Upstream (chainage 76000 m) – discharge 0.55 m^3/s, water temperature 14.7 °C, Dissolved Oxygen = 11.67 mg/l, BOD_5 = 1.6 mg/l (Biochemical Oxygen Demand)
2. Downstream (chainage 140000 m) - water temperature 14.7 °C, Dissolved Oxygen = 4.22 mg/l, BOD_5 = 3.1 mg/l; curve Q-h.

- simulation period 10/15/2017-11/15/2017; simulation time step 30 sec
- AD calculation.

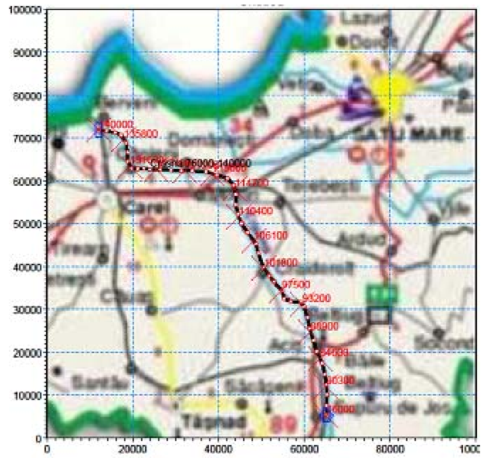

Figure 6. Crasna River sector network

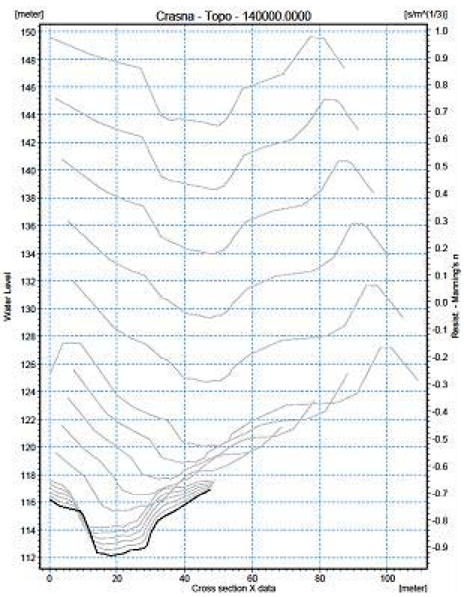

Figure 7. Crasna River sector cross-sections

4. RESULTS AND DISCUSSION

The results obtained from the simulation can be seen in the following figures.

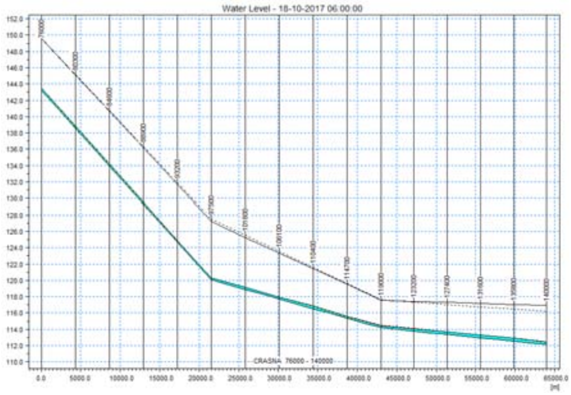

Figure 8. Water level in longitudinal profile

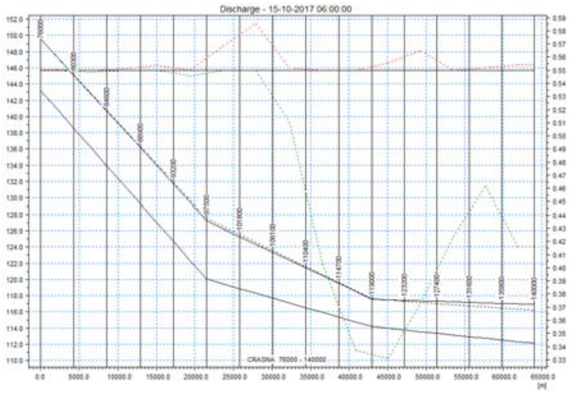

Figure 9. Discharge in longitudinal profile

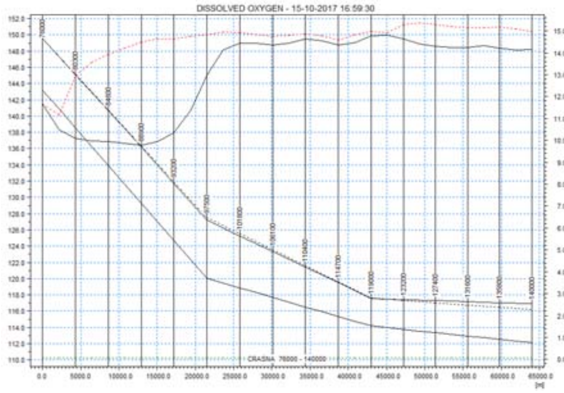

Figure 10. Dissolved Oxygen variation in longitudinal profile

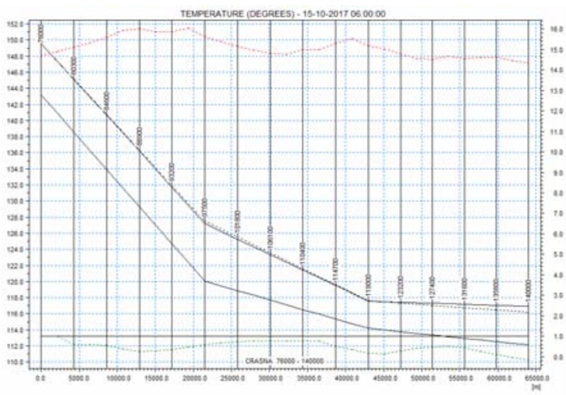

Figure 11. Temperature variation in longitudinal profile

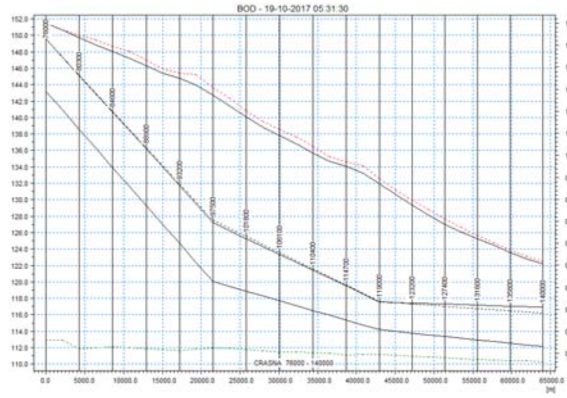

Figure 12. BOD_5 variation
in longitudinal profile

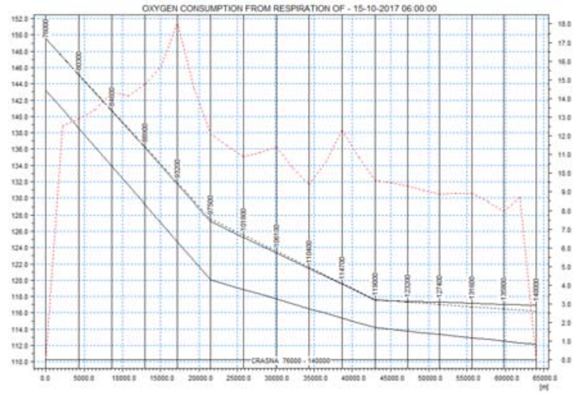

Figure 16. Oxygen consumption from respiration
of plants (mg/l/day)

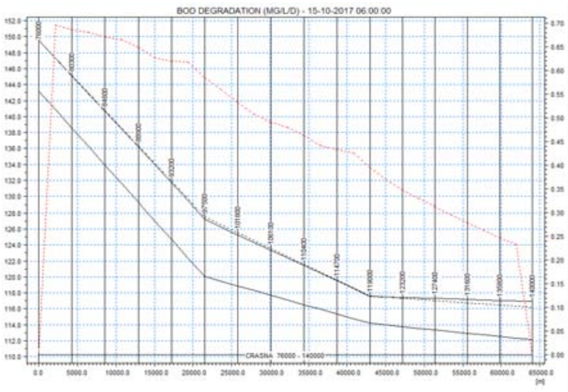

Figure 13. BOD_5 degradation (mg/l/day)

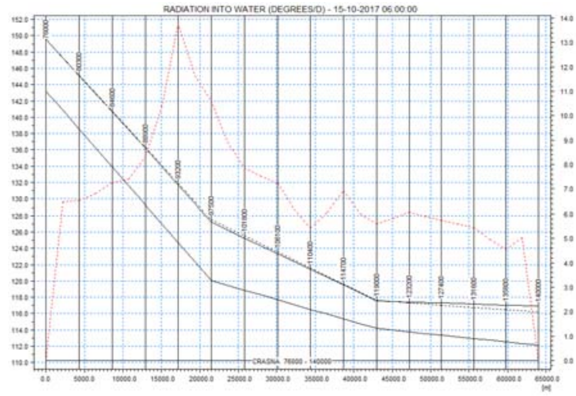

Figure 17. Radiation into water (degree/day)

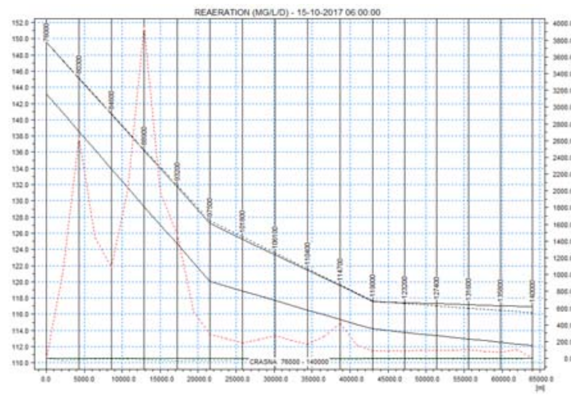

Figure 14. Reaeration (mg/l/day)

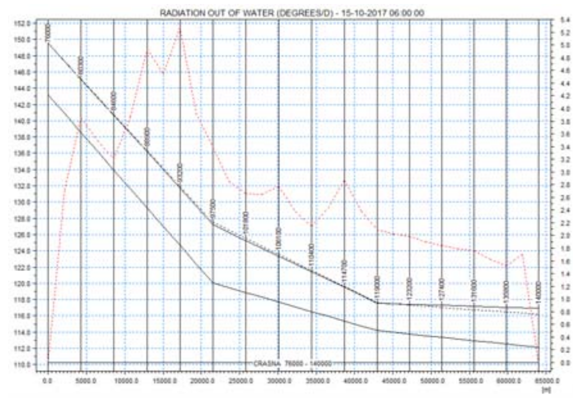

Figure 18. Radiation out of water (degree/day)

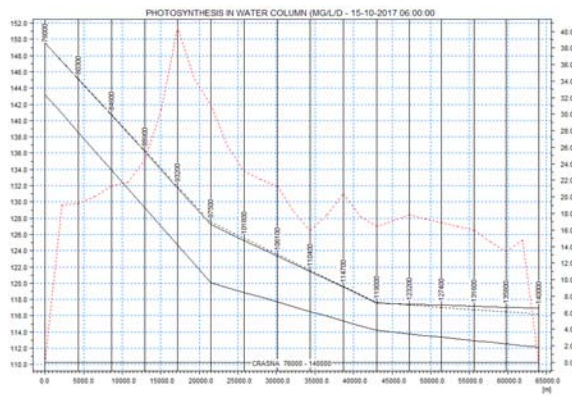

Figure 15. Photosynthesis in water column (mg/l/day)

From the above graphs we can see the evolution of each studied parameter (dissolved oxygen, water temperature, BOD_5, BOD_5 degradation, water reareation, oxygen consumption through plant respiration, photosynthesis in water column, radiation in and out of water) at any time during the simulation period and in all cross-sections along the river sector.

Parameter values are above the limit of detection and quantification, respectively abowe/below the limits allowed for Category A2 of surface water (Table 2), according to the regulations in force (Quality Standard to be met by surface water used for potable watering NTPA-013 from 07.02.2002).

Table 2

Parameter	Detection limit	Cuantification limit	Min/Max value	Allowed limits
Dissolved Oxygen (mg/l) (saturation level %)	0.067	0.200	11-16	> 50 %
Water temperature (°C)	-	-	14-16	< 22 (25)
BOD_5 (mg/l)	0.160	0.500	0.5-1.6	< 5

5. **CONCLUSIONS**

Parameters that dictate the choice and costs of a method of water treatment to meet the quality requirements of the users are: temperature, pH, nitrogen and phosphorus content, suspended particulate matter, BOD_5, COD, nature and concentration of toxic agents. These analyzes are added the establishment the influence of toxic agents on bacterial metabolism.

For this reason, knowing the evolution of surface water and groundwater quality is of particular importance to the specialists in the field.

The most effective methods are simulating the evolution of water quality using advanced hydroinformatic tools, such as MIKE11 – ECOlab module. Several scenarios for the evolution of water quality can be achieved in various cases of pollution: accidental or diffuse pollution.

The evolution of rivers water quality is important especially for cross-border water bodies, which are subjects to the bilateral conventions and EU directives.

ACKNOWLEDGMENT

This paper can be possible thanks to project: Development of knowledge centers for life-long learning by involving of specialists and decision makers in flood risk management using advanced hydroinformatic tools, AGREEMENT no LLP-LdV-ToI-2011-RO-002/2011-1-RO1-LEO05-5329. This project has been funded with support from the European Commission. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

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