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Modelling global nutrient retention by river damming: Phosphorus and silicon

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The phosphorus to silicon (P:Si) nutrient ratio is a key variable affecting ecosystem health in many aquatic environments. River damming represents a major anthropogenic perturbation of natural material flows along the aquatic continuum, with the potential to profoundly modify absolute and relative nutrient availabilities in surface waters. In this study, a multi-tiered approach for estimating global nutrient retention in man-made reservoirs is presented. We illustrate its application to the global riverine flux of reactive Si, using a database of dissolved reactive Si (DSi) budgets for 24 natural lakes and 22 artificial reservoirs. The database includes information on bedrock geology, surface water pH, water residence time, reservoir age and function, climate, and trophic status. Statistical analyses (ANOVA, t-test, PCA, linear plus non-linear regressions) are used to identify the best predictors of DSi retention and delineate how reservoir properties modulate nutrient dynamics. Results indicate that (1) reservoirs retain significantly less DSi than natural lakes, and (2) the water residence time, reservoir age and function (e.g., hydroelectrical production, irrigation, flood control) are the main system variables controlling DSi retention by dams. Next, a biogeochemical Si model is used to reproduce the previously derived statistical trends for DSi retention. Calibration of the model yields a relationship that enables one to predict annual in-reservoir siliceous productivity as a function of the external reactive Si supply. The model further accounts for the transition from reservoirs where reactive Si retention is primarily due to burial of allochtonous Si to those where in-reservoir DSi uptake by diatoms dominates. Finally, the statistical and mechanistic relationships are extrapolated to estimate that 25-28 Tg SiO_2 yr-1 are retained worldwide by dams, or 7% of the annual reactive Si load to watersheds. We are currently applying the same multi-tiered approach to the global P cycle. Our goal is to predict not only the effect of dams on reactive P retention, but also to determine how they are changing the P:Si ratios in river systems. Our preliminary results indicate that reservoirs are more effective in retaining nutrient P than Si.