Water Course Quality Evolution Near Animal Husbandry Farms

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Abstract
The sum of the chemical, physical, biological, and radiological characteristics of water determine the water quality evolution in water courses. Animal husbandry is one of the main causes of water courses pollution, especially if it does not have a wastewater treatment plant and they are discharged directly into the water course. The water quality determine the treatment technology and costs of water treatment to meet the quality requirements of the users in downstream, 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, especially in sectors where there are significant sources of pollution. 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, using the MIKEbyDHI software, an advanced hydroinformatic tool. 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: pig farm, wastewater, animal manure, water quality, pollution, modeling.

1. Introduction

Animal husbandry is one of the main causes of water courses pollution, especially if it does not have a wastewater treatment plant or the provided treatment plant does not correspond from a technical point of view (for example: undersizing, improper operation, failure to perform timely maintenance work, accidental malfunctions etc.) and the waste water are discharged directly into the water course. Watercourses in the vicinity of animal husbandry farms can be polluted either by direct discharge of untreated or insufficiently treated wastewater, or by their infiltration into the aquifers that supply the watercourse.

The water quality determines the treatment technology and costs of water treatment to meet the quality requirements of the users in downstream, 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, biochemical and chemical oxygen demand, 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].

An important aspect of the activity of water specialists is to monitor, analyze and forecast the evolution of water quality, especially in sectors where there are significant sources of pollution.

An appropriate method for water quality forecasting is mathematical modelling, using advanced hydroinformatic tools. Water quality modeling involves the prediction of water pollution using mathematical simulation techniques. A typical water quality model consists

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of a collection of formulations representing physical mechanisms that determine position and momentum of chemical substances/pollutants in a water body.

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

The need for an analysis of anthropogenic pressures on water resources and their impact is set out in Article 5 of the Water Framework Directive (2000/60/EC), which states: Each member state shall ensure that the impact of human activities on the state of surface and groundwater for each district of the river basin or for a portion of a district of an international river basin situated in its territory is reviewed.

Animal husbandry farms fall under the Integrated Pollution Prevention and Control Directive 96/61/EC (IPPC Directive).

2. Materials and methods

For analysis of water quality evolution near animal husbandry farms was considered a sector of Crasna River, located in north-western Romania, part of Somes –Tisa hydrographical space (Figure 1 and Figure 2). Crasna River catchment is represented in Figure 1.

Figure 1. Crasna River catchment (Bocoi, 2009)

Data necessary for model construction have been raised by the Romanian Waters, Somes-Tisa Basin Water Administration [2].

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. 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 [3].

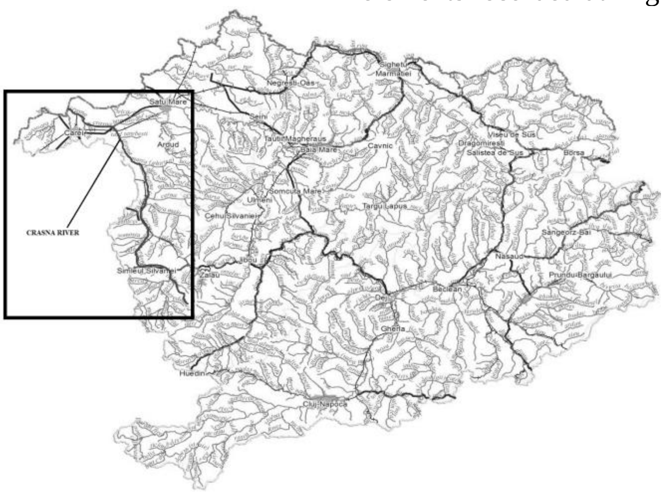

Figure 2. Somes –Tisa hydrographical space (Administratia Nationala “Apele Romane”)

In the Crasna River catchment valleys was evacuated in 2016 a volume of approx. 7995 thousand cubic meters of waste water from the different fields of activity (Table 1) [3].

Table 1. Volumes of waste water (thousand cubic meters)

Other activities	38.50
Water prelevation and treatment for supply	7,200.56
Trade and services for the population	14.41
Construction	16.95
Electrical and thermal energy	31.75
Food industry	31.03
Extractive industry	2.46
Metallurgical industry	17.28
Metallurgical+machinery industry	281.86
Wood processing industry	0.90
Chemical processing	241.98
Transport	12.51
Zootechnics	105.00

During 2016, the quantities of pollutants were discharged in the Crasna River basin, in natural emissaries, are shown in Table 2 [3]. The analysed are Crasna River sector have a length of 64 km, representative cross-sections 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.

Table 2. Quantities of pollutants (tons)

Ammonium (NH_4) 12.101696	Total N 68.764493	NO_3 5.642266
NO_2 1.872929	Total cyanides (CN) 0.02813	Chlorides (Cl) 841.878172
Total iron (all) 0.458087	Total phosphorus (P) 5.21295	H_2S+Sulfides (S_2) 0.151858
COD-Cr 340.776623	Total chromium 0.452168	Mg 0.537574
Cadmium and compounds 0	Ca 9.119943	BOD_5 71.564295
Cu 0.104533	Synthetic detergents 0.820084	Phenols 0.015255
Total manganese (all) 0.026989	Suspended materials 64.683418	Nickel and compounds 0.42344
Extractable substances 13.05794	Lead and its compounds 0.004597	Filterable residue 4855.611979
SO_4 467.943017	Zn 0.254564	1,2- Dichloro-ethane 0.002156
Benz (a) piren 0	Chloroform 0.005319	Diclormetan 0.003594
Benz(g,h,i) perilen, Indeno-(1,2,2-cd)-piren 0	Tetrachlor-ethylene 0.001258	Carbon tetrachloride 0.001258
Anthracene 0	Fluoranten 0	Trichlorethylene 0.001258
Benz (b) fluoranten, Benz (k) fluoranten 0		

In relation to the influence of the pollution sources mentioned in Table 1, the classification of the sections into quality categories is as follows (according to OM 161/2006):

Table 3. Water quality

Section	C1	C2	C3	C4	C5	C6	Global quality
Supuru de Jos - upstream	I	II	III	II	III	II	III
Berveni - downstream	I	II	IV	II	III	II	IV

C1-Thermal regime and acidification; C2-Oxygen regime; C3–Nutrients; C4–Salinity; C5-Specific toxic pollutants of natural origin; C6 - Organic toxic substances
Source: Annual report on the state of environmental factors in Satu Mare county-year 2009

There is a degradation of water quality between the two sections.

A 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 waste water 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 (H.G. 351/2005).

However, the possibility of accidental pollution is small, as the entire waste water transmission network is being replaced by new pipelines.

The United States Agriculture and Consumer Health Department has stated that the "main direct environmental impact of pig production is related to the manure produced" [4].

The environmental impact of pig farming is mainly driven by the spread of feces and waste to surrounding areas, polluting air and water with toxic waste particles. Waste water from pig farms can carry pathogens, bacteria (often antibiotic resistant), and heavy metals. Pig waste also contributes to groundwater pollution in the forms of groundwater seepage and waste water spray into neighboring areas with sprinklers [5].

To analyze the evolution of water quality, a numerical simulation was performed, using the MIKEbyDHI software, an advanced hydroinformatic tool, part of the DHI software products, a professional engineering software package for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. MIKE11 is a user-friendly, fully dynamic, one-dimensional modelling tool for the detailed analysis, design, management and operation of both simple and complex river and channel systems. The used modules for modeling are Hydrodinamic Module and ECOLab module [6].

The MIKE11 hydrodynamic module (HD) uses an implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries. The MIKE11 HD module solves the vertically integrated equations for the conservation of continuity and momentum, i.e. the Saint-Venant equations. The advection-dispersion model (AD) is based on the one-dimensional (vertically and laterally integrated) equation for the conservation of mass of a substance in solution. The equation reflects two transport mechanisms:

- advective (or convective) transport with the mean flow;
- dispersive transport due to concentrations gradients.

The module requires output from the hydrodynamic module, in time and space, in terms of discharge and water level, cross-sectional area and hydraulic radius [6].

ECOLab is a numerical lab for Ecological Modelling. It is an open and generic tool for customising aquatic ecosystem models to describe water quality, eutrophication, heavy metals and ecology. The module is mostly used for modelling water quality as part of an Environmental Impact Assessment of different human activities [7].

The user can use predefined ECOLab (WQ) templates or can choose to develop own model templates. The Water quality (WQ) module deals with the basic aspects of river water quality in areas influenced by human activities and containing the mathematical descriptions of ecosystems. The WQ-module is coupled to the AD module. The WQ module solves the system of coupled differential equations describing the physical, chemical and biological interactions in the river. The module is developed to describe chemical, biological, ecological processes and interactions between state variables and also the

physical process of sedimentation of components can be described [8].
Dependent on the nature of the water quality problem under consideration, the model can be adjusted to different levels of detail. There are six basic Model levels, which in turn can be completed for maximize the applicability of the model.

For the simulation was use Model level 4, which is very applicable to general studies of the effects of discharges from municipal and industrial waste and agricultural run-off. The model was completed with phosphorus. State variables are: Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), ammonia, nitrate, temperature, OrthoPhosphate and Particulate Phosphorus [8].

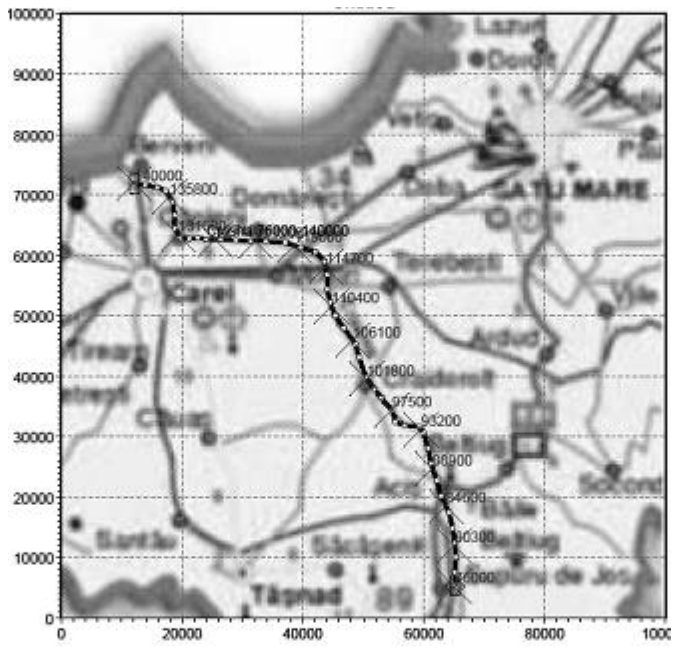

Figure 3. Crasna River sector network

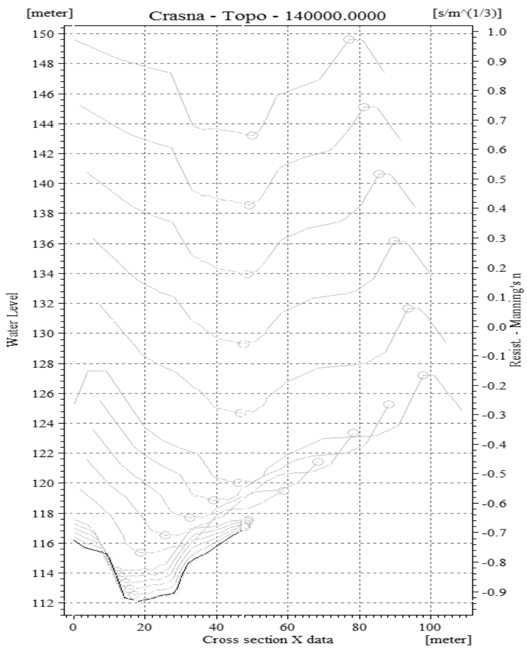

Figure 4. Crasna River sector cross-sections

Input data are river network (Figure 3) and cross-sections (Figure 4); boundary conditions:
1. Upstream (chainage 76000 m)–discharge 0.55 m^3/s, water temperature 14.7°C, DO=11.67 mg/l, BOD_5=1.6 mg/l, Ammonia=0.27 mg/l, Nitrate=2.61 mg/l, OrthoPhosphate=0.38 mg/l, Particulate Phosphorus=0.25 mg/l.
2. Downstream (chainage 140000 m)-water temperature 14.7°C, DO=4.22 mg/l, BOD_5=3.1 mg/l; curve Q-h, Ammonia=2.66 mg/l, Nitrate=4.09 mg/l, OrthoPhosphate=1.46 mg/l, Particulate Phosphorus=0.49 mg/l.
- simulation period 10/15/2017-11/15/2017; simulation time step 30 sec;
- AD calculation.

3. Results and discussion

The simulation results can be seen in the Figures 5-21. The figures show the variation of different parameters and processes along the studied river sector.
Graphs show the minimum and maximum values achieved by different parameters. From the graphs we can see the variation of all the analyzed parameters and processes, at each step of time, in each cross section along the studied sector.
The analysis of the variation of the concentrations of the different nutrients is also important from the point of view of the eutrophication of the watercourse.
For the highest possible accuracy of the obtained results, special attention must be paid to the measurements made in the field, to the taking of water samples, to their laboratory analysis, respectively to the introduction of the data in the simulation program.

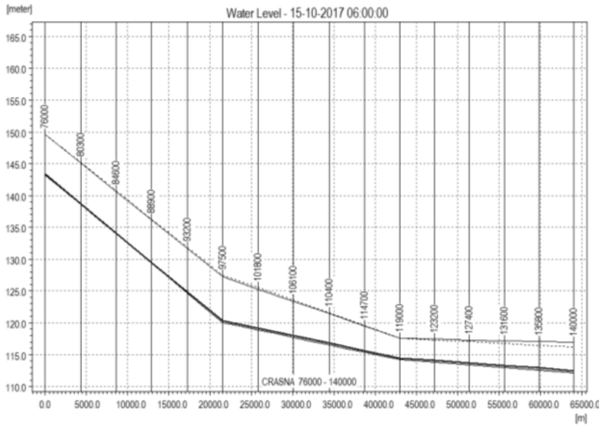

Figure 5. Water level variation

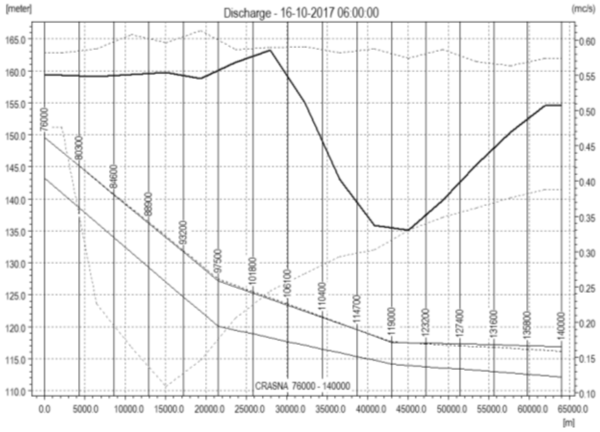

Figure 6. Discharge variation

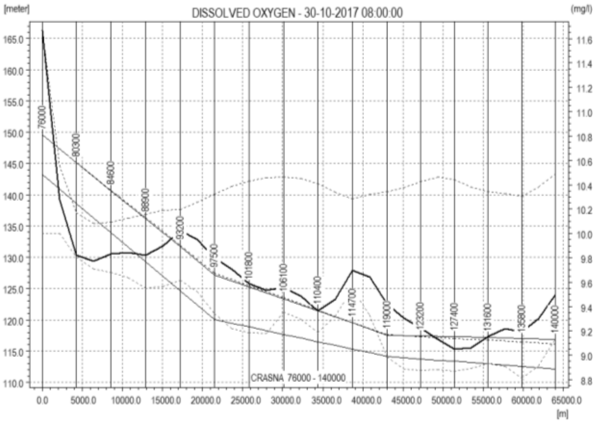

Figure 7. Dissolved Oxygen variation

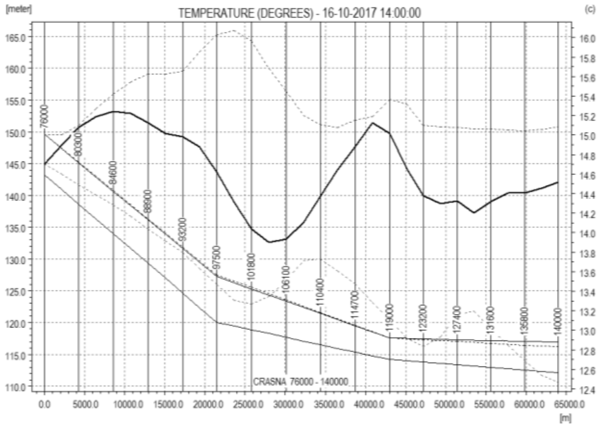

Figure 8. Water temperature variation

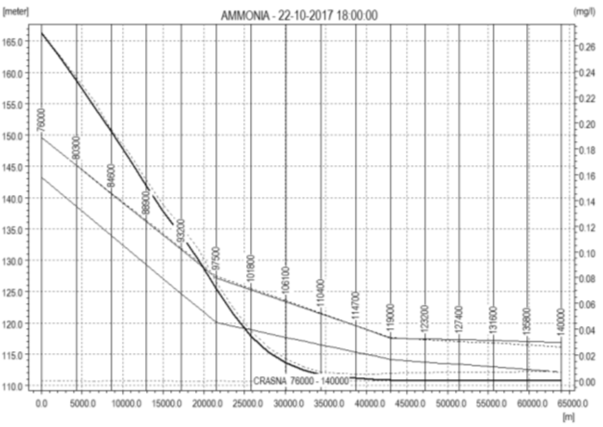

Figure 9. Ammonia concentration variation

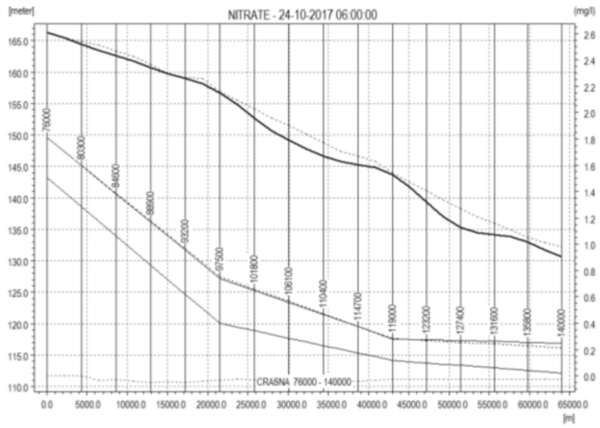

Figure 10. Nitrate concentration variation

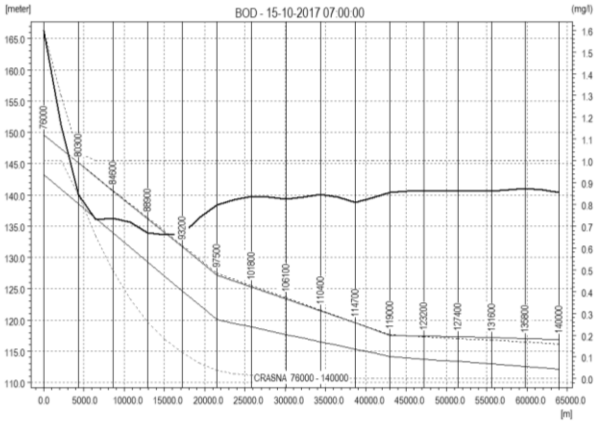

Figure 11. BOD concentration variation

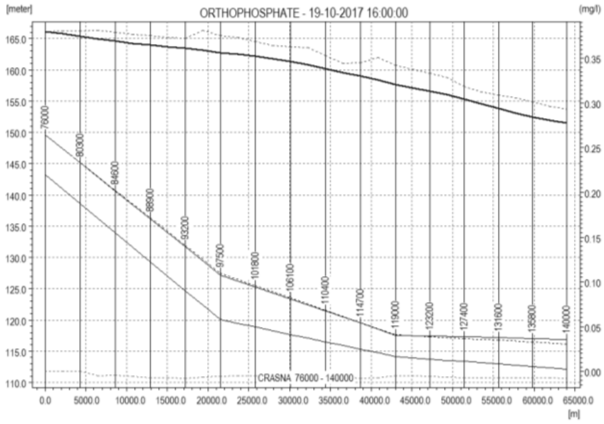

Figure 12. OrthoPhosphate concentration variation

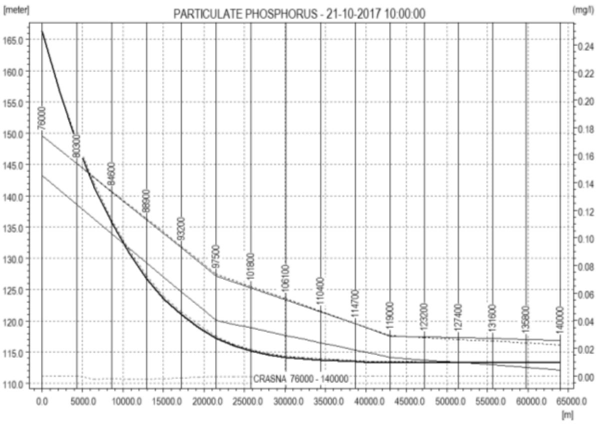

Figure 13. Particulate Phosphorus concentration variation

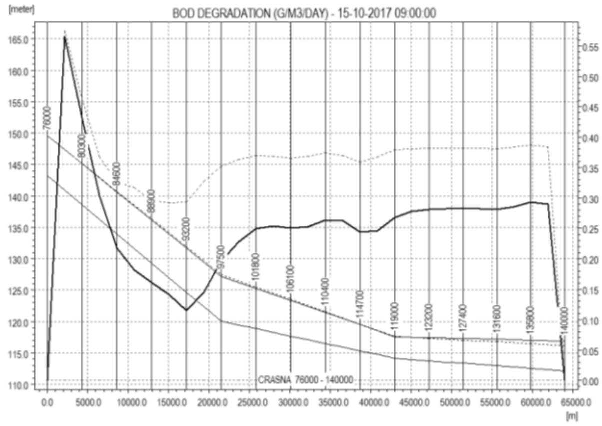

Figure 14. BOD degradation variation

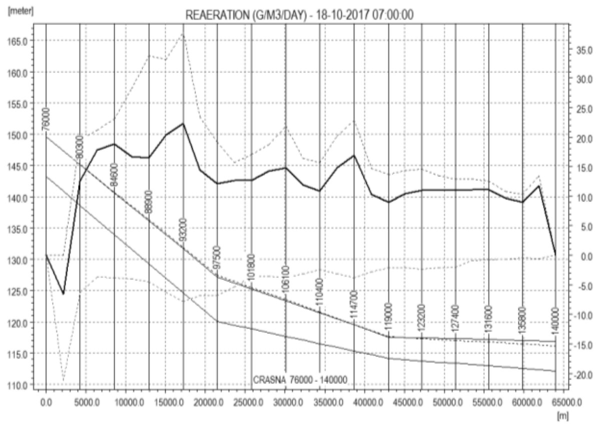

Figure 15. Reaeration variation

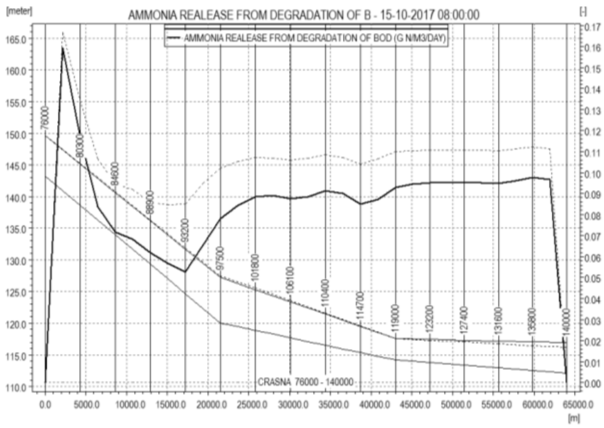

Figure 16. Ammonia release from degradation of BOD variation

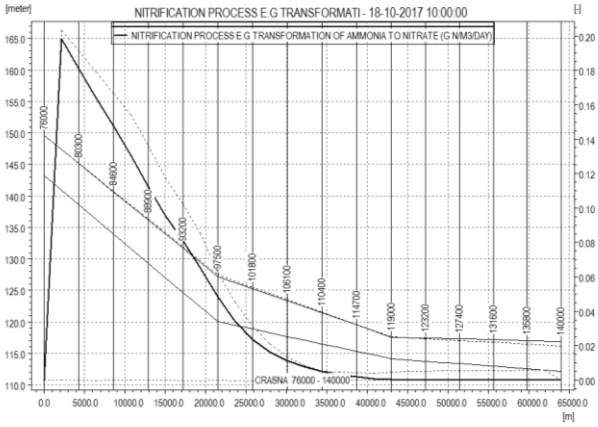

Figure 17. Nitrification process variation

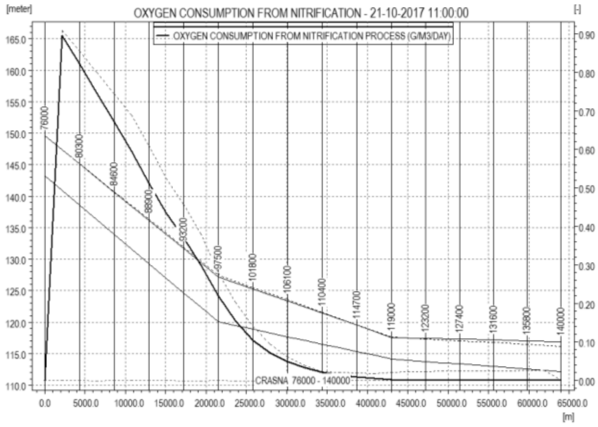

Figure 18. Oxygen consumption from nitrification process variation

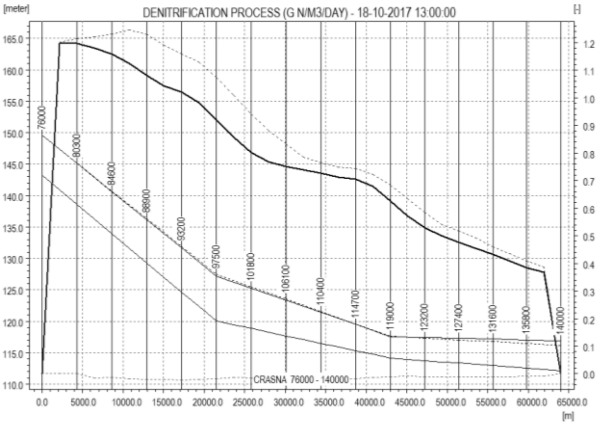

Figure 19. Denitrification process variation

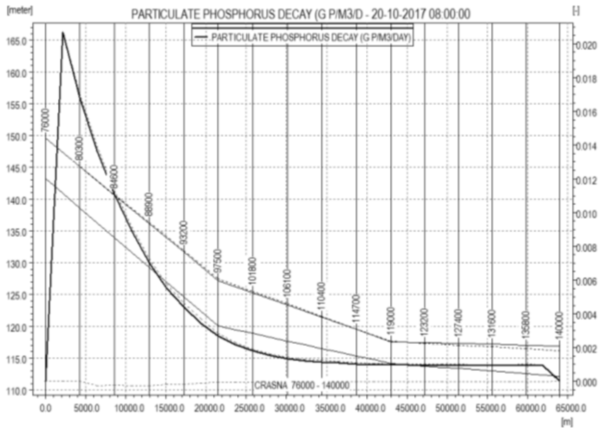

Figure 20. Particulate Phosphorus decay variation

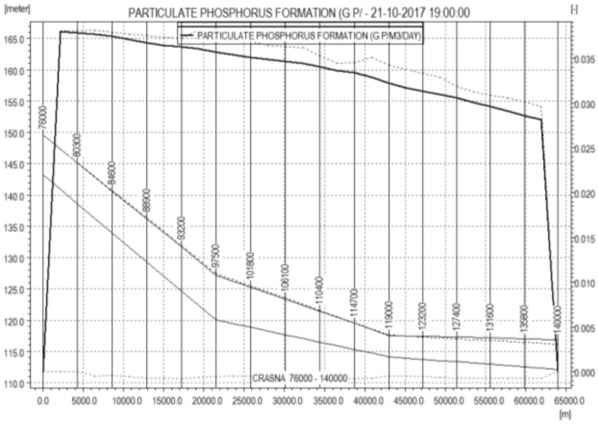

Figure 21. Particulate Phosphorus formation variation

The variation of the analysed parameters and of the afferent processes depends on the water level and discharge, on the shape of the cross section, on the velocity of the water, on the type of vegetation in the riverbed.

The advanced hydroinformatic modeling tools for water quality provides satisfactory results with regard to the status of water quality both in normal periods and in case of accidental pollution.Various pollution scenarios can also be made, in order to be able to elaborate an intervention plan in case of accidental pollution. The detailed results obtained from modeling and forecast increase general understanding of the evolution of water quality in water bodies and support authorities to act (in time and space), in case of accidental pollution, according to the plans of action in emergency situations, based on plans risk management of pollution of watercourses. These results can also be used to optimize the operation of water treatment plants for drinking and use in various industries, and of wastewater treatment plants for wastewaters coming from various users.

4. Conclusions

Agriculture has become, over time, an important and permanent source of pollution of the environment, and especially of water.

The pollution coming from the zootechnical activities is due to the high density of the animals in relation to the agricultural surface afferent to the zootechnical sector; improper location of farms near surface water, or on land with shallow groundwater or with very permeable soils; faulty effluent storage and drainage mode; excessive use of manure accumulated in livestock farms, which results in contamination of soil and surface and groundwater with excess nutrients.

In order to prevent or reduce pollution due to livestock farms, special attention must be paid to the following aspects: the choice of farm location; the establishment of technologies implemented on farms and animal husbandry systems for obtaining agri-food raw materials; the quantitative and qualitative dynamics of production; the trend of the variation of animals number and the way in which the environmental factors are influenced by the residues resulting from the exploitation; the ways and the financial possibilities of farms for the development of appropriate solutions for an efficient management (processing, treatment and possibilities to recovery) of manure, the technologies needed for treatment of resulted wastewaters.

An important aspect is the correct elaboration of the environmental impact studies for the animal husbandry farms.

The competent authorities must be very careful when issuing permits and authorizations (water, environment, waste, etc.) for livestock farms, in order to ensure that their operation complies with the regulations in force and protects the environment.

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