Fate of dissolved organic carbon and organic trace pollutants in the artificial groundwater recharge site Lange Erlen (Basel)

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Abstract of PhD Thesis

In this study, the artificial groundwater recharge (AGR) site “Lange Erlen” situated near Basel (Switzerland) in the upper Rhine catchment was investigated where ground water is enriched by spreading surface water from the River Rhine on wooded infiltration sites (IS). After infiltration of surface water, the concentration of many trace pollutants and dissolved organic carbon (DOC) is reduced during the underground passage from IS to abstraction wells. To understand, which mechanisms (i.e., dilution with natural groundwater, biodegradation and sorption) contribute to the fate of DOC and organic trace pollutants, field studies and laboratory column percolation experiments were conducted. The focus was put on parameters which may impair or enhance the removal efficiency of the AGR site for DOC and trace pollutants.

Overall, DOC concentration from infiltrated water was reduced by 47±14 % during subsoil passage. Dilution with natural groundwater (determined with stable isotope ratios $\delta^{18}O$ and $\delta^{2}H$ and with chloride concentration) reduced initial DOC concentration by 12 % while sorption and biodegradation accounted for 35 % of the fate of DOC. The biologically most active zone was located in depth of 1.3 to 2.6 m below the surface of IS by monitoring concentration and stable isotope ratio $\delta^{13}C$ of CO_2. N_2O and CH_4 concentrations up to 3.5 ppm and 39 ppm, respectively, indicated denitrification and methanogenesis within the generally oxic environment of the vadose zone and aquifer.

The prevailing process in the fate of DOC seemed to be oxidative biodegradation paired with temporary nitrate consumption, proved by mass balances for DOC, dissolved oxygen (DO), nitrate and total inorganic carbon (TIC). A comparison of soil organic carbon (SOC) and organic carbon stocks in the solid phase below IS (26 and 40 years of use) and sites without water spreading revealed no indices for long-term sorption of the removed DOC. Further, $\delta^{13}C$ of TIC, SOC and CO_2 indicated preferential release of light ^{12}C from SOC/DOC degradation via gas phase (CO_2) and water phase (TIC) and an enrichment of ^{13}C in the residual SOC of the solid phase by a Rayleigh-type process. Further, release of excess TIC pointed to degradation of SOC.

Unsaturated column percolation experiments with sandy-gravelly bulk substrate from IS and filtrated Rhine water were performed to study the removal of DOC and trace pollutants. Time-weighted mean removal efficiency for iohexol, iomeprol, iopromide, ioxitalamic acid, caffeine, and galaxolide ranged between >30 and >73 %. Little or no removal was observed for atrazine, tris-(2-chloroethyl)phosphate (TCEP), iopamidol and amidotrizoic acid in the column experiments. Pollution of the Rhine with easily biodegradable organic compounds was simulated by addition of saccharose. Moderate saccharose addition was compensated by increased biodegradation and 21-42 % of DOC was removed under background and moderate pollution level. Moreover, moderate saccharose addition stimulated removal of iohexol, iomeprol, ioxitalamic acid, iopromide, and galaxolide compared to background conditions. During high saccharose load the columns initially retained up to 86 % of DOC input, but effluent DOC concentration increased soon and the columns’ capacity to buffer strong pollution was exhausted after 3 days. High level saccharose addition shifted redox setting from oxic to anoxic/reducing. The latter slightly stimulated removal of iopamidol and hampered removal of iomeprol, ioxitalamic acid, and iopromide.

Overall, DOC and trace pollutants investigated in this study are mostly efficiently removed in the AGR site Lange Erlen and subsoil horizons play an important role in this process. The main removal mechanism was biodegradation, ensuring the future use of the system. Factors like temperature, pollution with easily biodegradable organic compounds, the redox setting, or lacerations of the loamy top soil causing shorter retention time have an impact on the removal efficiency, but as long as a certain level is not exceeded, no negative consequences for drinking water production result regarding DOC and the trace pollutants investigated and the system can adapt to the new conditions. Although low level pollution can even cause a positive priming effect and stimulate the removal of certain trace pollutants, spills of easily biodegradable compounds can cause long-lasting problems for AGR systems and should be critically considered in surface water monitoring.