CAN SUBMERGED PLANTS IN THE LITTORAL ZONE OF GROUNDWATER-DOMINATED LAKES ACT AS HYDRAULIC BARRIERS?

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Lake Hampen in Denmark used to be a clear-water lobelia lake, but is now experiencing a transition from being an oligo-trophic to meso-trophic lake. About two-thirds of the input of water is from groundwater, with adjacent agricultural field sites accounting for about 96% of the input of Nitrogen (N) with concentrations up to ~ 100 mg/L NO3- right below the lake bed and a few mg/L at the sediment-water interface. In-situ plant experiments with L. uniflora and M. alterniflorum have previously demonstrated that relative growth rates are higher in zones with higher nutrient and CO2 availability. On the one hand the submerged plants therefore act as a filter of N. On the other hand, with as many as 12000 plants per m2, the plant cover may also act as hydraulic barrier to flow because; (i) the drag exerted by the small but many plant canopies promotes sedimentation of finer material and (ii) due to biogeochemical processes forming iron pans near the roots (~ 5 per plants). There could be a fine balance (and feed-back effects) between nutrient availability/discharge on promoting plant growth, but also a barrier. Some evidence of the barrier is observed from many seepage meter measurements from the presence of a double-peaked discharge distribution with one peak in discharge near the lake shore and another peak in discharge further off-shore. Thus, a proportion of groundwater discharges near the shore line another proportion flows beneath the barrier and discharges off-shore.

Simple hydraulic experiments (grain size analysis of samples from rhizosphere, hydraulic tests on undisturbed and disturbed barriers/rhizospheres), stable isotope and chemical profiles) all indicate that the hydraulic conductivity of the ~ 15 cm thick rhizosphere is much lower than the hydraulic conductivity of the aquifer. Currently, 10 t emperature probes with 10 t hermistors across the rhizosphere and lake bed below are installed in order to use temperature as a tracer to detect flow patterns close to the barrier and possible changes over a season.

A 2D Feflow model has been developed for the field site based on an aquifer characterization in the near-shore environment (geophysics, slug-tests) and the characterization of the rhizosphere. The 15 cm thick rhizosphere is directly implemented in the model using a highly resolved mesh near the lake bed. The model is calibrated to observed heads (from a network of piezometers), stable isotopes (diffusion samplers), temperature profiles, and finally to the observed two-peak discharge to the lake (seepage meter). Reactive transport of nitrate (denitrification) is simulated. The results show that it is not possible to match the observed discharge and nitrate distribution without incorporating a thin rhizoshpere with (i) a significantly lower hydraulic conductivity (in agreement with field experiments) and (ii) a much higher denitrification rate (in agreement with lab experiments) and the model results demonstrate that substantial amounts of nitrate discharge to the lake off-shore. Although the plant cover is efficient in filtering N it may at the same time be the reason why there still is a loading of N to the lake off-shore and why the lake over a period has changed from being oligo-trophic to meso-trophic. This is something that often goes unnoticed since experiments and sampling are mostly done in the near-shore environment, where maximum discharge is (theoretically) expected.