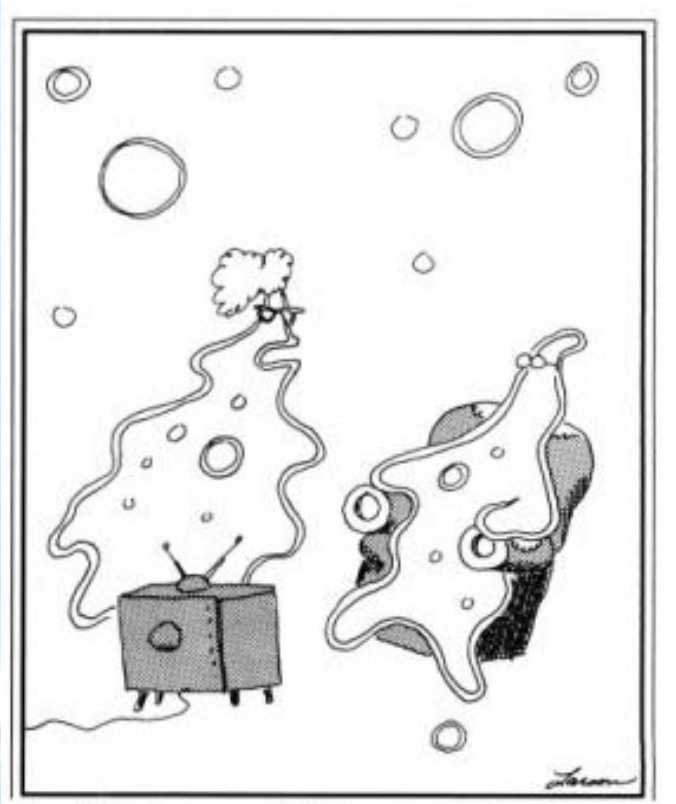
Letting the Bugs do the Work
Biological Filtration in Drinking Water



"Stimulus, response! Stimulus, response! Don't you ever *think*?"

Lee H. Odell, P.E.

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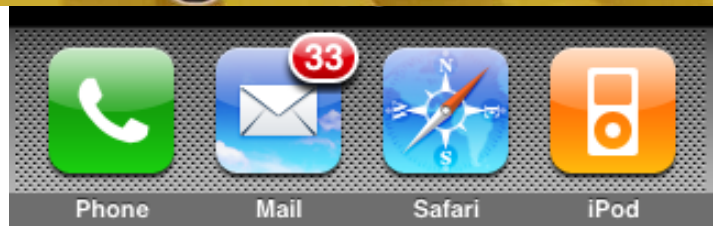
Overview

- Applications
- Design Considerations
- Examples
- Regulatory Issues

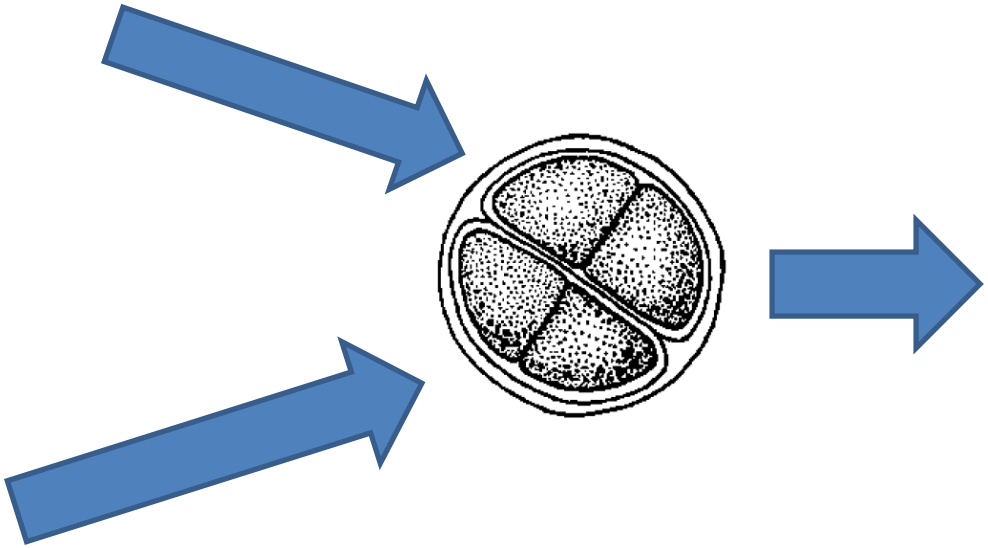


Who Uses Biological Filtration?

Facility Name	Location	Capacity (MGD)
McCarrons WTP	St. Paul, MN	130
David L. Tippin WTP	Tampa, FL	120
Winnipeg WTP	Winnipeg, Manitoba	106
Twin Oaks Valley WTP	San Diego, CA	100
Lakeview WTP	Peel, Ontario	96
Albuquerque WTP	Albuquerque, NM	93
Upper San Leandro WTP	San Leandro, CA	90
Jonathan W. Rogers WTP	El Paso, TX	60
Sobrante WTP	El Sobrante, CA	60
Ann Arbor WTP	Ann Arbor, MI	50
Lawton-Medicine Park WTP	Lawton, OK	40
Rockdale County WTP	Rockdale County, GA	22
Whittier Narrows Treatment Facility	Los Angeles, CA	20
Lake Washington WTP	Melbourne, FL	20
Upper Trinity Regional WTP	Lewisville, TX	20
Lake Whitney WTP	New Haven, CT	15
Burbank Operating Unit	Burbank, CA	13
Lake Texoma Surface WTP	Sherman, TX	10
City of Kauai WTP	Kauai, Hawaii	10
Southeast WTP	Lawton, OK	10

What is Biological Filtration?

Electron Acceptor: Oxygen, nitrate, bromate, chlorate etc



Water
Nitrogen
Chloride
Bromide

Electron Donor: DOC, Hydrogen, sugars, alcohol

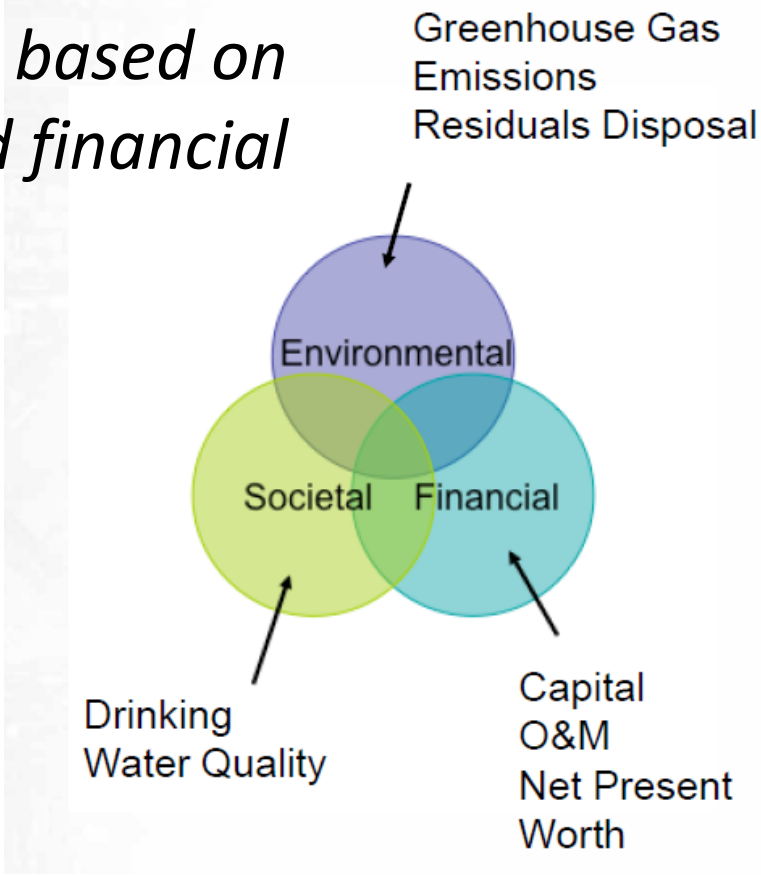
Why Use Biological Filtration?

- Biological Stability in the Distribution System
- Lower Disinfection By Products
- Lower Chemical Use
- Specific Contaminant Removal
  - Perchlorate
  - Nitrate
  - Iron
  - Manganese
  - Arsenic

When to Use Biological Filtration?

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

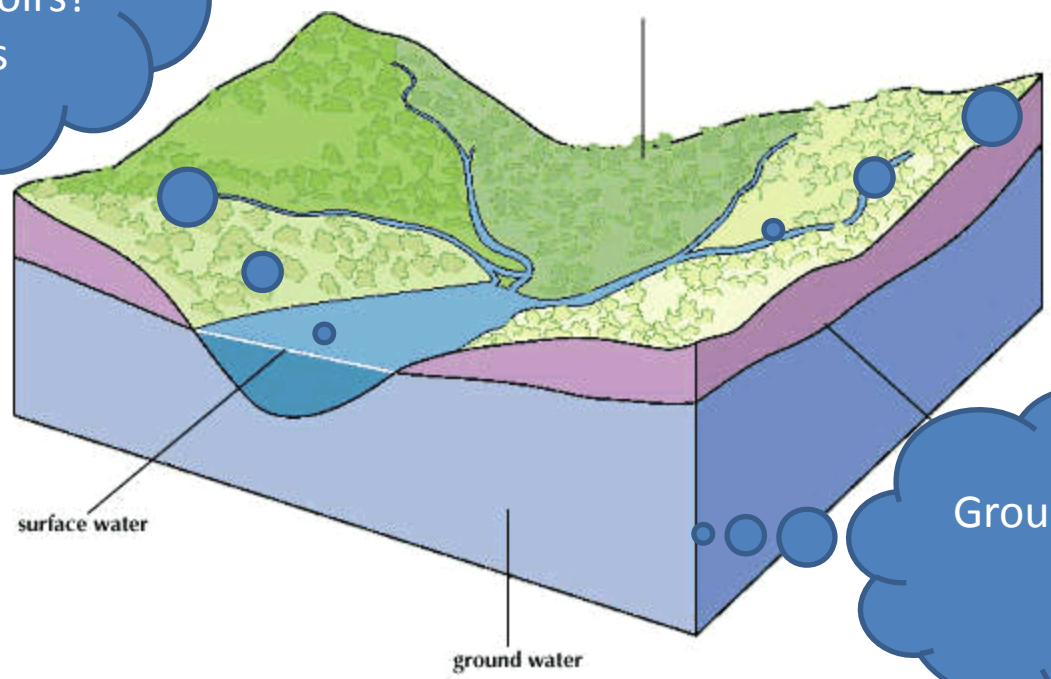
Triple Bottom Line



Where to Use Biological Filtration

Lakes & Reservoirs? Yes

Rivers? Yes



Groundwater? Yes

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Applications for Biological Filtration

Source Water	Compounds	Treatment Goals
Surface Water	Natural Organic Matter, Color, Heterotrophic Bacteria	Reduce Fouling on Membranes, Lower DBPs, Distribution Stability
	Geosmin, MIB, Endocrine Distruption Compounds	Remove/Reduce Compounds
Groundwater	Iron, Manganese, Nitrate, Arsenic, Perchlorate,	Meet MCLs, Reduce Biofilm in Distribution System
	Natural Organic Matter	Reduce DBPs

Examples

- Iron
- Nitrate
- Surface Water – AOC, DBPs, T&O

Biological Iron Removal

Fairbanks
Ruth Burnett Sport Hatchery
3 MGD
Iron – 7 mg/L
Manganese – 0.8 mg/L

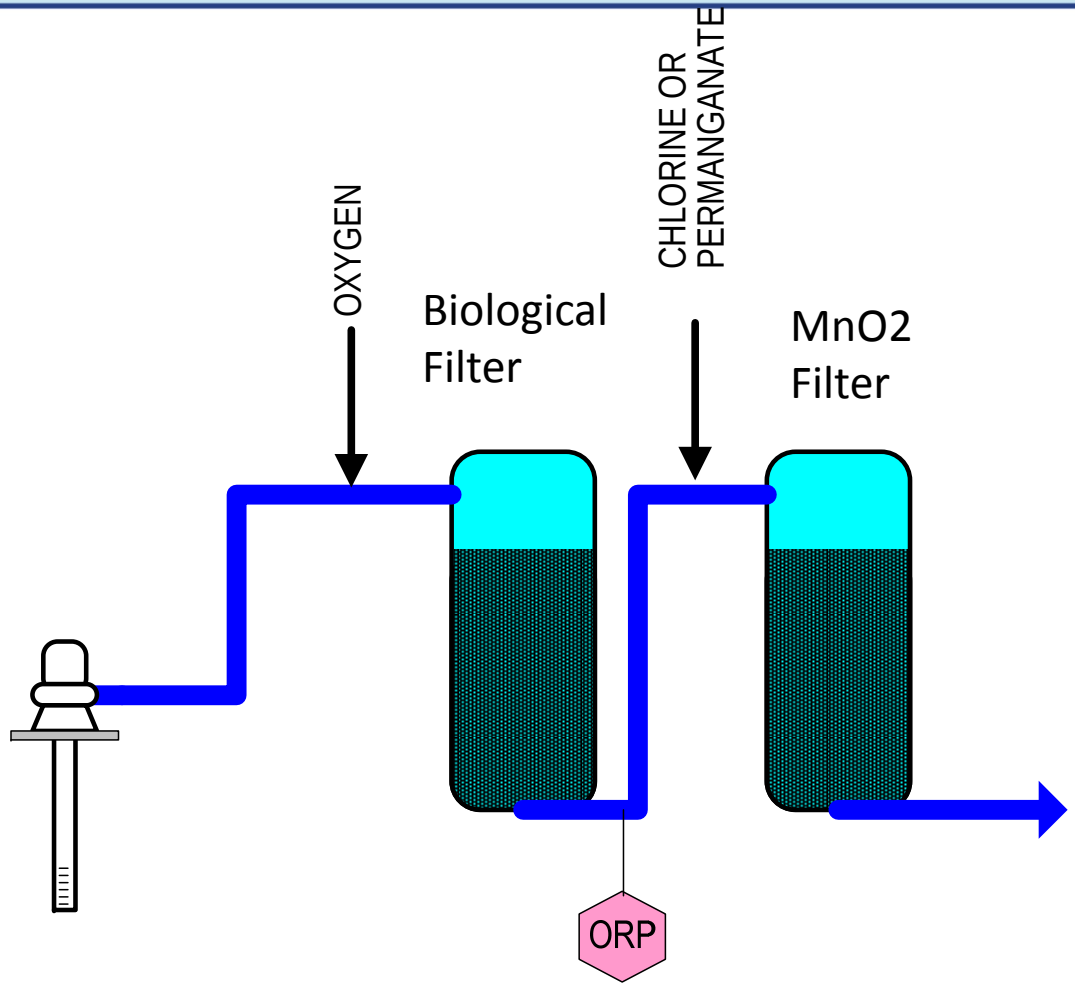
Jefferson PUD
Sparling Well
2 MGD
Iron – 6.5 mg/L
Manganese – 0.35 mg/L

Heda Oya Well Field,
Pottuvil , Sri Lanka
2 MGD
Iron – 7 to 21 mg/L
Manganese – 0.2 to 2.5 mg/L

Biological Fe-Mn Filtration

- Iron Related Bacteria:
- Facultative Autotrophs:
  - Gallionella
  - Sheathed IRB
    - Leptothrix
    - Crenothrix
    - Sphaerotilus
- Heterotrophic IRB

Combined Biological & Adsorptive System: Schematic Flow Diagram



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Biological Fe-Mn Filtration

Oxidation Reduction Potential Conditions for Biological Removal of Iron and Manganese				
	pH 6.0	pH 7.0	pH 8.0	pH 9.0
Iron Removal	100 – 500 mV	50 – 350 mV	0 – 130 mV	
Manganese Removal			320-570 mV	230 – 320 mV

Source: *Biological Iron and Manganese Removal, Pilot and Full Scale Applications, B. Gage, et al, 2001*

Combined Biological & Adsorptive System

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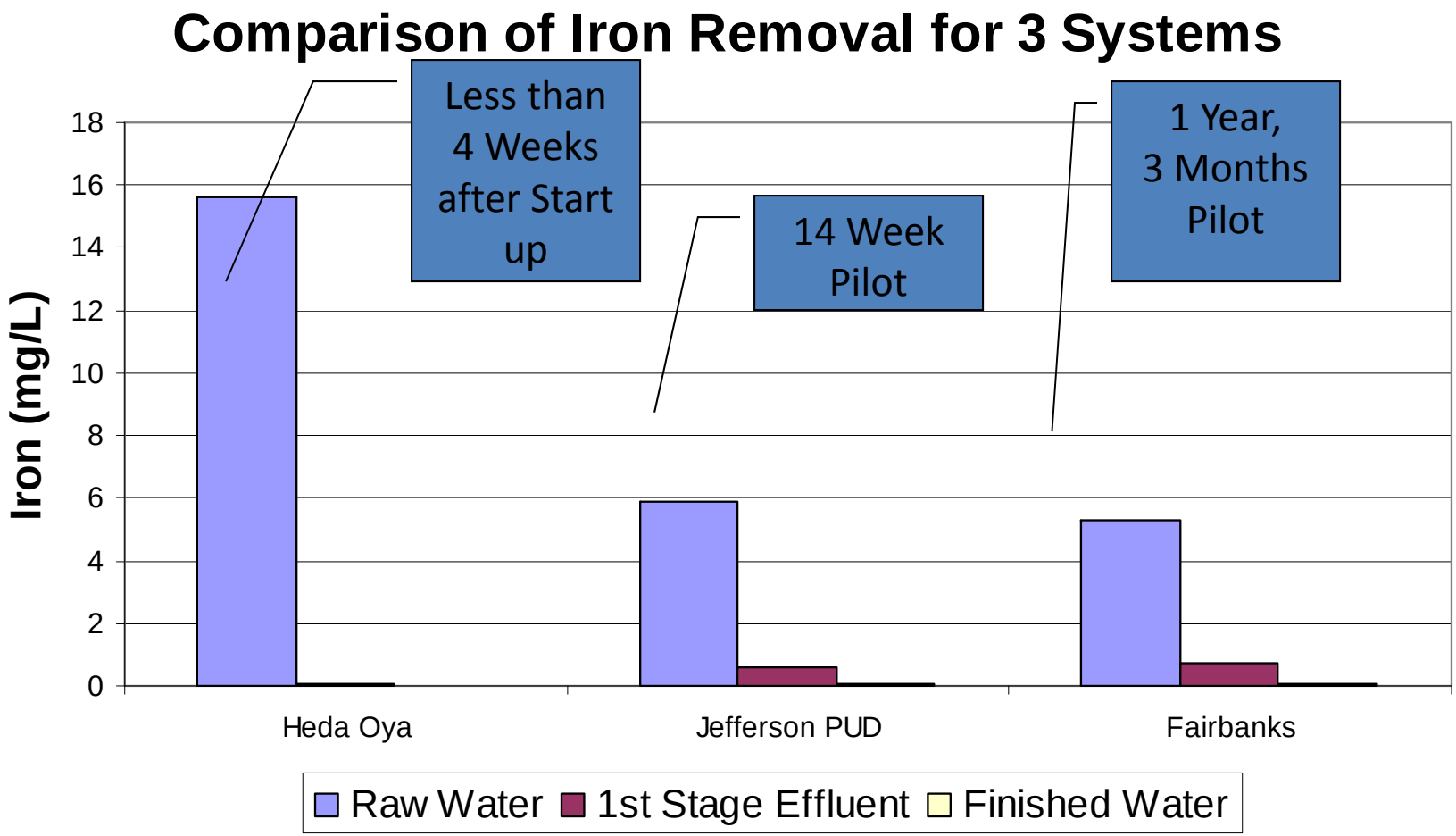
Iron Results



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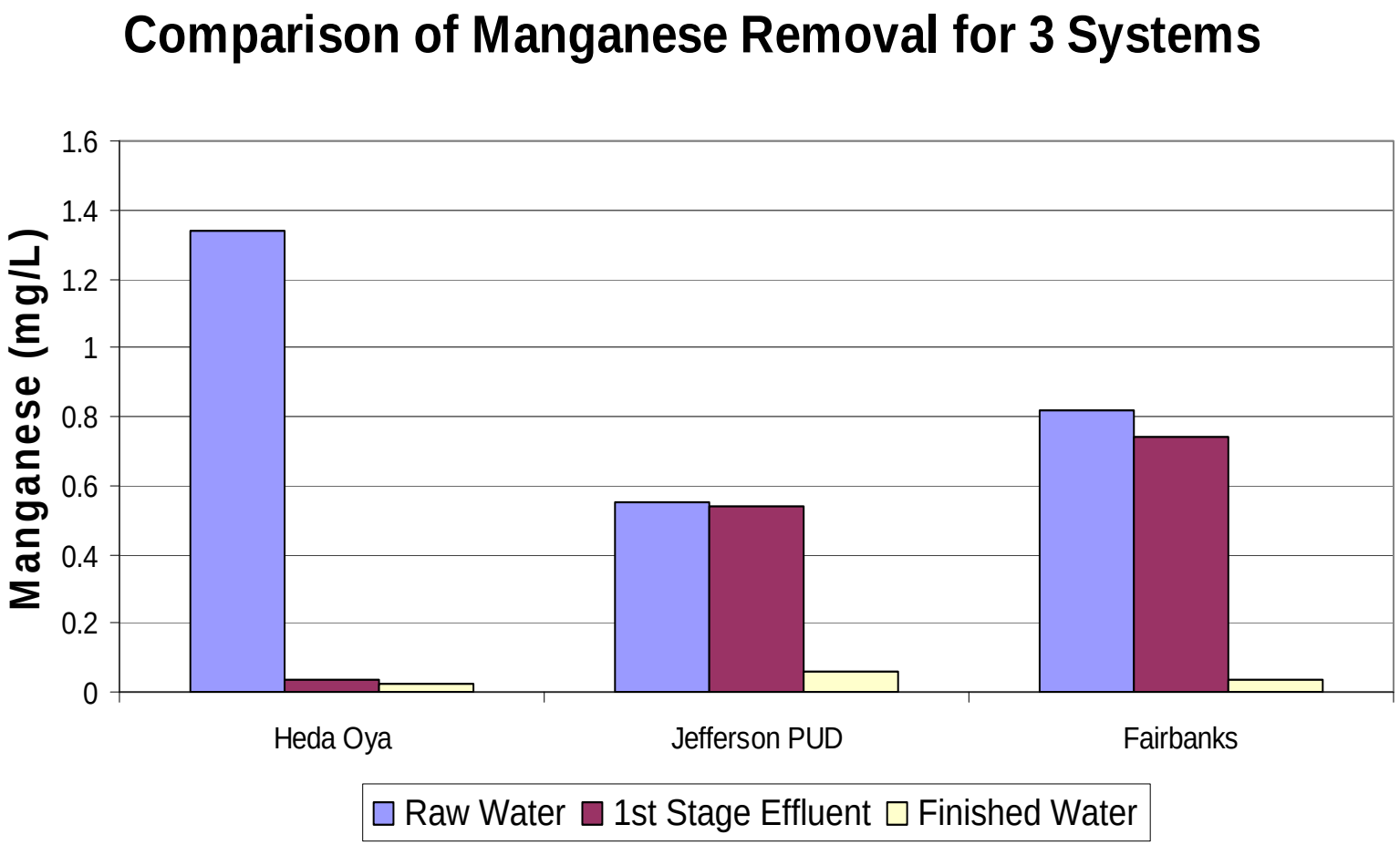
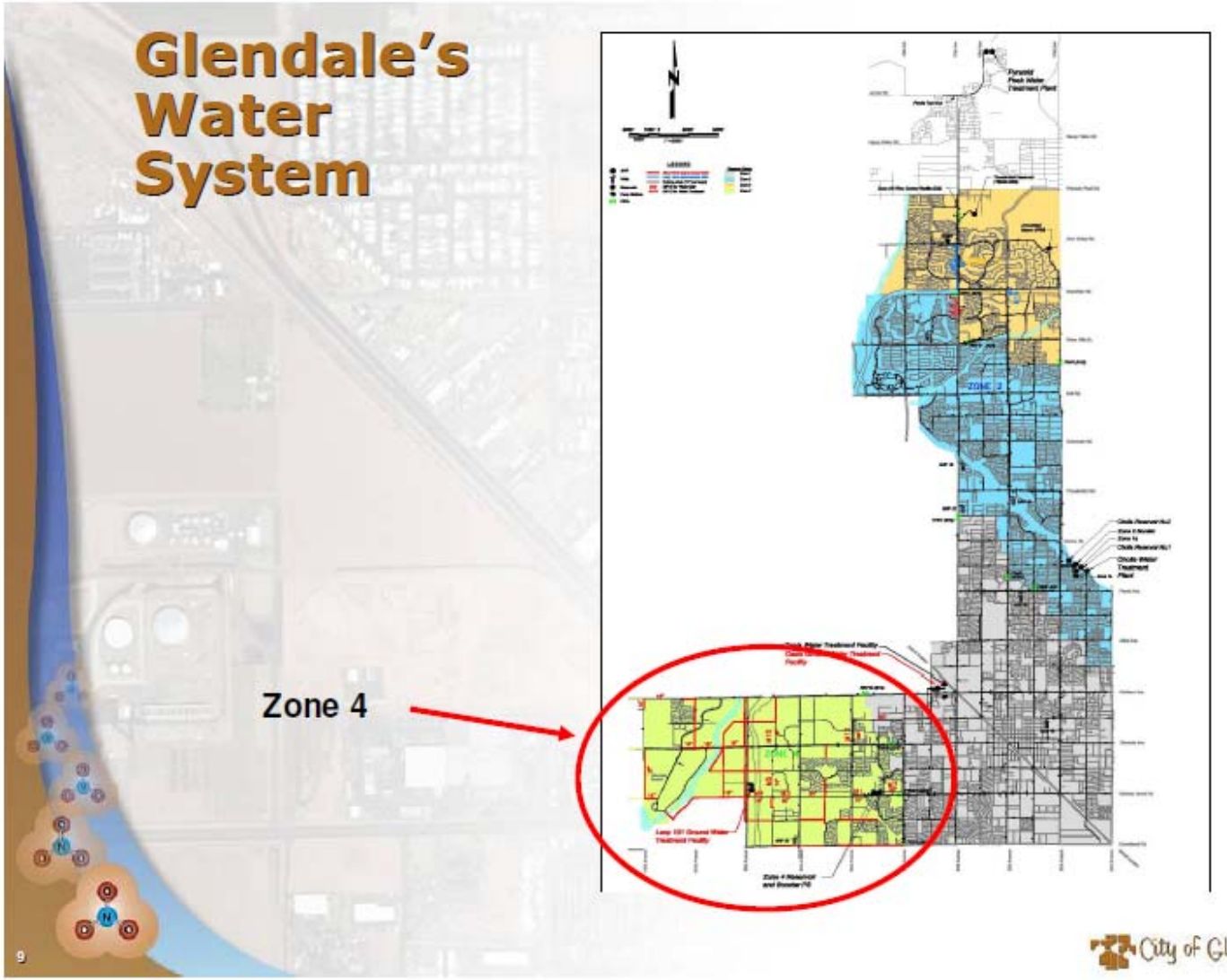
Manganese Results



Chemical & Cost Savings

	Heda Oya/ Pottuvil	Fairbanks	Jefferson PUD
Capacity	1,500 gpm	2,000 gpm	1,500 gpm
Average Flow	500 gpm	400 gpm	400 gpm
Annual Chemical Costs			
Raw Water Cl2 & KMnO4	$76,000/Yr	$37,000/Yr	$109,000/Yr
Combined System	$23,000/Yr	$26,000/Yr	$21,000/Yr
Savings	$53,000/Yr	$11,000/Yr	$88,000/Yr

Biological Nitrate Removal



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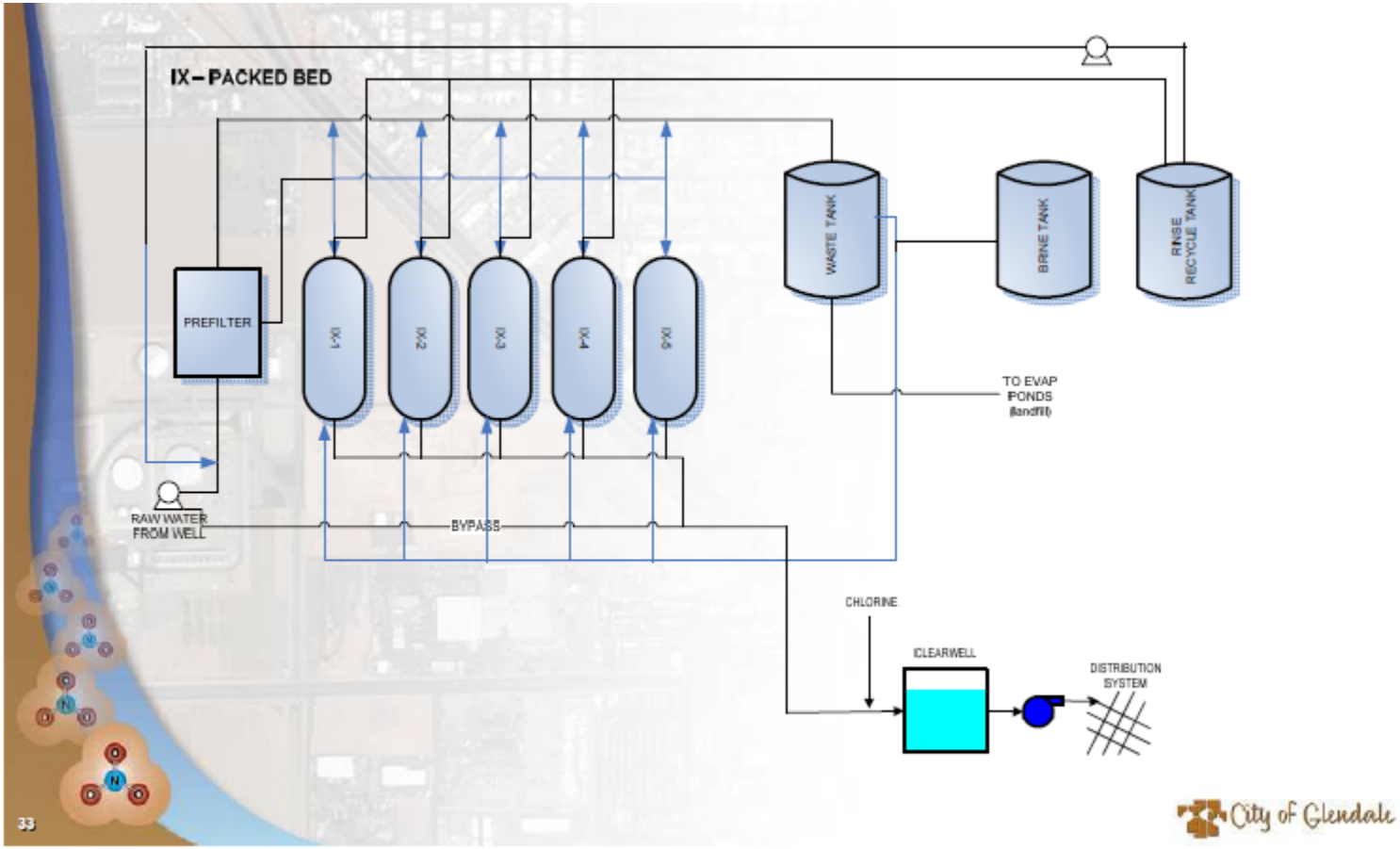
Glendale Ion Exchange
10 MGD Z4GWTP



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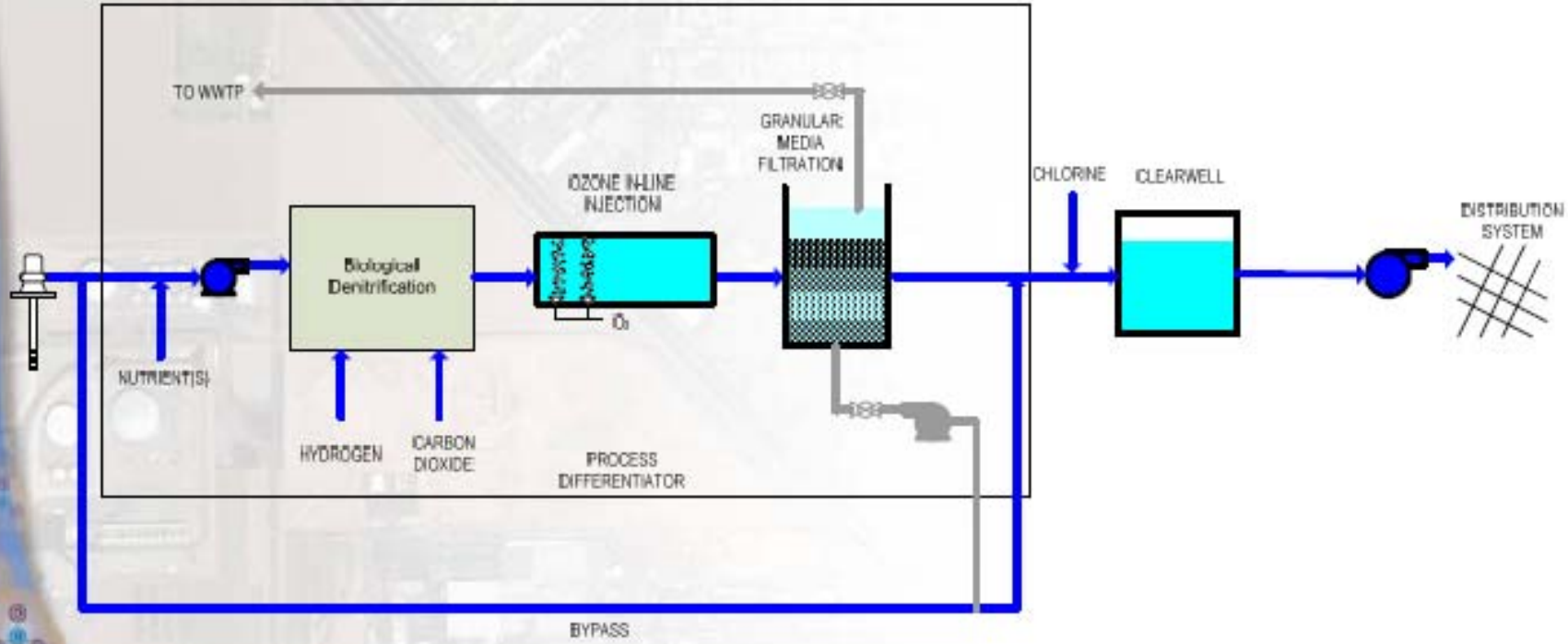
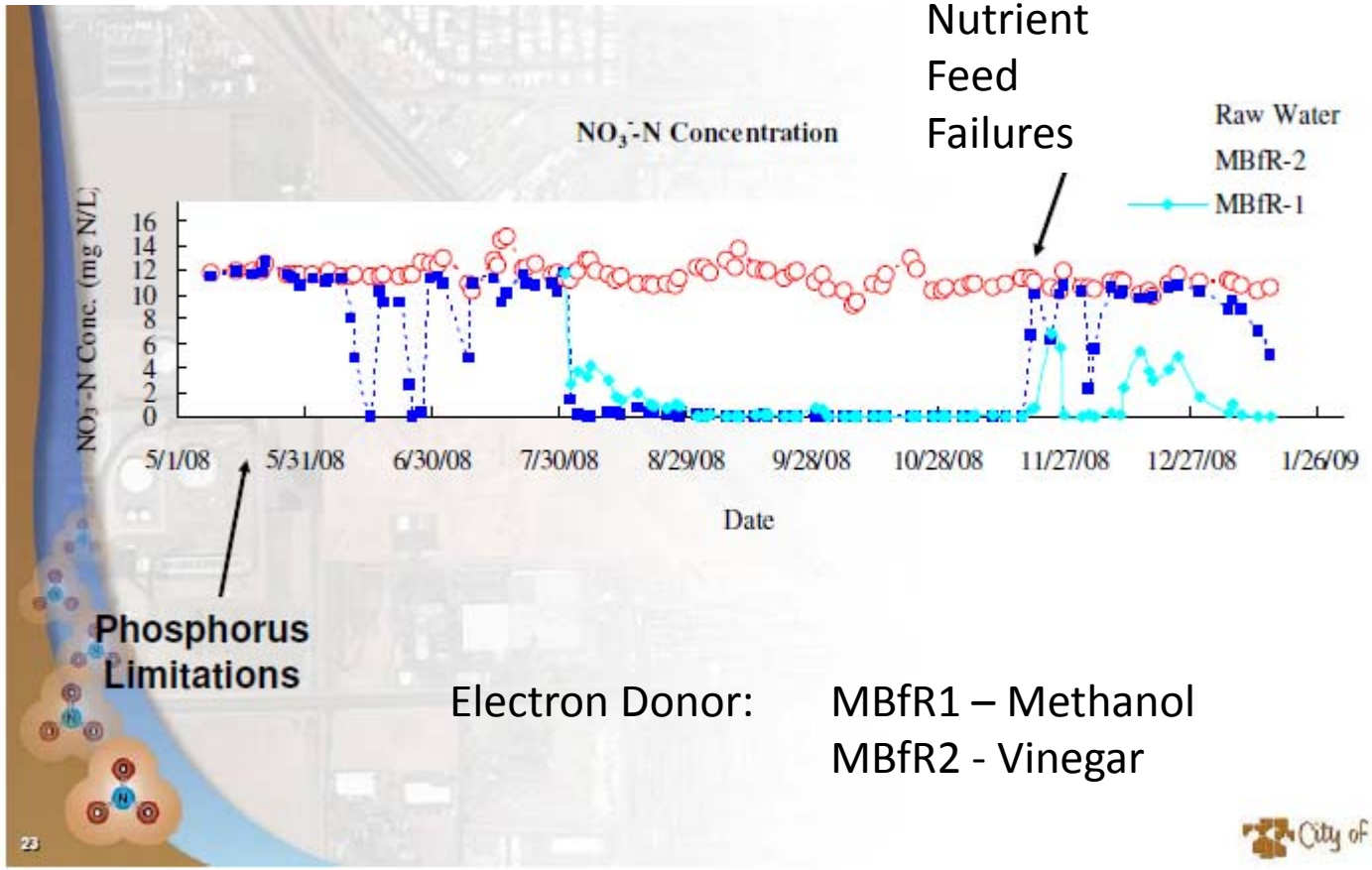
Glendale Research Study
Membrane Bioreactor & Fixed Bed Bioreactor



City of Glendale

Glendale Membrane Bioreactor



Electron Donor: MBfR1 – Methanol
MBfR2 - Vinegar

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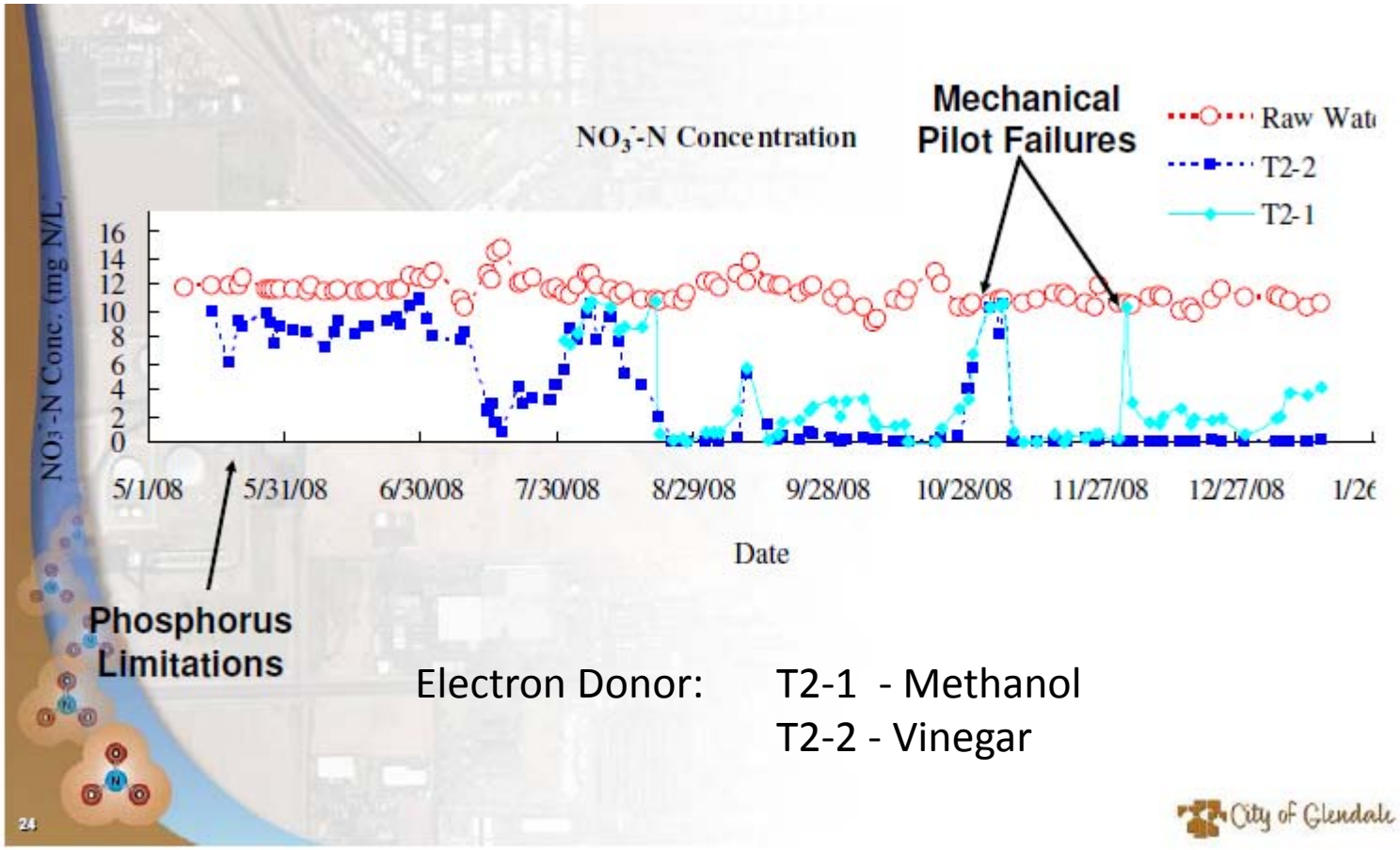
Glendale Fixed Bed Bioreactor



Electron Donor: T2-1 - Methanol
T2-2 - Vinegar

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Recommendation for Glendale Future Facility

Nitrate Treatment Alternatives Cost Summary

	10-mgd Alternative Costs		
	Capital	O&M	Life Cycle
Ion Exchange	$16,445,900	$3,175,100	$56,014,900
Membrane Bioreactor	$23,844,400	$3,429,000	$66,593,500
Fixed Bed Bioreactor	$19,652,000	$2,712,000	$53,449,900

- See Water Research Foundation Final Report for design assumptions for each unit process

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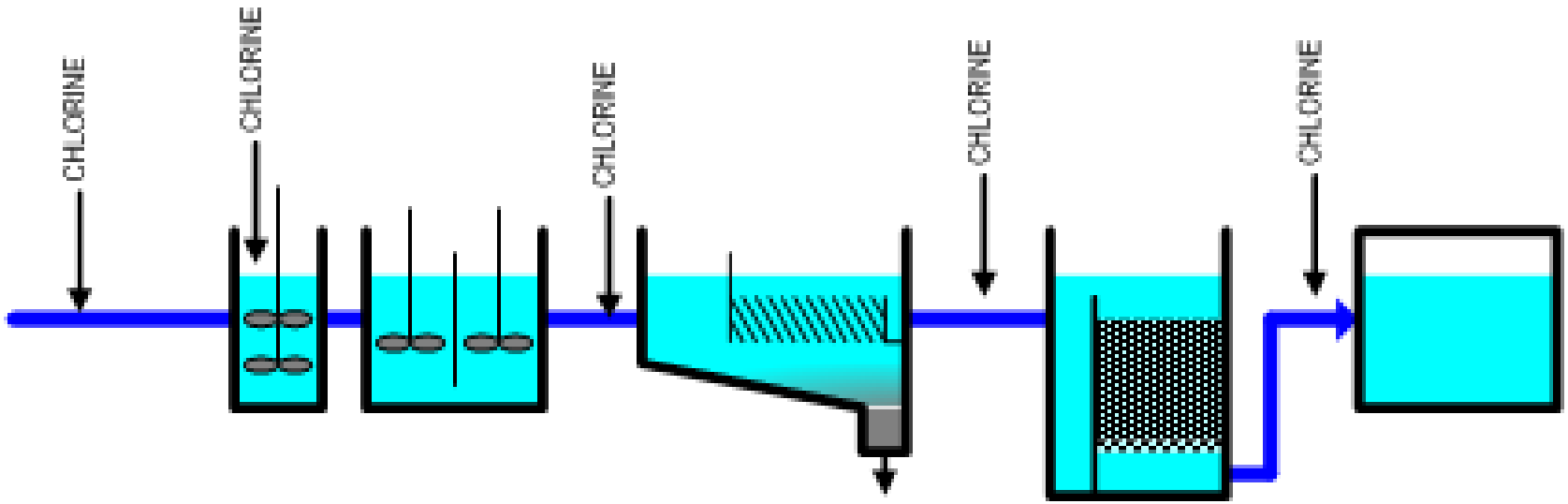
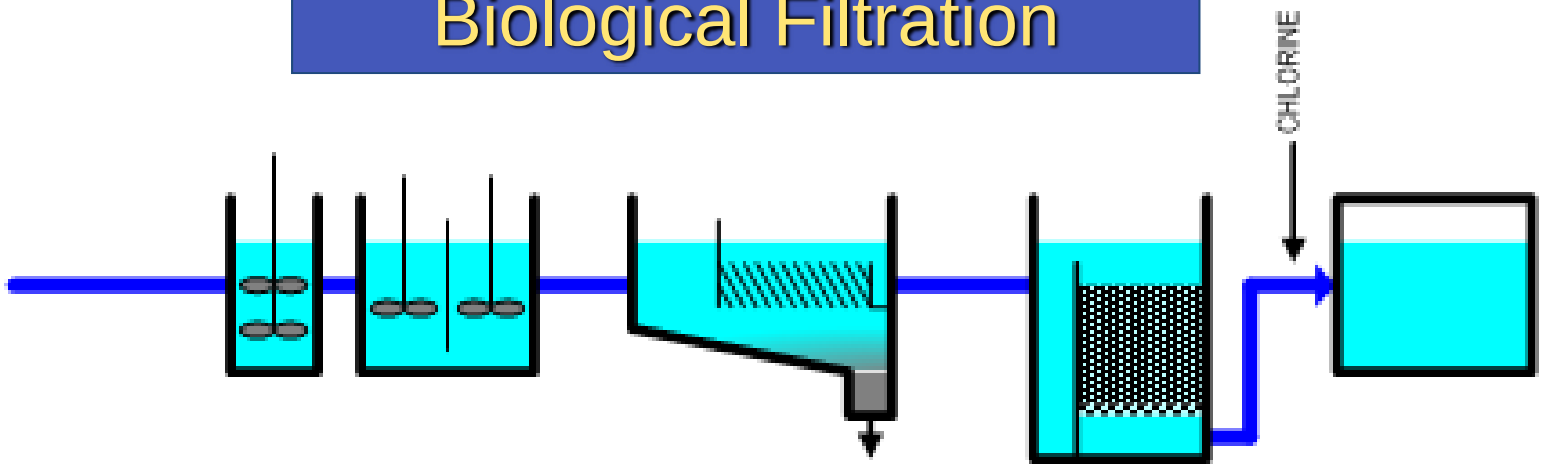
Surface Water Biological Filtration

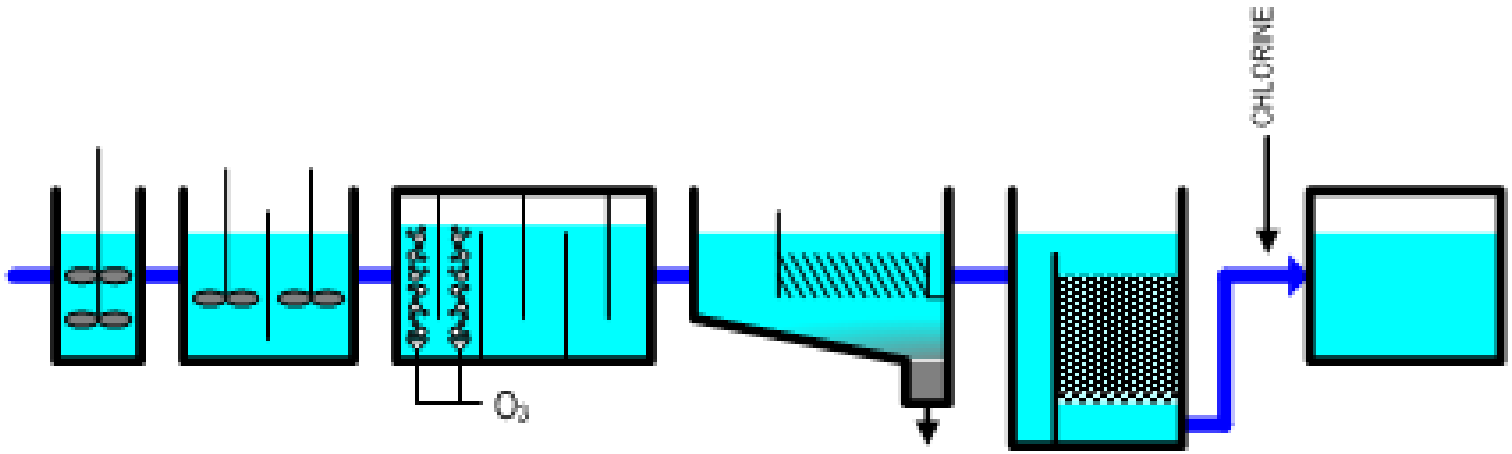
Conventional Treatment



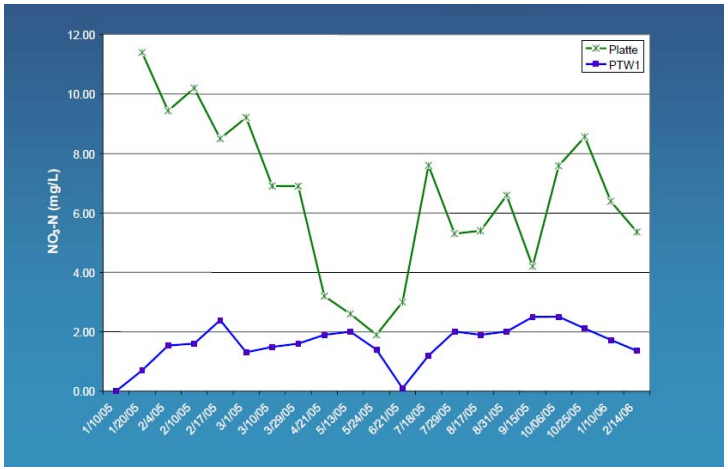
Surface Water Biological Filtration

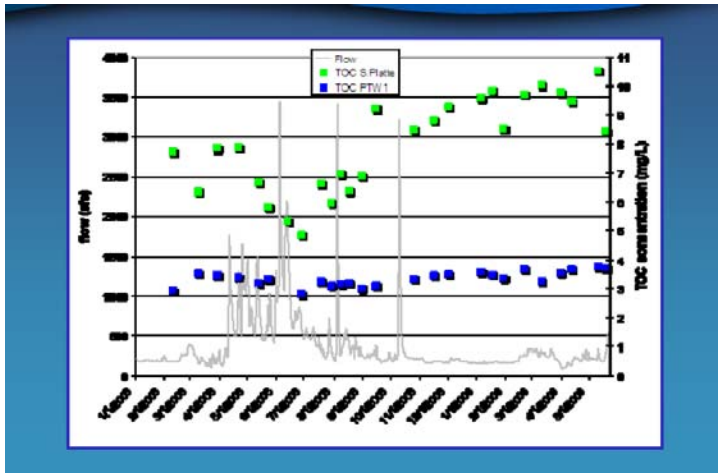
Biological Filtration





Other Biological Process for Surface Water: RBF & SSF

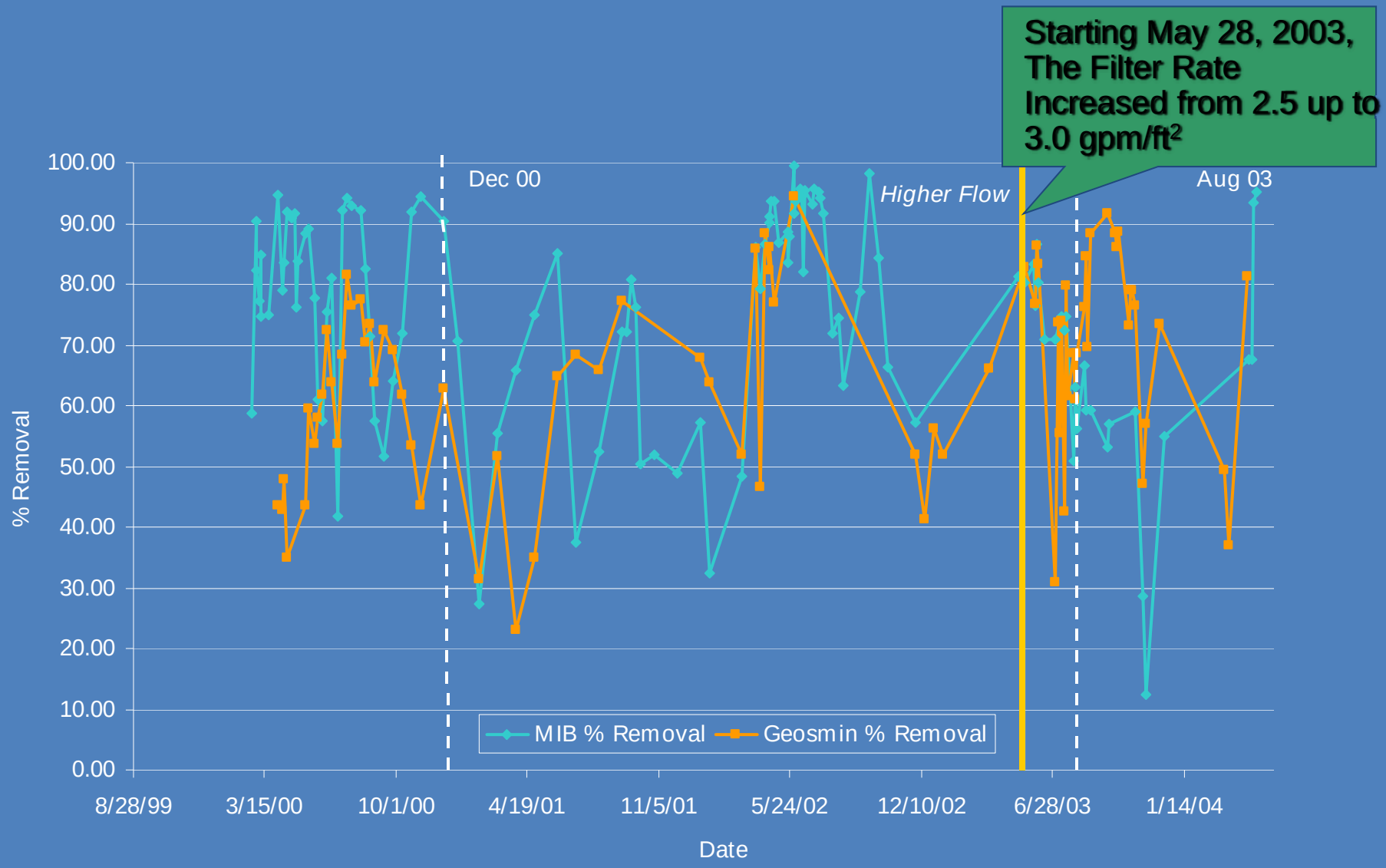




Parameter	Removal by **RBF** (Partinoudi, 2004)	Removal by **SSF** (Partinoudi, 2004)	Removal by **SSF** (based on literature)
DOC	41-85%	13-19%	8-25%
Total Coliforms	>1-1.6 logs*	>1.8-2.2 logs	>1-2 logs*
E.coli	>0.3-0.8 logs*	>1.8logs	>3-4 logs*
Aerobic spores	>1.9-3.5 logs*	>2.1-2.3logs*	>2 logs
Turbidity	77-99%	75-90%	60->90%

* Reduced to detection limit

MIB and Geosmin Removal Percentages through Biological Sand Filters: GCWW RMTP



Comparison of BDOC and AOC Removal

Conventional/Anthracite

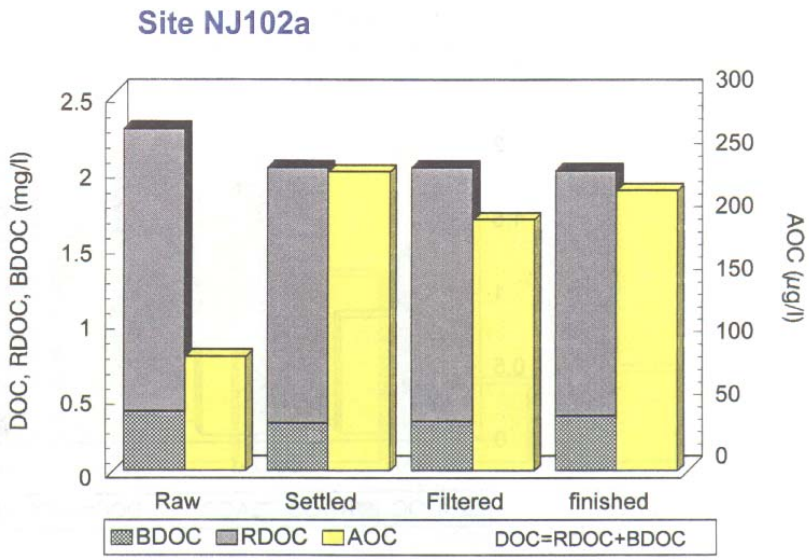


Figure 15. Changes in DOC, BDOC and AOC concentrations (geometric means) during water treatment for site NJ102a.

Conventional/BAC/Sand Filters

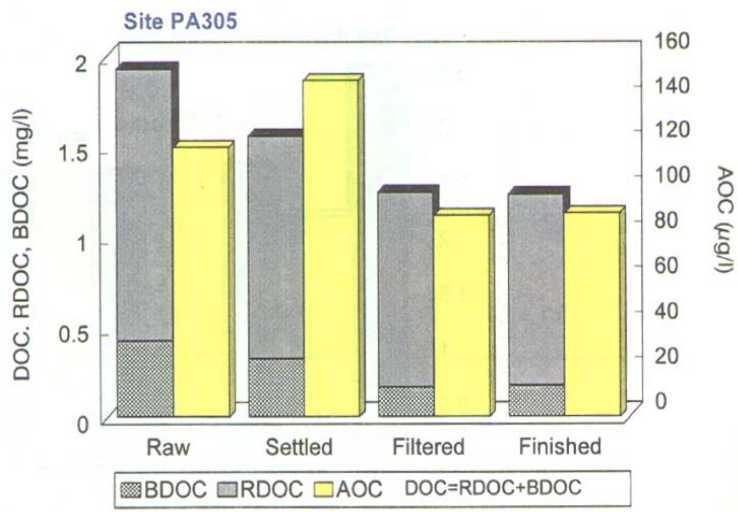


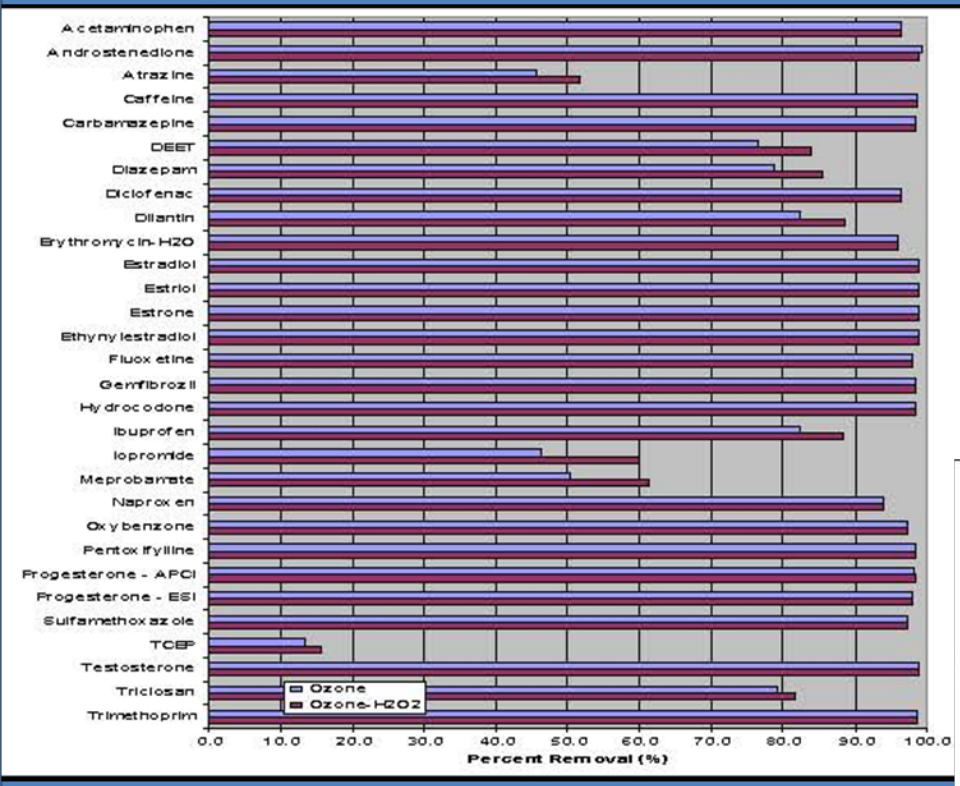
Figure 18. Changes in DOC, BDOC and AOC concentrations (geometric means) during water treatment for site PA305.

American Water Works Service Company
Mark W. LeChevallier

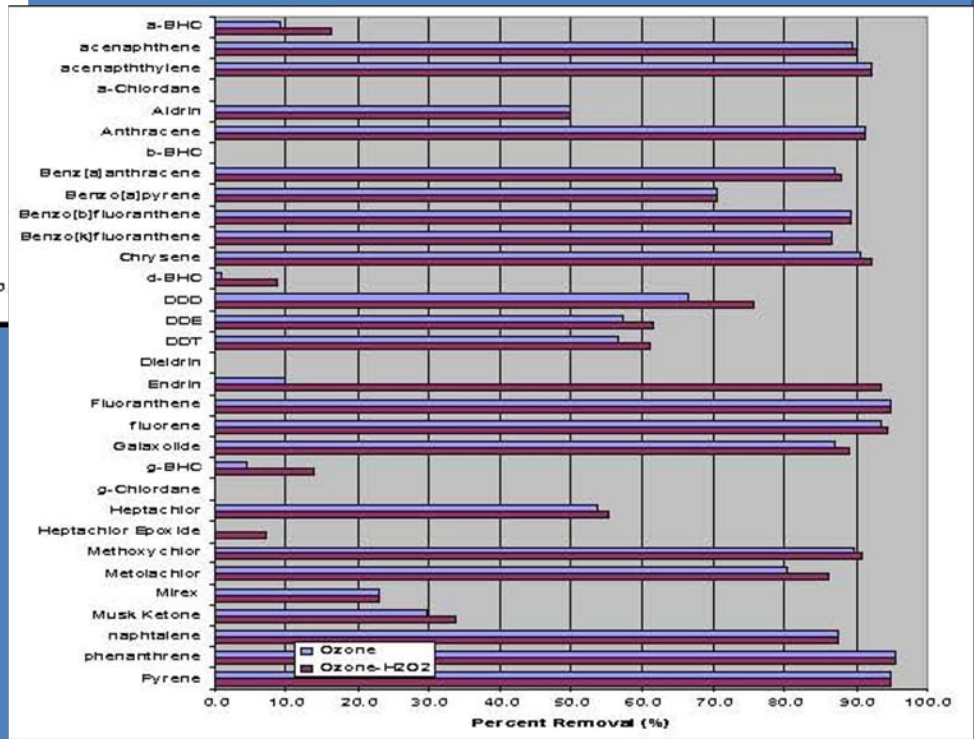
Pre Ozonation Benefits with Biologically Active Filtration

- Disinfection without THMs or HAAs
- AOC & BDOC removal of 50 to 100 percent
- Microflocculation
- Color removal
- Iron and manganese removal
- Reduction of taste and odor
- Removal of ozonation by-products
- Control of biological regrowth
- Increased stability of the residual chlorine
- Destruction of Some EDC, PPCPs

Ozonation Effectiveness *(Source: Snyder and Westerhoff)*



- Ozone for 0.1-0.3 mg/L residual after 5 minutes
- For AOP, 0.025 mg peroxide/mg ozone added after 1 minute



Source: S. Snyder, and P. Westerhoff. Removal of EDCs and Pharmaceuticals by Conventional and Advanced Water Treatment

Regulatory Issues

- Post Filtration – Required for Some Biological Processes
- Heterotrophic Bacteria
- Other Post Treatment for electron donor removal
- Off Line & Acclimation

Thank You

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