Abstract

This work focuses on the removal of pathogens from reclaimed water injected into a fractured aquifer model (FAM). The objectives of the work are to simulate the field conditions of the Nardo aquifer in Southern Italy (Masciopinto et al., 2008), where the fractures are not “clean,” and to monitor pathogen behavior during transport in a FAM. Pathogens are considered to be biocolloids that deposit onto fracture surfaces and can lead to hydraulic conductivity reduction and clogging of the FAM.

Background

Reclaimed wastewater is increasingly used worldwide for artificial groundwater recharge in order to reverse the rapid depletion of aquifers subject to growing demands for water, and to inhibit saline intrusion in coastal aquifers. Biocolloid retention or removal in fractured and porous media leads to a reduction in void spaces and saturated hydraulic conductivity or removal in fractured and porous media leads to a reduction in void spaces and saturated hydraulic conductivity. Biocolloid deposition. The mass of the deposited biocolloids (viable plus inactivated) is given by:

\[ m(t) = \frac{1}{2} \rho \mu V \frac{\dot{q}}{k_B} \]

where \( \rho_c \) is the density of the biocolloids, \( \mu \) is the dynamic viscosity of water, \( V \) is the volume of the deposited biocolloids, \( |\dot{q}| \) is the magnitude of the volumetric flow rate of the feed solution, and \( k_B \) is the hydraulic conductivity of the formation.

Materials and Methods

Two pilot-scale fractured aquifer models (FAMs) consisting of horizontal limestone slabs were employed. Each FAM employed in this study consisted of a closed PVC box. A storage tank with a 35-L volume was used to feed wastewater into the FAM. The wastewater was obtained from the Bari-West treatment plant in Bari, Italy. The wastewater effluent was fed directly into FAM 1, while for FAM 2 the wastewater effluent was additionally treated by a laboratory-scale aerobic membrane-type reactor.

Clogging model

A simple mathematical model is developed for physical clogging in fractured limestone aquifers caused by biocolloid deposition. The mass of the deposited biocolloids (viable plus inactivated) is given by:

\[ m(t) = \frac{1}{2} \rho \mu V \frac{\dot{q}}{k_B} \]

where \( \rho_c \) is the density of the biocolloids, \( \mu \) is the dynamic viscosity of water, \( V \) is the volume of the deposited biocolloids, \( |\dot{q}| \) is the magnitude of the volumetric flow rate of the feed solution, and \( k_B \) is the hydraulic conductivity of the formation.

Table 1: Operational parameters and wastewater quality characteristics of the two FAMs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FAM 1</th>
<th>FAM 2</th>
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<tbody>
<tr>
<td>T (°C)</td>
<td>18.4 ± 0.4</td>
<td>17.8 ± 0.4</td>
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<tr>
<td>pH</td>
<td>7.50 ± 0.15</td>
<td>7.80 ± 0.15</td>
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<tr>
<td>EC (μS/cm)</td>
<td>70 ± 10</td>
<td>74 ± 10</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>60 ± 10</td>
<td>62 ± 10</td>
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Figure 1: Schematic diagram of the experimental setup.

Figure 2: Breakthrough concentrations of the conservative tracer (electrical conductivity, solid circles), and viable somatic coliphages (open circles).

Figure 3: Observed effluent COD concentrations at FAM 1 (triangles), and FAM 2 (diamonds).

Figure 4: FAM 1. Effluent (solid circles) and blank (open circles) concentrations for viable: (a) somatic coliphages, (b) total bacterial count, TB, at 22°C, (c) total bacterial count, TB, at 37°C, (d) total coliforms, TC, (e) fecal coliforms, FC, (f) E. coli, (g) enterococci, and (h) sulphite-reducing clostridium spores, CS.

Figure 5: FAM 2. Effluent (solid circles) and blank (open circles) concentrations for viable: (a) somatic coliphages, (b) total bacterial count, TB, at 22°C, (c) total bacterial count, TB, at 37°C, (d) total coliforms, TC, (e) fecal coliforms, FC, (f) E. coli, (g) enterococci, and (h) sulphite-reducing clostridium spores, CS.

Conclusions

All viable pathogen concentrations in FAM 1 gradually decreased with time. During the early stages of the experiment, the somatic coliphages concentrations in the effluent from FAM 2 were at considerably higher levels than those in the blank vessel; this was attributed to previously deposited biocolloids. The pathogen removal shown in Figures 4 and 5 is in perfect agreement with field observations at the Nardo fractured aquifer where significant pathogen removal was observed (Masciopinto et al., 2008).

Both FAMs showed decreased hydraulic conductivity over the 230-day period. The K of FAM 1 was reduced by 6.2% and 4.8%, respectively. The K reduction was more pronounced in FAM 1 than in FAM 2 because FAM 1 was supplied with secondary effluent containing higher concentration of organics and pathogens than the membrane reactor effluent of FAM 2.

References

