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THE MODELLING OF POLLUTION PROCESSES IN THE AREA OF INDUSTRIAL WASTE

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Abstract: The industrial waste deposits determine an increased pollution of underground waters. The paper presents the modelling of the pollution phenomenon of underground water in an industrial waste deposit area. The pollution phenomenon is analyzed in time, during the period of the deposit exploitation and conservation. The results obtained through modelling allow the application of some environment protection measures.

Key words: industrial waste deposits, pollution flow modeling, pollution phenomenon, protection.

1. INTRODUCTION

Waste products represent one of the most acute problems of environment protection in the current stage of economic and social development. In Romania, large quantities of waste products are generated because of the economic development, growth of production and consumption.

The inappropriate management of industrial waste and their deposits determine numerous cases of air, soil and underground pollution, with a negative impact on the environment and population health.

The mass of deposited waste represents the main source of pollution of soil, underground waters and surface waters in certain cases, from the area of the placement of deposits and industrial waste stock-piles, both directly, by changing the use of the occupied land, and indirectly, through the contamination of neighbouring surfaces.

The soil is the most stable environment factor, which keeps the traces of pollution for a long period of time, the soil pollution implicitly leads to the pollution of the underground water.

Fig. 1. Deposit of industrial wastes.

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2. THE PHYSICAL - MATHEMATIC MODEL OF POLLUTANTS TRANSPORT

We opted for a model of transport type, applicable to: 1° the flow processes through porous unsaturated/saturated media, in the stationary / transitory regimes; 2° the processes of miscible /non-miscible pollutants transport from porous unsaturated/saturated media, in transitory regime.

These mathematic models consisted in:

1° - non-governing equations (also called basic) of the flow and/or transport processes;

2° - contour conditions;

3° - initial conditions (only for the processes dependent of the time *t*).

The equations governing the flow consist of the equations of the fluid mass balance – named also the continuity equation and, respectively, moment equation, the famous Darcy's equation, generalized to non-saturated porous media; these can be presented under the following general form [Voss, C.I., 1984]:

where the symbols present the following significations:

$$\frac{\partial\left(n\cdot S_w\cdot\rho\right)}{\partial t}=-\nabla\cdot\left(n\cdot S_w\cdot\rho\cdot\mathbf{v}\right)+Q_p\rho \qquad (1)$$

$$\mathbf{v}=-\left(\frac{\underline{\underline{\mathbf{k}}}\cdot k_r}{n\cdot S_w\cdot\eta}\right)\left(\nabla p-\mathbf{g}\cdot\rho\right) \qquad (2)$$

$n=\mathrm{n}\left(x,y,t\right)$ - porosity [1];

$\rho=\rho\left(T\left(x,y,t\right)\right)=$ water density, $[ML^{-3}]$, temperature dependency *T*;

∇ - *nabla* differential operator, $[L^{-1}]$;

$\mathbf{v}=\mathbf{v}\left(x,y,t\right)=$ the average speed vector of the fluid (water) through the pores of the porous medium $[LT^{-1}]$;

$Q_p=Q_p\left(x,y,t\right)=$ the intensity of the distributed (punctiform) source of volume (specific debit) of fluid, $[T^{-1}]$;

$\eta=\eta\left(T\left(x,y,t\right)\right)$- the dynamic viscosity of water, $[ML^{3}T^{-1}]$, dependent on the *T* temperature;

$p=\mathrm{p}\left(x,y,t\right)=$ fluid pressure from the pores, $[ML^{-1}T^{-2}]$ (the relative pressure in relation with the atmosphere pressure; the manometric pressure for $p\geq 0$ or the vacuum manometer pressure $p\leq 0$);

$\mathbf{g}=\mathbf{g}\left(x,y\right)=$ the vector of the gravitational acceleration, $[LT^{-2}]$.

Thenceforth, the definition relations for each of the classical types of contour conditions are:

1° *type 1 contour conditions* (Dirichlet), where there are the values of the dependent *H* variable on the frontier,

$$H(x,y,t)=H_{\Gamma_1}(t),\ (x,y,t)\in\Gamma_1\times\left[t_I,t_F\right] \qquad (3)$$

2° *type 2 contour conditions* (von Neumann), where are given the values of the H size flow, according to the ***n*** direction of the normal to the Γ frontier, flow marked with $q_{n_H}(x,y,t)$:

$$-e_{ij}\cdot\frac{\partial H}{\partial x_j}\cdot n_i=q^R_{H\_\Gamma_2}(t),\ (x,y,t)\in\Gamma_2\times\left[t_I,t_F\right] \quad (4)$$

Where, according to the rule of mute indices, for $i,j\in\left\{x,y\right\}$,

When $q^R_{H\_\Gamma_2}(t)\equiv 0$, the conditions (4) are named *natural contour conditions*. In this case, the frontier is considered impermeable for the flow of *H* size.

$$e_{ij}\cdot\frac{\partial H}{\partial x_j}\cdot n_i=\left(e_{xx}\frac{\partial H}{\partial x}+e_{xy}\frac{\partial H}{\partial y}\right)n_x+\left(e_{yx}\frac{\partial H}{\partial x}+e_{yy}\frac{\partial H}{\partial y}\right)n_y \quad (5)$$

3° *type 3 contour conditions* (Cauchy), when the values of the flow $q_{n_H}(x,y,t)$ depend also on the *H* variable, according to a law considered as linear:

$$-e_{ij}\cdot\frac{\partial H}{\partial x_j}\cdot n_i=-\Phi_{H\_\Gamma_3}\left[H^R_{\Gamma_3}(t)-H\right],\ (x,y,t)\in\Gamma_3\times\left[t_I,t_F\right] \quad (6)$$

Where the function $H^R_{\Gamma_3}\left(t\right)$ generates the values for the *H* variable, imposed on the frontier Γ_3, and $\Phi_{H\_\Gamma_3}$ is the rate of the transfer (coefficient) which generally depends on the sense of the q_{n_H} flow.

$$\Phi_{H\_\Gamma_3}=\begin{cases}\Phi^{in}_{H\_\Gamma_3} & for\ H^R_{\Gamma_3}\left(t\right)\rangle H\\ \Phi^{out}_{H\_\Gamma_3} & for\ H^R_{\Gamma_3}\left(t\right)\leq H\end{cases} \qquad (7)$$

The numerical simulations achieved for different scenarios and for a certain period of time can appreciate the dispersion of a pollutant in a carrier of water.

The observation period regarding the underground water layer was between 2005…2009. In this period, we collected data regarding the pollution phenomenon parameters. For the prognosis, we considered a period of 10 years, respectively 2010…2019.

the analysis carried out on the main pollutant substances indicated for the first prognosis stage the consideration of the anion from the NH_4 ammonium.

For solving the proposed problems, we achieved a conceptual model, for which we elaborated a mathematic model of pollutants transport. The mathematic model represents the flow and transport of pollutants from one layer of underground water from the analysis field. In the analysis, we used a complex of basic data specific to the case study. The data introduced in the calculation model come from systematic measurement in 13 observation wells positioned in the location of the industrial waste deposit.

The climatic data was acquired from the meteorological station. In the analysis, we also used the data from two hydrometric stations placed on the nearby water flows. The basic data was processed with different frequencies: daily, monthly, trimestrial, every semester etc.

For the numerical simulation, we used the FEFLOW program package.

3. EXPERIMENTAL RESULTS

The numerical simulation using the FEFLOW program package requires going through three distinctive stages: pre-processing of the basic data, the effective processing of basic data and the post-processing of the resulted data.

We successively treated a flow problem in four scenarios and two flow and transport problems (therefore, in total, 6 calculation variations):

1. The flow problem for the study duration, $t \in [0, 1825]$ days (01.01.2005 – 31.12.2009) in four scenarios regarding the functioning of drillings from the area of the closed deposit (for establishing the optimal scenario)
   a) Without pumping;
   b) With pumping from the drillings P1 (P.O. 14) and P2 (P.O. 15);
   c) With pumping from the drilling E2 (P.O. 23);
   d) With pumping from the drillings E1 (P.O. 24) and E2 (P.O. 24).

2. The flow and transport problem for the study duration, $t \in [0, 1825]$ days (01.01.2006-31.12.2009), in the scenario established as being optimal within the flow problem (for monitoring the pollution phenomenon in all the interest points from the domain Ω; taking into account the different periods for which we collected study data from the 13 observation drillings, the interval [0, 1825] days was divided in three adjacent disjoint sub-intervals:

$$[365,1825]=[365,775]\cup[775,956]\cup[956,1825] \quad (8)$$

It must be emphasized that on each of the three sub-intervals, we dispose of contour conditions of *I type,* with own forms.

3. The flow and transport problem in the perspective of the following decade, $t \in [0, 1825]$ days (01.01.2010-31.12.2019), in the scenario established as being optimal within the flow problem 1° and through the simulation of the contour conditions and variation of the material parameters (for the prognosis of the evolution of the pollution phenomenon in all the interest points from the domain Ω).

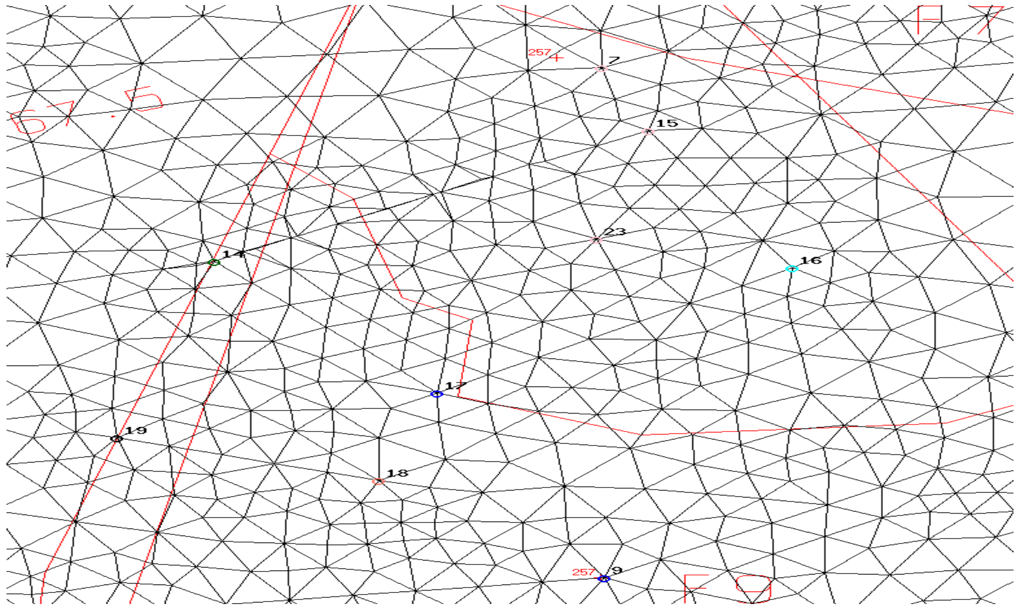

Fig. 2 EF scheme in the study area waste industrial dump.

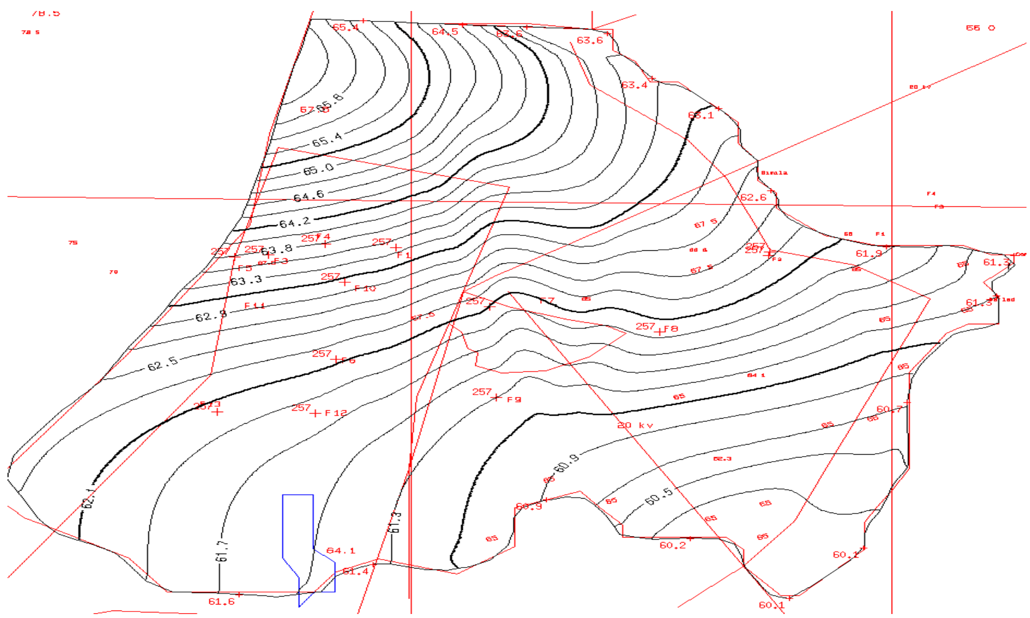

Fig. 3. The altitude of the basic layer of the carrier of water represented through isohypses (the numbers in red colour represent the altitude of the support points).

The study data were pre-processed, regarding:

1. The natural environment (topographic – the lay-out plan of the study area; climatic – precipitations and evapotranspiration ; hydrological – levels and debits in the hydrometric stations Bârlad and Râpa Albastră; hydro-geological – levels of the underground water and the depth of the basic layer, impermeable, of the carrier of water in the observation drillings and the material constants of the aquiferous layer regarding the processes of mass flow and transport);

2. The analyses regarding the qualitative indicators of the soil and underground water and from the rivers;

3. The quarterly rate of waste depositing (garbage, industrial non-recyclable wastes-emulsions, slime, ash, cinder etc.) and the monthly rate of sediment powders upon emission and their concentration in NH_4.

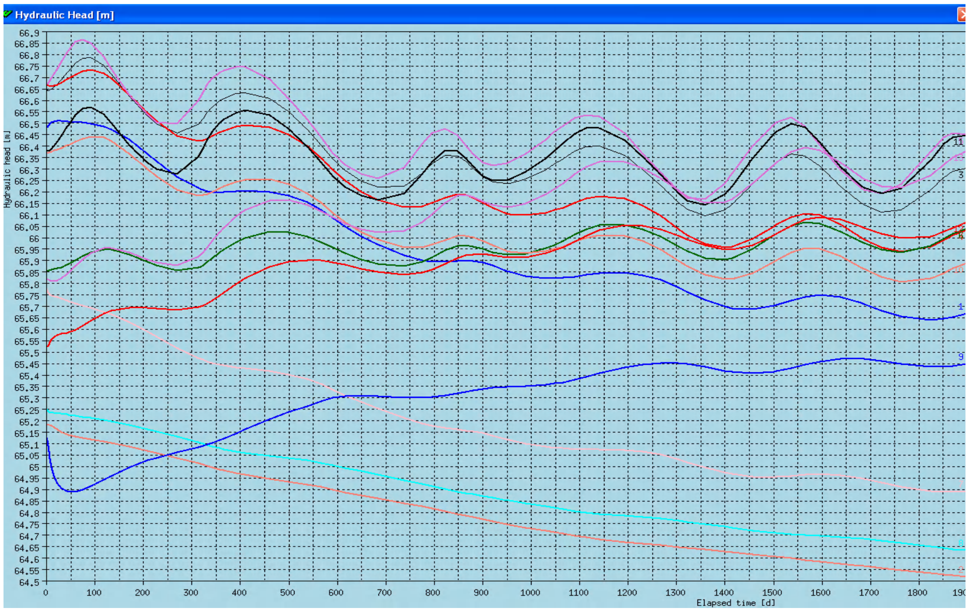

Fig. 4 The variation of the hydraulic load in the observation drillings F1...F13 (P.O. 1...13) bottom-up 5, 11, 13, 3, 12, 6, 4, 10, 1, 9, 7, 8, 2 in the time interval [0, 1825] days.

After pre-processing this study data, we determined the concrete numerical constants for the entry parameters and elaborated the input data files in the FEFLOW program package.

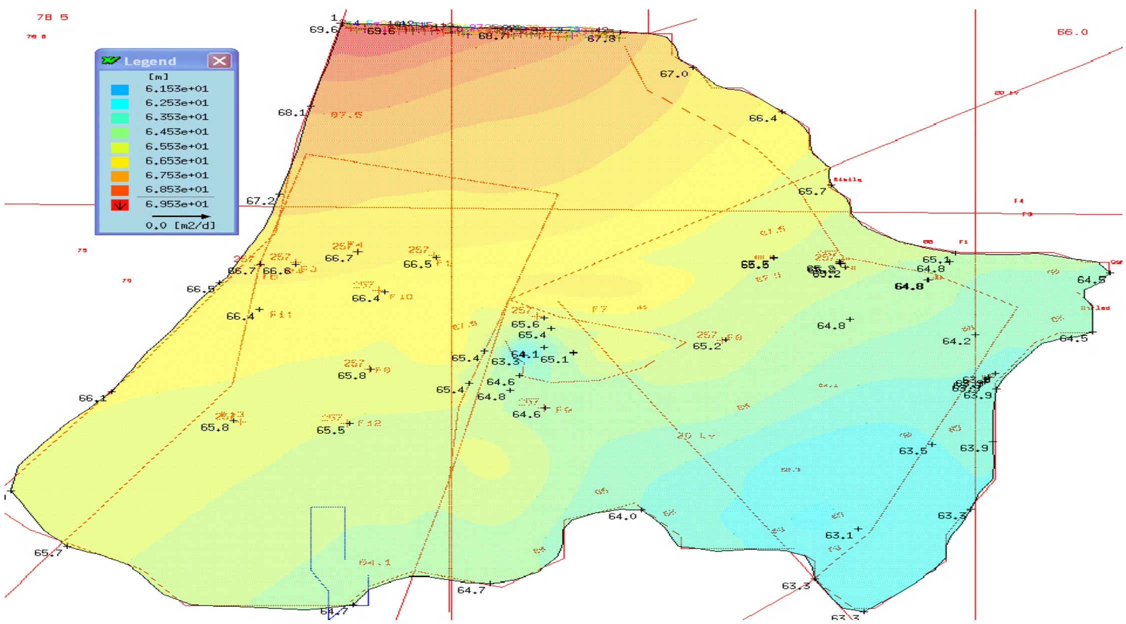

Fig. 5. The initial piezometric load field for the flow problem (t_1 = 0 days, on 01.01.2005) represented through the colour code (numbers in black colour represent the piezometric load of the support points).

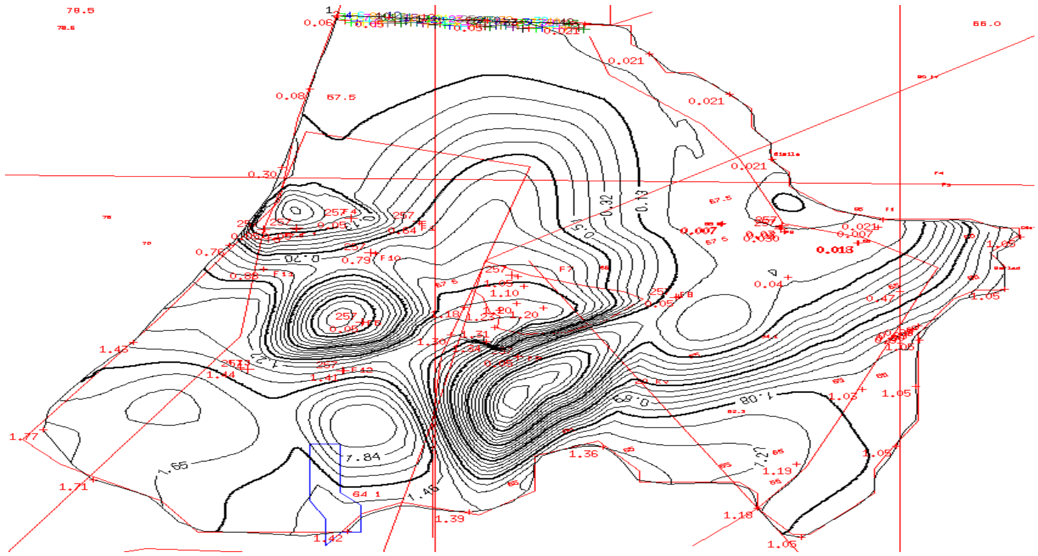

Fig. 6. The NO_4 initial concentration (t = 365 days, on 01.01.2006) represented by isolines of equal concentration.

A part of the accidentally polluted water sources can be subject to a depollution process, of certain duration, in order to be reintroduced in the circuit of water supply for either industry, or population.

Through the analysis and prognosis model conceived, we attempted a response to this problem that has been affecting, lately, the underground medium, more and more stringently.

In order to determine the evolution of the pollution process in the entire interest field, we can only make interpolations on bi-dimensional fields, according to certain mathematic techniques accepted in this field.

The intensity of the evacuation process of a pollutant soluble in water (NH4, in the present study), through pumping, at a constant debit, decreases to the diminishment of its concentration in the carrier of water, and in order to obtain /maintain an acceptable intensity of this process, the pumped debit must be increased, or certain processes of the pollutant biotransformation be activated.

4. CONCLUSIONS

The interpretation of the data obtained allows the enunciation of the following general conclusions:

1. Modelling the transport of pollutants in the soil in the area of industrial waste deposits has a special importance for the protection of underground waters.

2. The simulation model elaborated allows the analysis of the pollutant transport in the area of underground waters by emphasizing the variation of concentrations in time and space.

3. The simulation model through the FEFLOW program package has allowed the analysis and the methods of underground waters depollution for a certain determined period of time.

4. Using the numerical simulation techniques, we can solve both the problems regarding the monitoring of the pollution process for the entire duration of the experimental measurements (approached problems, but insufficiently solved through the current monitoring techniques), but also the future evolution, on the extended periods, in different scenarios, of the pollution and/or depollution processes.

5. The simulation model can also be generalized for similar situations in the industrial waste deposits.

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