

Influence of a Porous Corrosion Product Layer on the Corrosion Phenomenon of Carbon Steel Pipelines

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Introduction: The influence of a porous corrosion product layer (CPL) on the internal corrosion of carbon steels pipeline in a de-aerated and carbonated medium is examined. Based on the literature, a 1D numerical model taking into account a porous CPL is built with COMSOL Multiphysics ®.

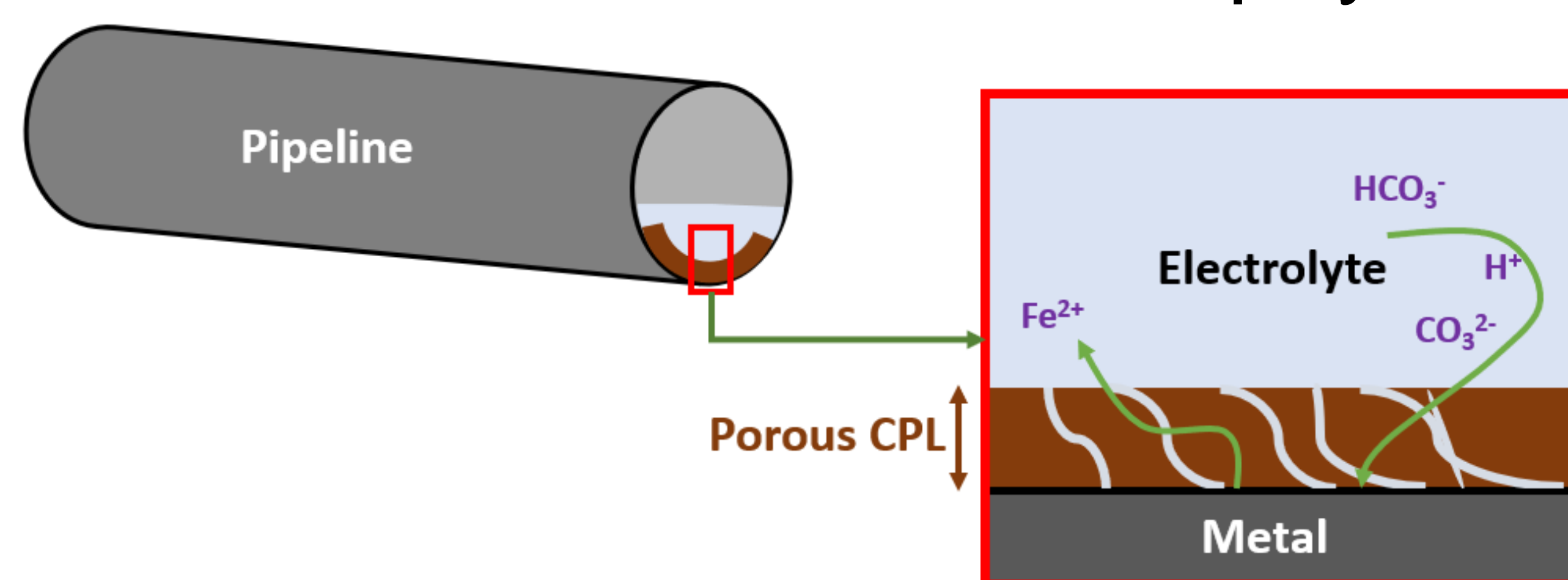


Figure 1. Schematic representation of a porous corrosion product layer (CPL) formed on a carbon steel pipeline.

Computational Methods: The model is based on the resolution of the Nernst-Planck equation accounting for the diffusion and migration transport phenomenon. Note that ε_L equals 1 in the electrolyte.

$$\frac{\partial(\varepsilon_L c_i)}{\partial t} + \nabla \cdot \left(\sum_i (-D_{i,eff} \nabla c_i - z_i u_{i,eff} F c_i \nabla \phi_L) \right) = R_i \cdot \varepsilon_L$$

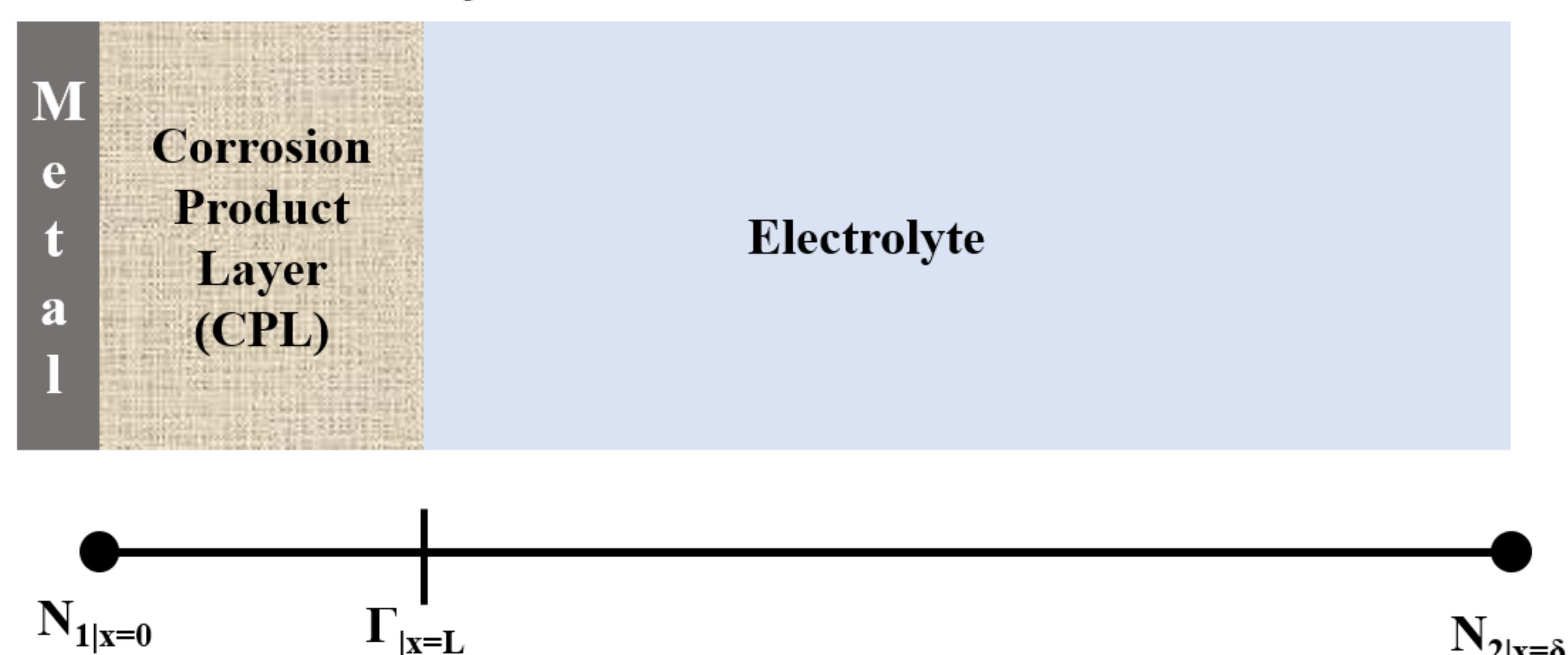


Figure 2. Main equation and schematic representation of the simulated domain. Where D_{ieff} , z_i , u_{ieff} , F , c_i , R_i and ϕ_L are the diffusion coefficient, the charge number, the mobility, the Faraday constant, the concentration, the reaction term and the electrostatic potential of the solution respectively.

At the metal surface ($N_{1|x=0}$) a Neumann boundary condition is used : fluxes $N_i=f(i_{a,c})$. At the diffusion boundary layer ($N_{2|x=L}$) a condition of concentration is imposed modelling an open boundary. Reactions are considered at equilibrium.

Results: In *Figure 3* the influence of the CPL porosity on the corrosion rate, by covering the metal, surface is presented : **a dense layer involves high surface coverage and thus a low corrosion rate.** In *Figure 4*, it can be seen that the porosity of the internal layer controls the corrosion rate. The transport phenomenon has a negligible effect on the corrosion rate with respect to the effect of the metal covering as highlighted in the second case (Case B). However, this negligible effect is no longer true concerning the chemical evolution of the medium. **In the case B, the pH (Figure 4b) and the saturation level (>>1) increase significantly** indicating a more favorable conditions for the corrosion products to precipitate.

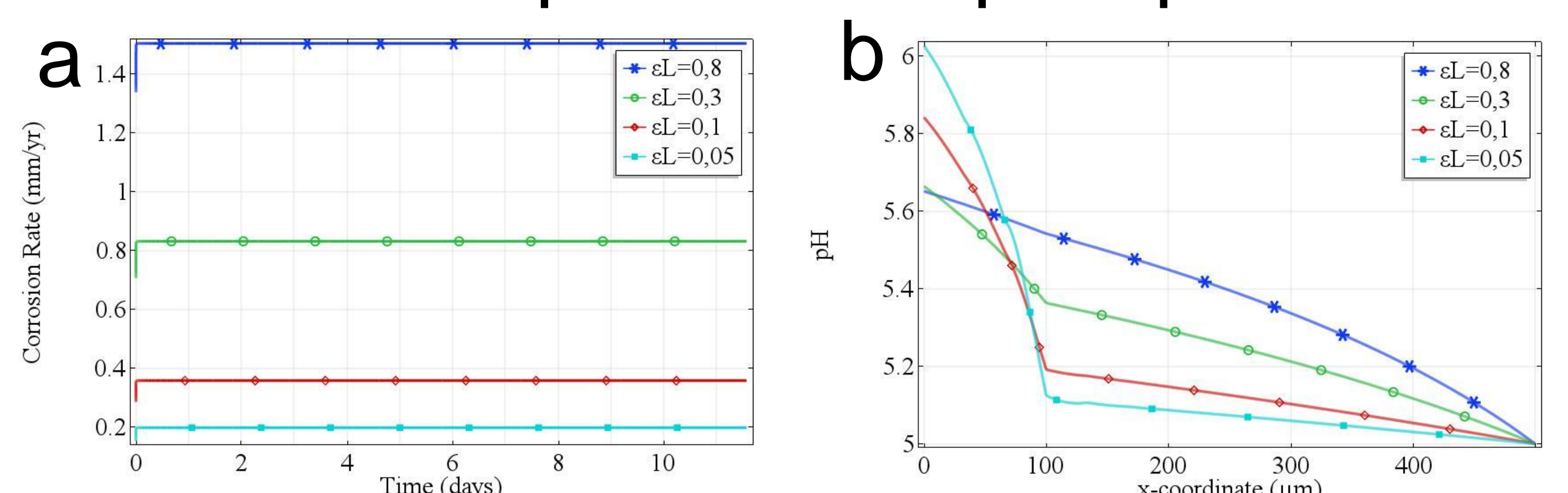


Figure 3. (a) Evolution of the corrosion rate and (b) Distribution of the pH for different CPL's porosity.

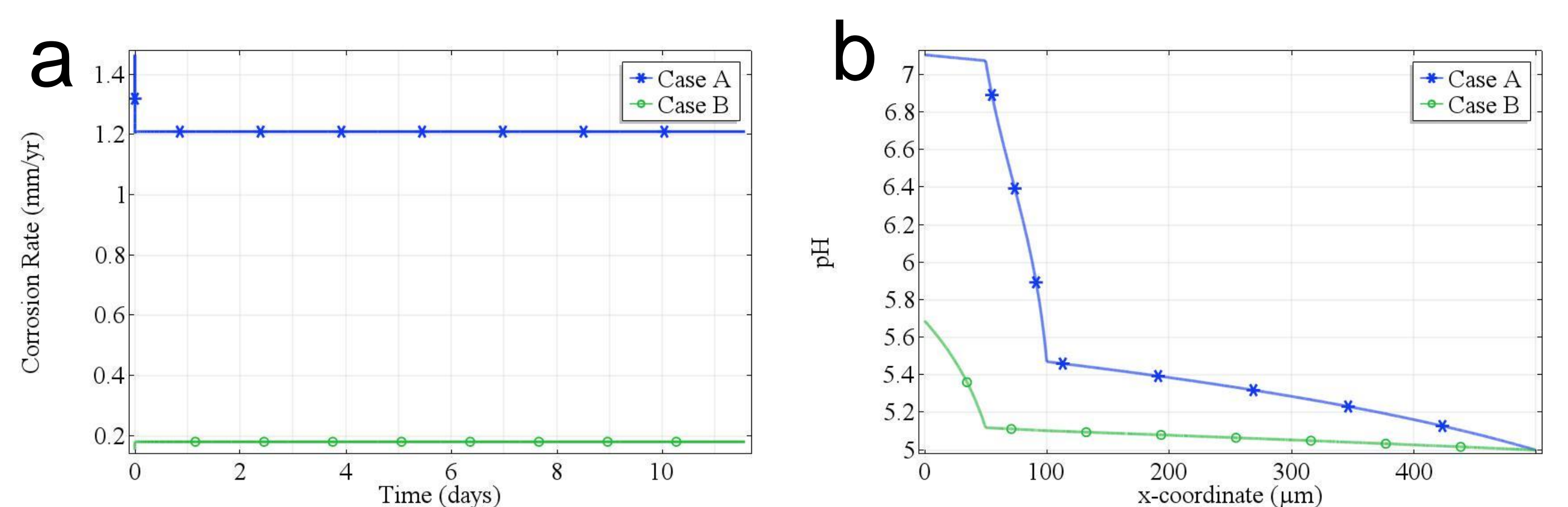


Figure 4. (a) Evolution of the corrosion rate and (b) Distribution of the pH for a bilayer structure of the CPL.

Conclusions: Two results are highlighted :

- the corrosion rate depends largely on the porosity of the internal part of the CPL that covers the metal surface ;
- an external dense layer affects mainly the chemical composition and thus the corrosion process by limiting the transport at the external part.