Immobilised Particles in Gel Matrix-Type Porous Media. Homogeneous porous media model

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Diffusion in pure gels and gels with immobilised cells were analysed. A model of diffusion in immobilised cell gel assuming of homogeneous cells distribution in gel was improved by introducing a tortuosity value. By theoretical analysis and numerical modelling it was shown that tortuosity of a gel with immobilised cells is the result of two factors: 1) a tortuosity generated by cells, T_c, and 2) a tortuosity of the gel matrix, T_g. Both variables are function of cell volume fraction, ϕ_c. Hence, the total path length in the gel with immobilised cell is $L_\Sigma = T_c T_g L$ and total tortuosity will be $T_\Sigma = L_\Sigma / L = T_c \cdot T_g$.

Based on this approach it is possible to analyse the data for a gel + cells system, where in general tortuosity seems too large. It is shown in this work that the diffusivity $\eta = D_e / D_0$ for this system is a complex function of: 1) diffusivity in gel, η_g and 2) diffusivity in immobilised cells, ♒c. Hence $\eta_c = D_e / D_g$, or $D_e = \eta_c D_g$, and $D_e / D_0 = \eta_c \dfrac{D_g}{D_0} = \eta_c \eta_g$, where D_g is the diffusion coefficient in pure gel matrix, and D_0 is the diffusion coefficient in bulk liquid. Diffusion in a pure gel without immobilised cells is represented by the equation $\eta_g = D_g / D_0 = \varepsilon_g / T_g$, where ♏g is the gel porosity, and T_g is the pure gel tortuosity (average ratio of molecule path to porous media thickness).

The total diffusivity, with tortuosity T_c and T_g depending on volume fraction of immobilised cells $(1-\phi_c) = \varepsilon_c$, is $\eta = \eta_g \eta_c = \dfrac{\varepsilon_g}{T_g} \cdot \dfrac{\varepsilon_c}{T_c(\varepsilon_c) \cdot T_g(\varepsilon_c)}$.

For the general case, the tortuosity created in the matrix by cells presence is $T_c(\varepsilon_c) = 1/\varepsilon_c^{\beta} = 1/(1-\phi_c)^{\beta}$ and the tortuosity of gel matrix filled with cells is $T_g(\varepsilon) = 1/\varepsilon_c^{\gamma} = 1/(1-\phi_c)^{\gamma}$. Thus: $D_e / D_0 = \eta_g \cdot (1-\phi_c) \cdot (1-\phi_c)^{\beta} (1-\phi_c)^{\gamma} = \eta_g (1-\phi_c)^{\alpha}$, and $\alpha = 1 + \beta + \gamma$, where β and γ are order values in the range from 0 to 1, and ♒g is the ratio D_g/D_0 for pure gels. In the particular case when $T_g(\varepsilon_c) = T_c(\varepsilon_c) = T$, and $T \sim 1/\sqrt{\varepsilon_c}$ the equation becomes $\eta = \dfrac{D_e}{D_0} = \dfrac{\varepsilon_g}{T_g} \cdot \dfrac{\varepsilon_c}{T^2} = \eta_g \varepsilon_c^2$.

The developed model gave the possibility to describe the dependence of D_e / D_0 on ϕ_c. Comparison with numerous published experimental data showed a good approach. Not all experimental data could be fitted with this homogeneous model. These deviations case might be explained by non-homogeneous cell distributions inside the gel matrix.