

Spread of organic contamination from a river to an aquifer

Course GEO4-1421 — Reactive Transport in the Hydrosphere

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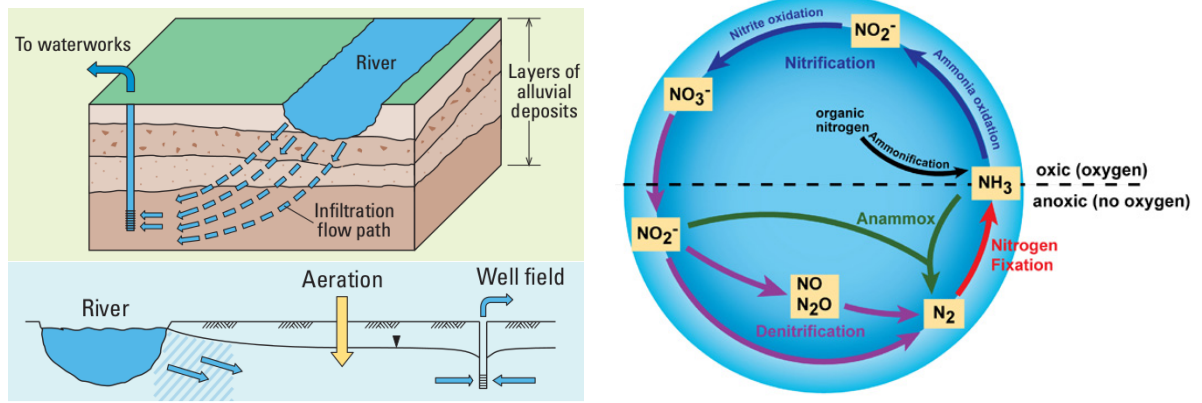


Figure 1: (a) Schematic diagram of river-bank filtration (Ref. 1). (b) The nitrogen cycle. Depicted are the known processes and nitrogen compounds involved (Ref. 2).

Context

Surface and ground waters cannot be considered as isolated components of the hydrosystem, as they can interact with the wider environment through the advective exchange of water. In the case of a connected river-aquifer system, when the water level of the river is greater than the aquifer's piezometric head, water tends to move from the river towards the aquifer as a result of the hydrostatic pressure difference. If the river is contaminated with a pollutant such as dissolved organic matter (DOM), this advective exchange poses a contamination risk of the drinking water extracted from the aquifer. However, the contaminant can be removed along the flow path from the river to the aquifer. For example, the DOM can be mineralized through a wide range of microbially driven processes. This “bank filtration” technology can be used for water (pre-)treatment for drinking water production (Fig. 1a).

In this project we focus on a subset of processes involved in organic matter mineralization, specifically those connected to the nitrogen cycle (Fig. 1b). First, if molecular oxygen (O_2) is available, DOM mineralization occurs via aerobic respiration (Eq. 1).

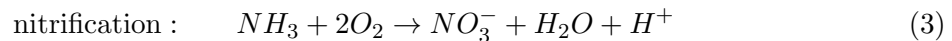


When O_2 becomes limited, mineralization through the process of denitrification becomes important, using nitrate (NO_3^-) instead of O_2 as the terminal electron acceptor (Eq. 2).



In both cases break-down and mineralization of OM leads to the release of fixed nitrogen in the form of ammonia (NH_3 ; not shown in Eqs. 1–2). Under aerobic conditions, NH_3 can be used

as energy source by nitrifying bacteria, leading to the production of nitrate (Eq. 3), which can further be utilized in denitrification.



Additionally, denitrification leads to the production of nitrogen gas (N_2 ; Eq. 2), and thus, ultimately, to the removal of fixed nitrogen from the system. As shown in Fig. 1b, there are additional important components (e.g., NO_2 and N_2O) and processes in the nitrogen cycle (e.g., anaerobic ammonium oxidation, ANAMMOX; dissimilatory nitrate reduction to ammonia, DNRA; nitrogen fixation), but for simplicity these will not be considered in this project.

Aim

The aim of this project is to understand the role of organic matter mineralization in the removal of dissolved organics entering the groundwater from a contaminated river. Specifically, your task is to write a model that can predict the concentrations of DOM, O_2 , NO_3 , NH_3 and N_2 along the flow path of water from the river through the aquifer. First, you will use the model to fit the given profiles of O_2 and NH_3 in order to obtain the rate constants of aerobic DOM degradation, nitrification and groundwater aeration. Then you will apply the model to predict how the quality of potentially drinking water extracted from a well in the aquifer depends on the concentrations of DOM, NO_3 and NH_3 in the river. Your ultimate question is: **How does the coupling of processes of aerobic respiration, nitrification-denitrification and groundwater aeration determine water quality along an aquifer adjacent to a river contaminated with organics?**

Further reading (available via Blackboard)

1. N. Tufenkji, JN Ryan, M. Elimelech (2002). The Promise of Bank Filtration— A simple technology may inexpensively clean up poor-quality raw surface water. *Environ. Sci. Technol.* 36(21): 422A–428A.
2. <http://www.nature.com/scitable/knowledge/library/the-nitrogen-cycle-processes-players-and-human-15644632>
3. van Cappellen & Wang (1995) Metal cycling in surface sediments: modeling the interplay of transport and reaction.
4. Soetart et al. (1996) *Geochimica et Cosmochimica Acta* 60(6): 1019–1040.
5. Spiteri et al. (2008) *Geochimica et Cosmochimica Acta* 72: 3398–3412.
6. Reed et al. (2011) *Geochimica et Cosmochimica Acta* 75: 5540–5558.