

## Subsurface fate and transport of sulfamethoxazole, 4-nonylphenol, and 17 $\beta$ -estradiol

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**Abstract** Subsurface fate and transport of the antibiotic sulfamethoxazole (SX), the non-ionic surfactant degradation product 4-nonylphenol (NP), and the sex hormone 17 $\beta$ -estradiol (E2) were evaluated in a plume of contaminated groundwater at Cape Cod, Massachusetts, USA. The plume is the result of 60 years of wastewater treatment plant effluent disposal into rapid infiltration beds. Natural-gradient, *in situ* tracer experiments were used to evaluate subsurface transport of SX, NP, and E2 (injected at 300, 530, and 0.55  $\mu\text{g/L}$ , respectively) relative to the conservative tracer bromide. Two geochemical zones were evaluated: (1) uncontaminated groundwater overlying the plume, and (2) contaminated groundwater within the plume that has recently become oxic after decades of anoxic conditions. The uncontaminated groundwater is characterized by a microbial community unacclimated to treated wastewater, whereas the contaminated groundwater is characterized by microbes acclimated to wastewater contaminants. Results from the tracer tests in both zones showed that the antibiotic SX was co-transported with the conservative tracer bromide, with little retardation or mass removal. In contrast, NP and E2, which are more hydrophobic and biodegradable, showed sorption (relative retardation factors ranged up to 5.9) and mass loss at both the uncontaminated and contaminated sites.