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Dominant controls of water quality dynamics at catchment scale – a Germany-wide analysis

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Nutrient inputs from human activities resulting in fertilizer applications and wastewater inputs have increased pressures on aquatic ecosystems. The health of these ecosystems and eutrophication are linked to levels and temporal variability of nutrient concentrations in the streams. Moreover, temporal dynamics of nutrient concentrations and discharge control the nutrient loads exported from catchments to the oceans. Catchments are the spatial unit at which water quality management is implemented. However, catchments are complex units within which multiple biogeochemical and physical processes interact at different scales. Here, top-down approaches addressing the integrated response of concentration and discharge at the catchment outlet can provide valuable insights into the hierarchy and dominance of processes. Previous studies have found evidence that nitrate export dynamics in many agricultural catchments exhibit a chemostatic export regime with low concentration variability at high concentration levels, which may hamper mitigation measures to reduce exported nutrient loads to improve water quality. The chemostatic regime is attributed to homogenization of source areas due to the legacy of high inputs in the past, while chemodynamic regimes are hypothesized to be related to heterogeneous source areas and variable discharge generating zones. It remains insufficiently understood for which type of agricultural catchments and how widespread chemostatic nutrient export can be observed. Therefore, we investigated dominant controls of nutrient export dynamics over a wide range of catchments with varying characteristics such as climatic, geologic, topographic and land cover conditions. To this end, we analyzed integrated catchment responses of nitrate and phosphate concentrations and discharge using a Germany-wide dataset of about 800 stations with biweekly to monthly samples. Mean concentrations and metrics of concentration-discharge (C-Q) relationships were linked to catchment characteristics as descriptors in a partial least squares regression analysis. The Germany-wide analysis shows clear spatial patterns in mean nitrate levels, but also in C-Q-metrics, which we assume are related to spatial patterns in catchment characteristics. The analysis revealed that (1) Mean nitrate concentrations are positively but heteroscedastically related to the fraction of agricultural land use and (2) Several but not all highly managed, agricultural catchments exhibit a chemostatic nitrate export behavior. Chemodynamic accretion patterns for nitrate have been found, suggesting that other processes such as source heterogeneity, connectivity and reactivity can play a dominant role. Relating the export regime to catchment characteristics, such as the drainage density, land cover distribution and aquifer type, will shed more light at the controls of nutrient export regime at national scale.