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Diffusion of organic pollutants within a biofilm in porous media

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The occurrence of aquatic pollution is an inevitable environmental impact resulting from human civilization and societal advancement. Either from the natural or anthropogenic sources, the aqueous contaminants enter the natural environment and aggravate its quality. To assure the aquatic environment quality, the attached-growth biological degradation is often applied to removing organic contaminants by introducing contaminated water into a porous media which is covered by microorganism. Additionally, many natural aquatic systems also form such similar mechanism to increase their self-purification capability. To better understand this transport phenomenon and degradation mechanism in the biofilm for future application, the mathematic characterization of organic contaminant diffusion within the biofilm requires further exploration.

The present study aimed to formulate a mathematic representation to quantify the diffusion of the organic contaminant in the biofilm. The BOD was selected as the target contaminant. A series of experiments were conducted to quantify the BOD diffusion in the biofilm under the conditions of influent BOD variation from 50 to 300 mg/L, COD:N:P ratios of 100:5:1 and 100:15:3, with or without auxiliary aeration. For diffusion coefficient calculation, the boundary condition of zero diffusion at the interface between microbial phase and contact media was assumed. With the principle of conservation of mass, the removed contaminants equal those that diffuse into the biofilm, and eq 1 results, and the diffusion coefficient (i.e., eq 2) can be solved through calculus with equations from table of integral.

$$D_f \frac{\partial^2 S_f}{\partial z^2} = R_f \tag{1}$$

$$D_f = \frac{(\mathrm{QS}_{\mathrm{in}} - \mathrm{QS}_{\mathrm{out}})^2 Y}{2\mu_{\max} x_f (S_b + K_s \ln \frac{K_s}{S_b + K_s})} \tag{2}$$

Using the obtained experimental data, the diffusion coefficient was calculated to be 2.02*10^{-6} m^2/d with influent COD of 50 mg/L at COD:N:P ratio of 100:5:1 with aeration, and this coefficient increased to 6.02*10^{-6} m^2/d as the influent concentration increased to 300 mg/L. Meanwhile, the diffusion coefficient decreased to 2.61*10^{-7} m^2/d as the retention time increased to 3 hours. Generally, the variation in diffusion coefficients between different COD:N:P ratios exhibits similar pattern with a slight decrease for the ratio of 100:15:3. The difference in diffusion coefficients between 1 and 2 hours was apparently greater than that between 2 and 3 hours, implying the diffusion was a critical factor for contaminant removal for the treatment condition with retention time of 1 hour or less, because higher retention time leads to better microbial degradation due to sufficient contact time for biological reactions. For 1 hour retention time, the increase in diffusion coefficient becomes limited as the influent COD concentration was equal to or above 150 mg/L. These obtained diffusion coefficients were applied to estimating the treatment efficiency for real domestic sewage. The result was found that the estimated effluent BOD concentrations were quite comparable to that obtained through experimental measurements.