Geophysical Research Abstracts
Vol. 21, EGU2019-108, 2019
EGU General Assembly 2019

Numerical modelling of nitrogen transformation and transport in the dynamic environment of capillary fringe

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Abstract: Nitrogen widely exists in domestic wastewater and has been a serious contamination problem in the world. The surplus nitrogen can percolate toward groundwater, affect the water quality and threaten public health. Capillary fringe is considered to be the last barrier to protect groundwater from being contaminated due to the complex and dynamic redox environment. Thus, research related to nitrogen transformation and transport in capillary fringe is becoming significant. Considering intermittent discharge of wastewater, the aim of this study is to establish a mathematical model to study nitrogen dynamics across the capillary fringe under different discharge frequencies.
In the model, water flow, solute transport, biochemical reaction, gas flow and adsorption are considered. The water flow is governed by the Richards equation. Multiple solute transport is modelled by the advection-dispersion equation, involving biochemical reaction, gas transfer and adsorption (where applicable) as the sink/source terms. Biochemical reactions mainly refer as the nitrogen transformation are described by multiple-Monod reactions, considering suppressing and supporting environmental conditions. The gas flow is described by advection-diffusion equation, considering Henry's equilibrium law to address the transfer between aqueous and gas phases. The linear kinetic adsorption model is considered for ammonium adsorption.
The results show that the ammonium and nitrate concentration show different fluctuation trends from 0.2 to 5 times/day discharge frequencies due to the distinct alternative oxic and anoxic environment. Nitrate and dinitrogen gas transformation rates increase with water discharge frequencies. Ammonium and nitrate leaching rates generally decrease with water discharge frequencies. This study can be used to instruct treated wastewater discharge in practice.
Key words: nitrogen transformation, capillary fringe, biochemical model, dynamic environment