Flow of polymer solutions in porous media. Retention phenomena.

M.V. D’Angelo and M. Rosen.
Grupo de Medios Porosos, Facultad de Ingeniería, Universidad de Buenos Aires. Argentina.

Abstract
In this work we study the miscible displacement of a scleroglucan polymer solution on porous structures. This polymer has shear-thinning characteristics allowing to increase the contrast between high and low permeability zones in the medium. The porous media consists of a 3D nonconsolidated bed (simple porosity). The experiments are hold using radioactive tracers that are either free in solution or chemically bonded to the macromolecules, which allows to follow macromolecules inside the medium and, complementarily, identify the interactions fluid-wall of the pore. From concentration profiles obtained experimentally it is possible to identify different retention processes, which depend on the characteristics of the displacement, and on the properties of macromolecules.

It was possible to quantify the amount of polymer retained inside the bed by pure mechanical and hydrodynamic processes of retention. Through the calculation of the dispersivity (related to the decorrelation length of the velocity field) it is deduced that it is influenced by the existing mechanisms of retention.

Introduction
For a passive tracer, the mean tracer concentration can be written through a macroscopic convection-diffusion equation:

\[ \frac{D}{\varepsilon^2} \frac{\partial C}{\partial t} = \nabla \cdot (\mathbf{U} C) + \nabla \cdot (f \mathbf{U} C) \]

(1)

\[ \frac{D}{U L} = \frac{D_0}{U L} + (1 - f) \frac{T}{T_0} \]

(2)

\( U \) : local average velocity, \( C \) : the mean tracer concentration, \( D \) : the dispersion coefficients, \( f \) : concentration in the stagnant volume, \( f \) : characteristic exchange time between stagnant and flowing fluid, \( D_0 \) : generalized dispersion coefficient, \( f \) : porous fraction of non stagnant regions. \( D_0 \) : asymptotic coefficient, \( T_0 \) : transit time.

Scleroglucan
Semi-rigid macromolecule

\( t_0 = 1 \text{ g/mL} \)
\( q = 180 \text{ g/m}^3 \)
\( D_0 = 2 \text{ mm} \)
\( R_{c,d} = 800 \text{ mm} \)

Porous medium

Retention in a porous medium
In agreement to which retention mechanism will be, the macromolecules are accumulated in different places inside the porous medium (Figure 1).

Experimental procedure and discussion of results
Direct stage, three types of Experiments, II and III (Table 1)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial condition</th>
<th>Injected solution</th>
<th>Radioactive condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Polymeric solution w/ 1g/l (NaNO3)</td>
<td>Polymeric solution w/ 2g/l (NaNO3) and radioactive Na214</td>
<td>Na214 free in solution</td>
</tr>
<tr>
<td>II</td>
<td>Polymeric solution w/ 2g/l (NaNO3)</td>
<td>Polymeric solution w/ 2g/l (NaNO3) and radioactive Na214</td>
<td>Na214 chemically bonded to macromolecules</td>
</tr>
<tr>
<td>III</td>
<td>Water w/ 1g/l (NaNO3)</td>
<td>Polymeric solution w/ 2g/l (NaNO3) and radioactive Na214</td>
<td>Na214 chemically bonded to macromolecules</td>
</tr>
</tbody>
</table>

Table 1: Types of experiments.

Inverse stage, only for Experiment II, starting from the final conditions of the previous stage, we inject at the same rate the non marked polymer solution of equal concentration and saline tracer concentration of 1 g/l.

Experiment I
Free tracers (ionic and radioactive) display similar behavior and can flow along the same paths.

Experiment II
Different sections inside the porous medium

We find a slope after the "Gaussian" classical solution. Growth tail processes at constant rate.

Experiment III
Slope associated with retention process is less marked.

We quantify the amount of polymer retained inside the bed by pure mechanical and hydrodynamic retention processes. Semi-rigid character of the polymer chain, and the characteristics of 3D medium retention processes are strongly influenced by the configuration of the macromolecule.

Values above the Saffman curve: heterogeneities due to retention processes.

Values found under Saffman curve: characteristics lengths vary and paths accessible to the macromolecules become fewer owing to the trapping processes.

Conclusions: