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Simultaneous Removal of Arsenic, Iron, Ammonia and Manganese by Biological Water Treatment

Water Supply and Water Resources Division
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Team

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Multiple Contaminant Ground Water Sources

- Reflect source water characteristics, local geology, agricultural practices, etc.
- Can complicate drinking water treatment options
  - One treatment typically does not treat all contaminants
  - Multiple treatment stages/process may be necessary
  - Can be expensive capital and O&M costs
  - Complexity
  - Residuals disposal concerns
- Impacts small water systems

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Multiple Contaminant Ground Water Scenario

- Ammonia
  - Can impact some treatment processes, nitrification in the DS
- Iron
  - 0.3 mg/L SMCL
  - Staining, red water, may accumulate contaminants
- Manganese
  - 0.05 mg/L SMCL
  - Staining, black/brown water
- Arsenic
  - 0.010 mg/L MCL
  - Known health implications

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Ammonia Treatment Options

- Monochloramine formation (difficult to manage)
- Breakpoint chlorination (DBP concerns)
- *Biological treatment*
- Others: ion exchange, reverse osmosis, and chemical oxidation

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Iron and Manganese Treatment

- Iron (Fe^{2+}) and manganese (Mn^{2+}) are typically forms when present indicative of reducing source waters
- Reduced forms are soluble and can be removed by some approaches (e.g., ion exchange)
- More commonly, oxidation followed by filtration is the preferred treatment strategy
  - Oxygen effective for iron
  - Strong oxidants (e.g., permanganate, ozone, chlorine/manganes coated media) for iron and manganese
  - *Biological treatment (oxidation)*

Arsenic Treatment

- As (V) more effectively removed than As (III) by most treatment technologies
- As (III) must be oxidized a strong oxidant: free chlorine, permanganate, ozone
- Iron coagulation, removal and adsorption; anion exchange
- *Biological treatment*
- Arsenic oxidizing bacteria have been reported extensively in the literature:
  - Agrobacterium, Alcaligenes, Bacillus, Micrococcus, Hydrogenophaga, Herminiimonas, Rhizobium
  - Primary sources of isolation include acid mine drainage, hot springs, and arsenic polluted soil
  - Lytle *et al.* (2007) reported a full-scale treatment plant in Ohio that regularly met the arsenic MCL

Objective

Evaluate an innovative biological treatment approach to remove ammonia, arsenic, manganese and iron from a ground water at a small system in Iowa during a year long pilot study.

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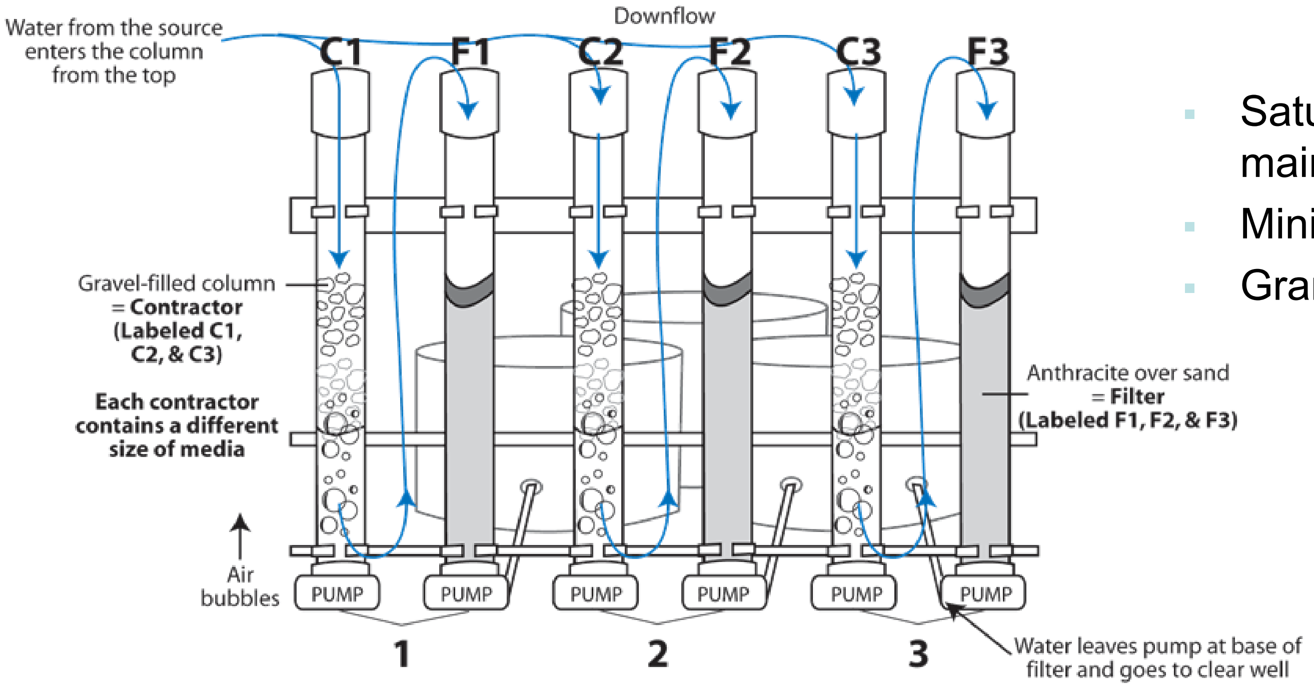
Source Water Quality

Parameter	Raw
Arsenic	23 μg/L
Alkalinity	410 mg $CaCO_3$/L
Fe	2.91 mg/L
Mn	0.08 mg/L
P	0.32 mg/L
TOC	2.68 mg/L
S	0.12 mg/L
Cl^-	7.4 mg/L
Mg	26.30 mg/L
NH_4	2.91 mg-N/L
NO_2	0.01 mg-N/L
NO_3	0.02 mg-N/L
PO_4	0.43 mg PO_4/L
pH	7.63
Temp °C	13.3

Pilot Study – Gilbert, IA

- Two-stage treatment approach:
  - *Aeration contactor-* biological support, oxidation of ammonia, iron, manganese and arsenic, sorption of arsenic to iron
  - *Conventional dual granular media filtration-* additional oxidation and sorption, particle removal.
- Saturated oxygen levels maintained throughout contactor
- Contactor requires minimal backwashing
- Only chemical feed is phosphate (0.3 mg PO_4/L).

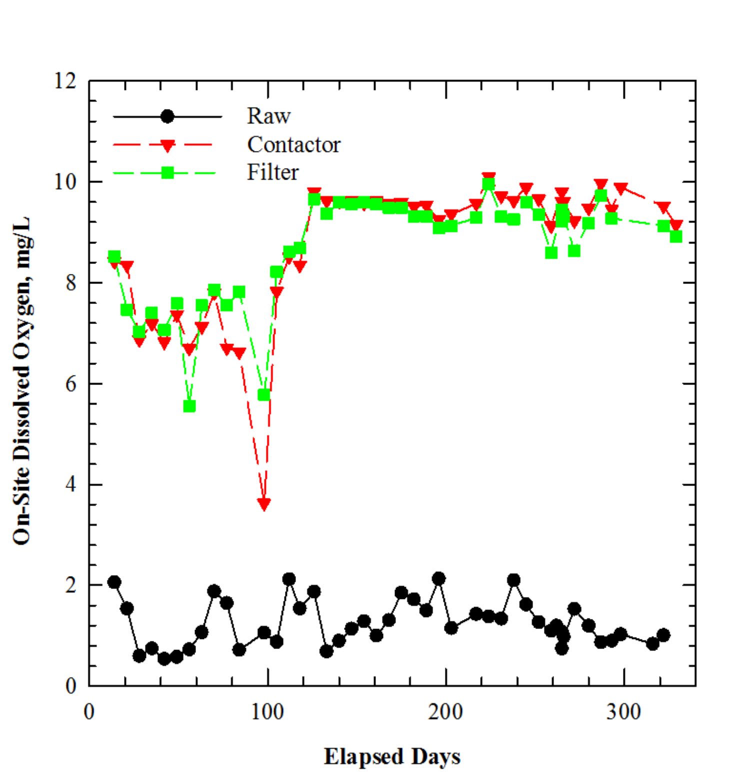
Aeration Contactor Configuration

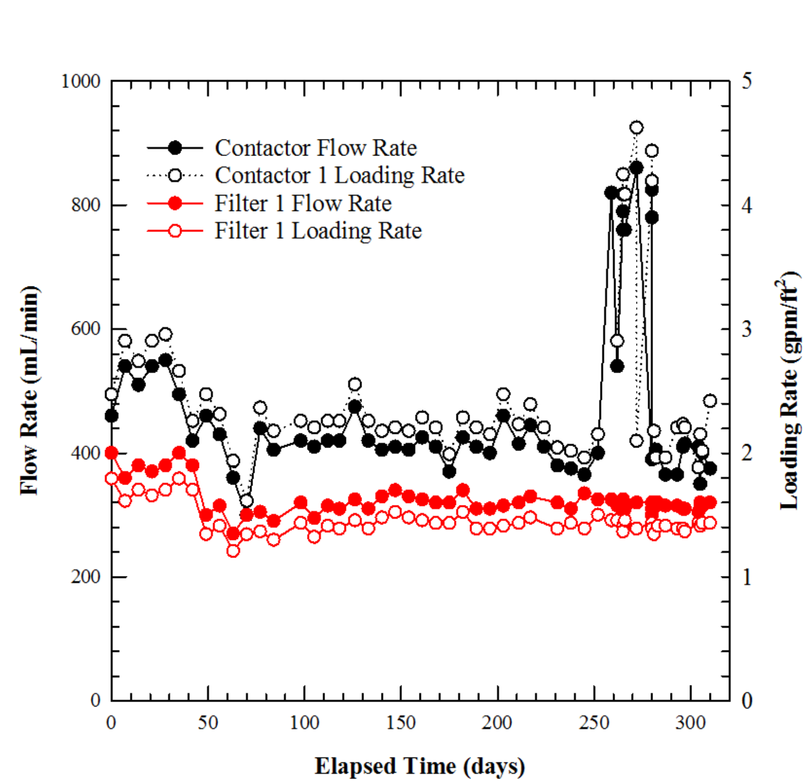


- Saturated oxygen levels maintained throughout contactor
- Minimal backwashing needs
- Granular filter follows in series

Important Operating Conditions

Oxygen and Hydraulic Loading Rate





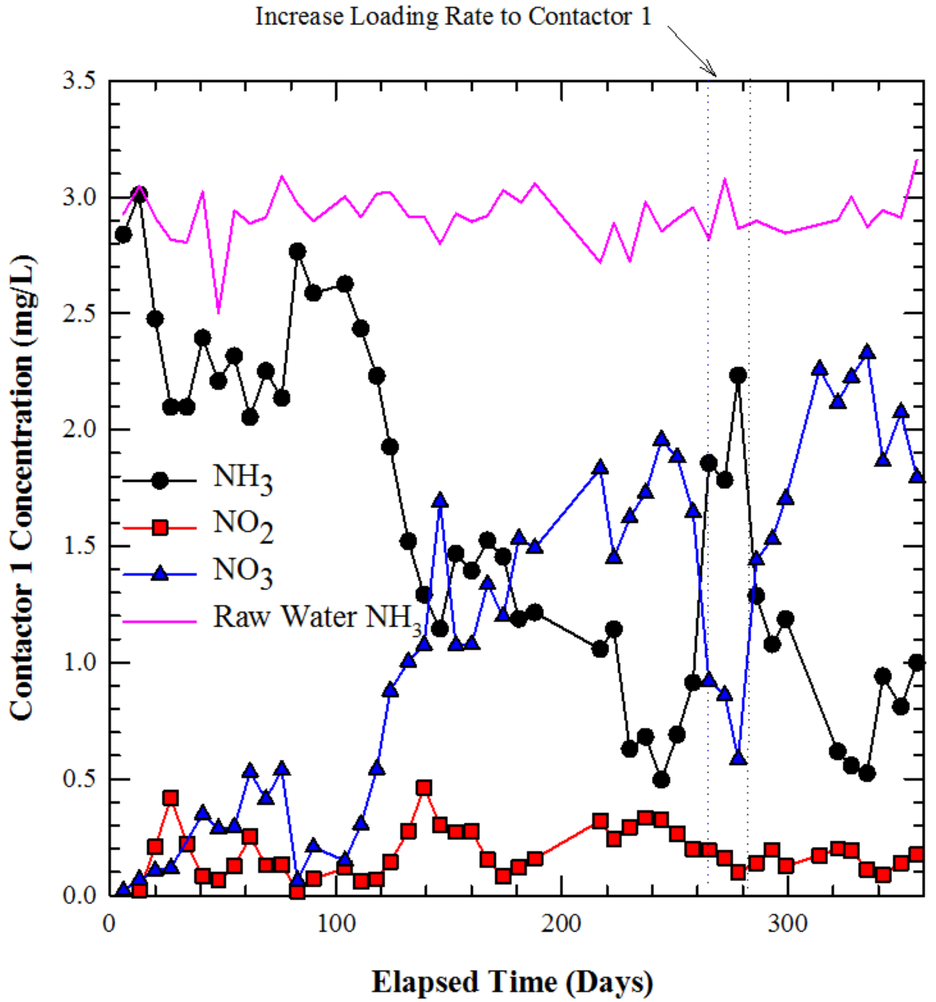
<u>Final Design LR</u>

Contactor: 2.2 gpm/ft^2

Filter: 1.8 gpm/ft^2

Ammonia, Nitrite and Nitrate

Contactor 1

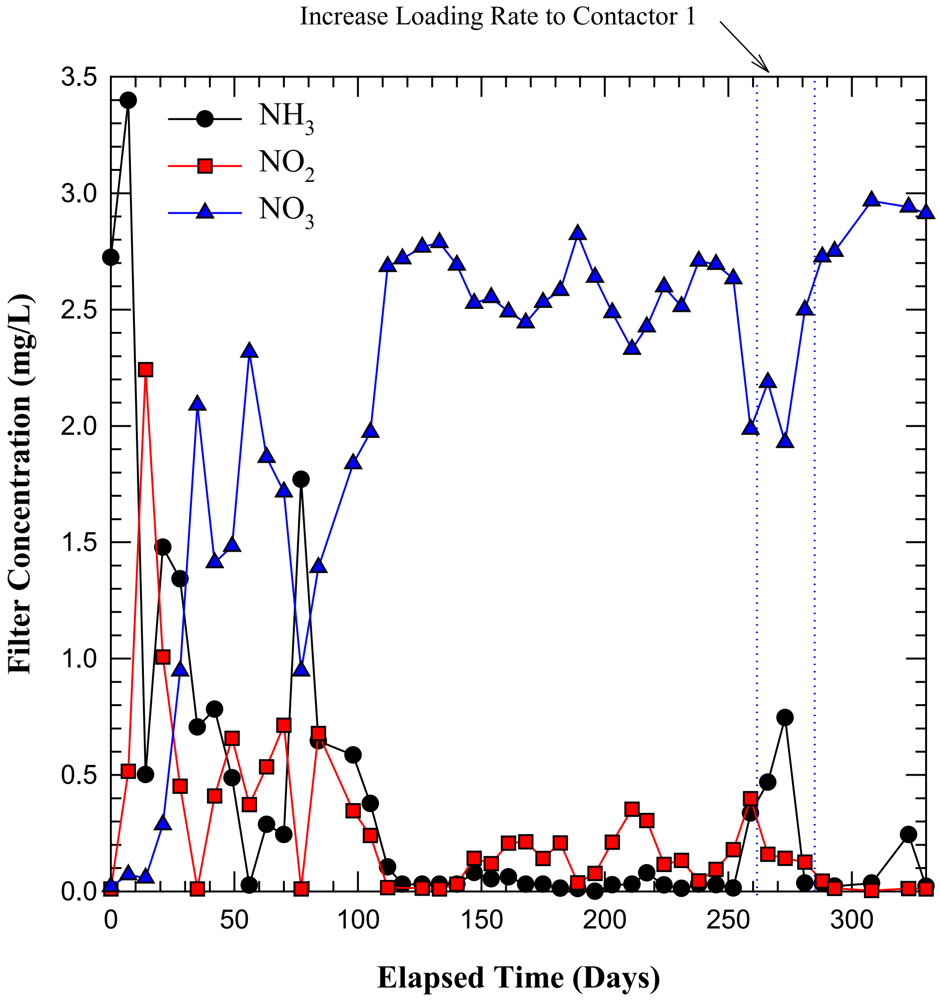


Flow: co-current (water/air)
Bed Depth: 55 inch
Media: 0.5 inch diameter
Air Flow: 2.5 L/min
Backwash: monthly, 5 minutes at 50 gpm/ft^2
Operation: <8 hors/day, 5 days/week

Medium gravel C1

50 mm

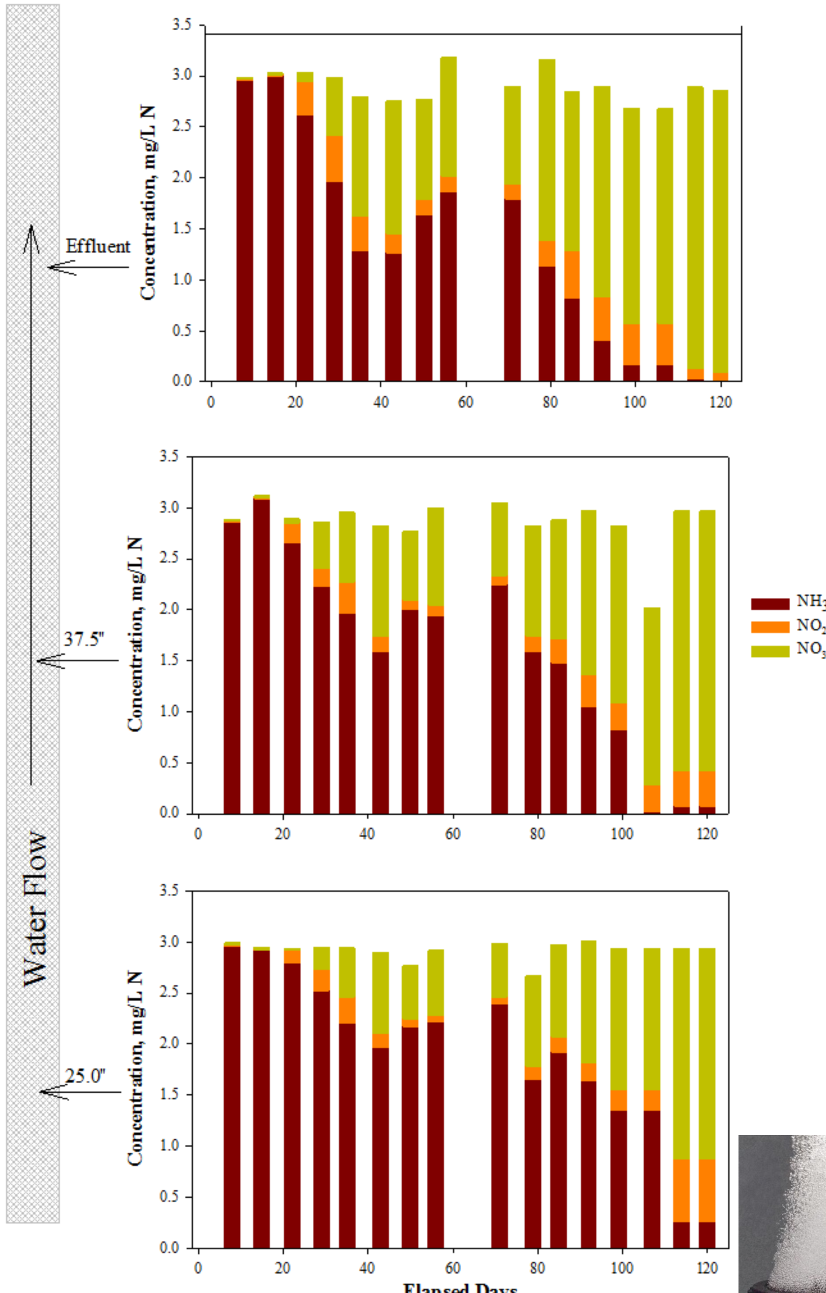
Ammonia, Nitrite and Nitrate Filter



Bed Depth: 40 inches
Media: 10 inches anthracite over 30 inches of ADGS silica sand
Backwash: every 24 hours of operation

Ammonia, Nitrite and Nitrate

Contactor 2

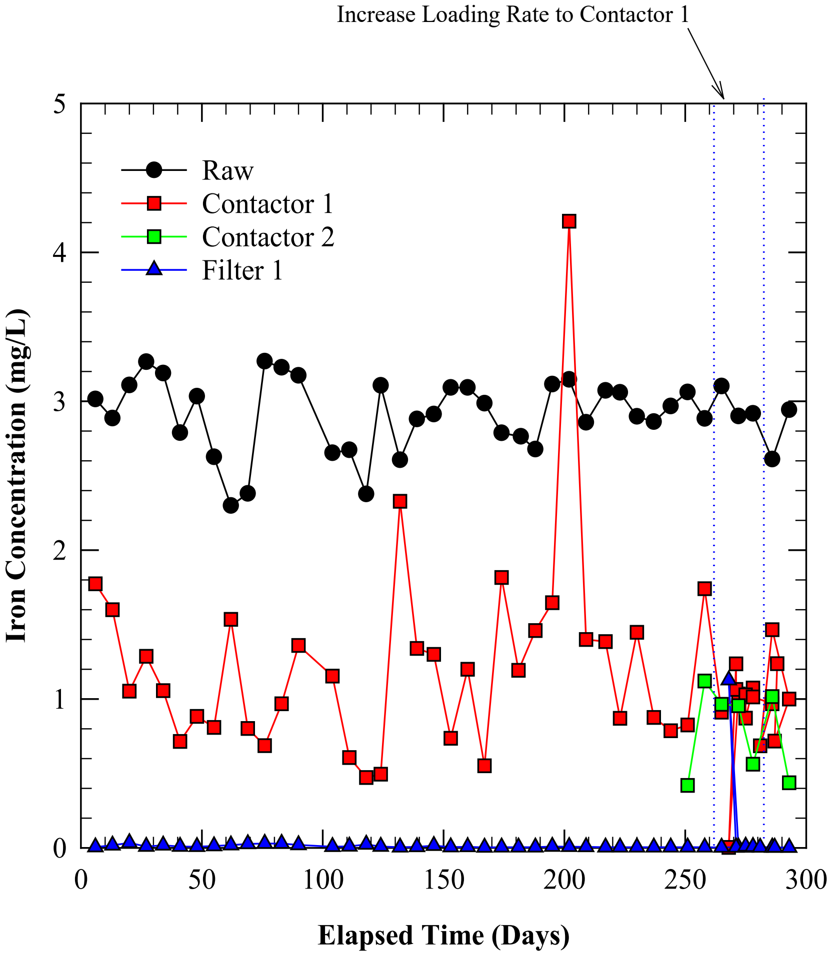


Flow: co-current
Bed Depth: 55 inch
Media: 0.25 inch diameter
Air Flow: 2.5 L/min
Backwash: monthly, 5 minutes at 50 gpm/ft^2

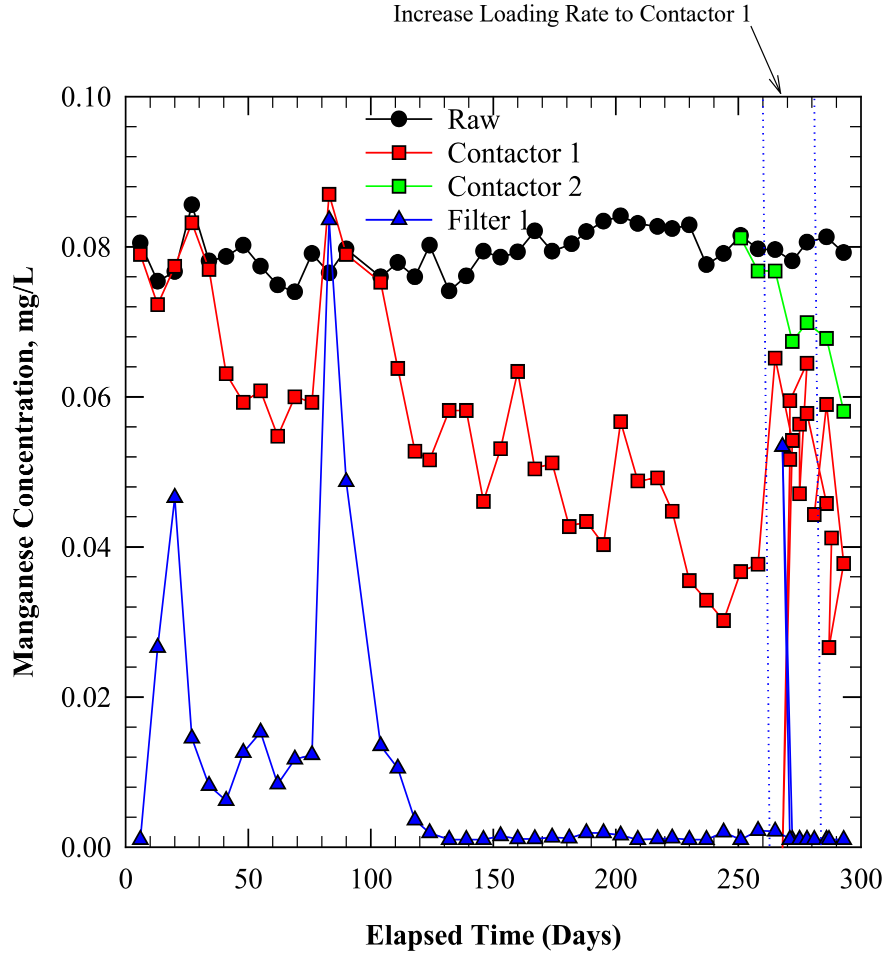
Small gravel
C2

Iron and Manganese Removal

Contactor 1 and 2, Filter



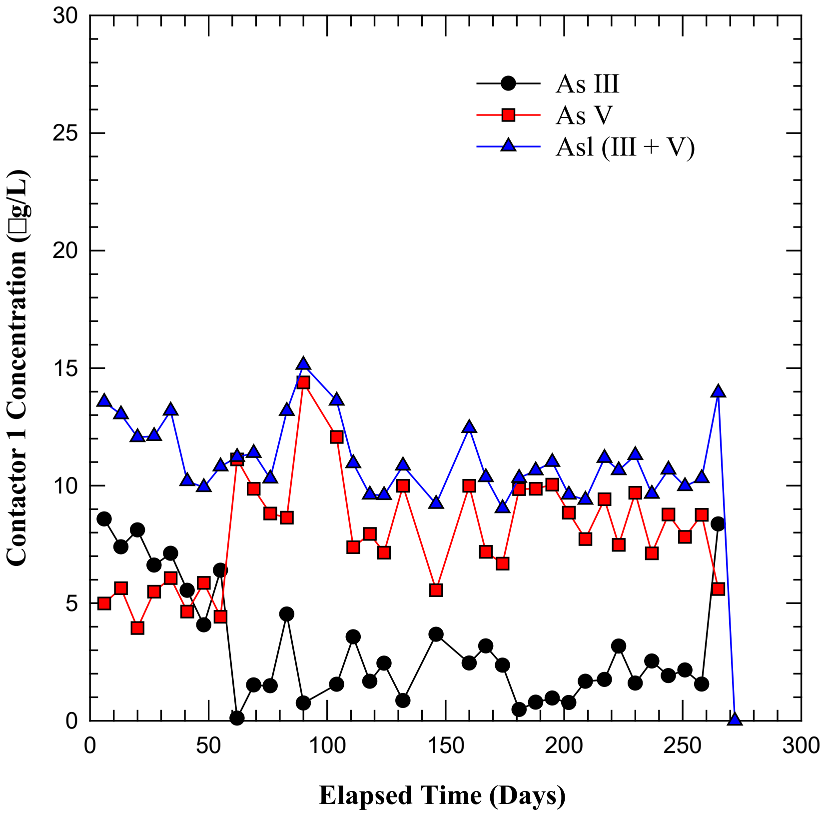
Iron: SMCL 0.3 mg/L

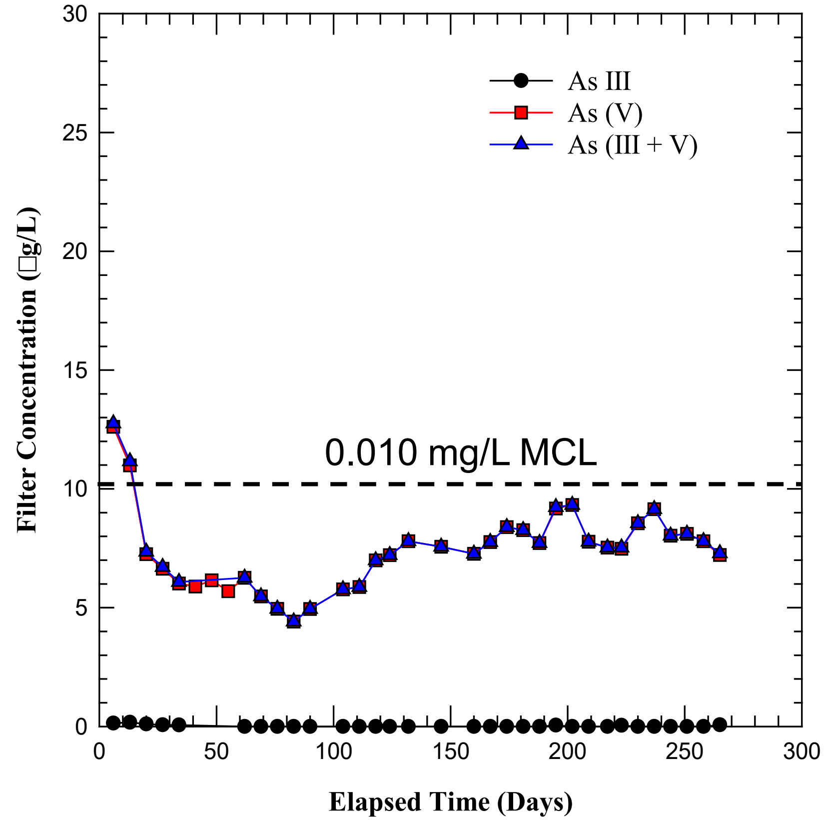


Manganese: SMCL 0.05 mg/L

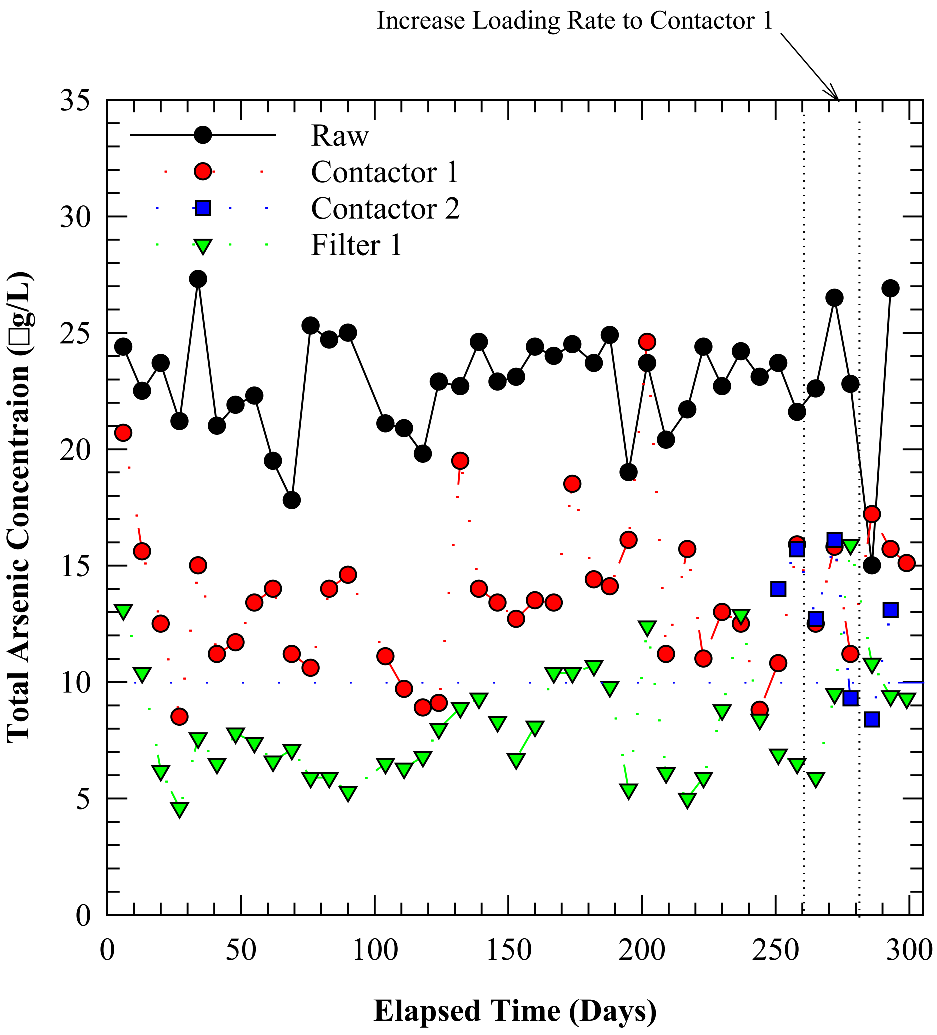
Dissolved Arsenic (III) and (V)

Contactor 1 and Filter

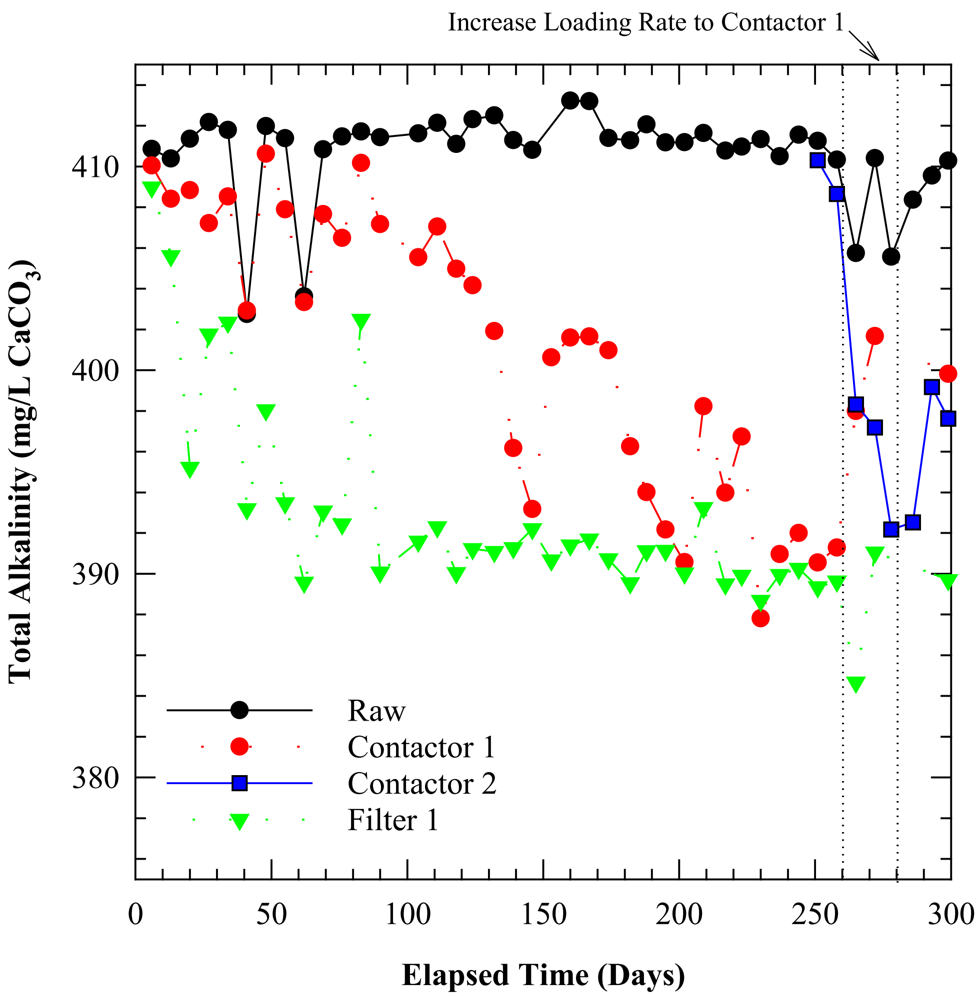




Total Arsenic
Contactor 1 and Filter



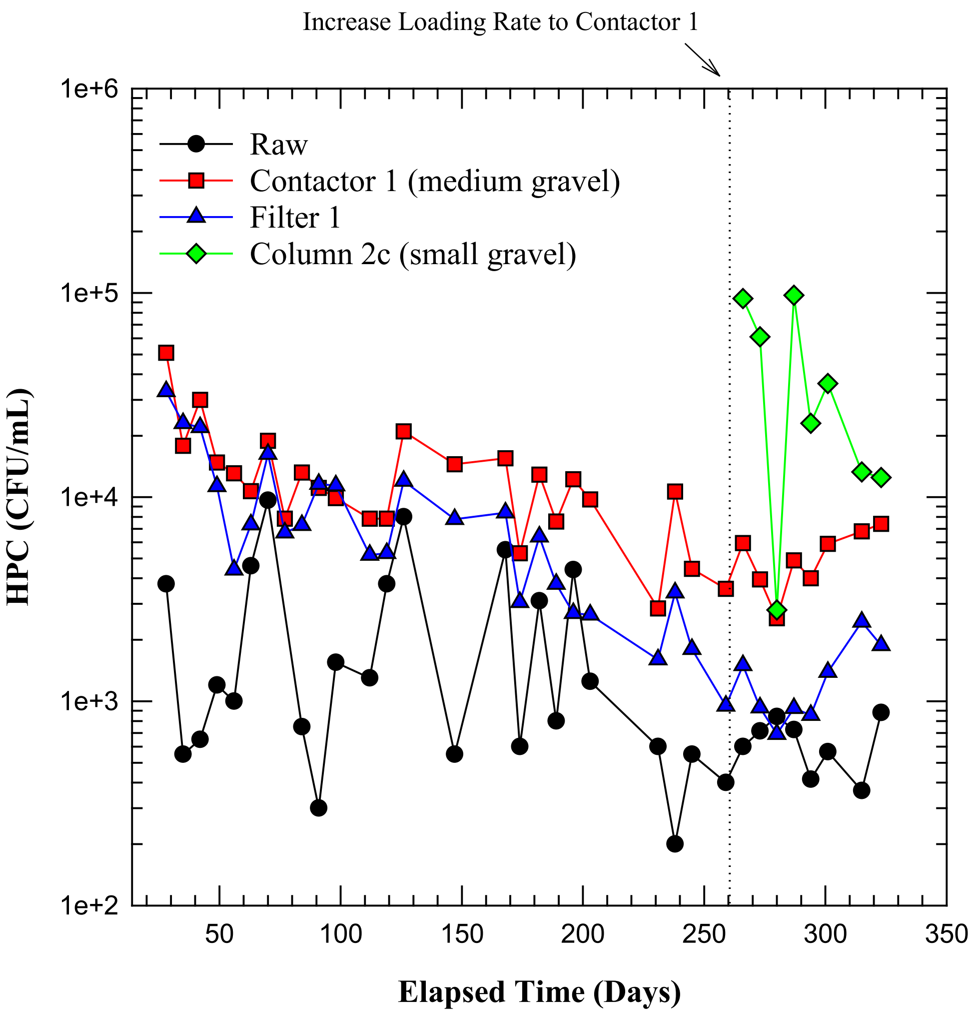
Total Alkalinity
Contactor 1 and Filter



7.1 mg $CaCO_3$/L consumed per 1 mg N/L ammonia

Heterotrophic Plate Counts (HPCs)

Contactor 1 and Filter



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Conclusions

- Arsenic, iron and manganese have primary or secondary MCLs. Ammonia is not regulated, but can cause problems in distribution systems
- Aerobic biological treatment can be relatively simple approach and was shown to remove multiple contaminants (ammonia, Fe, Mn, As).
- Media size, loading rate, nutrient addition, and oxygen levels are important design factors
- Biological aerobic treatment was robust
- Biological aerobic treatment is a viable and cost effective treatment technology that can be suitable for small systems

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Notice

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Questions?

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