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A novel method to image the 3D structure of denitrification zone in the subsurface

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Nitrogen contamination is one of the major threats to aquatic ecosystems and human health around the world. To better predict the transport and fate of nitrate pollution, thus, the spatial information of where nitrate goes and disappears is essential. However, due to the spatial and temporal heterogeneity of nitrate transport pathways and denitrification reactions, it is challenging to upscaling point-scale field measurements to the catchment level as well as quantifying nitrate reduction using numerical models. In this study, therefore, we have attempted to tackle this challenge by synthesizing geophysical, geological, and geochemical information in four catchments in Denmark. The study catchments are intensively used by agriculture and are underlain by Quaternary glacial deposits. The 3D resistivity models of these catchments revealed a high degree of complexity in the hydrogeological structure mainly due to glacio-tectonic deformation. Long-term monitoring data of groundwater and stream chemistry of these catchment as well as this study's detailed geochemical surveys were used to 1) delineate different denitrification zones; 2) identify the denitrification processes; and 3) to quantify the denitrification rates. This geochemical information, which was at the point scale, was upscaled to the catchment level by analyzing the relationships between the resistivity and redox conditions. Based on this relationship, a 3D image of the subsurface structure of denitrification zone of each catchment was produced. We found that the hydrogeological structure may be the first order control of the denitrification zone structure, and the relationship between resistivity and redox conditions are highly empirical and site specific. This relationship differed even within the catchment in some cases. The denitrification measured in this study varied several orders of magnitude; however, the rates showed a bimodal lognormal distribution in each site, which could be simplified as slow and high reduction zones. The denitrification hotspots were found mainly around organic-rich postglacial sediments or the hydrogeological interfaces. Here, we propose that such detailed and comprehensive information of denitrification zone structure may contribute to bridge the gap between the field observations and numerical modelling and to better predict the nitrate pollution in aquatic environments.