# *Small Drinking Water Treatment Technologies for Compliance with the Enhanced Surface Water Treatment Rules*

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**Region 9 Product Expo**

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# Today's Presentation

- Small Systems Overview
- Bag/Cartridge Filter Background
- Bag/Cartridge Filter Studies
- Bag Filter Field Studies
- LT1 and LT2 ESWTR Overview
- Arsenic Demonstration Program
- Future Small Systems Research

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## Small Systems Overview

160,000 Small Community and Non-Community Drinking Water Systems

- 50,000 Community
- 110,000 Non-Community Systems
- Account for 68 million people
- Serving transient and non-transient populations of 10,000 people or less

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# Small Systems Overview

Small Systems (FY2003) contribute to:

- 94% of the Safe Drinking Water Act Amendment violations
- Health-Based Violations
  - 77% Maximum Contaminant Level
  - 23% Treatment Technique

EPA remains focused on improving small system compliance

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# U.S. EPA Test & Evaluation Facility


**EPA's Small Systems Research Center**

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## Small Systems Research U.S. EPA T&E Facility

Current Drinking Water Research

- Filtration
- Disinfection
- Advanced Oxidation
- Point-of-Use
- Water Reuse
- Remote Telemetry
- Distribution Systems
- International Collaborations

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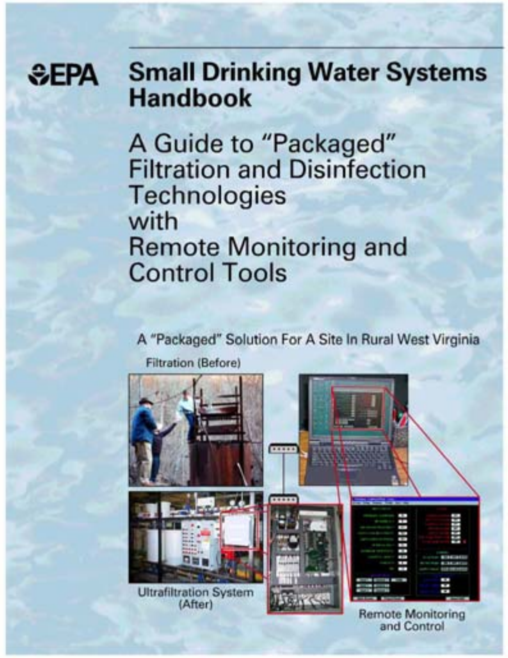

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# Further Information

**Upload "Small Drinking Water Systems Handbook" at the following web address:**

**http://www.epa.gov/ORD/NRMRL/Pubs/600R03041/600R03041.pdf**

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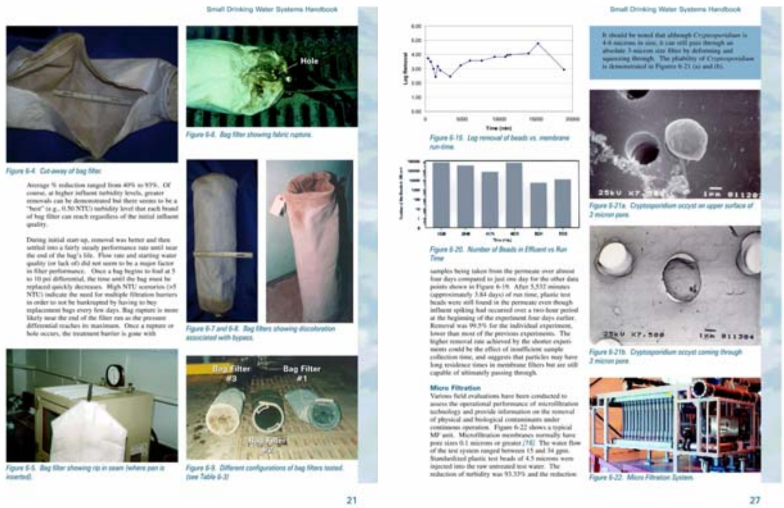
# Small Systems Handbook



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## *Cryptosporidium Oocysts*

*Cryptosporidium oocyst* on upper surface of a 3 µm pore

*Cryposporidium oocyst* coming through a 3 µm pore

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# Crypto Method 1623 Costs

| Additional Equipment/Supplies Required for Method 1623 | Startup Costs ($) |
|---|---|
| Sampling and Sample Processing | $5,700 |
| ImmunoMagnetic Separation | $1,600 |
| Chemicals | $900 |
| Total | $8,100 |

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# *Comparison of Bead Removal with Crypto Removal*

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Beads provide a surrogate that is more difficult to remove than *Cryptosporidium*

| **Bag Filter** | **PSL Beads Log Removal** | ***Crypto* Log Removal** |
|---|---|---|
| Strainrite GBP1-2SB | 1.3 | 1.41 |
| 3M 523A | 2.1 | 3.4 |
| Strainrite SWT1P + HPM97-CC-2SS | 1.92 | 2.7 |

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# Summary of Results
# Bag and Cartridge Filter Studies Conducted at the T&E Facility in Cincinnati, Ohio

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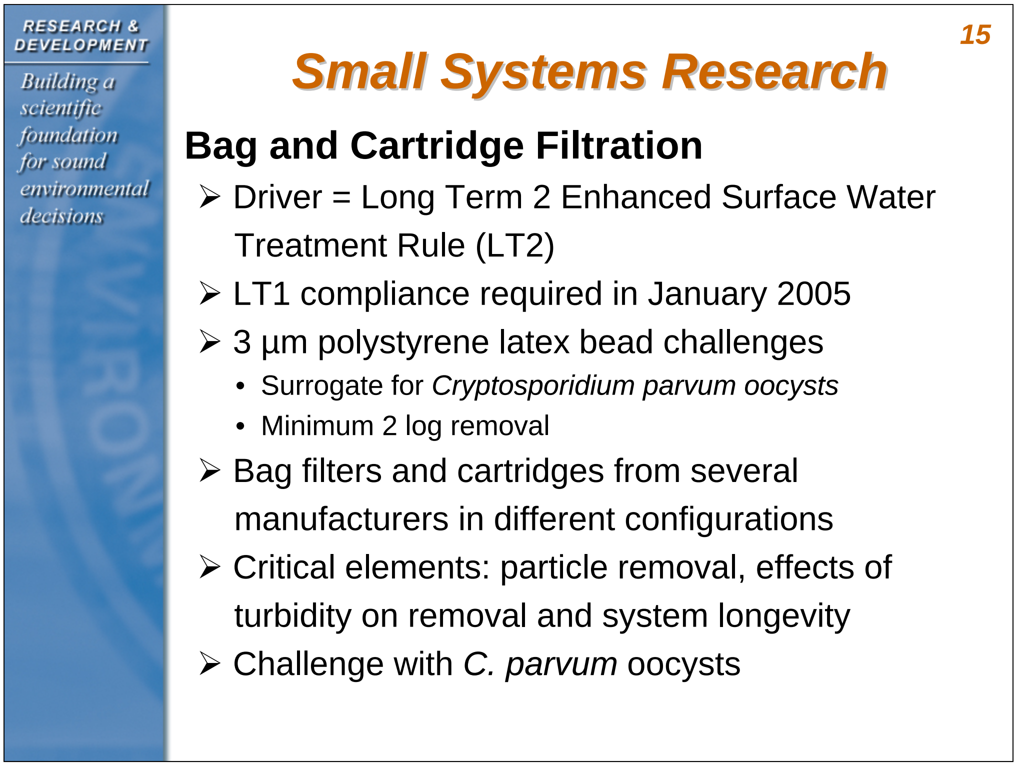
## Disclaimer

**Mention of trade names or commercial products in this presentation does not constitute an endorsement or recommendation for use**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Small Systems Research
Bag and Cartridge Filtration
➢ Driver = Long Term 2 Enhanced Surface Water Treatment Rule (LT2)
➢ LT1 compliance required in January 2005
➢ 3 µm polystyrene latex bead challenges
• Surrogate for *Cryptosporidium parvum oocysts*
• Minimum 2 log removal
➢ Bag filters and cartridges from several manufacturers in different configurations
➢ Critical elements: particle removal, effects of turbidity on removal and system longevity
➢ Challenge with *C. parvum* oocysts

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# Bag, Cartridge, and Ceramic Filtration Research Systems

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# History of Bag and Cartridge Filter Research at T&E Facility

| Years | Filter Configuration | Turbidity | Particle Size Range | Bead Size |
|---|---|---|---|---|
| 1994-1998 | Individual Bags/Cartridges | 0.5-10 ntu | Mass Loading | None |
| 2000-2002 | Individual & In-Series Filters | 0-2 ntu | 3-7 µm | 4.5 µm |
| 2002-2003 | Prefilter + 1 µm Filters | 0-2 ntu<br>0-1 ntu | 1-5 µm | 3 µm |
| 2004 | Prefilter + 1 µm + 1 µm Filters | 0-1 ntu<br>0-5 ntu | 1-5 µm | 3 µm |

# Comparison of Small System Technology Costs

| Technology | Purchase Price | Filter Replacement Cost | Expected Filter Life |
|---|---|---|---|
| Bag Filter (In-Series) | $4,000 | $10-$100 | hrs/days/wks |
| Cartridge Filter (In-Series) | $4,500 | $100-$600 | hrs/days/wks |
| UF Filter | $50,000 | $5,000 | up to 3 years |

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# 5000 Gallon Tank for Turbidity Control Using a Mixture of Mill Creek and Tap Water


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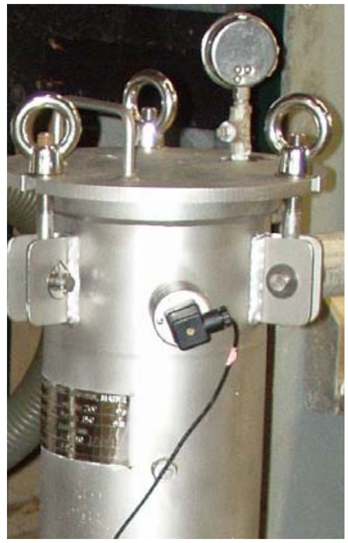
# Automated Turbidity and Differential Pressure Sensors for Shutdown at Startup, Intermediate, and Terminal Pressure Drop

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# Bag and Cartridge Filter In-Series Automation Costs



| Technology with Datalogging | Pressure and Flow Automation ($) |
|---|---|
| Paperless Chart Recorder | $2,700 |
| Pressure Transducers (3) | $800 |
| Magmeter for Flow Rate | $3,700 |
| Total | $7,200 |

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## *Automated In-Line Particle Counting*

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## Bead Study Injection and Filter Manifold

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# Bag and Cartridge Filter System Pretreatment Options

- Frequency of filter replacement depends on
  - Turbidity levels
  - Nature of turbidity
- Pretreatment may be necessary
  - At turbidities > 1 ntu
  - To reduce filter replacement costs
- Pretreatment options include
  - Settling basins
  - Backwashed pressure sand filters
  - Diatomaceous earth filters
  - Cartridge prefilters
  - Bag prefilters

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# Optimum System Configurations for Crypto Removal

- Depends on:
  - Source water quality
  - Preliminary test results
- Typically:
  - Pretreatment provides gross particulate removal
  - Filters are configured with progressively finer micron ratings with 1 µm absolute filters at the end of the treatment train
  - Cartridge filters (1 µm) are placed after bag filters (1 µm) to protect cartridge filter life and reduce costs

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# Advantages of Filters In-Series

Filters in-series (two 1 µm filters):

- Guard against short circuiting
- Provide a secondary barrier in case of filter splitting, bursting or rupture

A 5 µm prefilter with two 1 µm filters in-series

- Increases system longevity
- Results in higher initial cost, but lower operating cost

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## Comparison of Filters In-Series and Individual Filters

- Adding filters in-series marginally increases removal
- Removal efficiency based on smallest micron rating

| Primary Housing | Secondary Housing | Beads Log Removal |
|---|---|---|
| 3M 525A | 3M 525A | 1.18 |
| 3M 525A | 3M 522A | 2.90 |
| 3M 522A | 3M 522A | 2.86 |
| Empty | 3M 522A | 2.63 |

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# General Conclusions from T&E Results

| System Configuration | PSL Beads |
|---|---|
| Bag+Cartridge Filters | >3 Log Removal |
| Several Bag+Bag Filters (1 micron absolute) | >2.5 Log Removal |
| Cartridge-Type Filters in Bag Filter Housings | >3 Log Removal |

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# Filters that May Be Eligible for LT2 Crypto Removal Credit

| Inlet Turb. (ntu) | Primary Housing | Secondary Housing | Beads (Log Removal) |
|---|---|---|---|
| 2.5 | Rosedale bag (GLR) | Rosedale bag (GLR) | 3.6 |
| 2.5 | Rosedale bag (PS520) | Rosedale bag (GLR) | 3.36 |
| 2.5 | Rosedale bag (PS520) | Rosedale bag (PS520) | 3.49, 3.34 |
| 0.13 | Strainrite bag (SWT1P2S8T) | Strainrite bag (GBP1-2SB) in Rosedale housing | 2.98, 2.84, 2.63 |
| 0.2 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM97-CC-2SS) | 2.65, 2.70, 2.65 |
| 0.13 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM99-CGD-2SS) | 3.26, 2.55 |
| 0.12 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM99-XCGD-2SS) | 2.75, 2.57 |

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# Filters that May Be Eligible for LT2 Crypto Removal Credit

| Inlet Turb. (ntu) | Primary Housing | Secondary Housing | Beads (Log Removal) |
|---|---|---|---|
| NA | Strainrite bag (HPM99-CGD-2SS) | Strainrite bag (HPM99-XCGD-2SS) | 2.74 |
| NA | Strainrite bag (HPM99-XCGD-2SS) | Strainrite bag (HPM99-XCGD-2SS) | 2.91, 2.67 |
| 2.53 | 3M 522A in R-P Housing | 3M 522A in R-P Housing | 2.90, 2.86, 2.71 |
| 0.6-1.6 | GAF bag (1 µm nominal) | Cycron cartridge (1 µm absolute) | 4.56, 3.74, 3.28 |
| 0.1-0.2 | GAF bag (1 µm nominal) | Harmsco cartridge (1 µm absolute) | 3.43, 3.27, 3.03 |
| 0.1 | Strainrite bag (1 µm nominal) | Harmsco cartridge (1 µm absolute) | 3.94, 3.19 |

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## Bag and Cartridge Filter System Filter Longevity

Filter life is water quality dependent:

- Coatings from algae or other organic materials may reduce life
- Remaining filter life quickly diminishes after reaching the manufacturer recommended change-out pressures of from 5 to 15 psi
- Rupture typically occurs at differential pressures >25 psi

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# Examples of Filter Run Times

| Inlet Turb. (ntu) | Primary Housing | Secondary Housing | Beads Log Removal | Run Length |
|---|---|---|---|---|
| ~0.2 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM97-CC-2SS) | 2.65 | 6.4 months* |
| 0.10 | Strainrite bag (1 µm nominal) | Harmsco cartridge (1 µm absolute) | 3.94 | 61 days |
| 0.13 | Strainrite bag (SWT1P2S8T) | Strainrite bag (GBP1-2SB) in Rosedale housing | 2.98 | 49 days* |
| 0.13 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM99-CGD-2SS) | 3.26 | 34 days |
| 0.12 | Strainrite bag (SWT1P2S8T) | Strainrite bag (HPM99-XCGD-2SS) | 2.75 | 15 days |
| ~0.1 | GAF bag (1 µm nominal) | Harmsco cartridge (1 µm absolute) | 3.03 | 13 days |

*** Incomplete run***

# Examples of Filter Run Times



| Inlet Turb. (ntu) | Primary Housing | Secondary Housing | Beads Log Removal | Run Length |
|---|---|---|---|---|
| 0.2<br>0.15 | GAF bag (1 µm nominal) | Harmsco cartridge (1 µm absolute) | 3.43<br>3.27 | 15 hrs*<br>bags split |
| 2.5 | Rosedale bag (GLR) | Rosedale bag (GLR) | 3.60 | 3.6 hrs |
| 2.5 | Rosedale bag (PS520) | Rosedale bag (PS520) | 3.49 | 1.4 hrs |
| 2.5 | Rosedale bag (PS520) | Rosedale bag (GLR) | 3.36 | 32 min |
| 1.6 | GAF bag (1 µm nominal) | Cycron cartridge (1 µm absolute) | 3.74 | 32 min |
| 0.7<br>0.6 | GAF bag (1 µm nominal) | Cycron cartridge (1 µm absolute) | 4.56<br>3.28 | 34 min<br>22 min |

*** Incomplete run**

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## Bag and Cartridge Filter System Maintenance Issues

- Shelf-life impacts filter integrity
- Some filters require preconditioning
- Startup and shutdown filter systems gradually to prevent pressure surges (water hammers) from compromising filter integrity
- Avoid prolonged shutdowns to prevent algae growth

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## Bag and Cartridge Filter System Maintenance Issues

- Only use manufacturer recommended housing/filter combinations
- Use caution during filter installation to protect the fabric from scraps, tears and puncture
- Avoid crimping the bag at the top of the housing

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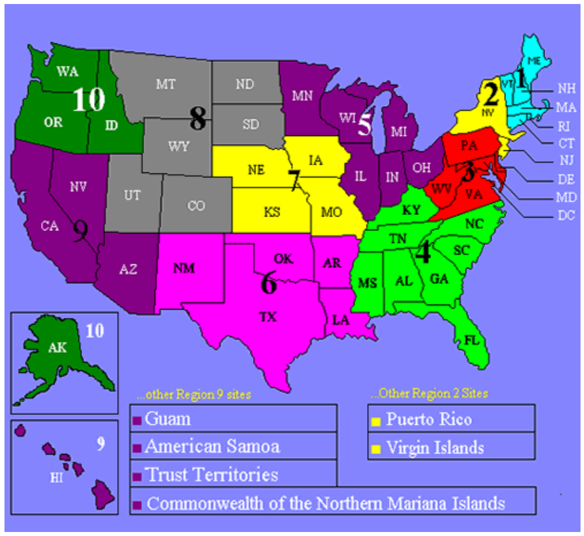
# Recent Field Studies in Support of EPA Regions 5 &10 (MN & WA)




**U.S. EPA Regions**

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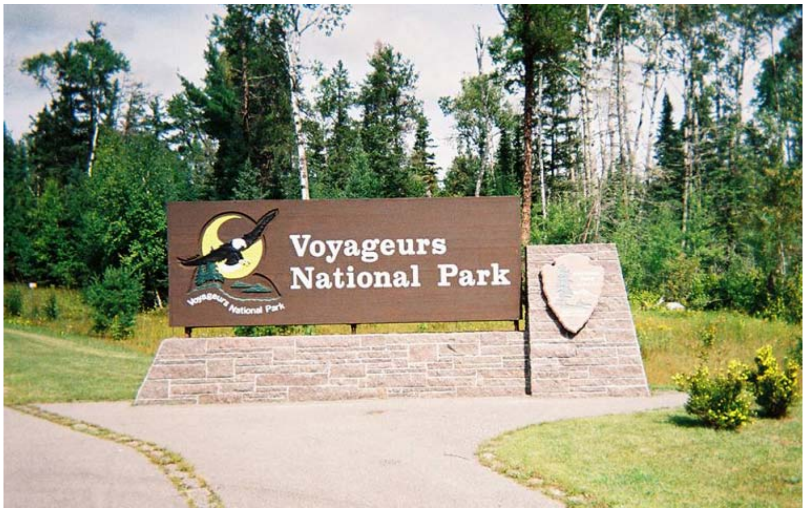
## Summary of Results
## Field Bag Filter Studies Conducted at Lake Kabetogama, MN



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# Northern Minnesota

- Lake resorts
  - Open seasonally
  - Some year round
- Source water
  - Surface (lake) water
  - Groundwater
- Bag filtration
  - 3M bags still being used in RP housings
  - 3M dropped support of 3M bag filters for drinking water purposes in 1999

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# Rocky Point Resort Treatment Plant

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# Typical Treatment Train

Lake water is typically treated as follows:

- Submersible pump in the lake
- Pressure tanks to maintain water pressure
- Prechlorination
- Pressure sand filters
- A single bag filter with 3M 522A bags
- Zenon membrane filters in some locations

# Test Apparatus

Test apparatus set up in a trailer at the Rocky Point Resort

- Resort treatment system bypassed to "load" filters for one-week study
- Two bag filter housings in series
- Bead challenge solutions, injection pump, and bead testing manifold
- Analytical equipment

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# Research Trailer with Bead Study Equipment

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# Bead Study Test Apparatus 3 micron (Crypto-Sized) Polystyrene Latex Beads

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# Summary of Lake Water Tests (Turbidity: 2 to 3 ntu)

| 3M Bag Filter 1 | 3M Bag Filter 2 | Filter Status | Beads Log Removal |
|---|---|---|---|
| 525A | 522A | Fouled | 2.03 |
| 525A | 522A | Clean | 2.34 |
| 525A | 522A | Intermediately Fouled | 2.21 |
| 525A | 522A | Fouled | 2.71 |

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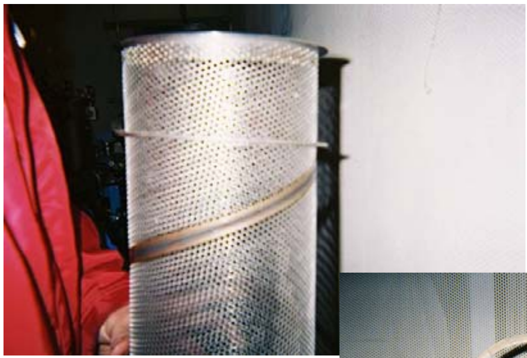
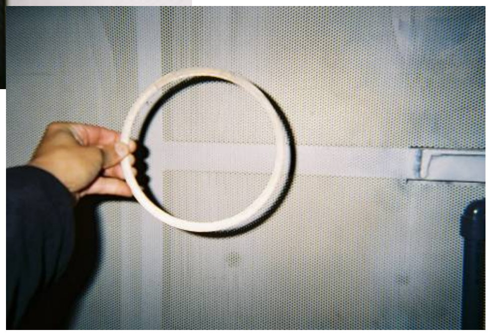
# Removal of Housing O-Ring Creates Improper Bag Filter Fit







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# Summary of Lake Water Tests without O-Ring (Turbidity: 1 to 3 ntu)

| Strainrite Bag Filter 1 | Strainrite Bag Filter 2 | Filter Status | Beads Log Removal |
|---|---|---|---|
| SWT1P2S8T | HPM99-XCGD-2SS | Clean | 0.35 |
| SWT1P2S8T | HPM99-XCGD-2SS | Fouled | 0.44 |
| SWT1P2S8T | HPM97-CC-2SS | Clean | 0.20 |
| SWT1P2S8T | HPM97-CC-2SS | Fouled | 0.00 |

# Bead Study Filters (Lake Kabetogama Water)



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# Fouled Bead Study Bag

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# Lake Water Treatment Train at Campground in MN

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# Summary of Results Bag Filter Studies Conducted at the Paradise Inn/Visitor Center in Mt. Rainier National Park, WA

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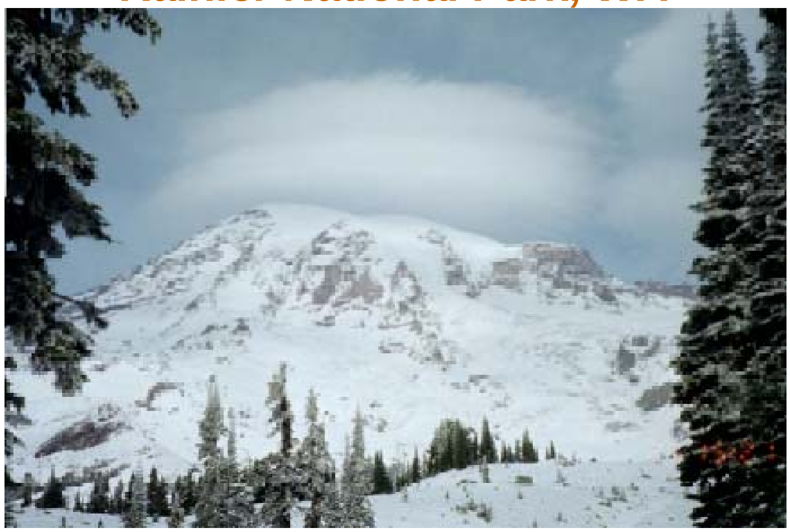

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# Bag Filter Bead Study 3 micron (Crypto-Sized) Polystyrene Latex Beads

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## Mt. Rainier National Park, Washington

- Park Drinking Water Systems
  - 9 Surface water + 2 Well water
  - 9 Seasonal + 2 Year round
- Paradise Water Treatment Plant
  - Paradise Inn
  - Jackson Visitor Center
- Longmire Water Treatment Plant
  - National Park Inn
  - Park Service Employee Village

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# Paradise Inn/Visitor Center Watershed

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# Water Supply Reservoir (2000 Feet Uphill from Plant)

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# Possible Source of *Cryptosporidium*?

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# Paradise Inn/Visitor Center Treatment Plant

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# Paradise Water Treatment Plant

- One 50 micron Cartridge Filter
- Two 5 micron Cartridge Filters (in series)
- Four 1 micron Bag Filters (in parallel)
- Post-Chlorination


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## Clear Well Storage

Pumps lift treated water to an underground storage tank for gravity feed to supply points

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# Treatment Plant Automation


- Treatment plant well equipped with turbidity meters and automation
- Operated in manual mode due to ongoing system modifications and lightning strikes

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# Bead Test Apparatus

# Bead Test Apparatus

Equipment Configuration:

- Treatment system by-pass line
- Two RP bag filter housings in-series
- Bead challenge solutions
- Injection pump
- Bead test manifold
- Analytical equipment

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# Bead Study Bag Filters Snowmelt Turbidity (0.12 ntu)

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# Mt. Rainier National Park, WA
# Bead Study Test Results

| Strainrite Bag Filter 1 | Stainrite Bag Filter 2 | Filter Status | Beads Log Removal |
|---|---|---|---|
| HPM99-CGD-2SS | HPM99-XCGD-2SS | Clean | 2.74 |
| HPM99-XCGD-2SS | HPM99-XCGD-2SS | Clean | 2.91 |
| HPM99-XCGD-2SS | HPM99-XCGD-2SS | Clean | 2.67 |
| HPM97-CC-2SS | HPM97-CC-2SS | Clean | 2.36 |

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# Mt. Rainier National Park, WA
# Bead Study Test Results

| 3M Bag Filter 1 | 3M Bag Filter 2 | Filter Status | Beads Log Removal |
|---|---|---|---|
| 525A | 525A | Clean | 1.18 |
| 525A | 522A | Clean | 2.90 |
| 522A | 522A | Clean | 2.86 |
| Empty | 522A | Clean | 2.63 |

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# Longmire Water Treatment Plant
## (Diatomaceaous Earth/Bag Filters)

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## *Longmire Water Treatment Plant (Chlorination/Aboveground Storage)*

Chlorinator with Automated Chlorine Dosage and Turbidity Chart Recorder

Above Ground Storage Tank for Treated and Disinfected Drinking Water

## Bag and Cartridge Filtration under LT1ESWTR (1/14/02)

Public drinking water systems using surface water sources and serving less than 10,000 people must comply with LT1ESWTR by January of 2005

- Establishes 2-Log (99%) *Cryptosporidium* removal
- Strengthens combined filter effluent turbidity performance standards

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# Bag and Cartridge Filtration under LT2ESWTR (12/10/04)

Bag and cartridge filters are defined in the regulation as “pressure-driven separation devices that remove particulate matter larger than 1 micron using an engineered, porous filtration media.”

LT2ESWTR establishes *Cryptosporidium* removal credit based on challenge testing

- Up to 2.0 log credit for individual filters
- Potentially higher log credits for filters in series

Note: Prefilters do not count as filters in series

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# *Bag and Cartridge Filtration under LT2ESWTR*

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To comply with LT2ESWTR, challenge tests must:

- Test full-scale housings and filters in the same configuration as the proposed plant
- Test the filters using *Cryptosporidium* or a surrogate with a maximum feed water concentration of the challenge particulate 10,000 times the detection limit of the challenge particulate in the filtrate.
  Note: Gross measurements such as turbidity may not be used

# Bag and Cartridge Filtration under LT2ESWTR

To comply with LT2ESWTR, challenge tests must:

- Be conducted at the manufacturer's maximum design flow rate
- Last for a sufficient duration to reach 100% of the terminal pressure drop

Note: Log Removal Value (LRV) = LOG10(Cf)-LOG10(Cp)
LRV is the minimum LRV observed (<=20 filter tests)
LRV is the 10th percentile of the LRV observed (>20 filter tests)

# Bag and Cartridge Filtration under LT2ESWTR



Filters must be challenged at three times during the filtration cycle:

- Within two hours of start-up of a new filter
- Between 45 and 55 percent of the terminal pressure drop
- After reaching 100 percent of the terminal pressure drop

A factor of safety is applied to challenge test results:

- 1-log for individual filters
- Potentially lower for filters operated in series

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# Bag and Cartridge Filtration under LT2ESWTR

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If a previously tested filter configuration is modified, a new challenge test must be conducted and submitted to the State

The State may choose to grandfather test results consistent with LT2ESWTR criteria conducted prior to promulgation of LT2ESWTR

Assignment of removal credit does not extend to:

- Other pathogens
- Utilities mandated by the IESWTR or LT1ESWTR (Bin 1 of LT2ESWTR)
  Note: States may extend LT2ESWTR rules to other pathogens or Bin 1 plants

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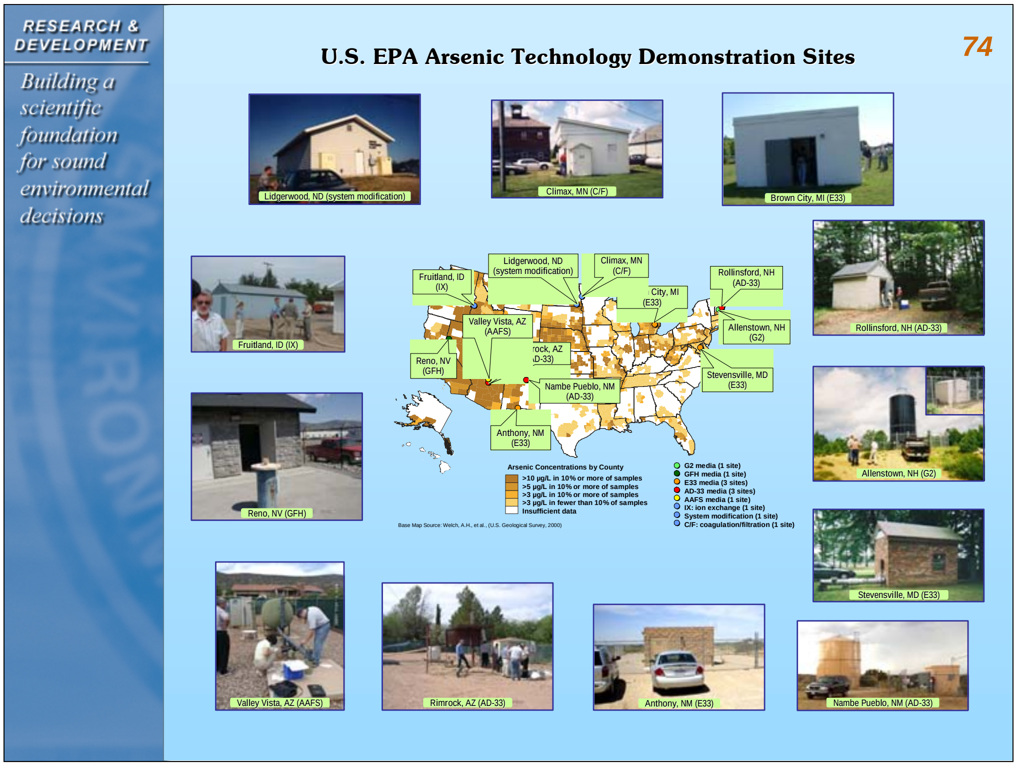
## Further Information

**LT1 ESWTR:**

**www.epa.gov/fedrgstr/EPA-WATER/2002/January/Day-14/w409.htm**

**LT2 ESWTR:**
**www.epa.gov/safewater/lt2/index.html**

**EPA Contact:**
**Dan Schmelling (202) 564-5281**
**schmelling.dan@epa.gov**



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U.S. EPA Arsenic Technology Demonstration Sites
Lidgerwood, ND (system modification)
Climax, MN (C/F)
Brown City, MI (E33)
Fruitland, ID (IX)
Rollinsford, NH (AD-33)
Reno, NV (GFH)
Allenstown, NH (G2)
Stevensville, MD (E33)
Valley Vista, AZ (AAFS)
Rimrock, AZ (AD-33)
Anthony, NM (E33)
Nambe Pueblo, NM (AD-33)
Fruitland, ID (IX)
Lidgerwood, ND (system modification)
Climax, MN (C/F)
City, MI (E33)
Rollinsford, NH (AD-33)
Allenstown, NH (G2)
Valley Vista, AZ (AAFS)
Reno, NV (GFH)
Nambe Pueblo, NM (AD-33)
Stevensville, MD (E33)
Anthony, NM (E33)
Arsenic Concentrations by County
>10 µg/L in 10% or more of samples
>5 µg/L in 10% or more of samples
>3 µg/L in 10% or more of samples
>3 µg/L in fewer than 10% of samples
Insufficient data
G2 media (1 site)
GFH media (1 site)
E33 media (3 sites)
AD-33 media (3 sites)
AAFS media (1 site)
IX: ion exchange (1 site)
System modification (1 site)
C/F: coagulation/filtration (1 site)
Base Map Source: Welch, A.H., et al., (U.S. Geological Survey, 2000)

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# Arsenic Demonstration Program

- October 31, 2001, Administrator announced lowering of arsenic drinking water standard to 10 ppb
- Also announced that "EPA plans to provide $20 million over next two years for research and development of more cost-effective technologies/training/technical assistance."
- Focused on small systems (10,000 population or less)

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# Arsenic Demonstration Funding

- $20 million targeted for two year program ($12M EPA; $8M Congress)
- Full-scale, long-term (1 year) evaluation studies
- Focused on commercially available technologies or engineering approaches

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# EPA Arsenic Demonstration Program Contact

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# Arsenic Demonstration Program Objectives

- Identify and evaluate new cost-effective technologies
- Demonstrate/verify performance of existing and new commercially available technologies
- Provide technical guidance to small communities, regulators and consulting firms on selection and design of cost-effective systems to meet the 10 ppb arsenic MCL

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# Arsenic Demonstration Program

Project Summary

- 43 Project sites
- 20 States
- 1 to 4 sites per State

Technical Proposals

- Round 1 = Funding 12 sites of 17 proposed sites
- Round 2 = Funding 31 sites of 32 proposed sites

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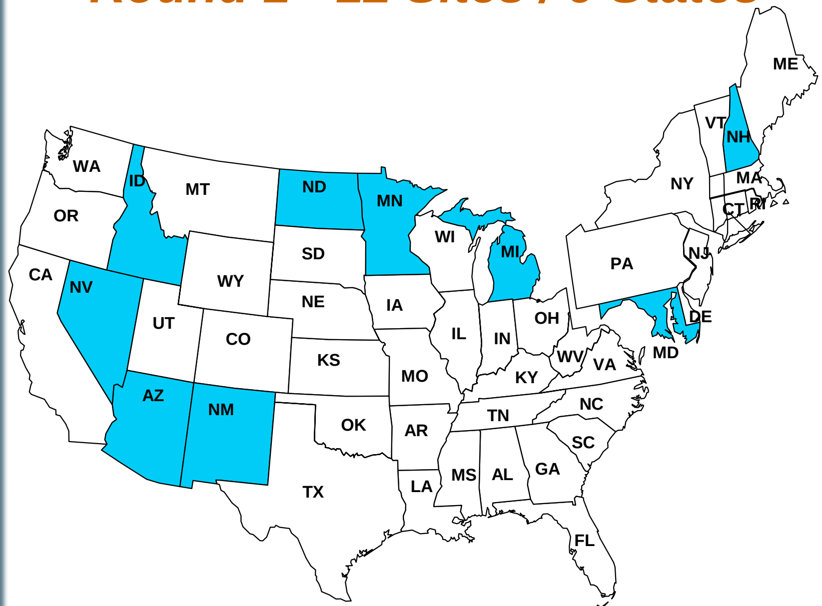
# Round 1 - 12 Sites / 9 States



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# Round 1 Technologies

- 9 Absorption media systems
  - 7 iron media (E33, GFH)
  - 1 Iron-based media (G2)
  - 1 Modified AA (AAFS50)
- 1 Anion exchange system
- 1 Iron removal system
- 1 System Modification

  (Iron removal process with Fe addition)

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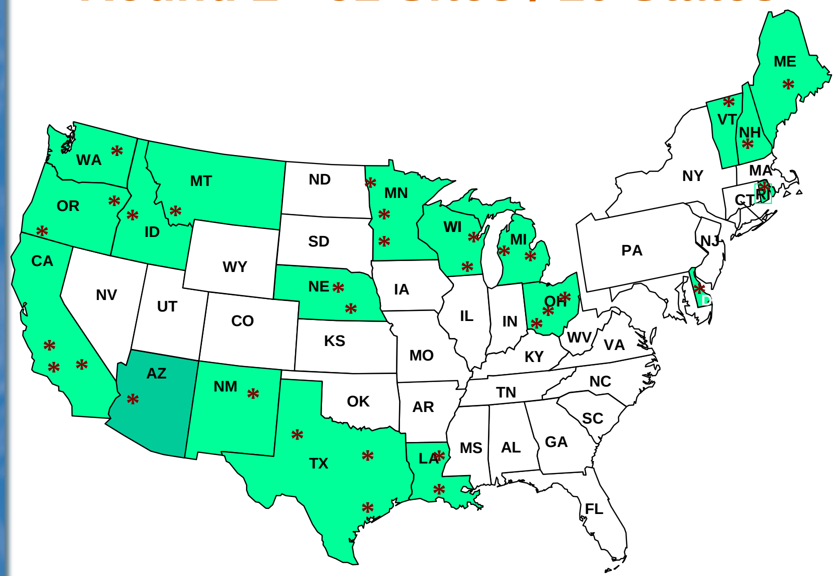
# Round 2 - 31 Sites / 19 States



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# Round 2 Sites

31 Sites Selected

- Community Water Systems (CWS - 27)
- Non-Transient Non-Community Water Systems (NTNCWS - 4)
- Multi contaminant sites (4)
  - Uranium
  - Gross Alpha
  - Nitrate
- Demonstrates Point-of-Use/Point-of-Entry Approaches

# Round 2 Technologies

- Adsorption technologies (60%)
- Oxidation/filtration
- Iron coagulation/filtration
- Ion exchange
- Process modification
- Dissolved air flotation/filtration
- Distillation (POU)
- Reverse Osmosis (POU)

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# Arsenic Demonstration Program

Checking the impact of treatment on the water chemistry in the distribution system and the water quality at consumers' taps

## Arsenic Demonstration Program

Project Outputs (each site)

- Performance Evaluation Reports
  - Six month report
  - One year report
- Summary Report
  - Round 1 studies
  - Round 2 studies

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# Small Systems Research Government Strategy Advisory Group

- Office of Ground Water Drinking Water (OGWDW)
- Office of Science and Policy (OSP)
- EPA Regions
- American Indian Environmental Office
- Office of Research and Development (ORD)

## Small Systems Research Non-Government Strategy Advisory Group



- National Rural Water Association
- Rural Community Assistance Programs
- American Water Works Association
- AWWA Research Foundation
- Water Reuse Federation
- Water Environment Research Foundation
- Rural Utilities Service (USDA)
- National Drinking Water Clearing House
- Water Quality Association
- Electric Power Research Institute
- Private vendors/consultants

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## Small Systems Research-Future Issues

- Radionuclides
  - Uranium
  - Radium
  - Radon
- Perchlorate
- MTBE
- LT2/Stage 2 DBP Rules
- Water Reuse
- POE/POU
- Remote Monitoring Control & Reporting

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# Thank You

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# Website Information

**Small Systems:**
www.epa.gov/ORD/NRMRL/wswrd/smallsys2.htm

**Upload "Small Drinking Water Systems Handbook":**
www.epa.gov/ORD/NRMRL/Pubs/600R03041/600R03041.pdf

**LT1 ESWTR:**
www.epa.gov/fedrgstr/EPA-WATER/2002/January/Day-14/w409.htm

**LT2 ESWTR:**
www.epa.gov/safewater/lt2/index.html

**Arsenic:**
www.epa.gov/ORD/NRMRL/arsenic/