# Modelling Water Courses Pollution Near Livestock Farms Using Advanced Hydroinformatic Tools

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**Abstract**
Animal husbandry is one of the main causes of water resources pollution: groundwater, water courses and lakes. The achievement of a reliable system of collection, treatment and evacuation/storage of wastewater and animal manure resulting from the process of animal husbandry has a special importance for reducing the impact of livestock farms on environmental factors (water, air, soil). Accidents can occur during operation of these systems and wastewater and animal manure can reach into nearby water courses, determining their pollution. This is a serious problem, especially if the water taken downstream for different use: drinking water or industrial supply, water for irrigation, recreation etc. This paper aims to present a way to model the spread of pollutants in water course in the vicinity of livestock farms, using the PMWIN software, an advanced hydroinformatic tool. On the basis of the results obtained from the modelling, the competent authorities can determine the degree of the pollution and the necessary measures to be taken to reduce the negative effects on water quality.

**Keywords**: animal manure, livestock farms, modelling, pollution, wastewater, water course

## 1. Introduction

Animal husbandry activities on livestock farms involve a very large number of effects on environmental.

One of the problems that represent an increased risk to the environment is animal manure. How they are collected, stored, handled, and their composition and quality are key factors that determine the level and density of emissions. Improper manure management generates the spread of various pollutants in air, water and soil.

Animal manure depots are potential sources of air emissions (ammonia and odour) and pose an increased risk of groundwater and surface water pollution. The initial determination of all environmental risk factors plays an important role in establishing measures to minimize and/or eliminate possible adverse effects. The size of the pollution risk depends on a number of factors:

• number of storage spaces;
• storage space capacity (to ensure volume storage required);
• the type and material from which the warehouses are built;
• time required for manure storage;
• how to deal with the problem of odour and emissions in atmosphere;
• leachate collection and treatment system from warehouses.

An important aspect is the transport and subsequent application of manure. Manure applied to cultivated land enriches the soil with nutrients (nitrogen and phosphorus), but there is a risk that these compounds will enter groundwater and surface water, especially if the soil is saturated with nutrients. For these reasons, it is necessary to rigorously analyse the possibilities of use/treatment of animal waste and choose the optimal option, with the least negative effects on environmental factors.

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When applying manure on agricultural land, a number of aspects must be taken into account: soil type, precipitation, land slope and the chemical composition of the soil on which the manure is applied.
The more modern and efficient the animal husbandry facility is, the smaller the impact on the environment [1].
Liquid, semi-liquid and solid manure from livestock farms as well as silage effluents contain large amounts of nutrients. The penetration into the bodies of water even of some small amounts of these substances can have serious consequences for the quality of the water in the respective water body and related water bodies. The chemicals from animal manure can reach watercourses either by leaking from the surface due to rainfall, or by infiltrating in the aquifers that supply the watercourses [2, 3].
Animal manure and plant debris are potential sources of pollution, mainly with organic substances and nutrients. The decomposition of most pollutants leads to a decrease oxygen in the water threatening the survival of aquatic life forms (plants, fish, invertebrates) [4].
The main effect of pollution of surface waters with nutrients is eutrophication. Eutrophication of surface waters is the phenomenon of accelerated growth of algae and other aquatic plants due to the high content of nitrogen and phosphorus compounds in water. The result of eutrophication is the deterioration of the balance of aquatic organisms (plants and animals), which contributes to the decrease of water quality [5].
The main negative effects induced by high concentrations of nutrients in water are:
- accelerated/uncontrolled development of algae, which can have toxic effects, affecting the health of humans and animals;
- excessive growth of aquatic plants which can lead to a decrease in the amount of oxygen in the water resulting in the death of fish;
- diminishing the clarity of the water;
- loss of biodiversity, extinction/reduction of better quality fish species in favour of lower quality ones;
- diminishing the economic and water use value (example for fishing, leisure and tourism);
- increasing the costs for water treatment, caused by the need to remove pollutants, algae, odours and toxins.

The main effect of nitrate pollution of water is the decrease in water potability [6].
At European level, the main regulatory act whose main objective is related to water quality is Directive 2000/60/ EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, transposed in Romania by Water Law no. 107/1996, with subsequent amendments and completions. The Water Framework Directive emphasizes the achievement of the "good" water quality status.
Council Directive 91/676 / EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources was transposed into the national legislation by Government Decision no. 964/2000 on the approval of the Action Plan for the protection of waters against pollution with nitrates from agricultural sources, with subsequent amendments and completions, having as objectives the reduction of water pollution caused by nitrates from agriculture and the prevention of this type of pollution [7].

## 2. Materials and methods

A way to model the propagation of pollutants in groundwater in the vicinity of livestock farms is the use of hydroinformatic tools.
Hydroinformatics provides a symbiosis, and even a synergy, between ICT and water science and technologies, hydrology and hydraulics, with the objective of satisfying social requirements: the more that society becomes aware that it depends upon water, the more it understands that water is esentiale for sustained development of human society.
The rationale and purpose of hydroinformatics is to develop a new relationship between the stakeholders and the users and suppliers of the systems regards to water: to offer the basis (systems) which supply useable results, the validity of which cannot be put in reasonable doubt by any of the stakeholders involved.
Hydroinformatics is a technology, not a science, is limited to aquatic environments, to water and all elements with which water interacts [8].
One such hydroinformatic tool is PMWIN (Processing MODFLOW) software, developed by Simcore Software, USA, for simulating and

predicting groundwater conditions and groundwater/surface-water interactions.

A groundwater equation describing flows in saturated sedimentary rocks can be derived by introducing Darcy's law to the mass conservation law. A widely accepted groundwater equation based on groundwater head (hydraulic head of groundwater) is:

$$S_S \frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) + Q$$

Where: h is the groundwater head (L) in the porous medium; Q is the volumetric flux at sources or sinks per unit volume of the porous medium ($T^{-1}$); $S_s$ is the specific storage ($L^{-1}$) for the porous medium; $K_x$, $K_y$, and $K_z$ are anisotropic hydraulic conductivity ($LT^{-1}$) for the porous medium in x, y, and z directions, respectively; and t is time (T) [9].

Groundwater modeling aims at solving the groundwater equation along with an initial condition, boundary conditions, sinks, and sources. Many numerical methods have been successfully implemented, including the finite difference method, the finite element method, the finite volume, the analytic element method and the lattice Boltzmann method [10].

Processing MODFLOW is one of the most complete three-dimensional groundwater and transport simulation systems in the world. The text and the companion full-version software (PMWIN) offer a totally integrated simulation system. PMWIN comes with a professional graphical user-interface, supported models and programs and several other useful modeling tools. The model tools include a Presentation Tool, a Result Extractor, a Field Interpolator, a Field Generator, a Water Budget Calculator and a Graphic Viewer.

Processing MODFLOW targeted at novice and experienced groundwater modelers, working as a hydraulician, hydrological, hydrogeological or environmental consultant, in a water company, in a regulatory agency or a university [11].

To exemplify the modeling of water course pollution using advanced hydroinformatics tools, a pig farm was chosen.

Pollution scenario: cracking of the foundation of the animal manure storage basin, thus resulting in the infiltration in groundwater of a discharge of 1 l/s leachate; permanent source; it reaches the neighboring water course through groundwater infiltration.

The situation plan and the domain discretization, respectively the location of the farm, of the crack point of the foundation of the manure storage basin, as well as the location of the three observation wells are presented in Figure 1. Also in Figure 1 are shown the boundary conditions on the domain boundary.

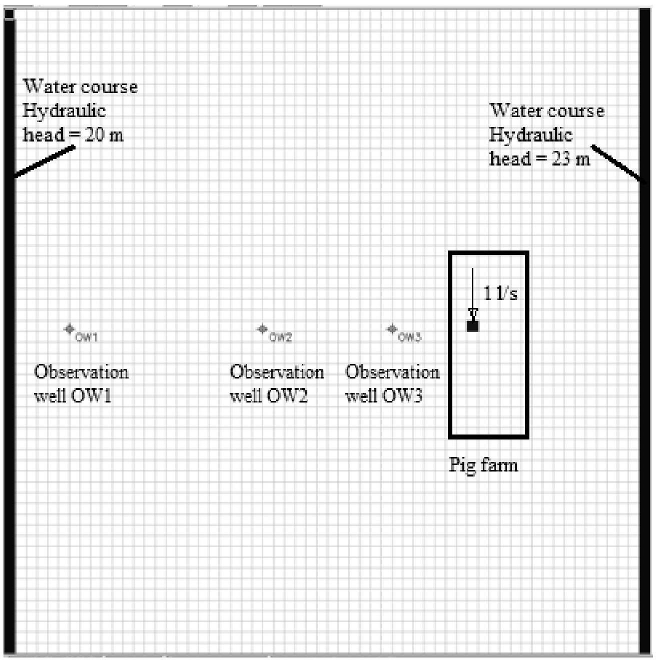


**Figure 1.** Situation plan

The input data are:
- domain area 2.25 $km^2$ (1.5 km x 1.5 km);
- the aquifer is unconfined, homogeneous and isotropic;
- the top and bottom elevations of the aquifer are 25 m and 0 m, respectively;
- the aquifer is simulated using a grid of one layer, 60 columns and 60 rows;
- grid spacing is regular (25 m x 25 m);
- the layer type is unconfined;
- two boundaries are fixed hydraulic head boundaries and two boundaries are no-flow boundaries;
- the average horizontal hydraulic conductivity is 0.000121 m/s; the effective porosity is 0.25;
- three observation wells.

## 3. Results and discussion

Simulations are making in calibrated model in different significant time period: 5, 10 and 20 years. The hydroips lines and the trajectory of the pollutant are presented in Figure 2.
The variation of the pollutant concentration in the observation wells is shown in Figure 3.
Results are presented in figures under polluted extending areas with different concentrations (isoconcentrations) for 5, 10 and 20 years (Figure 4, 5 and 6).

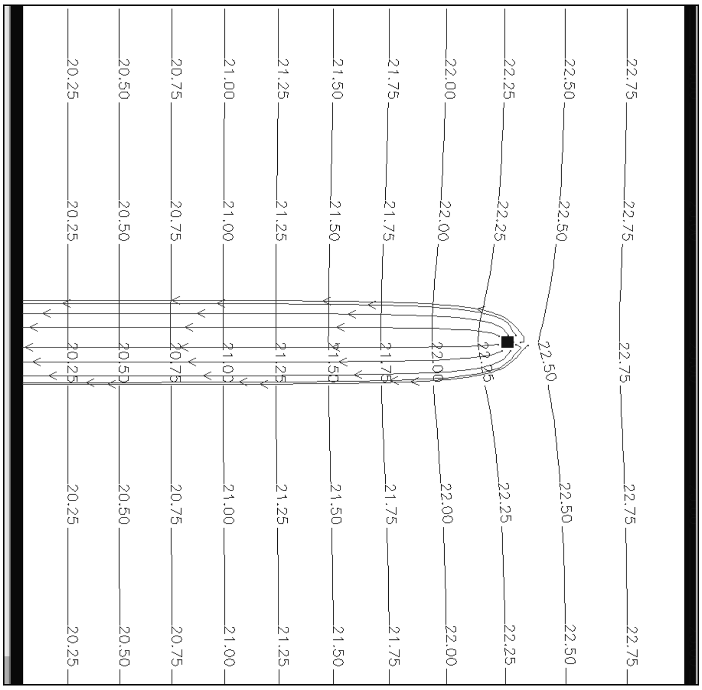


**Figure 2.** Hydroips lines and the trajectory of the pollutant

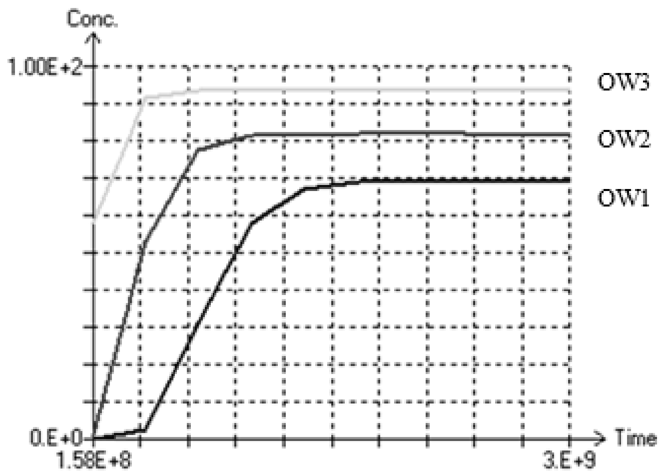


**Figure 3.** The variation of the pollutant concentration in the observation wells

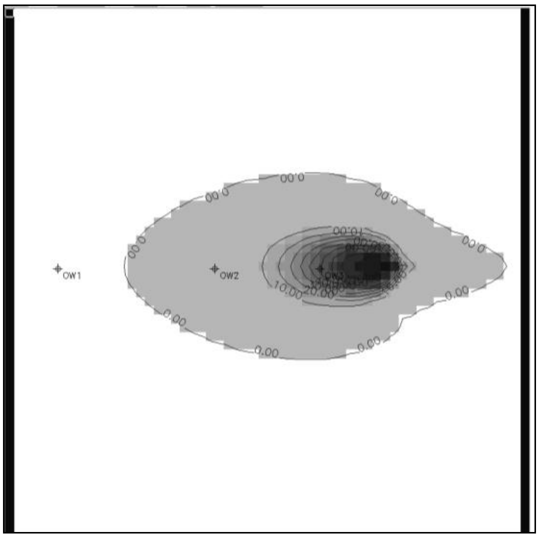

**Figure 4.** Concentration at 5 years

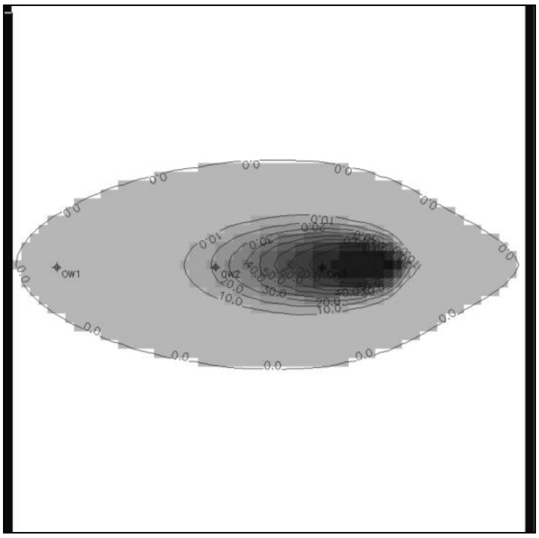

**Figure 5.** Concentration at 10 years

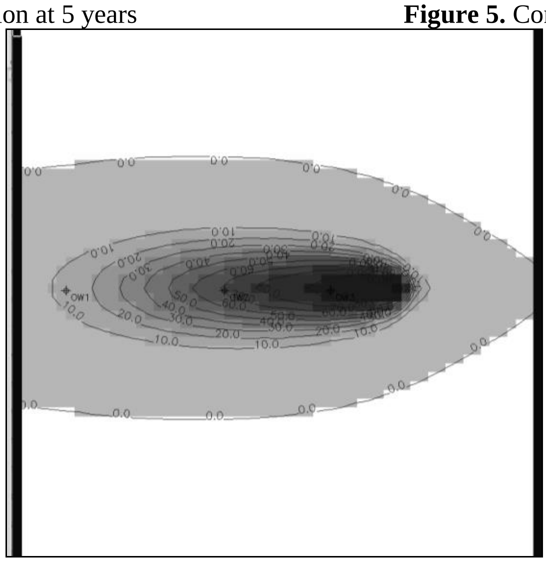

**Figure 6.** Concentration at 20 years

The highest concentration of the pollutant is observed in observation well 3, here the pollutant reaches the maximum concentration the fastest.

The pollutant reaches the river in about 10 years.

After about 20 years the concentration of the pollutant that reaches the river is 10% of the initial concentration. If the pollutant reached an aquifer under pressure, these times would be much shorter.

Is too mentioned in modeling with PMWIN isn't necessary to specify polluted mature.

Concentration is a general parameter and maybe serve base for calculation an absolute concentration (for example mg/l) for all dissolved pollutants in water.

In order to obtain results with a degree of accuracy as high as possible, detailed pedological, hydrological and topographic studies must be performed in the affected area. Also, detailed laboratory analyzes of pollutants with risk of infiltration into the groundwater must be made, in order to know the concentrations of different dangerous substances.

## 4. Conclusions

Result of simulation are permitted quantity exactly evolution of concentrations in time for all points of polluted zones. The realization of the observation wells is necessary, as well as the establishment of a sampling program and the analysis of the groundwater and surface water quality.

This think is especial important to make technical to limit, reduce or eliminate a pollution.

On the basis of the results obtained from the modelling, the specialists can determine the extent of the pollution and the necessary measures to be taken to reduce, limit and control the negative effects on water quality in water course.

The specialists must determine if and whether measures are needed to reduce or prevent the infiltration of pollutants into groundwater and then in the surface water that is fed from that aquifer. Also, a technical-economic analysis must be made regarding the costs/benefits of maintaining the operation of livestock farms, the costs of implementing the measures considered necessary for protection, respectively the costs of treating the affected surface water, to bring them back at an adequate quality.

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