# ADVANCING A NOVEL PROCESS FOR POST-ANOXIC DENITRIFICATION

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Two publications: Coats et al. (2011), Post-anoxic denitrification driven by PHA and glycogen within EBPR, Bioresource Technology; Winkler et al. (2011), Advancing post-anoxic denitrification for biological nutrient removal, Water Research.

## INTRODUCTION

Reclaimed water standards are becoming increasingly stringent, pushing wastewater treatment facilities (WWTFs) to expand. For total nitrogen removal, WWTFs must integrate internal flow recycling and increase bioreactor volumes. With regard to phosphorus removal, WWTFs must incorporate chemical treatment systems, which significantly increase capital and operational costs as well as the sludge production. With current treatment approaches, the benefit of improved effluent quality is offset by increased energy usage, increased operational costs, and decreased operational flexibility; this arguably adds cost both to the environment and to the taxpayer. In our view, for a truly sustainable society, water reclamation and reuse objectives should be centered on effluent quality in relation to energy consumption, facility footprint, capital and operational costs, and process control and flexibility.

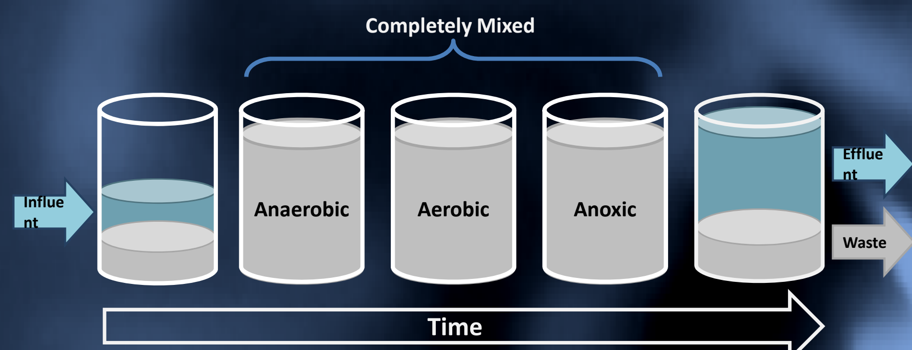
## STUDY OBJECTIVES

1) Assess the effectiveness of the proposed post-anoxic denitrification with EBPR process
2) Identify the carbon source driving denitrification
3) Assess specific denitrification rates (SDNRs) under variable operating conditions
4) Determine the importance of EBPR and VFA augmentation
5) Evaluate the stability of the process in terms of phosphorus removal and nitrate removal under varied loading conditions
6) Investigate operational changes that optimize the process
7) Characterize the bacterial population for Phosphorus Accumulating Organisms (PAOs) and Glycogen Accumulating Organisms (GAOs)

## PROPOSED PROCESS

### Post-Anoxic Denitrification associated with EBPR:

The proposed process would operate similar to conventional post-anoxic denitrification, but without carbon addition. Instead, the process makes use of Enhanced Biological Phosphorus Removal (EBPR) carbon reserves to efficiently remove phosphorus, ammonia, and nitrate from the wastewater



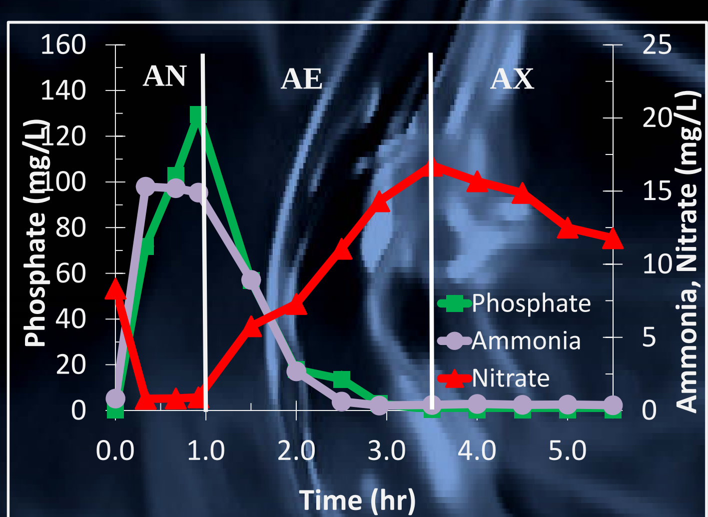

- Reactors were inoculated with biomass from the Moscow, ID WWTF
- Real Wastewater was fed to the reactors
- VFA rich fermenter liquor was added to wastewater
- Solids Retention Time (SRT) = 20 days
- Hydraulic Retention Time (HRT) = 18 hrs

## ADVANTAGES OF POST-ANOXIC EBPR

- Eliminates need for internal recycle flows
- Reduces facility footprint
- Eliminates need for anoxic carbon addition
- Achieves high Phosphorus and Nitrogen removal efficiencies
- High operational flexibility and Control
- Readily retrofitted to existing SBR facilities

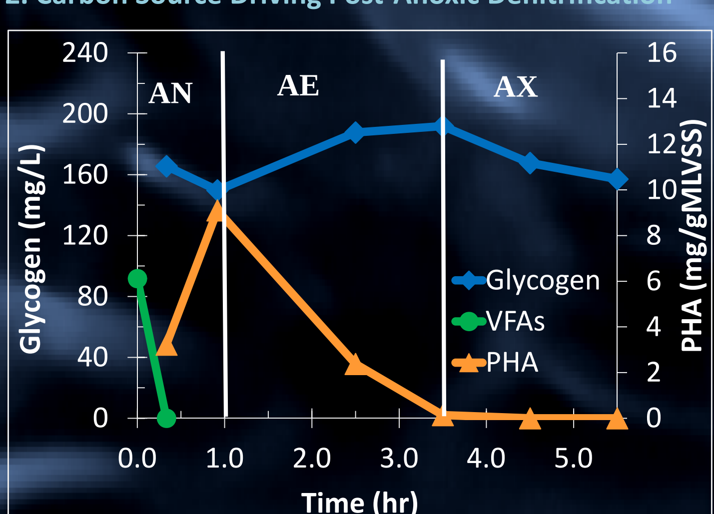
## RESULTS

### 1.Effectiveness of Post-Denitrification with EBPR



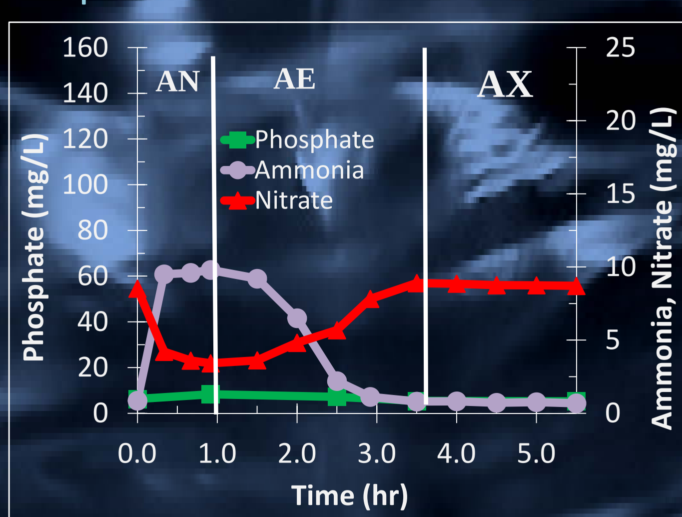

- Post-Anoxic Nitrate Removal occurred without compromising EBPR performance
- P removal Efficiencies on average exceeded 96%
- N removal Efficiencies averaged 74%- 92%
- High SDNRs : 0.85-1.17 mg $NO_3$ (hr-g MLVSS)$^{-1}$

### 2. Carbon Source Driving Post-Anoxic Denitrification



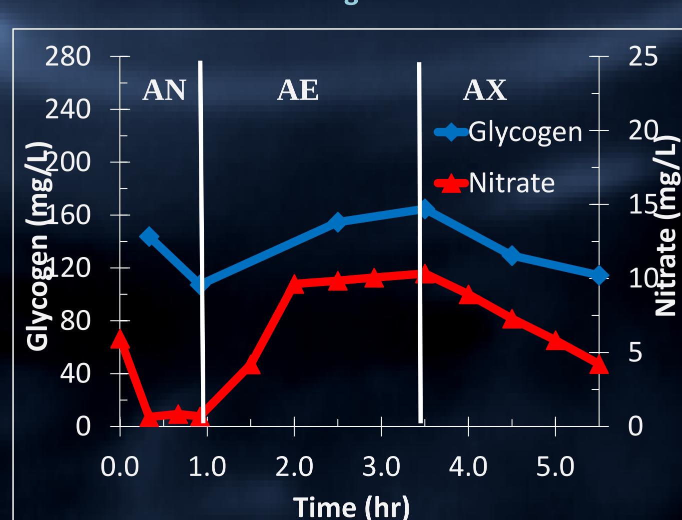

- VFAs and internally stored polyhydroxyalkanoates (PHA) are not present anoxically
- No change in MLVSS was observed therefore cell death cannot be responsible for nitrate removal
- Glycogen utilized anoxically to drive denitrification
- The cycling of PHA and glycogen drives the process

### 3. Importance of VFAs and EBPR



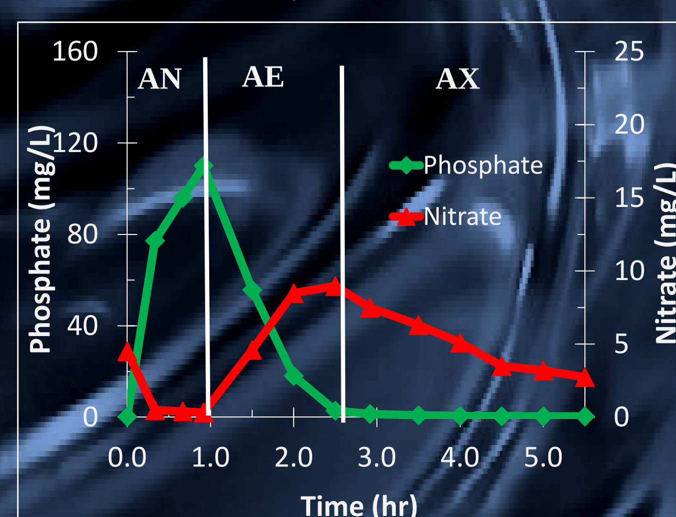

- Process is sensitive to VFA concentration in influent
- EBPR behavior is fundamental for process success as it initiates the cycling of PHA and glycogen which is necessary to drive post-anoxic denitrification

### 4. Effects of Excess VFA augmentation




- High Nitrate Removal efficiencies (>84%)
- Effluent Nitrate < 3.2 mg/L
- Effluent Phosphorus < 0.09 mg/L
- High SDNRs (1.36 mg $NO_3$ (hr-g MLVSS)$^{-1}$
- More influent VFAs = more PHA = more glycogen available for denitrification = better nitrate removal

### 5. Towards Process Optimization




- N removal efficiency >90%
- Decreasing the aerobic time and lengthening the anoxic time enabled us to access the full denitrification potential of the microorganisms

## CONCLUSIONS

- Post-anoxic denitrification can accomplish near-complete soluble inorganic N and P removal (> 99%). Process success is enhanced at elevated aeration rates, but significant removal can be achieved at reduced aeration.
- Intracellular glycogen, synthesized associated with EBPR, is an important carbon source used by the mixed microbial consortium to achieve denitrification. A positive correlation between the SDNR and intracellular glycogen concentration was observed. Furthermore, glycogen oxidization for denitrification does not compromise subsequent anaerobic VFA uptake and PHA storage, which is critical to EBPR.
- A mixed VFA substrate (HAc, HPr, HBu, and HVa) appears to be more beneficial to process performance and supports a higher percentage of PAOs than an acetate-dominated substrate.
- Post anoxic secondary P release can occur with $NO_x$ depletion. However, P release was only observed when SOT was prevented, and the rate of release was such that effluent P was only moderately increased.
- The proposed process configuration is potentially sensitive to low influent ammonia (< 20 mgN/L), but stable performance can be maintained by minimizing SOT.
- All tested reactor configurations achieved significant P removal despite variability over time in the relative PAO fraction, and also considering a relatively significant GAO population.

The post-anoxic biological nutrient removal process represents a potentially sustainable wastewater treatment process: high nutrient removal efficiencies coupled with a small facility footprint, no recycle flows, and no post-anoxic carbon supplementation translate to lower energy requirements and better effluent quality. In addition to reducing energy consumption and operating costs, current EBPR facilities can be readily retrofitted with the proposed process and therefore significantly reduce capital costs associated with a typical process upgrade.

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