



HAL
open science

Pollutant migration through fractured porous media

Pascale Royer, Jean-Louis Auriault, Jolanta Lewandowska, Christophe Serres

► **To cite this version:**

Pascale Royer, Jean-Louis Auriault, Jolanta Lewandowska, Christophe Serres. Pollutant migration through fractured porous media. 33rd Solid Mechanics Conference, Sep 2000, Zakopane, Poland. pp.331-332. hal-01718279

HAL Id: hal-01718279

<https://hal.science/hal-01718279>

Submitted on 5 Sep 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

POLLUTANT MIGRATION THROUGH FRACTURED POROUS MEDIA

P. Royer¹, J.-L. Auriault¹, J. Lewandowska², C. Serres³

¹ Laboratoire Sols, Solides, Structures (3S), UJF, INPG, CNRS, Grenoble, France.

² Laboratoire d'études des Transferts en Hydrologie et Environnement (LTHE), UJF, INPG, CNRS, IRD, Grenoble, France.

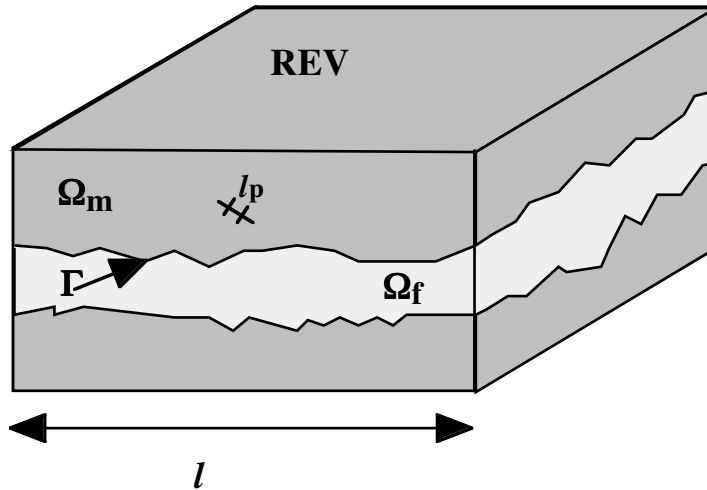
³ Institut de Protection et de Sûreté Nucléaire (IPSN), Fontenay-aux-Roses, France.

1. Introduction

This work is aimed towards deriving mathematical models that describe pollutant migration through fractured porous media. A homogenisation method is used, i.e. macroscopic models are rigorously deduced from the physical description which is valid within a Representative Elementary Volume (REV). The fundamental assumption behind homogenisation is the separation of scales which is expressed by: $l/L = \varepsilon \ll 1$. In the present work, l is the characteristic size of the REV, i.e. at the fracture's scale and L is the characteristic macroscopic size. The approach introduced in [1] is used. This methodology is on the basis of definition and estimation of dimensionless numbers arising from the description at the REV's scale. The domains of validity of the derived macroscopic descriptions is provided by means of the orders of magnitude of the local dimensionless numbers.

2. Dimensionless local description

The REV consists of a porous matrix domain, Ω_m , and a fracture domain, Ω_f , whose common boundary is denoted by Γ . The medium is saturated by water and a solute is diluted in water. In the fracture's domain fluid flow is described by Stokes equations and solute transport by the diffusion-convection equation. In the porous matrix, the filtration of the liquid is described by Darcy's law and the solute transport is described by a diffusion-advection law that accounts for diffusion in the solid and diffusion and convection in the pores. Note that the behaviour at the porous matrix scale of the process of diffusion in both the solid and the micropores may be different from that considered here [2].



The methodology consists in writing the local description in a dimensionless form and then in estimating the dimensionless numbers with respect to the scale-ratio ε . This leads to the following formulation of the equations:

In the fractures (Ω_f):	In the porous matrix (Ω_m):	On the boundary (Γ):
$\varepsilon^2 \mu \Delta \vec{v}_f - \vec{\nabla} p_f = \vec{0}$ $\vec{\nabla} \cdot \vec{v}_f = 0$ $N \frac{\partial c_f}{\partial t} - \vec{\nabla} \cdot (\mathcal{D}_f \vec{\nabla} c_f - P e_f c_f \vec{v}_f) = 0$	$\vec{v}_m = -\mathcal{K}_m \vec{\nabla} p_m$ $\vec{\nabla} \cdot \vec{v}_m = 0$ $N \frac{\partial c_m}{\partial t} - \vec{\nabla} \cdot (\mathcal{D}_m \vec{\nabla} c_m - \alpha^2 P e_f c_m \vec{v}_m) = 0$	$\vec{v}_f = \alpha^2 \vec{v}_m$ $p_f = p_m$ $(\mathcal{D}_f \vec{\nabla} c_f) \cdot \vec{n} = (\mathcal{D}_m \vec{\nabla} c_m) \cdot \vec{n}$ $c_f = c_m$

This local description depends upon the following parameters: $Pe_f = \frac{LV_{f_c}}{D_{f_c}}$; $N = \frac{L^2}{D_{f_c}T_f}$; $\alpha = \frac{l_p}{l}$.

Pe_f is the Péclet number in the fractures. l_p is the characteristic pore-size. V_{f_c} and D_{f_c} are characteristic values of the fluid velocity and of the molecular diffusion in the fractures, respectively. T_f is the characteristic time of the transport process in fractures.

It can be shown that the cases of interest, i.e the cases that lead to distinct macroscopic behaviours are the following:

Case 1: $Pe_f = O(\varepsilon)$; $N = O(1)$; $\alpha = O(\varepsilon)$ (predominant diffusion in the fractures)

Case 2: $Pe_f = O(1)$; $N = O(1)$; $\alpha = O(\varepsilon)$ (equivalent diffusion and convection in the fractures)

Case 3: $Pe_f = O(\varepsilon^{-1})$; $N = O(\varepsilon^{-1})$ (predominant convection in the fractures)

Case 3.a: $\alpha = O(\varepsilon^{1/2})$; Case 3.b: $\alpha = O(\varepsilon)$.

3. Derived upscaled models

The derived macroscopic models are the following:

Fluid flow

$$\vec{V}_f = -\mathcal{K}_f \vec{\nabla} P$$

$$\vec{\nabla} \cdot \vec{V}_f = 0$$

Solute transport

$$\text{Case 1: } \frac{\partial C}{\partial t} - \vec{\nabla} \cdot (\mathcal{D}_{eff} \vec{\nabla} C) = 0 \quad (\text{purely diffusive behaviour})$$

$$\text{Case 2: } \frac{\partial C}{\partial t} - \vec{\nabla} \cdot (\mathcal{D}_{eff} \vec{\nabla} C - C \vec{V}_f) = 0 \quad (\text{convection-diffusion})$$

$$\text{Case 3.a: } \frac{\partial C}{\partial t} - \varepsilon \vec{\nabla} \cdot [\mathcal{D}_{disp} \vec{\nabla} C - \frac{1}{\varepsilon} C (\vec{V}_f + \varepsilon \vec{V}_m)] = 0 \quad (\text{dispersion with influence of the porous matrix})$$

$$\text{Case 3.b: } \frac{\partial C}{\partial t} - \varepsilon \vec{\nabla} \cdot (\mathcal{D}_{disp} \vec{\nabla} C - \frac{1}{\varepsilon} C \vec{V}_f) = 0 \quad (\text{dispersion})$$

\mathcal{K}_f is the effective permeability tensor. \mathcal{D}_{eff} is the effective diffusion tensor and \mathcal{D}_{disp} is the apparent dispersion tensor. They are defined by boundary-value problems to be solved over the REV. \mathcal{K}_f is a symmetrical tensor and depends only upon the geometry of the REV. \mathcal{D}_{eff} is also symmetrical and depends upon the cell-geometry and the molecular diffusion. \mathcal{D}_{disp} is not symmetrical in the general case and depends upon the pressure gradient.

4. References

- [1] J.-L. Auriault (1991). Heterogeneous medium. Is an equivalent macroscopic description possible? *Int. J. Engn. Sc.*, **29**, 7, 785-795.
- [2] J.-L. Auriault and J. Lewandowska (1995). Non-Gaussian Diffusion Modeling in Composite Porous Media by Homogenization: Tail Effects, *T.I.P.M.*, **21**, 47-70.
- [3] J.-L. Auriault, and P. Adler (1995). Taylor Dispersion in Porous Media: Analysis by Multiple Scale Expansions, *Adv. Water Res.*, **18**, 4, 217-226.