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Bifurcation analysis of an impulsive system describing Partial Nitritation and Anammox in a hybrid reactor

Low-energy nitrogen removal under mainstream conditions is a technology that has received significant attention in recent years as the water industry drives towards long-term sustainability goals. Simultaneous partial nitritation-Anammox (PN/A) is one process that can provide substantial energy reduction and lower sludge yields. Mathematical modeling of the PN/A process offers engineers insights into the operating conditions necessary to maximize its potential. Laureni et al., Water Res. (2019) published a reduced mechanistic model of the process operated as a sequencing batch reactor, highlighting the effect of three key operating parameters on performance (Anammox biofilm activity, dissolved oxygen concentration, and fraction of solids wasted). Their analysis was limited to simulation with relatively few discrete parameter sets. We demonstrate using bifurcation theory applied to an impulsive system that the parameter space can be partitioned into regions in which the system converges to different fixed points that represent different outcomes: either the washout of nitrite oxidizing bacteria or their survival. Mapping process performance data onto these spaces allows engineers to target suitable operating regimes for specific objectives. We note that the nitrogen removal efficiency is maximized close to the curve of transcritical bifurcation points that separates the regions in parameter space where nitrite oxidizing bacteria washout from the region in which they survive. Further, control of solids washout and Anammox biofilm activity can also reduce oxygen requirements while maintaining an appropriate Hydraulic Retention Time. This approach is useful given the possibility for using such a methodology for models of increasing complexity.