Can retention by dams counterbalance anthropogenic phosphorus loading to rivers?

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Humans already built in excess of 15 million reservoirs and 70,000 large dams worldwide. With rising water stress and demand for energy, these numbers will continue to increase in the foreseeable future. The number of large hydroelectric dams, for example, is expected to nearly double over the next 20 years. River damming traps phosphorus (P) and, hence, may help offset the transfer of this limiting nutrient element to downstream lakes and, utimately, the coastal zone. In this study, we use a mechanistic approach to model the retention and transformation of P speciation associated with the construction of dams. We develop probability distribution functions (PDFs) to describe riverine P fluxes and transformation processes in reservoirs. These PDFs are then used in Monte Carlo simulations to generate P retention relationships as a function of the hydraulic residence time in reservoirs. A key finding is that these relationships are quite similar to those derived originally by Vollenweider for lakes. We apply our model approach to calculate the expected reductions in riverine P loads by reservoirs in 1970, 2000 and 2030, following the Millennium Ecosystem Assessment projections. Our results represent the first spatially explicit, global estimations of the effects of river damming on the riverine fluxes and speciation of P. Between 1970 and 2000 we estimate that the mass of total P (TP) retained in reservoirs nearly doubled, with more than 11% of the TP loading to watersheds retained in reservoirs in 2000. Despite the current damming boom, TP retention will not increase significantly by 2030, largely due to the short water residence times of most new reservoirs. The largest increases in reactive P retention will take place in the Yangtze, Mekong and Amazon basins, where, by 2030, 142, 121 and 184 new dams will be built, respectively. Results additionally indicate that reservoirs preferentially retain unreactive forms of P, thus enhancing the bioavailability of riverine P. Overall, our results imply that, despite massive river damming, P retention in artificial reservoirs cannot offset the anthropogenic loading of P to rivers and streams.