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The Grounds Contaminate, Modelisation of the Transfer of the Particles in a Aquifere

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Abstract: The presence of the contaminated groundwater in the soil has important repercussions for several spheres of activities and can involve serious environmental imbalances within the ecosystems and constitute a direct threat for public health. The estimate of the risk of underground pollution waters, non-renewable natural resource, became an essential aspect of management of the sites and potentially polluted grounds and in particular in the vicinity of the industrial poles. The present study lies within the scope of the draft study of the contamination of subsoil waters by the polluted grounds, from point of view modeling and prediction of the process of infiltration, by the use of the concept of the variation of the contamination in an aquifer. A significant number of models, numerical and analytical, were developed to deal with this problem. In our study, we present a practical model of calculation of transfer of the polluting particles emitted by a source of pollution through an aquifer.

Key words: Polluted site, model, modeling, aquifers contaminated, environment

INTRODUCTION

Of the whole of water present on ground, only (2,6%) is fresh water. Approximately (2%) are blocked in the caps refrigerators and the glaciers. The remainder is in the ground (0.586%) where it is directly accessible: Lakes, rivers, rivers, etc. (0.014%). Thus, less than (1%) of the supply fresh water on ground can be used like drinking water (Anguela, 2004). The modelling of the quality of subsoil waters is a sector under development which could play an important part because of the high cost and the possible side effects of the gathering of the data. Indeed, many drillings necessary to evaluate the contamination of the ground well can make fear an increased contamination of the ground water (Broissia, 1987). To this effect, we use a mathematical approach to study the impact and the evaluation of the risk of underground water contamination begotten by the industrial activities of the unit of production of paintings of the city of SOUK AHRAS (that is to the extreme northeast of Algeria) on the health of the local population. In the classic theory of the drainage, the flows are supposed to be vertical in the Zone No Saturated (ZNS) and horizontal in the tablecloth. It is the concept of the mixture layer. However, of many authors (Vauclin *et al*., 1979; Romano *et al*., 1999; Kao *et al*., 2001; Silliman *et al*., 2002) underline the existence on the one hand meaningful of the infiltration that flows out horizontally in this zone. Therefore, the Zone No Saturated (ZNS), play a very important role in the process of infiltration, because it is in this interfacing that exchanges of water, pollutants and micro-organisms toward the tablecloth or the atmosphere produce occur.

MATERIALS AND METHODS

Since the construction in the end of years seventy, of a factory of painting production in the city of SOUK AHRAS, no scientific survey has not been made to verify the risk of pollution of the existing underground water in the under soil of the factory. One using laws of physical behavior and mathematical model, one is going to try to understand mechanisms of transfer of water and solutes(2) in a ground variably saturated, in flow bi and three-dimensional and in the presence of a drained water tablecloth and to appreciate the potential of the pollution risk. In this goal, a set of taking of soil samples that spreads on a period of six months of the 11/2006 at 04/2007 has been done for analysis to the laboratory in view of the determination of the physical features of soil. In the specialized literature we can find various models

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existing in the field of the transport of aqueous solutions in the porous environments. These models can be gathered according to four mechanisms based on the principles of the equations of the mathematical physics:

- Stochastic-Convective Model (SCM). The volume of ground is regarded as "tubes" of flow independent the ones of the others. Speeds in the tubes are distributed according to a function considered often as lognormal
- Convection-Dispersion Equation (CDE). Suppose a uniform flow where the aqueous solution is propagated by a dispersive flow similar to the diffusion, obeying the law of Fick.
- Fractional Advection-Dispersion Equation (FADE). This model is intermediate between SCM and CDE.
- Continuous-Time Random Walk (CTRW). Described the movement of the aqueous solution by a random displacement in time

Equation of continuity: The law of Darcy indicates that the flow of a liquid (flow) through a porous environment is done in the direction of the driving force: the hydraulic gradient of load acting on the liquid. The flow also depends on a fundamental characteristic of the ground: the permeability, the current tendency tends to name it hydraulic conductivity. With the macroscopic scale, the law of Darcy can be generalized in the mediums variably saturated, by considering that hydraulic conductivity is a function of the potential of pressure:

$$\vec{q} = -\overline{\overline{K}}(\Psi)\cdot\vec{\nabla}\Phi \qquad (1)$$

Where:

q : Speed of Darcy [L,T^{-1}]
K(Ψ) : Represent hydraulic conductivity according to the matrix potential [L, T^{-1}]
∇Φ : Gradient of potential [L]

The equation of Richards described the transfers of water in a porous environment variably saturated. It rises from the combination of the law of Darcy generalized Eq. 1 with the equation of continuity:

$$\frac{\partial\theta}{\partial t} = -\vec{\nabla}\vec{q} \qquad (2)$$

Where:

θ : Water content volumetric [L^{3}L^{-3}]

The law of Darcy generalizes, developed in combination with the conservation equation of the mass, under the assumption of an incompressible fluid of density and of constant dynamic viscosity; the equation described by Richards gives (Chossat, 2004):

$$\frac{\partial\theta}{\partial t} = \operatorname{div}\left[-\overline{\overline{K}}(\Psi)\cdot\overrightarrow{\operatorname{grad}}\left(\Phi(x,y,z,t)\right)\right] \qquad (3)$$

The equation of Richards is a nonlinear equation of which the resolution requires numerical means in general (Simunek and Hopman, 1969). The resolution of the equation is nevertheless very sensitive to the determination of the relations. Describing the hydrodynamic parameters, in particular in the vicinity of saturation (Vogel *et al*., 2001).

The convection: The convection represents the drive of the suggestions for solution (the contamination C) in the movement of the fluid which moves. The aqueous solution is transported by the general movement of water, at the speed $\vec{q}$ defined by the law of Darcy. The principle of conservation of the mass makes it possible to write:

$$-\nabla\cdot\left(C\cdot\vec{q}\right) = \frac{\partial}{\partial t}(C\cdot\theta) \qquad (4)$$

Where:

C : Concentration [ML^{-3}]
q : The speed of Darcy [LT^{-1}]

The molecular diffusion: Physicochemical phenomenon which tends to make homogeneous the spatial distribution of the aqueous solution until a uniform concentration by diffusion towards the less concentrated zone (in a hypothetical case where fluid would be at rest). Its influence becomes important only in the cases of slow flows (<10-7 cm.h-1), (Anguela, 2004). In this optic, one can write the equation of the diffusivity:

$$\frac{\partial}{\partial t}(\theta\cdot C) = \nabla\left(\theta\cdot\overline{\overline{D}}\cdot\vec{\nabla}(C)\right) \qquad (5)$$

Where:

C : Concentration [M.L^{-3}]
$\overline{\overline{D}}$: The dispersion tensor [L^2.T^{-1}]

The classic equation of dispersion convection, CDE: If one considers that the total flux of solute is composed of flux dispersive and convective, the transport can be described by the classic equation of dispersion convection:

$$R\frac{\partial\theta C}{\partial t} = \frac{\partial}{\partial xi}\left(\theta\overline{\overline{Dij}}\frac{\partial C}{\partial xj}\right) - \frac{\partial}{\partial xi}(qiC) + \frac{qs}{\varepsilon}Cs \qquad (6)$$

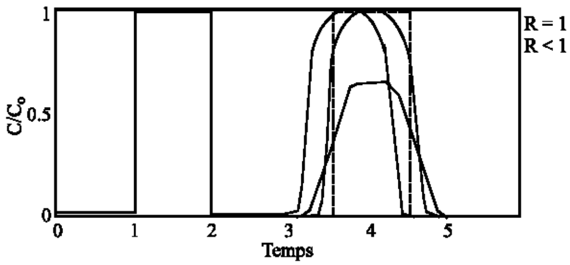

Fig. 1: Effect of the delay factor

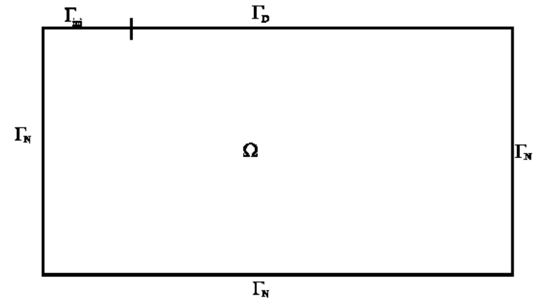

Fig. 2: Field of work

Where:

$\overline{\overline{Dij}}$	:	Tensor of the dispersion coefficient $[L^2.T^{-1}]$
qi	:	The component of the water flux $[L.T^{-1}]$
R	:	Factor of delay [-]
qs	:	Volumetric flux of water by unit of volume of aquifer, positive continuous source, negative for instantaneous sources.
ε	:	The porosity
Cs	:	Initial concentration $[M.L^{-3}]$

The speed of Darcy is known by the previous resolution of the equation of Richard. The factor of delay (R) intervenes only for the reactive solute, for the no reactive (ideal tracer), R = 1 (Fig. 1). This variable corresponds to the speed of water divided by the speed of the tracer. For the loaded ions negatively as the chloride or bromide: R < 1 (Wierenga, 1995).

That is to say Ω open limited space. It is supposed that the border ∂Ω breaks up into three disjoined parts.

$$\partial\Omega = \Gamma_{inj} \cup \Gamma_N \cup \Gamma_D$$

The border Γ_{inj} corresponds to the source of pollution. One imposes moreover of the conditions of the Neumann type is homogeneous on Γ_N and homogeneous Dirichelet on Γ_D (Fig. 2) (Allaire *et al*., 2004).

Several analytical solutions in steady operation of the Eq. 6 exist. They are based on various sets of initial conditions and in extreme cases. The choice of the boundary conditions must as well as possible represent the physical processes which proceed in extreme cases of the field (Anguela, 2004):

$$C(\pm\infty, t) = 0; C(x,y,z,0) = C_s[M.L^{-2}]$$

Where:

C_s : Initial concentration per unit of area

The solution is expressed using function of Green (Mohammadi and Saia, 2003):

$$C(x,y,z,t) = \frac{1}{\theta R}\int_0^t M(\tau)X_0(x,t-\tau)Y_0(y,t-\tau)Z_0(z,t-\tau)T(t-\tau)\delta\tau \quad (7)$$

$$X_0 = \frac{1}{2L}\left(\mathrm{erfc}\left[\frac{L/2 + x - ut/R}{\sqrt{4D_x t/R}}\right] + \mathrm{erfc}\left[\frac{L/2 - x + ut/R}{\sqrt{4D_x t/R}}\right]\right) \quad (8)$$

$$Y_0 = \frac{1}{2B}\left(\mathrm{erfc}\left[\frac{B/2 + y}{\sqrt{4D_y t/R}}\right] + \mathrm{erfc}\left[\frac{B/2 - y}{\sqrt{4D_y t/R}}\right]\right) \quad (9)$$

$$Z_0 = \frac{1}{\sqrt{\pi D_z t/R}}\exp\left[\frac{-z^2}{4D_z t/R}\right] \quad (10)$$

Where:

X_0, Y_0, Z_0	:	Are functions of Green for the transport in direction x, y, z
T	:	Is a function of degradation.
τ	:	Is a variable of integration.
u	:	Component of the speed $[L.T^{-1}]$
L, B	:	Languor and width of the source [L]
erfc	:	The complementary mistake function

$$\mathrm{erfc}(Y) = \frac{2}{\sqrt{\pi}}\int_Y^\infty e^{-\xi^2} d\xi \quad (11)$$

RESULTS

Qualitative response of the model has the analytical resolution: One the using Eq. 7-11 previously described, we established a computer program to calculate the degree of the pollution in the tablecloth of water, of the point of quantitative view and according to the time and the space. This simulation is done on one square meter of polluting surface. This unit surface is representative of the whole of the surface whole of the valued factory to 02Ha (Table 1).

Table 1: Data of the problem

Parameters of simulation	Test 01	Test 02	Test 03	Test 04	Test 05
Total distance [M]	100	100	100	25	05
Step of length [M]	01	01	01	01	01
The total time [d]	20-200000	20-200000	20-200000	200000	20000
Depth [M]	0	02	05	0-5-10	0-2-10
Speed of flow [Md^{-1}]	0.24	0.24	0.24	0.24	0.24
Thickness of aquifer [M]	10	10	10	10	10
The prompt injection mass [G]	1000	1000	1000	1000	1000
Degree of injection of source [Gd^{-1}]	2.74	2.74	2.74	2.74	2.74
The factor of delay [-]	01	01	01	01	01
Porosity effective [-]	0.25	0.25	0.25	0.25	0.25
The longitudinal dispersion [M]	02	02	02	02	02
The transverse dispersion [M]	0.2	0.2	0.2	0.2	0.2
The factor of degradation [d^{-1}]	0.01	0.01	0.01	0.01	0.01
Length of the source [M]	01	01	01	01	01
Width of the source [M]	01	01	01	01	01
Method of analyse$^{(3)}$ [-]	02	02	02	02	01

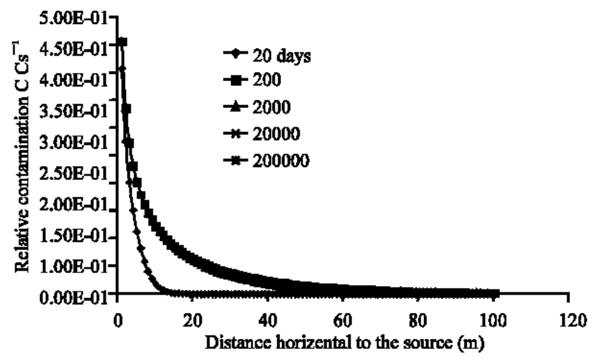

Fig. 3: State of the concentration on the surface (contamination by continuous injection). Test1

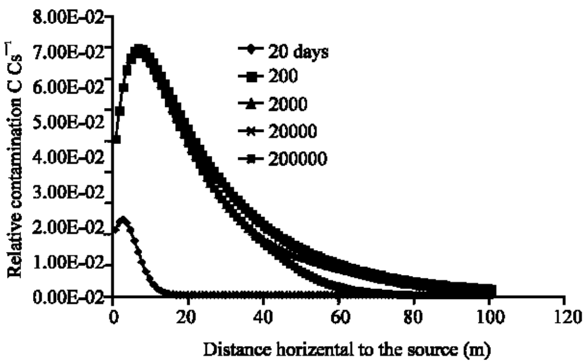

Fig. 4: State of the concentration to a depth of 02m (contamination by continuous injection). Test2

The gotten results are exposed in (Fig. 3-7)

DISCUSSION

Assessments according to the space: The particular shape of curves (bell) represented in Fig. (3-5), translates the increase of the contamination transported by the flow. According to the depth the concentration decreases

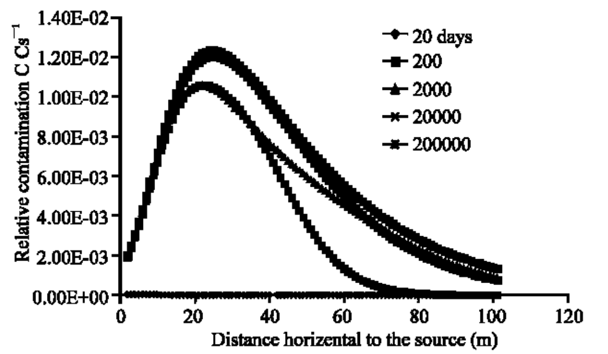

Fig. 5: State of the concentration to a depth of 05m (concentration by continuous injection) Test 3

for a constant time value, this reduction probably explains itself by the polluting particle fixing on grains of soil. One also notices that the big polluting mass displaces itself according to a tilted trajectory toward the depth. The whole of particles transported by the flow displaces itself according to a particular shape represented by a tilted full tube where the concentration goes while decreasing of the center toward the periphery.

Assessments according to the time: If one takes a stationary point of twisted (x, z), one observes a fast increase of the concentration between the twentieth days and the two hundredth days (Fig. 6 and 7). The increase becomes slow from the two thousandth days. This phenomenon is owed to an effect of saturation of the environments by the contaminant matter. From the Fig. 6 we observe the existence of the contamination to various depths and according to various degrees. The fast increase of the concentration then its stabilization to a certain degree all the long of the advancement of the solution (Fig. 7), beget a risk permanent of constant penetration of the polluting matter in the aquifers.

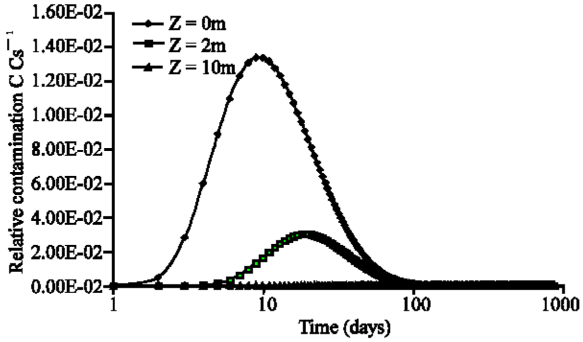

Fig. 6: State of the concentration to a constant position x = 05 m (contamination by specific injection) Test4

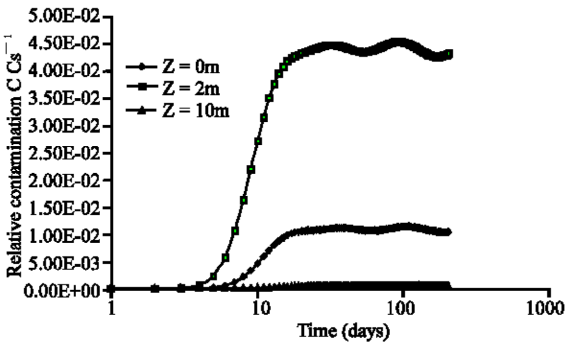

Fig. 7: State of the concentration to a constant position x = 25 m (contamination by continuous injection). Test5

CONCLUSION

Although preliminary, this study highlighted the existence of a real risk of contamination of the aquifer to the neighbourhoods of the surface. What puts in danger the health of the local population by the utilization of water wells contaminated. The done simulation, while using a model of particle transport coupled to a hydraulic flow behavior law, showed that the fast apparition and in some very strong concentration days after the application of the solute in surface explain itself by the concept of the preferential circulation corresponding to the fast flows. The real appreciation of the degrees of soil contamination by the factory achieves itself by the generalization of the simulation on the entire exposed surface and in knowledge whole of the quantity and the quality of matters contaminants, which enters in the production of paintings. For that of tracing studies achieved inside of the factory, be going to permit us to answer to these questions: which is ground under the effect of the hydrous and chemical constraints the evolution of space porous? Which is the exact time of residence of the aqueous solution in the ground, which quantity of water is necessary in order to wash the aqueous solutions present in the ground?

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