

Options for modifying TMDL models to better determine the mechanics of phosphorus and organic nitrogen mineralization in the natural environment

Mineralization Kinetics of Soluble Phosphorus and Soluble Organic Nitrogen in Advanced Nutrient Removal Effluents (NUTR1R06p)

The Central Issue

Many watershed protection plans (e.g., TMDLs) use total phosphorus (P) for setting limits to address eutrophication. Direct determination of P mineralization kinetics in advanced wastewater treatment facility effluents is crucial for developing protective strategies for minimizing eutrophication in receiving surface waters. It is very expensive to manage dissolved P in effluents using current detection methods, therefore a simpler and less expensive measurement tool is needed.

Context and Background

Excessive P is considered to be the primary cause for eutrophication in fresh waterbodies. In some instances, stringent discharge limits rely on models that use assumptions which oversimplify the complicated interactions of different P compounds in the nutrient cycle. The researchers tested whether nutrient co-limitation and/or effluent toxicity artificially depressed the percent of bioavailable phosphorus (BAP) estimates for the effluent samples. They also sought to determine the rates of dissolved P mineralization to PO_4 for effluent of five treatment facilities in the Spokane River/Long Lake System. These facilities included the City of Post Falls Water Reclamation Facility, Couer d'Alene Advanced Wastewater Treatment Plant, Hayden Wastewater Research Facility, Inland Empire Paper Company, and Spokane County Regional Reclamation Facility.

On a larger scale, the team tested whether dissolved nutrient recalcitrance is associated with a large portion of the nutrients in large molecular weight and size classes, while they simultaneously tested nitrogen and phosphorus bioavailability on a series of samples collected from five biological nutrient removal facilities across the nation: Blue Plains Advanced Wastewater Treatment Plant (DC), Broad Run Water Reclamation Facility (VA), Ruidoso Village Regional



The Coeur d'Alene (Idaho) Wastewater Treatment Plant was one of the facilities selected by the researchers to test whether nutrient co-limitation and/or effluent toxicity artificially depressed the percent of BAP estimates for the effluent samples.

Wastewater Treatment Plant (NM), Truckee Meadows Water Reclamation Facility (NV), and Western Branch Wastewater Treatment Plant (MD).

An appendix to the final report with full data quality assurance and quality control is available upon request.

Findings and Conclusions

The results suggest the mineralization rate determined in the first-order decay models could be seamlessly incorporated into existing TMDL models with only minor structural modifications. The outcomes of the current TMDL model could be significantly modified with the updated mineralization rates and account for the inert P fraction.

The bioavailable nitrogen (BAN) determination experiments suggested the classic cell growth bioavailability bioassay protocol is not suitable for BAN analyses, while the dissolved nitrogen bioassay uptake experiment seems a more reliable method for BAN determination. The researchers found that further investigation into the correlation between fractions with recalcitrant P and N and the proportion of nutrients with larger molecular sizes are important topics for future research to determine if the connection truly exists for a larger dataset.

Management and Policy Implications

The research presents a general approach for improving models used in managing nutrient impacted waterbodies similar to the Spokane River system in Washington and Idaho. Bioassay uptake experiments developed in this study could be a useful tool to describe the mineralization of P and organic N. Quantitatively and conservatively compared to insitu conditions, they could better determine the mineralization kinetics of dissolved P in the environment.

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Related WERF Research	
Project Title	Research Focus
Uptake by Algae of Dissolved Organic Nitrogen from BNR Treatment Plant Effluents (NUTR1R06e)	Investigates whether a professionally accepted method to measure forms of DON that are not readily taken up by algae can be used by treatment plant operators and regulators to more effectively understand and control eutrophication. Provides a relatively simple and robust method to determine the bioavailability of DON in the effluent from BNR wastewater treatment facilities.
Variability of Low Phosphorus Analytical Measurement (NUTR1R06f)	Provides information regarding the ability of wastewater treatment facilities and commercial laboratories to measure low levels of P (20 µg/L) accurately and reliably. Suggests that measurements to comply with very low limits will inherently vary, making it challenging to determine both the environmental impact of the discharge stream and the performance of the facility.
Nutrient Management: Volume 2 – Removal Technology Performance & Reliability (NUTR1R06k)	Highlights a comprehensive two-year study of 22 real-world, full-scale nutrient removal plants designed and operated over three years to meet very low effluent total nitrogen (TN) and total phosphorus (TP) concentrations (as low as 3 mg/L TN and 0.1 mg/L TP). Provides a database for key decision makers looking for proper choices for both technologies and rationale bases for statistical permit writing.
Phosphorus Fractionation and Removal in Wastewater Treatment – Implications for Minimizing Effluent Phosphorus (NUTR1R06l)	Investigates wastewater treatment configurations to determine the various P fractions, and their fate and susceptibility to a range of different P removal processes in order to gain better insight into the removal efficiency and mechanism of different P fractions through various treatment technologies.
The Bioavailable Phosphorus (BAP) Fraction in Effluent from Advanced Secondary and Tertiary Treatment (NUTR1R06m)	Examines current analytical methods and P speciation and BAP in 17 wastewater treatment plant effluents around the country to compare the different types of advanced secondary and tertiary P removal processes, the impact of chemical addition in the effluent from these advanced nutrient removal processes, and the influence of dissolved P molecular forms on recalcitrance and bioavailability.
Striking the Balance Between Nutrient Removal in Wastewater Treatment and Sustainability (NUTR1R06n)	Sustainability / impacts of nutrient removal in wastewater treatment – impacts of “unintended” consequences – GHG, energy and chemical costs, etc.
Bioavailability and Characteristics of Dissolved Organic Nutrients in Wastewater Effluents (NUTR1R06o)	Investigates the bioavailability and characteristics of various P fractions from effluents in advanced tertiary treatment processes that are targeted for extremely low effluent TP concentrations.
Surface Complexation Modelling and Aluminum Mediated Phosphorus – White Paper (NUTR1R06r)	Tests a conceptual surface complexation modeling framework which had originally been developed for ferric mediated removal finding that the same model framework described for ferric experiments also works for aluminum experiments, albeit at a different rate of removal.
Solids Role in Tertiary Chemical Phosphorus Removal by Alum (NUTR1R06t)	Examines the capacity and kinetics of P removal by chemical solids from wastewater and several factors that affect the reactions. Results from the study can help develop process flowsheets to take advantage of the sorptive capacity of these used solids in a cost-effective manner, which in turn could lead to ultra-low effluent P concentrations at significantly reduced alum doses.
Development of Sustainable Approaches for Achieving Low Phosphorus Effluents (NUTR1R06v)	Evaluates sustainable operational practices and performance results for water resource recovery facilities designed to meet very low effluent TP concentrations, focusing on maximizing what can be learned from existing facilities to help utilities operate more sustainably while achieving necessary levels of performance.
Phosphorus Analysis in Wastewater: Best Practices White Paper (NUTR1R06cc)	Examines best practices for low level P analysis in wastewater and discusses whether the lessons learned from freshwater analysis apply to wastewater, or if wastewater has unique characteristics that confound low level P measurements.

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