Preliminary response of a pristine aquifer when facing toluene contamination

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Toluene is a common groundwater contaminant due to the wide spread of gasoline and industrial solvents. The understanding of how and when ecosystems initially respond to the presence of toluene is yet limited, because field investigations rarely start before a contamination has occurred. In order to investigate for the first time such a scenario, a pristine indoor aquifer model ($0.8 \times 0.7 \times 5$ m) was constructed, filled with natural sediment, flushed with natural groundwater at a rate of 9 L/hr, and subsequently exposed to a toluene contamination. Investigation was done to the chemical and biological parameters of the model, including oxygen concentration (9.6 mg/L), nitrate concentration (5.8 mg/L), small organic carbon content (0.8 mg/L), microbial abundance (4×10^4 cell/mL), and ATP (0.01 nM). This agreed with the condition of a typical pristine and oligotrophic aquifer. A 30-hr aqueous toluene pulse (water saturated with toluene) was injected into the system together with a conservative tracer (90% D_2O). Water samples were collected 4.2 m away from the injection source. The comparison between the toluene and D_2O breakthrough curves indicated that a portion of toluene was removed by degradation at a pseudo 1st order rate of 0.017/hr. Stable carbon isotope values of toluene were also measured along with the breakthrough curves. δ13C values were more positive than the original input, confirming that biodegradation had taken place. Subsequent to the pulse, a constant injection of aqueous toluene together with bromide was applied to obtain a deeper insight of the biological and geochemical processes in the aquifer. High resolution water sampling over the entire aquifer model was conducted 80 hrs after the start of constant injection. Microbial abundance and living biomass (ATP) were observed to be $10 \times$ and $100 \times$, respectively, higher than under pristine conditions. Biodegradation was detected by comparing the concentration of toluene and bromide, and was confirmed by a significant depletion of oxygen concentrations in the center of the plume. Subsequent sediment sampling revealed a pronounced decrease in bacterial diversity and evenness in the toluene plume, indicating fast establishment of the degraders and disappearance of sensitive members. Changes of microbial community composition were accompanied by a build up of biomass and high bacterial carbon production rates. Our study shows that microbial degradation of toluene occurs immediately (within 50 hrs) after exposure of the pristine aquifer to the contaminant. Changes in biological and geochemical processes give additional evidences that the system responds very fast towards toluene contamination and has a high potential for natural attenuation.