Nitrification and Arsenic Removal in Biologically Active Filters: A Case Study

Darren A. Lytle
U.S. Environmental Protection Agency
ORD, NRMRL, WSWRD, TTEB
Cincinnati, Ohio 45268

Arsenic Rule

- Arsenic MCL was reduced from
  50 ug/L to 10 µg/L
- Established by EPA in January of 2001
- Compliance deadline—January 2006

Arsenic Chemistry

- Arsenic has two primary valence states:

  As (III) As^{3+} Arsenite

  As (V) As^{5+} Arsenate

- Arsenic Occurrence by valence state:
  - **Surface waters -** ***predominately As (V)***
  - **Ground waters –** ***usually found as As (III), however, concentrations of As (V) or a combination of As (III) and As (V) can be found***

Arsenic Chemistry

Arsenic species-pH dependent

As (III) - $H_3AsO_3^0$, $H_2AsO_3^{-1}$, $HAsO_3^{-2}$

As (V) - $H_3AsO_4^0$, $HAsO_4^{-1}$, AsO_4^{-2}

Arsenic Chemistry

What is the significance of arsenic speciation?

As (V) more effectively removed than As (III) by most treatment technologies

Arsenic Chemistry

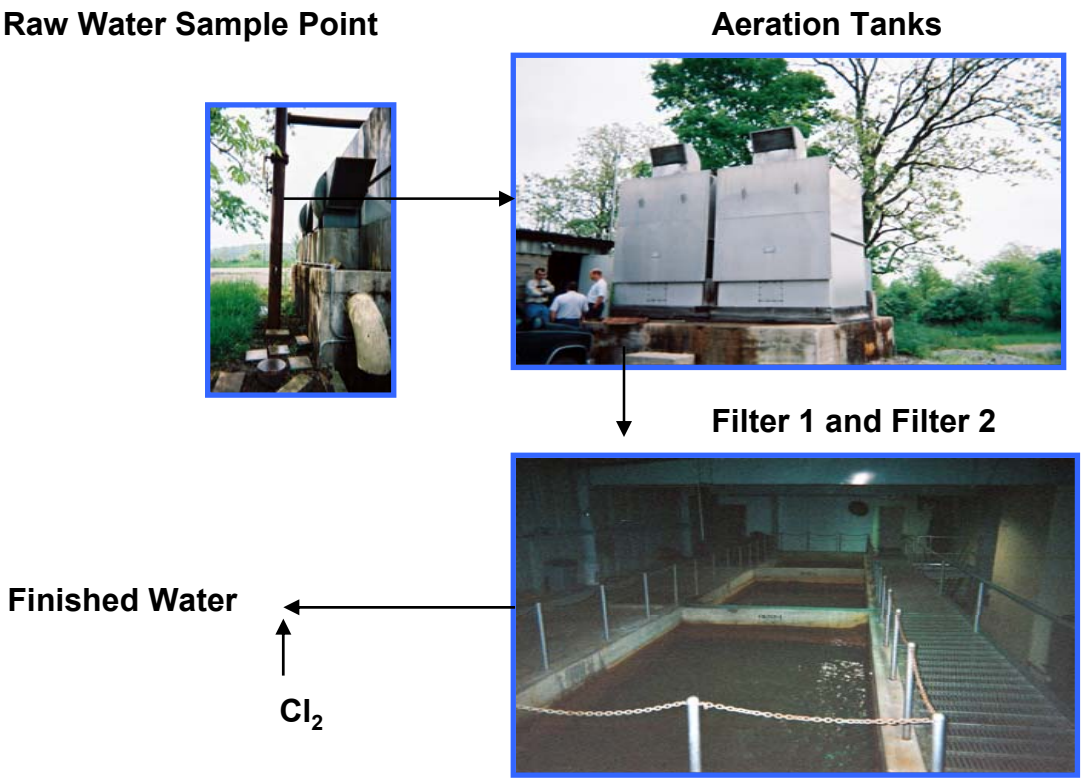
As III can be oxidized to **As V** by strong oxidants such as:

- chlorine
- ozone
- potassium
- permanganate

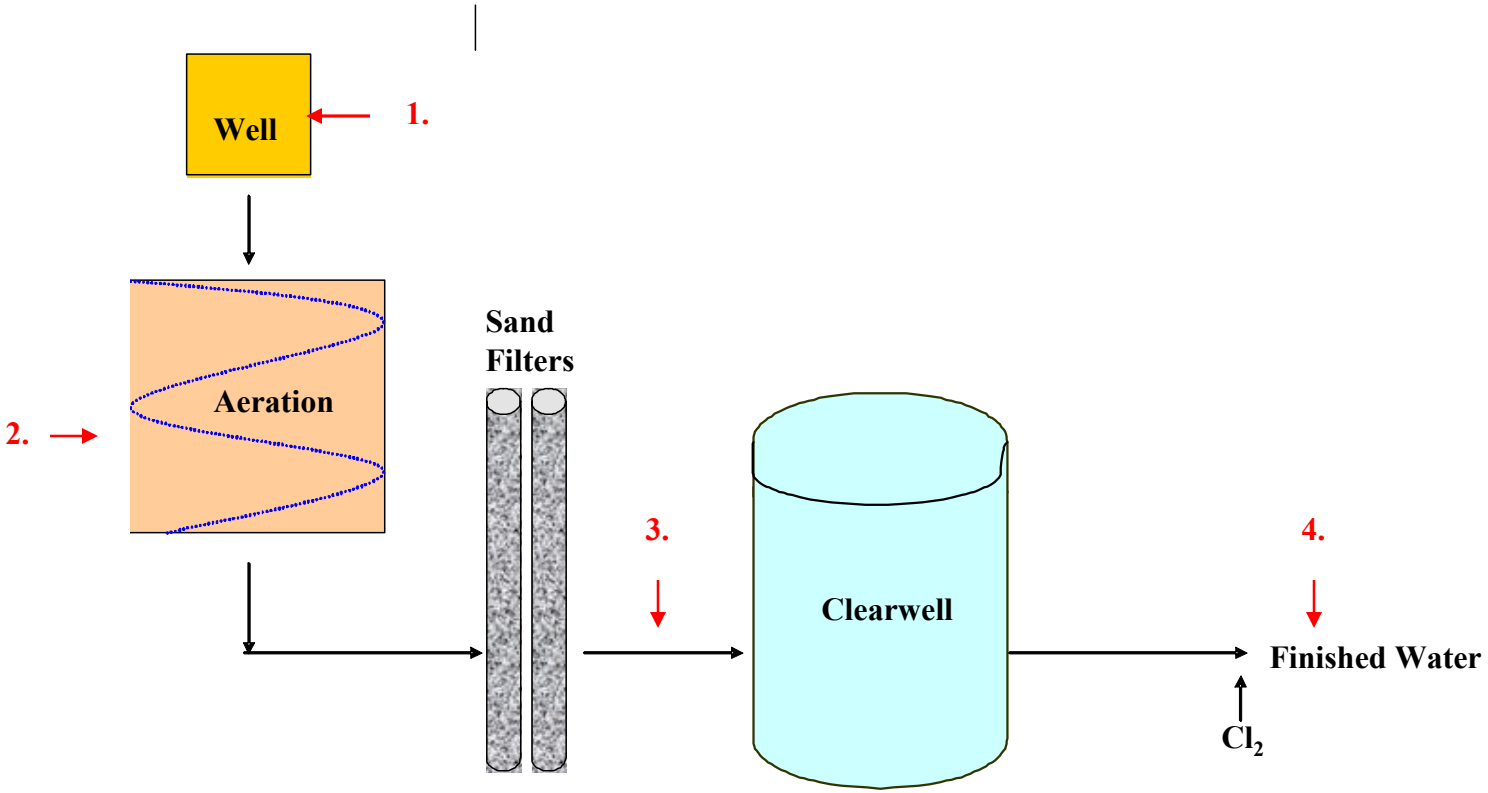
Oxidation of As III by aeration is NOT effective.

Greene Co. South Plant

Iron Removal



Greene Co. South Plant

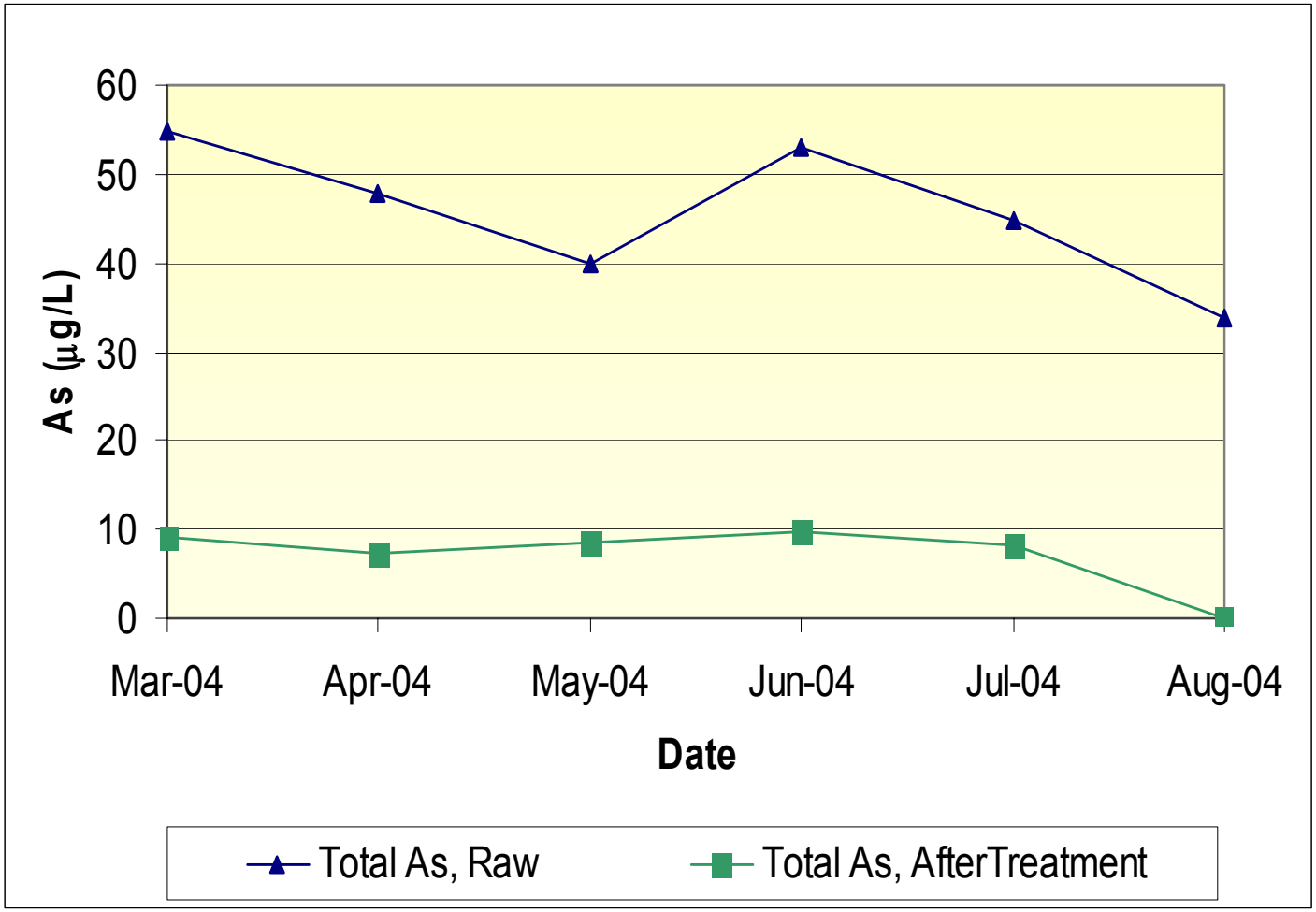


Greene Co. South Plant Water Summary

Speciation

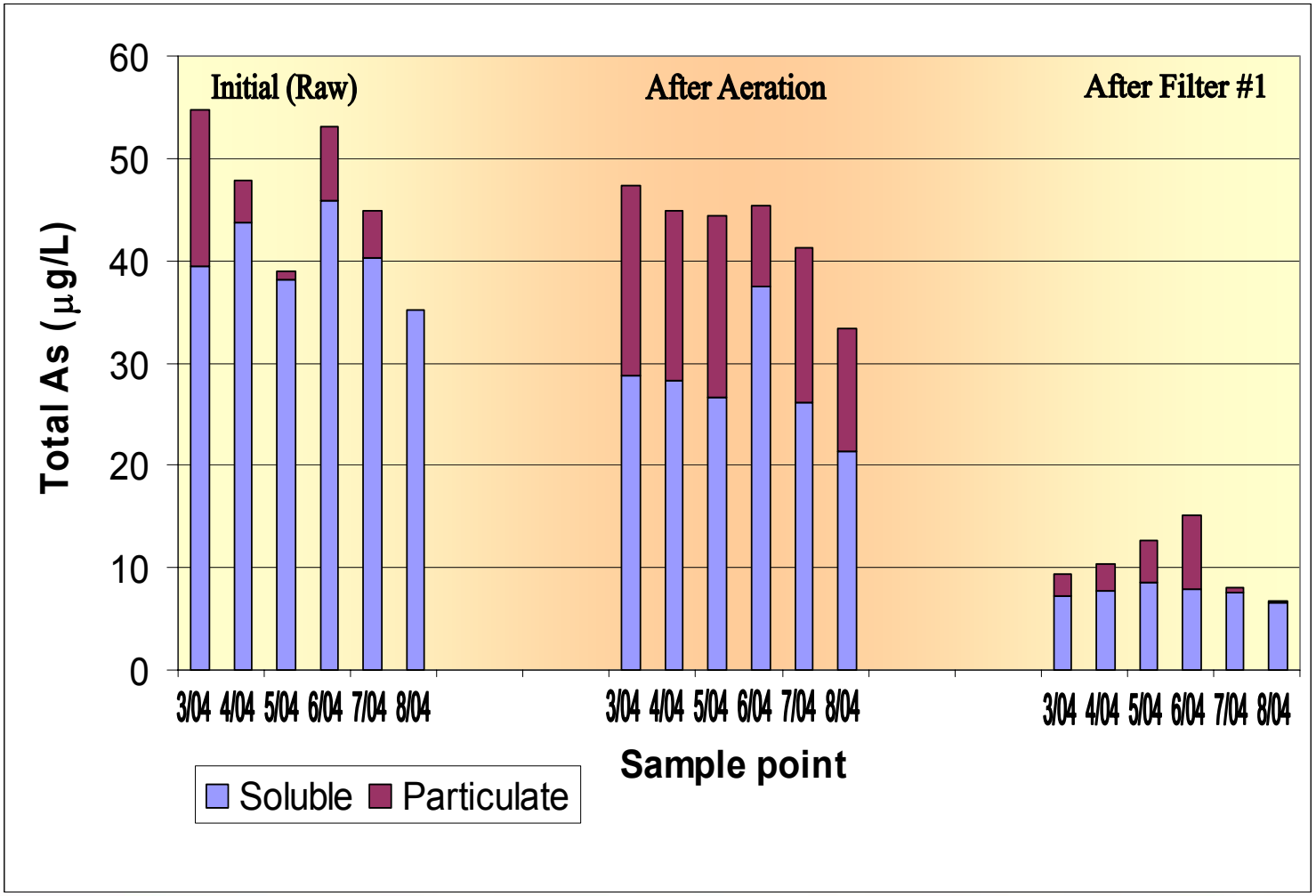
Parameter	Unit	Raw	Before Filter	After Filter #1
As (total)	µg/L	47	42	9.4
As (total soluble)	µg/L	41	28	7.5
As (particulate)	µg/L	5.0	14	1.8
As (III)	µg/L	37	23	1.4
As (V)	µg/L	3.4	5.7	6.1
Total Fe	mg/L	2.3	2.3	0.08
Dissolved Fe	µg/L	2.3	0.2	<0.025

Greene Co. South Plant
Arsenic Removal

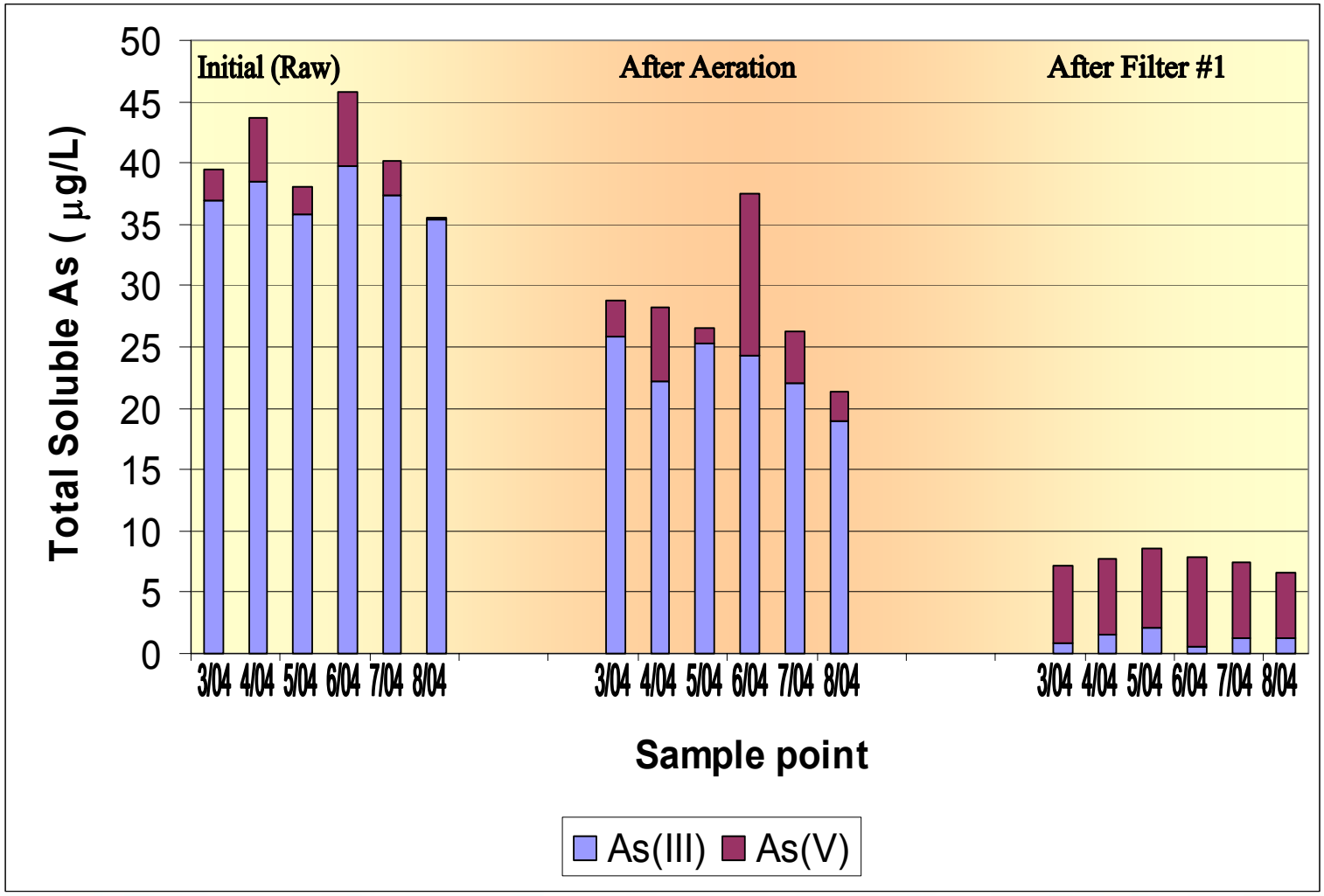


Greene Co. Southern Plant

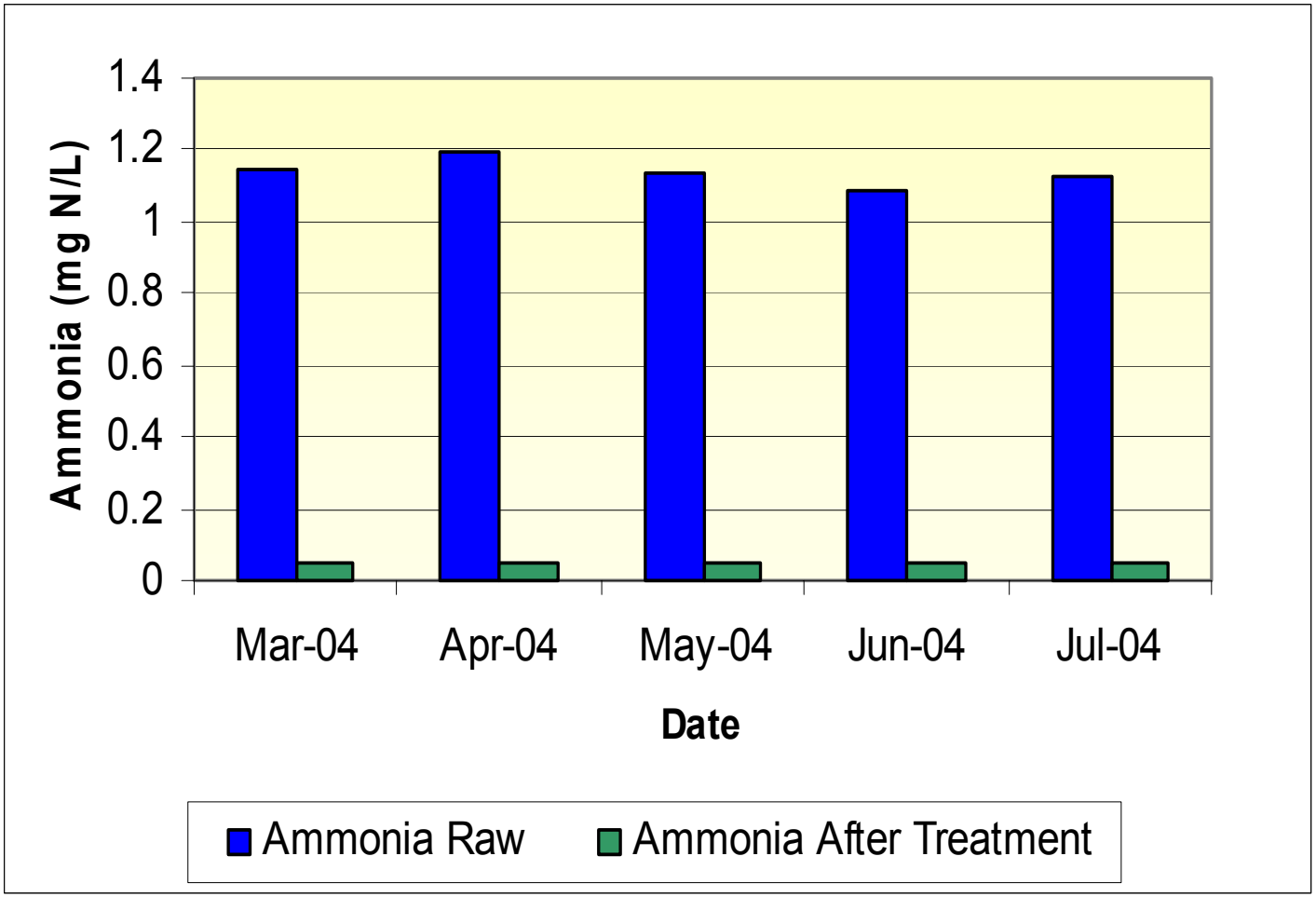
Arsenic: Particulate vs. Soluble



Greene Co. Southern Plant
Arsenic(III) vs. Arsenic(V)



Greene Co. South Plant Ammonia Concentration



Microbiological Results

Sample Description	Sample Date	HPC, Ave. CFU/mL	AOB, MPN/mL
Raw Water	12/7/2005	410	0.79
Finished Water	12/7/2005	<10	<.09
Filter Media	12/7/2005	45,333	2,900
Backwash Solids	12/7/2005	65,667	270

- **Total heterotrophic counts were by SM 9215 C Using R2A media and incubation at 22°C for 7days.**
- **Ammonia oxidizing bacteria were enunumerated based upon nitrite/nitrate detection following 30 days incubation at 28°C in Soriano-Walker media using most probable number estimates using 10 tubes/dilution**

Key Conclusions/Observations

- More than half (28 μg/L) of the arsenic entering filter is soluble
- More than half (23 μg/L) of the arsenic entering the filter is in As(III) form
- Unexpected and unexplained removal of arsenic through filter
- As(V) dominates filter effluent
- Complete nitrification takes place in filter

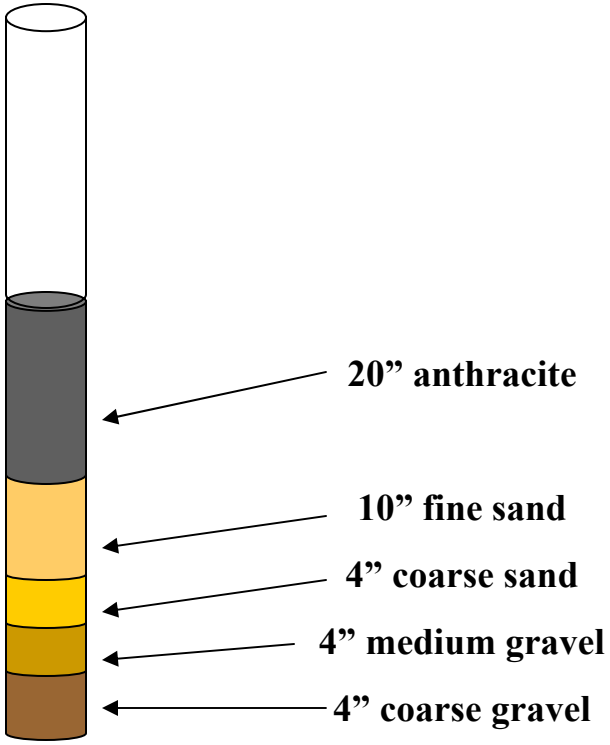
Question?

- How will replacing existing filter media impact arsenic removal and ammonia oxidation?
- What is the best way to bring new filters on-line to achieve previous biological activity?

Pilot-scale Filter Study

Methods and Materials

Six 8 ft tall, 2 in. ID glass gravity filtration columns



Methods and Materials (cont.)

- Loading rate = 2 gpm / ft^2, identical to full scale plant
- Backwashed for 15 minutes at 50% bed expansion, twice weekly
- Sampled weekly for ammonia (NH_3), nitrate (NO_3), and arsenic (As)
- Measured pH, DO, temperature weekly

Column Seeding

- **Columns 1-2 : Control Columns**

  Continuously ran aerated water through columns at loading rate of 2 GPM / ft^2 for 48 hrs

- **Columns 3-4 : Media Columns**

  Removed 3” anthracite from top of column

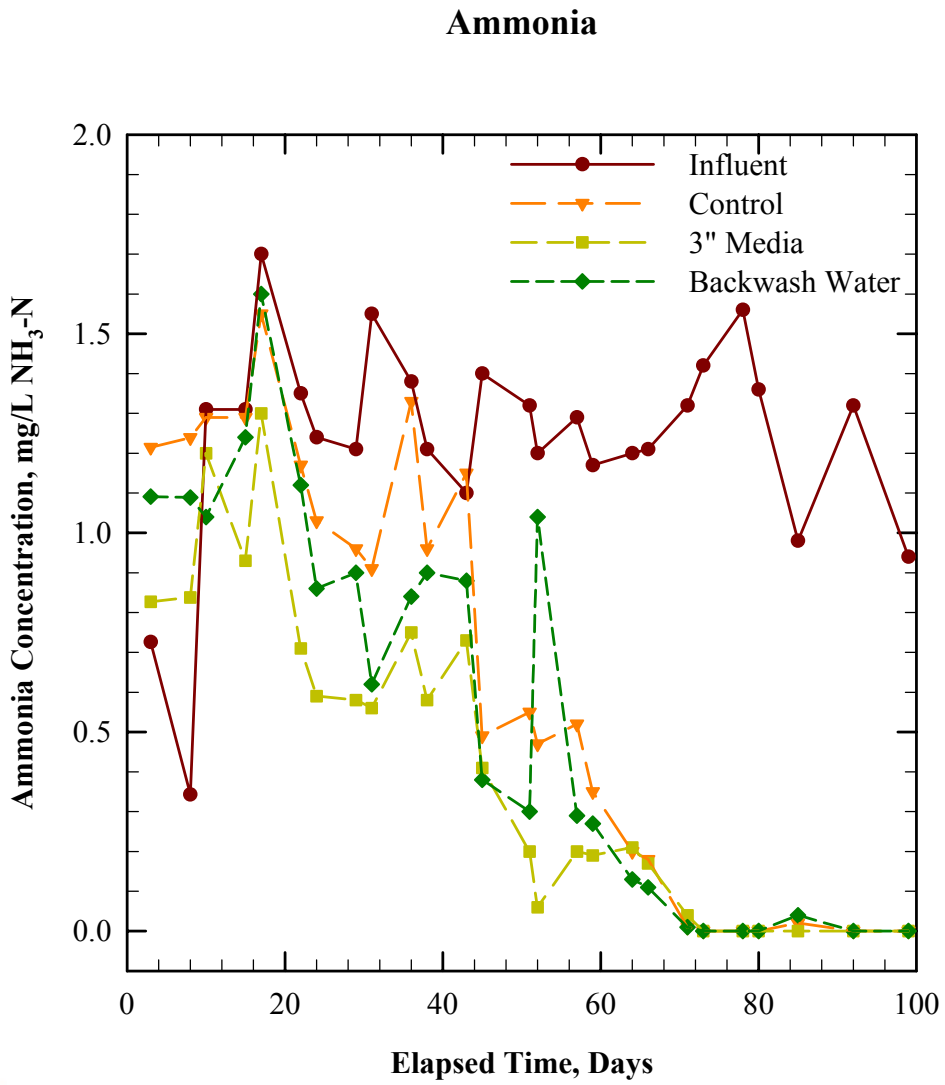
  replaced with 3” of media from #3 filter which was collected during backwashing

- **Columns 5-6 : Backwash Columns**

  Ran backwash water containing solids through columns at loading rate of

  2 GPM / ft^2 for 48 hrs

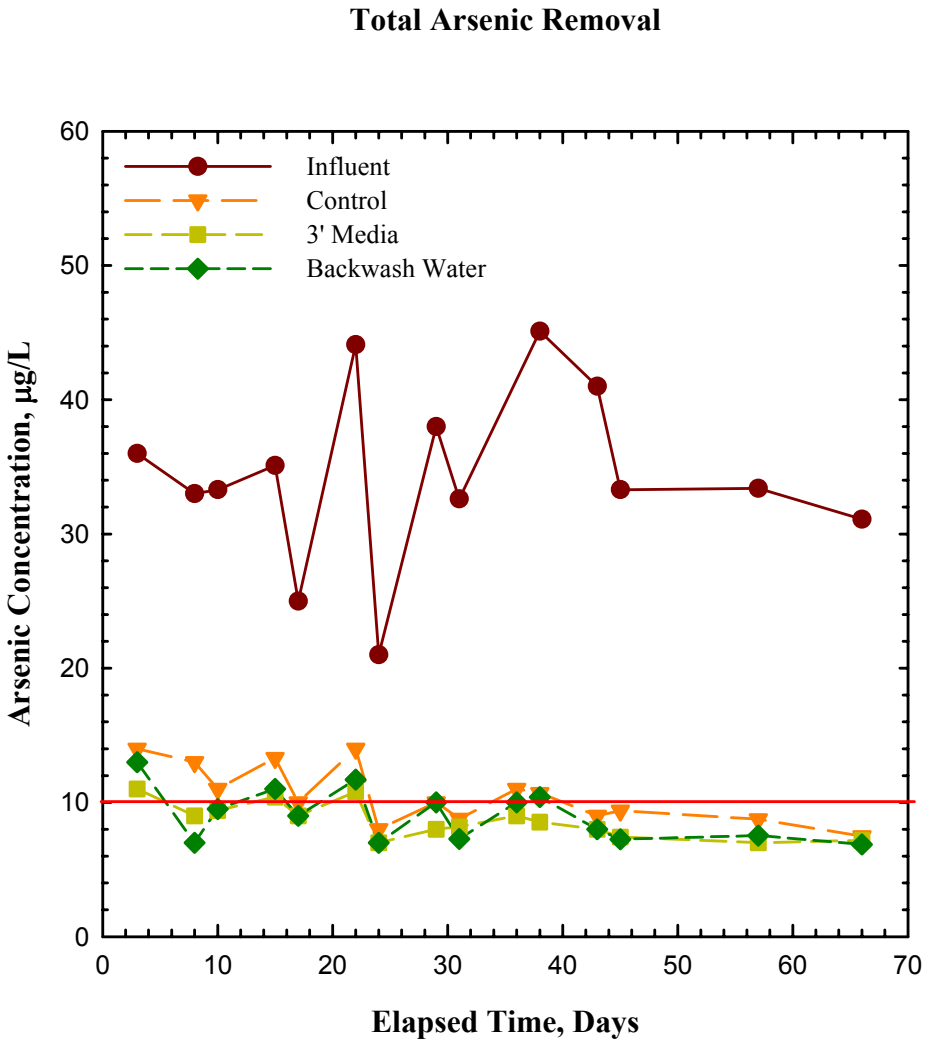
Ammonia Levels During Piloting



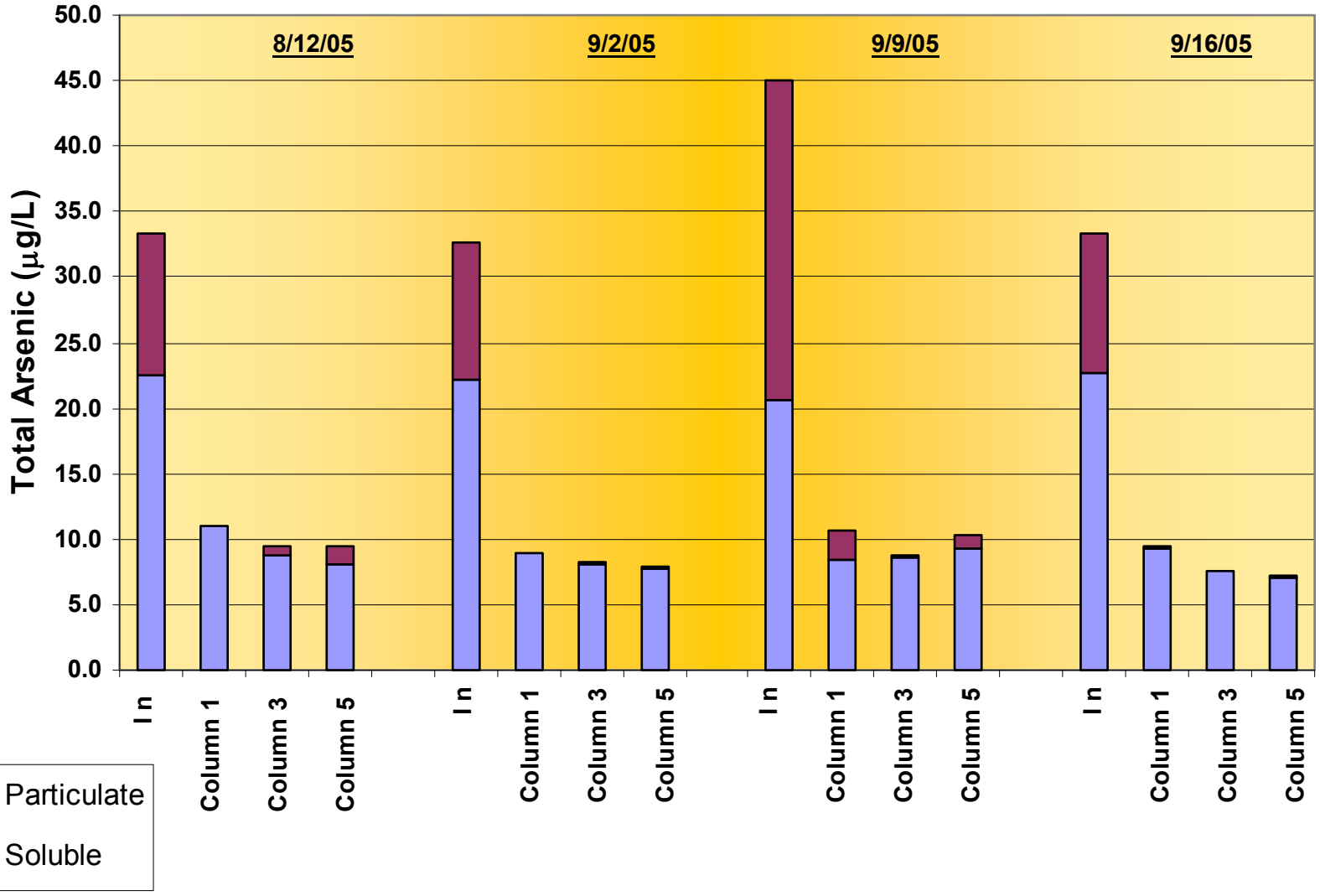
Key Conclusions - Ammonia

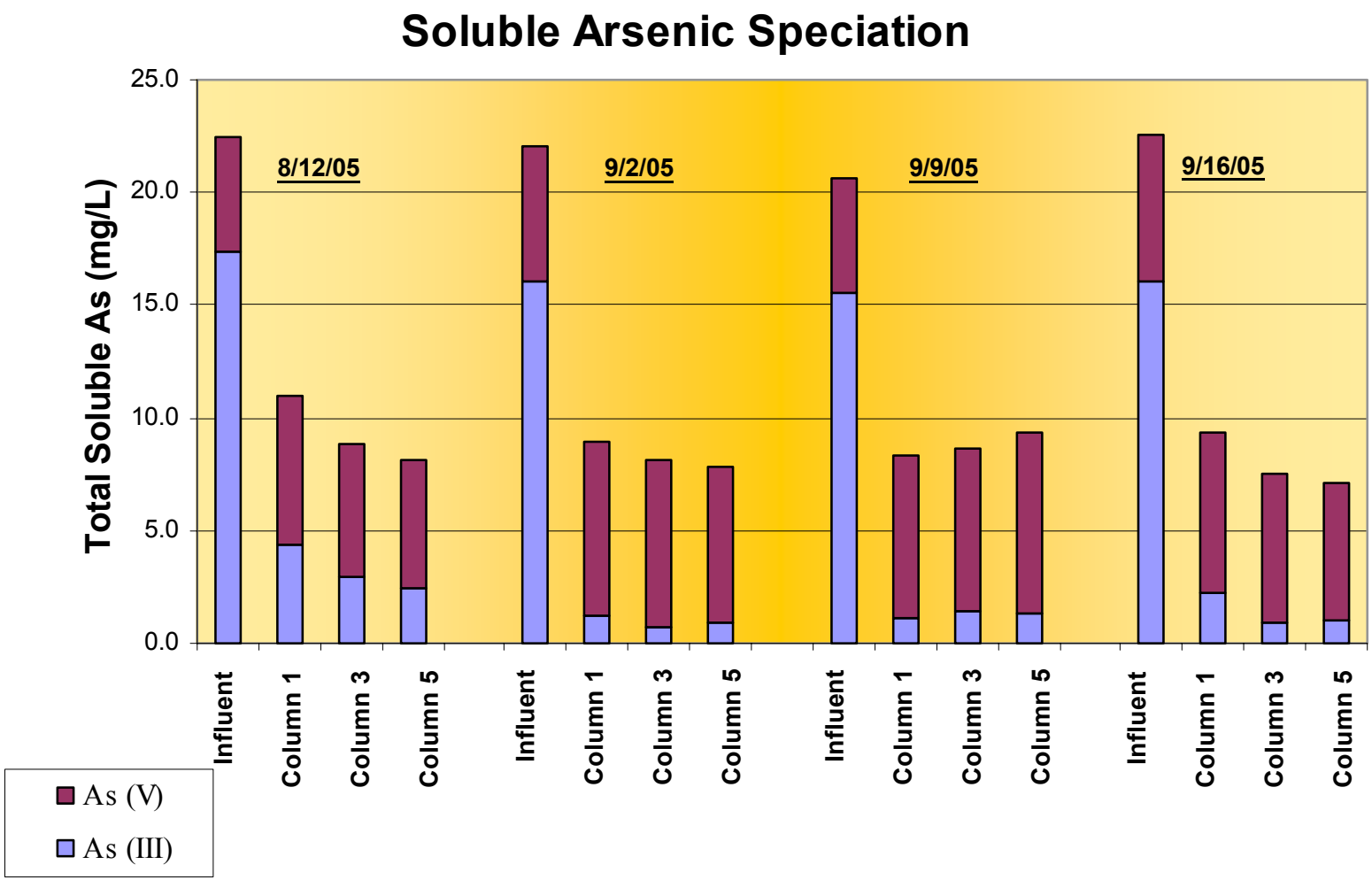
- Microbiological accumulation and complete nitrification ($NH_3 \rightarrow NO_3$) was achieved in all pilot filters by 71 days
- No significant difference between methods of seeding columns

Arsenic Levels During Piloting



Arsenic: Particulate vs. Soluble




Soluble Arsenic Speciation
Total Soluble As (mg/L)
25.0
20.0
15.0
10.0
5.0
0.0
8/12/05
9/2/05
9/9/05
9/16/05
Influent
Column 1
Column 3
Column 5
As (V)
As (III)

Key Conclusions - Arsenic

- Significant oxidation of As (III) to As (V) occurs during filtration (greater than 80% of soluble As (III)) shortly after start-up
- Filtration removes greater than 75% of total arsenic (presumably by iron adsorption of As (V)
- Residual arsenic is predominantly in the form of soluble As (V)
- Iron was effectively removed by pilot system at start-up

Conclusions

- Greene Co. South Plant achieves very good arsenic removal- meets MCL
- Removal efficiency is not predicted by typical arsenic removal mechanisms
- Microbiological filters enhance arsenic removal
- Results suggest that there are sufficient nitrifying bacteria present in raw water to achieve biologically active filters within 71 days at pilot scale
- It is important to note that biological nitrification is temperature-sensitive and becomes much less efficient at temperatures below 10 degrees C (Andersson et al)