Pilot Testing Biological Treatment of Nitrate-Contaminated Groundwater

MAG WATER AND WASTEWATER INFRASTRUCTURE WORKSHOP

January 12, 2010

Water Research Foundation Partners

- City of Glendale
- Water Research Foundation
- CH2M HILL
- The Biodesign Institute at Arizona State University
- Applied Process Technology (Vendor)

Background

- Nitrate contaminated groundwater
  - *Second most common contaminant found above the MCL in a survey of private drinking water wells.*
  - *Treatment Techniques*
    - *Ion-exchange*
    - *Reverse Osmosis*
    - *Biological Treatment*

When do you select biological treatment?

- Biological treatment is selected when it is the most *sustainable* choice based on environmental, societal, and financial considerations
- Triple Bottom Line

Greenhouse Gas Emissions
Residuals Disposal

Drinking Water Quality

Capital
O&M
Net Present Worth

City of Glendale

Background

- Advantages of Biological Treatment
  - *No brine*
  - *Targets wide range of contaminants*
  - *Sustainable*
- Challenges
  - *Not widely used in the United States*
  - *Typically requires substrate addition*
  - *May require proof of compliance for regulator approval*

Background

- Project Objectives
  - *To characterize the performance of biological nitrate removal technologies*
  - *To identify co-contaminant treatment*
  - *Evaluate ongoing ion-exchange pilot performance based on same criteria*
  - *Identify environmental issues for each technology*
  - *Develop cost comparison*
  - *Evaluate biological and ion-exchange systems based on criteria including the triple bottom line (TBL) of sustainability*

Background

- Biological Treatment Technologies
  - *Heterotrophic*
    - *well studied in Europe and in the U.S. in wastewater treatment*
    - *reliable*
  - *Autotrophic*
    - *less biomass*
    - *no residual substrate*
    - *easier to "dial-in" to fluctuating influent water quality*

Water Quality Implications of Biological Nitrate Reduction

- Water Quality Implications of Biological Treatment
  - *Treated water is anoxic*
  - *Even if carbon-based electron donor is removed or if the donor is inorganic (e.g. hydrogen), the treated water will contain some dissolved organic carbon from soluble microbial products*
  - *Heterotrophic plate counts are increased as a result of biofim detachment to varying degrees depending on the electron donor*
- An Aerobic Biologically Active Filtration Process Should Follow Biological Denitrification of Drinking Water.

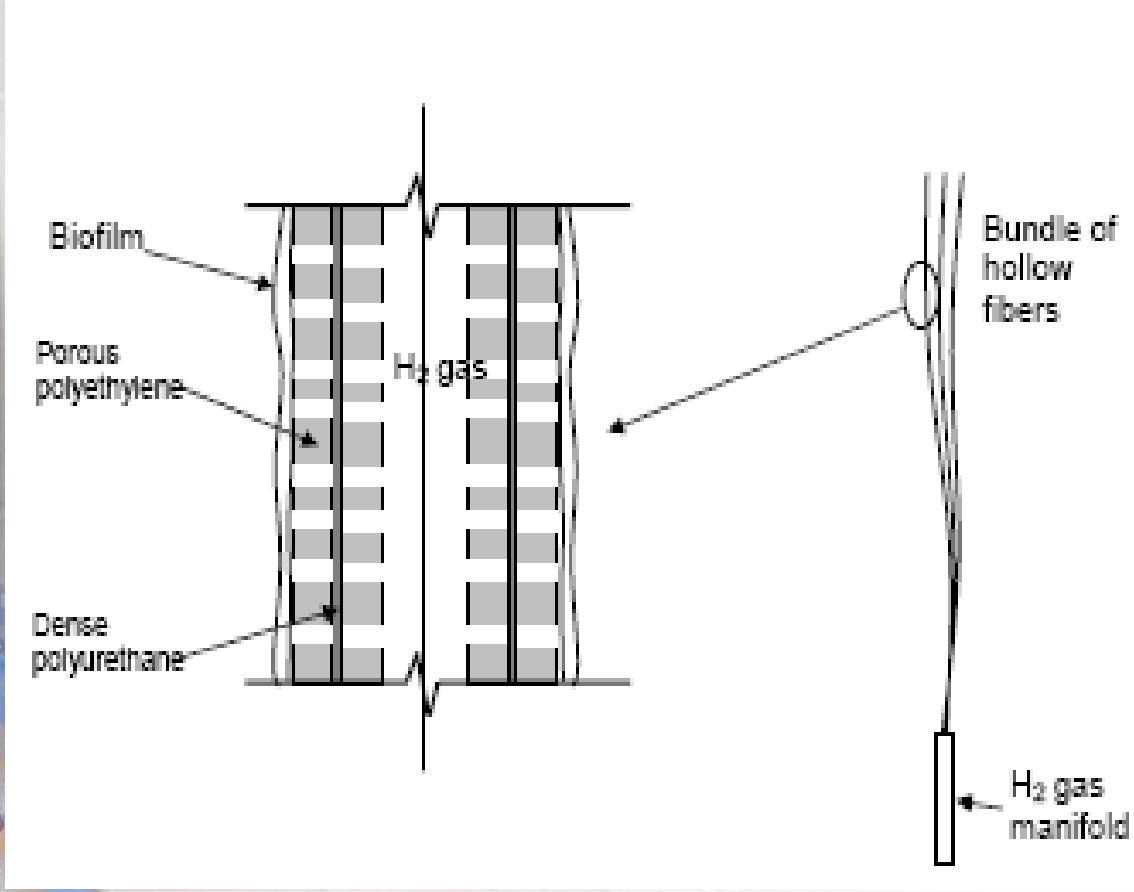
Current Regulatory Climate

- Many regulators are apprehensive about biological drinking water treatment despite the industry's long history with slow sand filtration, biological filtration and other biologically-based unit processes.
- Anoxic biological treatment is under more scrutiny than aerobic processes (less full-scale U.S. experience).
- Permits for biological groundwater treatment facilities in California are requiring post treatment that meets surface water turbidity standards and 4-log virus disinfection CT.

Pilot Processes

- Biological Nitrate Reduction
  - *Train 1 – Autotrophic Membrane Biofilm Reactor (MBfR)*
  - *Train 2 – Heterotrophic bioreactor – upflow bioreactor with plastic media*
  - *Train 3 – Heterotrophic bioreactor – upflow GAC bioreactor*
- Post Treatment
  - *Ozone Biological Activated Carbon*

Train 1 MBfR (Applied Process Technology, Inc.)



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Train 2 – Upflow Bioreactor with Plastic Media

- Stages (#) - Two
- Media type – expanded polystyrene
- Media surface area – 660 m2/m3
- Media depth - 180 inches
- Operating Mode – Upflow with limited backwash
- Max flow – 1.5 gpm (6.0 g-N/m^{2}d)

Ozone Skid

- Average dose ~ 2 mg/L
- Flexibility to run with and without ozone

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Post Filtration (Biologically Active Carbon)

- Stages (#) - One
- Media type – 1.1 mm GAC (exhausted)
- Media surface area – 3000 m2/m3
- Media depth - 72 inches of Exhausted GAC over 12 inches of Sand
- Filter Loading Rate – 4.5 gpm/sf

Pilot Conclusions

- Identifying the optimum carbon and nutrient requirements is critical.
- Effective nitrate removal (typical effluent values less than 0.1 mg-N/L) in the effluent was achieved by Train 1 and Train 2 within seven and twenty days of determining the optimal carbon and phosphorus dosing, respectively.
- Effluent turbidity from Trains 1 and 2 were less than or equal to 1 NTU, with typical turbidity values of 0.2 NTU from Train 1 and 0.5 NTU from Train 2.
- The turbidity introduced through biological treatment was removed through post-treatment, which consisted of either ozonation or aeration, following by granular media filtration.

Pilot Conclusions

- Effluent turbidity from Trains 1 and 2 were less than or equal to 1 NTU, with typical turbidity values of 0.2 NTU from Train 1 and 0.5 NTU from Train 2.
- The turbidity introduced through biological treatment was removed through post-treatment, which consisted of either ozonation or aeration, following by granular media filtration.
- Higher than reported surface area removal rates for Trains 1 and 2 (2.2 g-N/m2-d and 6.0 g-N/m2-d, respectively) were demonstrated during this study.
- Effluent dissolved organic carbon (DOC) and phosphate concentrations were well-controlled at levels slightly higher than were detected in the raw water.
- Finished water met SWTR and IESWTR requirements.

Triple Bottom Line (TBL) Systems Analysis

- Establish full-scale treatment objectives
- Select most feasible nitrate treatment alternatives
  - *MBfR (Pilot Train 1) + Ozone + Biologically Active Carbon Filtration*
  - *Static Upflow Bed with Plastic Media (Pilot Train 2) + Ozone + Biologically Active Carbon Filtration*
  - *Fixed Bed Ion Exchange + Evaporation Ponds/Landfill*
- Based on pilot data and design criteria, create conceptual design for 10-mgd biological denitrification plant(s)
- Summarize 10-mgd Zone 4 fixed bed ion exchange treatment facility conceptual design
- Calculate capital, O&M and life cycle costs for treatment alternatives
- Conduct TBL evaluation of biological denitrification versus ion-exchange

Full-Scale Treatment Objectives

10 mgd groundwater nitrate treatment facility:

- Meet all applicable groundwater treatment regulations
- Meet City of Glendale goal of <6 mg/L NO_3-N (post blending)

Select Most Feasible Treatment Alternatives

- MBfR + Ozone + BAC
- Pilot Train 2 (Upflow Bioreactor with Plastic Media) + Ozone + BAC
- IX + Evap Ponds + Landfill

Full-Scale Treatment Objectives

10 mgd groundwater nitrate treatment facility:

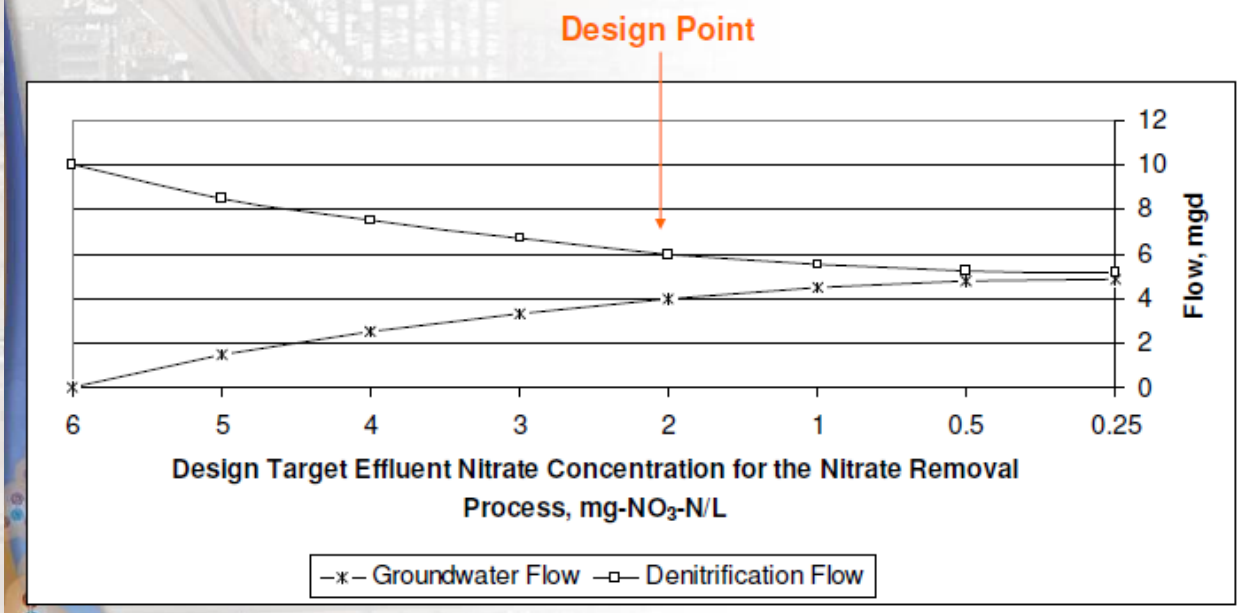
- Meet all applicable groundwater treatment regulations
- Meet City of Glendale goal of <6 mg/L NO_3-N (post blending)

Conceptual Design for Full-Scale Nitrate Treatment Plant Alternatives

- Nitrate-N = 12 mg/L
- Sulfate = 108 mg/L
- Dissolved Oxygen = 4.5 mg/L
- Nitrate Removal Process Effluent Conditions = <2 mg/L NO3-N

Conceptual Design for Full-Scale Nitrate Treatment Plant Alternatives

- Resulting blend ratio?
  - *6 MGD Nitrate Treatment Flow*
  - *4 MGD Raw Water Bypass Flow*



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TBL Decision Evaluation of Nitrate Treatment Alternatives

- Selected decision criteria representing important non-monetary benefits or attributes of an alternative that are independent, provide differentiation, and are measurable in some quantitative fashion.
- Weighted the decision criteria to prioritize the importance of the individual criterion to the decision process.
- Developed a quantitative measurement or scoring methodology to define the performance of each alternative with respect to each decision criterion.
- Scored the alternatives for each criterion. Calculated the non-monetary benefits offered by each alternative, based on the product of the weighting assigned to the criterion and the score.
- Calculated the benefit-to-cost ratio for each alternative.

Nitrate Treatment Alternatives Cost Summary

	10-mgd Alternative Costs		
	Capital	O&M	Life Cycle
IX + Evap Ponds + Landfill	$16,445,900	$3,175,100	$56,014,900
MBfR + Ozone + BAC	$23,844,400	$3,429,000	$66,593,500
Train 2 + Ozone + BAC	$19,652,000	$2,712,000	$53,449,900

TBL Decision Evaluation Conclusion

- The highest total benefit scores were associated with the two biological treatment options (Alternatives 1 and 2).
- Of these two alternatives, Alternative 2 had the lowest life-cycle cost, while Alternative 1 had the highest benefit score. Given the high benefit score and low life-cycle cost, Alternative 2 is the optimum alternative based on the highest benefit-to-cost ratio for the systems tested.
- Alternative 1 showed promising results. Based on pilot results, vendor is refining design to increase reliability and performance and reduce the cost.

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