

When do the costs of wastewater treatment outweigh the benefits of nutrient removal?

Striking the Balance Between Nutrient Removal in Wastewater Treatment and Sustainability (NUTR1R06n)

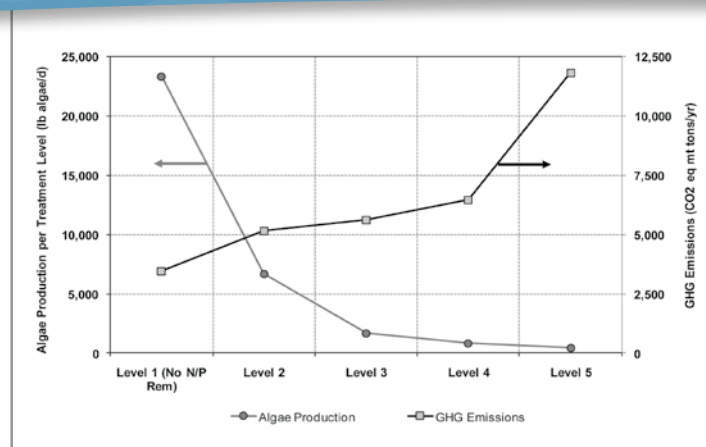
The Central Issue

High nitrogen and phosphorus loads from both point and non-point sources can impair water quality. Programs to restrict nutrient discharges have focused on receiving water quality, while largely ignoring corresponding impacts on air quality and other factors. This research presents the results of a “triple bottom line” approach that considers the three pillars (environmental, economic, and social) in a decision-making process to achieve a more sustainable solution.

Context and Background

Wastewater facilities are increasingly being asked or required to implement treatment process improvements to meet lower effluent nutrient (nitrogen, phosphorus) discharge limits. Communities are becoming increasingly aware of rising costs to meet these targets, primarily through increased water and sewer rate increases. They are also concerned about issues of sustainability, climate change, and as the costs and associated benefits of water quality improvements.

This study focused on the issue of sustainability from treatment plants implementing more advanced treatment technologies to meet increasingly stringent nutrient limits. The objective was to determine if a point of “diminishing returns” is reached where the sustainability impacts of increased levels of nutrient removal outweigh the benefits of better water quality. Five different hypothetical treatment trains at a nominal 10 MGD wastewater flow were developed to meet treatment targets that ranged from cBOD removal mode (Level 1) to four different effluent nutrient targets. These nutrient removal targets ranged from 8 mg N/L; 1 mg P/L (Level 2) to the most stringent at <2 mg N/L; <0.02 mg P/L (Level 5). Given that sustainability is a broad term, the industry-accepted three pillars of sustainability were evaluated and discussed, and particular emphasis was placed on the environmental and economic pillars. The following variables received the most attention: greenhouse gas (GHG) emissions, a water quality surrogate that reflects potential algal growth, capital and operational costs, energy demand, and consumables such as chemicals, gas, or diesel.



GHG Emissions and Algae Production per Treatment Level.

Level 1 – Secondary Treatment (No nutrient removal)

Level 2 – Biological Nutrient Removal (BNR) TP 1 mg/L TN 8 mg/L

Level 3 – Enhanced Nutrient Removal (ENR) TP 0.1-0.3 mg/L TN 4-8 mg/L

Level 4 – Limit of Treatment Technology (LOT) TP <0.1 mg/L TN 3 mg/L

Level 5 – Reverse Osmosis (RO) TP <0.02 mg/L TN 2 mg/L

Findings and Conclusions

This study found that use of treatment technologies for point sources along with existing best management practices (BMPs) for non-point sources is more sustainable for achieving comparable water quality improvements. Instead of focusing strictly on point source dischargers and requiring Level 4 or 5 treatments, Level 3 or 4 treatments complimented with BMPs of non-point sources is more sustainable and can achieve similar results.

The GHG emissions results suggest that a point of diminishing return is reached at Level 4 (3 mg N/L; 0.1 mg P/L). GHG emissions show a steady increase from Levels 1 to 4, followed by a 65% increase when moving from Level 4 to 5. Despite a 70% increase in GHGs, the discharged nutrient load only decreases by 1% by going from Level 4 to 5. The primary contributors to GHG emissions are energy related (aeration, pumping, mixing). GHG emissions associated with chemical use increases when meeting the more stringent nutrient targets that require chemical treatment in addition to biological nutrient removal.

Because wastewater nutrient removal is intended to improve water quality by reducing eutrophication from algal production in receiving waters, a surrogate parameter – “potential algal production” – was used to assess water quality improvement. Every 100 pounds of algae produced requires 7.2 lbs. of N and 1.0 lbs. of P. This relationship was used to calculate the reduction in algae production as a function of N or P reduction and it showed that nearly 95% of

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the potential algae production is reduced by changing from Level 1 to Level 3 treatment. A remaining 4% of potential algae production is reduced from Levels 3 to 5; however, this incremental improvement almost doubles the GHG emissions.

The total project capital cost increases approximately one-third for changing from Level 1 to 2, followed by a more than doubling in cost when changing from Level 1 to 5 (total project capital costs in this report are for a Greenfield (new) plant). The operational cost increase between levels is more pronounced than total project capital cost with more than a five times increase from Level 1 to 5.

Although the GHG emissions and cost of wastewater treatment both increase as nutrient removal is implemented, there were some positive benefits associated with plants performing nutrient removal:

- Lower BOD/TSS discharge load.
- Higher removal of trace organic compounds and heavy metals.
- Improved water quality and benefit to downstream users and for ecosystem habitat, especially as it relates to biodiversity and eutrophication.

Management and Policy Implications

This study elucidates the significant issues associated with advanced levels of nutrient removal and itemizes them in terms of GHGs, water quality improvements through reduced algae growth, use or consumption of chemicals and energy, and the management and disposal of residuals.

Development of a more encompassing approach to receiving water nutrient loading, such as requiring “best practices” for non-point sources, would be much more beneficial than requiring treatment plants to remove nutrients to levels that adversely impact sustainability. Further dialog with regulators on a national and local level is needed to find a regulatory framework that best protects water quality and manages GHG emissions using both non-point and point source control.

Related WERF Research

Project Title	Research Focus
Nutrient Farming and Traditional Removal: An Economic Comparison (03WSM6CO)	Compares total, average, and marginal costs of removing nutrients to the extent necessary to meet recommended nutrient criteria, using conventional wastewater treatment systems and large treatment wetlands, known as nutrient farms.
Greenhouse Nitrogen Emissions from Wastewater Treatment Operations Phase I – Molecular Level Through Whole Reactor Level Characterization (U4R07)	Biological nutrient removal treatment operations can result in the production of gaseous oxidized nitrogen products, which can have a greater greenhouse gas impact than carbon dioxide. This study helps characterize their formation and release so that generation and release are reduced.
Nutrient Management: Regulatory Approaches to Protect Water Quality Volume 1 – Review of Existing Practices (NUTR1R06i)	Provides a better understanding of key nutrient management issues and technical challenges that currently confront point source wastewater dischargers and regulators nationwide in setting and meeting low nutrient effluent limits.
Nutrient Management: Volume 2 – Removal Technology Performance & Reliability (NUTR1R06k)	Comprehensive two-year study of 22 real-world full-scale nutrient removal plants designed and operated over three years to meet very low effluent TN and TP concentrations (as low as 3 mg/L TN and 0.1 mg/L TP). Provides database for key decision makers about proper choices for both technologies and rationale bases for statistical permit writing.

Principal Investigators:

JB Neethling, Ph.D., P.E., BCEE
David J. Reardon, P.E., BCEE
HDR Engineering

Research Team:

Michael W. Falk, Ph.D., P.E.
HDR Engineering

David J. Kinnear, Ph.D., P.E.
HDR Engineering

Michael K. Stenstrom, Ph.D., P.E.
University of California at Los Angeles

Technical Reviewers:

Kartik Chandran, Ph.D., P.E.
Columbia University

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For more information, contact Amit Pramanik at apramanik@werf.org.