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Do bioretention cells reduce urban stormwater phosphorus and nitrogen loads? Insights from the International Stormwater Best Management Practice Database

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Bioretention cells are promoted as a best management practice (BMP) to attenuate phosphorus (P) and nitrogen (N) loads exported with urban stormwater. However, despite their broad implementation, reported P and N reduction performances are highly variable. We analyzed hydrologic and nutrient concentration data, including total P (TP), soluble reactive P (SRP), total N (TN), and dissolved inorganic N (DIN) from the International Stormwater BMP Database to assess nutrient reduction performance of bioretention cells. We also evaluated the seasonal and multi-year trends in P and N reduction performances. We applied correlation analysis and machine learning methods to identify the most important factors influencing the nutrient reduction efficiencies, including watershed properties, climate conditions, event characteristics, design parameters and cell age. We show that while bioretention cells typically increase the concentrations of TP, SRP and DIN, they usually decrease the loads of TP and DIN, mainly because the cells tend to decrease the surface water flow. Moreover, because TP and SRP are removed less efficiently than TN and DIN, the TN:TP and DIN:SRP ratios tend to decrease in stormwater runoff leaving bioretention cell systems. Changes to N speciation were also prevalent, with cells typically decreasing the concentrations of NH_4^+ and increasing those of NO_3^-+NO_2^-. Our analyses identified cell age and inflow concentrations as key variables modulating changes to SRP concentration between in- and outflow while, for DIN, climate variables were found to exert more influence on the concentration reduction performance. Overall, our findings demonstrate that, although bioretention cells typically reduce nutrient loads, their efficacy for the mitigation of downstream eutrophication risks may depend on the local context. We suggest that the potential of groundwater recharge, specific nutrient control targets, and the site-specific climate and runoff characteristics should be considered when designing and implementing bioretention cells as a eutrophication control measure. We also present a data-driven model to predict P and N reduction performances of bioretention cells.