U.S. EPA's Research Program for Management of Arsenic in Drinking Water

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Acknowledgments

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Bob Thurnau, P.E.

Jeff Adams

Dr. William Sidle

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OUTLINE

- **Background**
  - Office of Research and Development
  - Arsenic Standard
- Arsenic chemistry and how it influences treatment
- Research model for control of contaminants in drinking water
- USEPA's Arsenic Rule Implementation Research Program

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Research and Development at EPA

- 2,000 employees
- $700 million budget
- $100 million extramural research grant program
- 13 lab or research facilities across the U.S.
- Credible, relevant and timely research results and technical support that inform EPA policy decisions

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High Priority Research Areas

- Human Health
- Particulate Matter
- **Drinking Water**
- Clean Water
- Global Change
- Endocrine Disruptors
- Ecological Risk
- Pollution Prevention
- Homeland Security

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Arsenic Drinking Water Standard in the United States

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What's Required to Regulate a Contaminant in Drinking Water

- ✓ Proven adverse health outcome
- ✓ Occurrence in drinking water
- ✓ Analytical method
- ✓ Treatment technology - Best Available Technology (BAT)

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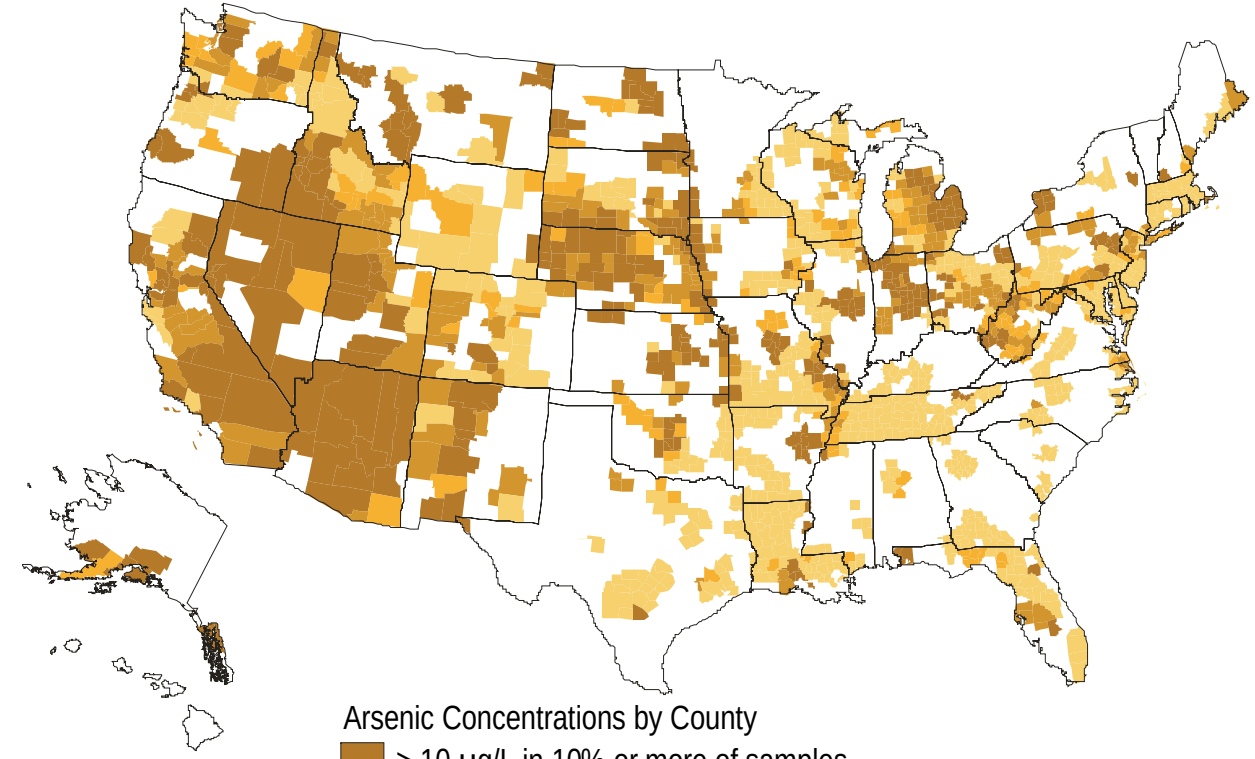
Arsenic Occurrence



Source: Welch, A.H., et al.,
U.S. Geological Survey, 2000

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Arsenic Regulatory History

- 1976- National Interim Primary Drinking Water Regulation for arsenic of 50 ppb established
- 1986- Directive to promulgate National Primary Drinking Water Regulations for 83 contaminants, including arsenic
- 1996-Safe Drinking Water Act reauthorized
  - Included directive to issue a final revised arsenic standard by January 1, 2001

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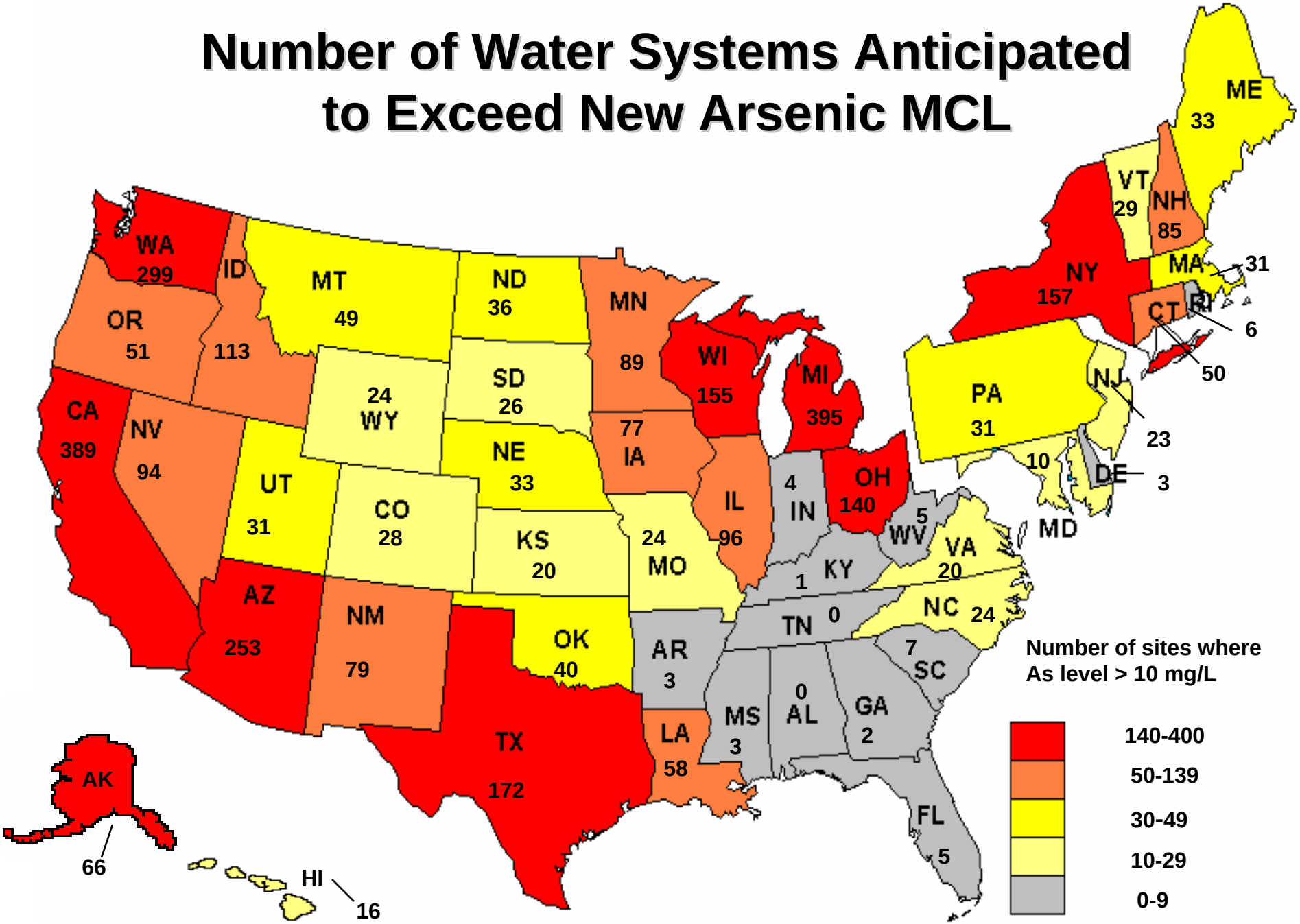
Arsenic Regulatory History

- 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 and technical assistance.”

Number of Water Systems Anticipated to Exceed New Arsenic MCL



Source: USEPA (2000a), (2000b)

ARSENIC CHEMISTRY

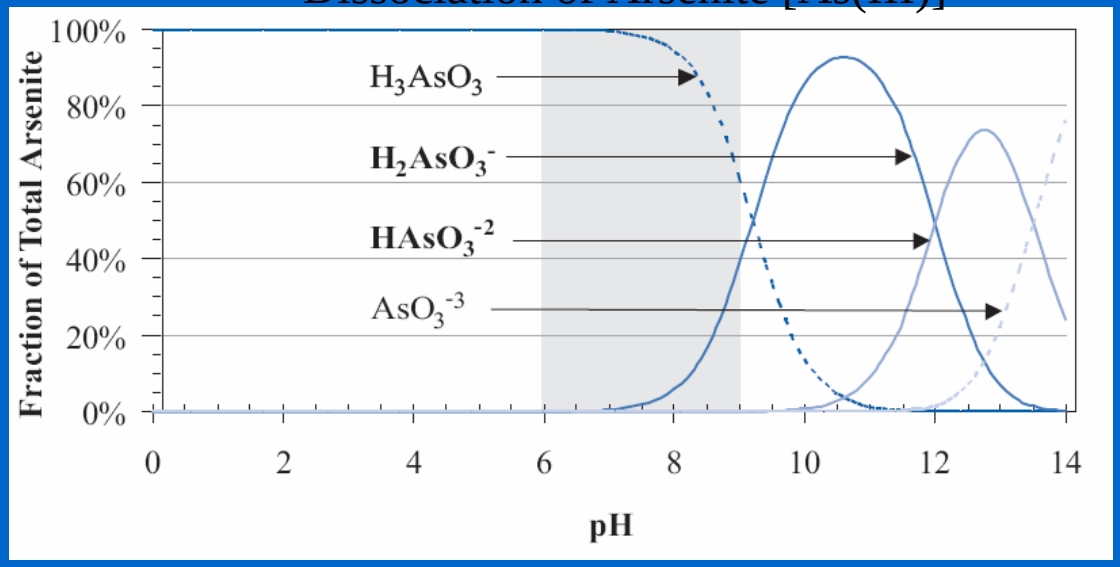
Arsenic Chemistry

Two primary valence states

As (III), As +3, arsenite

As (V), As +5, arsenate

Dissociation of Arsenite [As(III)]

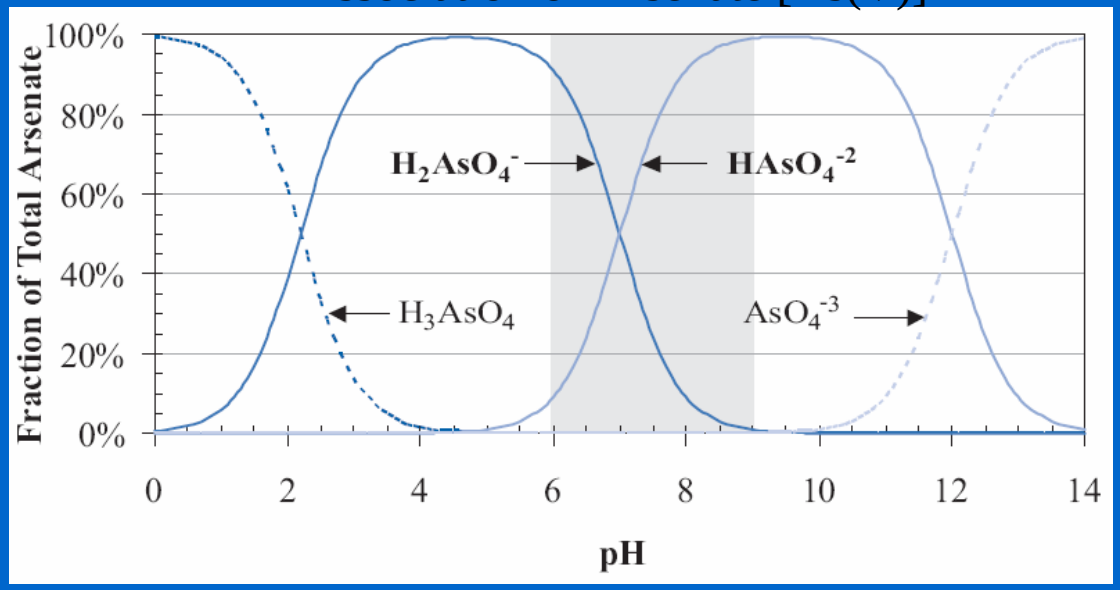


❖**Arsenite**

[AsO_3^{3-}, As(III)]

Difficult to remove at neutral pH, more toxic

Dissociation of Arsenate [As(V)]



❖**Arsenate**

[AsO_4^{3-}, As(V)]

Easier to remove

Arsenic Occurrence

WATER TYPE	DOMINANT FORM
Surface waters	As (V)
Ground waters	As (III)
	As (V)
combined	As (III)/As (V)

Effect of Arsenic Species on Removal Efficiency

Treatment Process	Percent Removal	
	As III	As V
Lime soft. (pH 10)	18	55
Lime soft. (pH 11.5)	78	98
Reverse Osmosis	60	98
Anion Exchange	0	99

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Recommendation!

Oxidize As (III)

to As (V)

before applying treatment

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As (III) Oxidation

Effective!

- Free Chlorine
- Potassium Permanganate
- Ozone
- Solid Oxidizing Media (MnO_2 solids)

Ineffective

- Chloramine
- Chlorine Dioxide
- UV Radiation
- Aeration

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Arsenic Treatment Technologies

Precipitative Processes

Process	BAT	Small System
Lime Softening	**+**	**-**
Coagulation/Filtration	**+**	**-**
Coagulation/MicroFil	**-**	**+**
Coagulation/DirFil	**+**	**+**
Oxidation/Filtration	**+**	**+**

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Arsenic Treatment Technologies

***Sorption* Processes**

Process	BAT	Small System
Ion Exchange	**+**	**+**
Activated Alumina	**+**	**+**
Iron Based Sorbents	**Research Needed**	

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Arsenic Treatment Technologies

***Membrane* Processes**

Process	BAT	Small System
Reverse Osmosis	**+**	**+**

Best Available Technology (BAT)

Technology	Maximum Percent Removal (As V)
Ion Exchange	95
Activated Alumina	90
Reverse Osmosis	>95
Modified Coag/Filtration	95
Modified Lime Softening	80
ElectrodialysisReversal	85
Oxidation/Filtration (20:1 Fe/As)	80

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WATER QUALITY ANALYSIS

Prior to determining management approach:

- Conduct comprehensive study of water chemistry
- Field speciation of arsenic is recommended
- Phosphate, silica, pH, sulfate, iron are essential measurements

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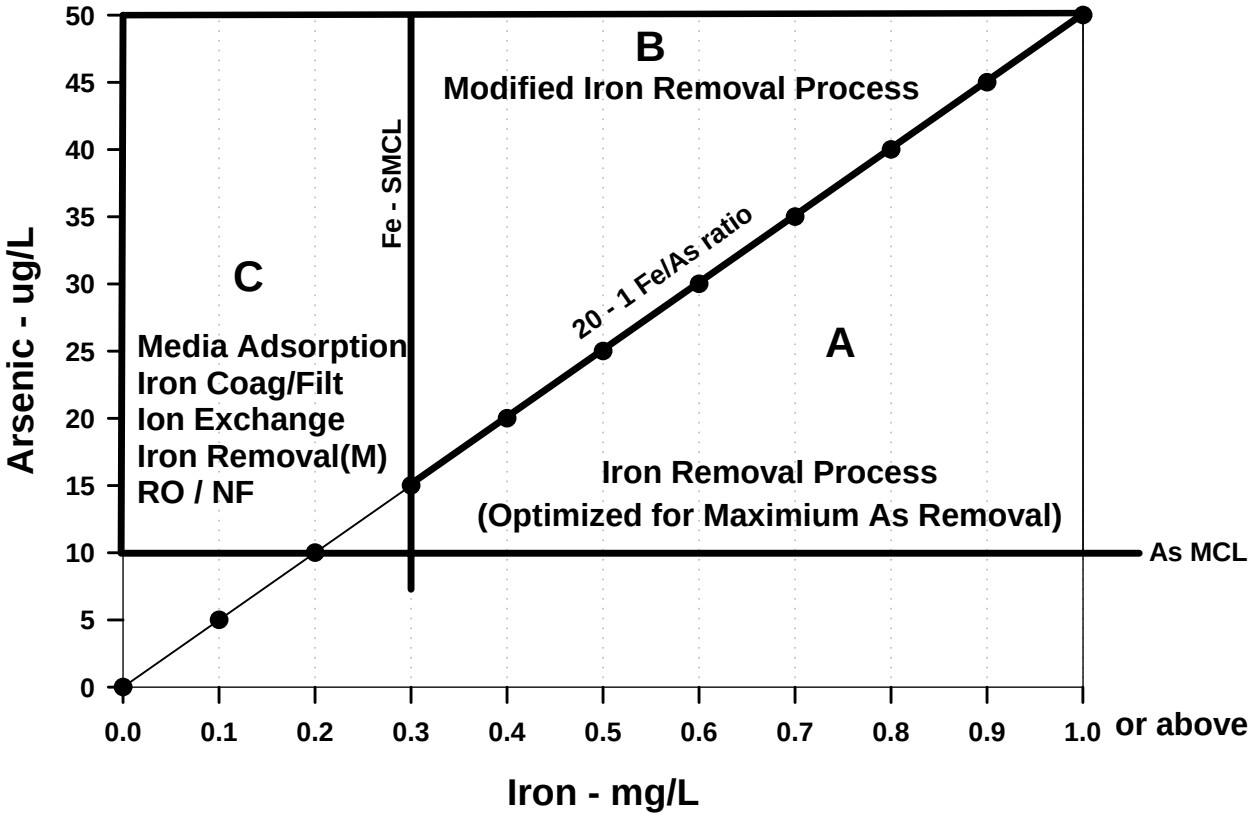
Arsenic Treatment - Process Selection Guide



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Iron-Based Arsenic Removal Processes

- Adsorptive properties of iron mineral toward arsenic are well known
- That knowledge is the basis for many arsenic treatment processes
  - *IRON REMOVAL*
  - Coagulation with iron coagulant
  - Iron-based adsorption media

IRON REMOVAL = ARSENIC REMOVAL

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CASE STUDY

Iron Removal Processes

Air/Chemical Oxidation/filtration

Arsenic removal with iron impacted by:

- Arsenic species – As III / As V
- pH of source water – low / high pH
- Competitive anions – silica / phosphate
- Adsorption kinetics – contact time

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Iron Removal System - Holly, MI
Source Water Quality

Arsenic	**0.019 - 0.024**
As III	**95 %**
As V	**5 %**
Calcium	74 - 84
Magnesium	30 - 33
Iron	0.5 - 0.6
Manganese	0.02
Sulfate	50 -60
Silica	12 - 13
pH	7.1 - 7.3

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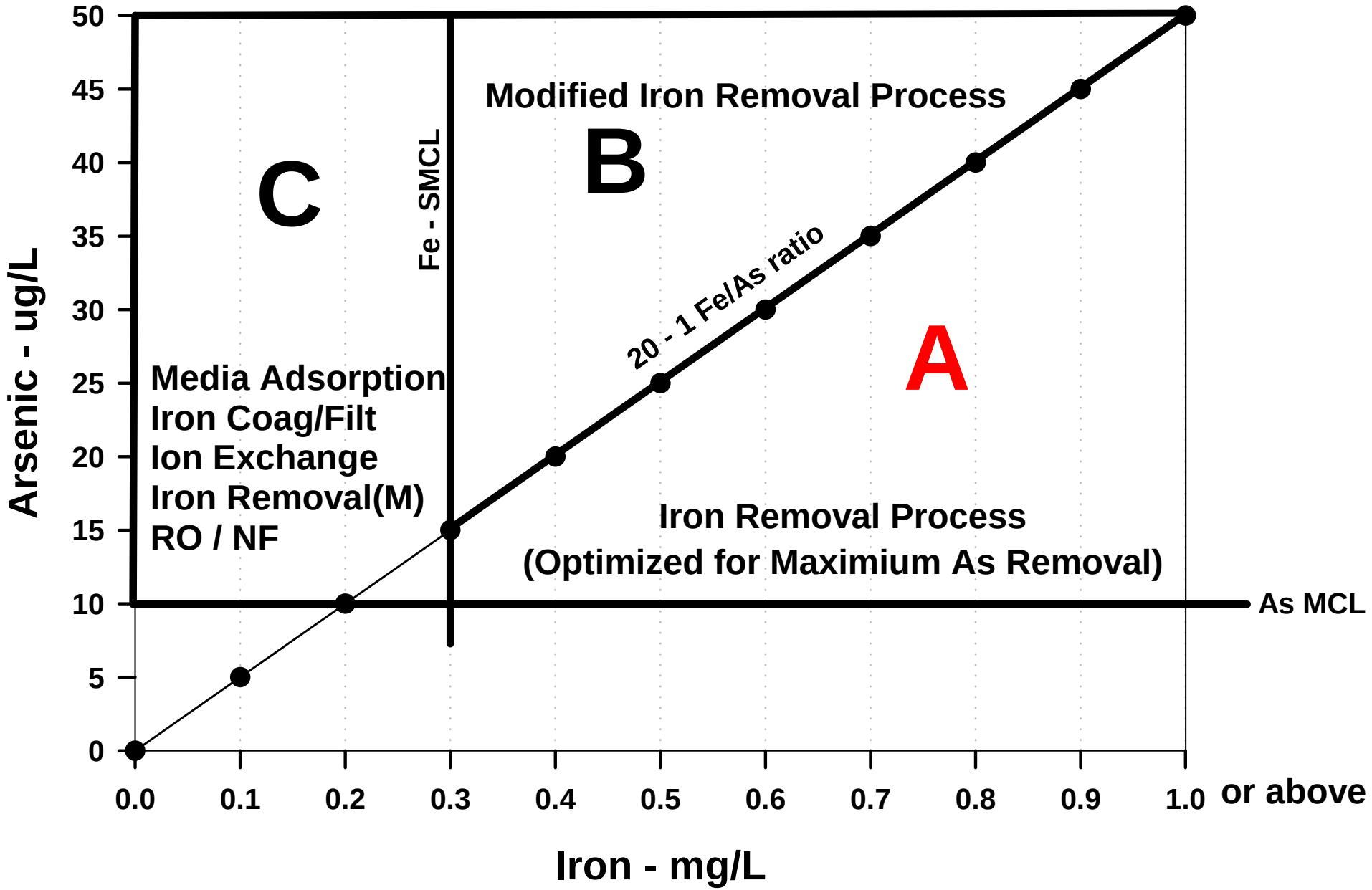
Iron Removal System, Holly MI
Source Water Quality

Arsenic concentration 19- 24 ug/L

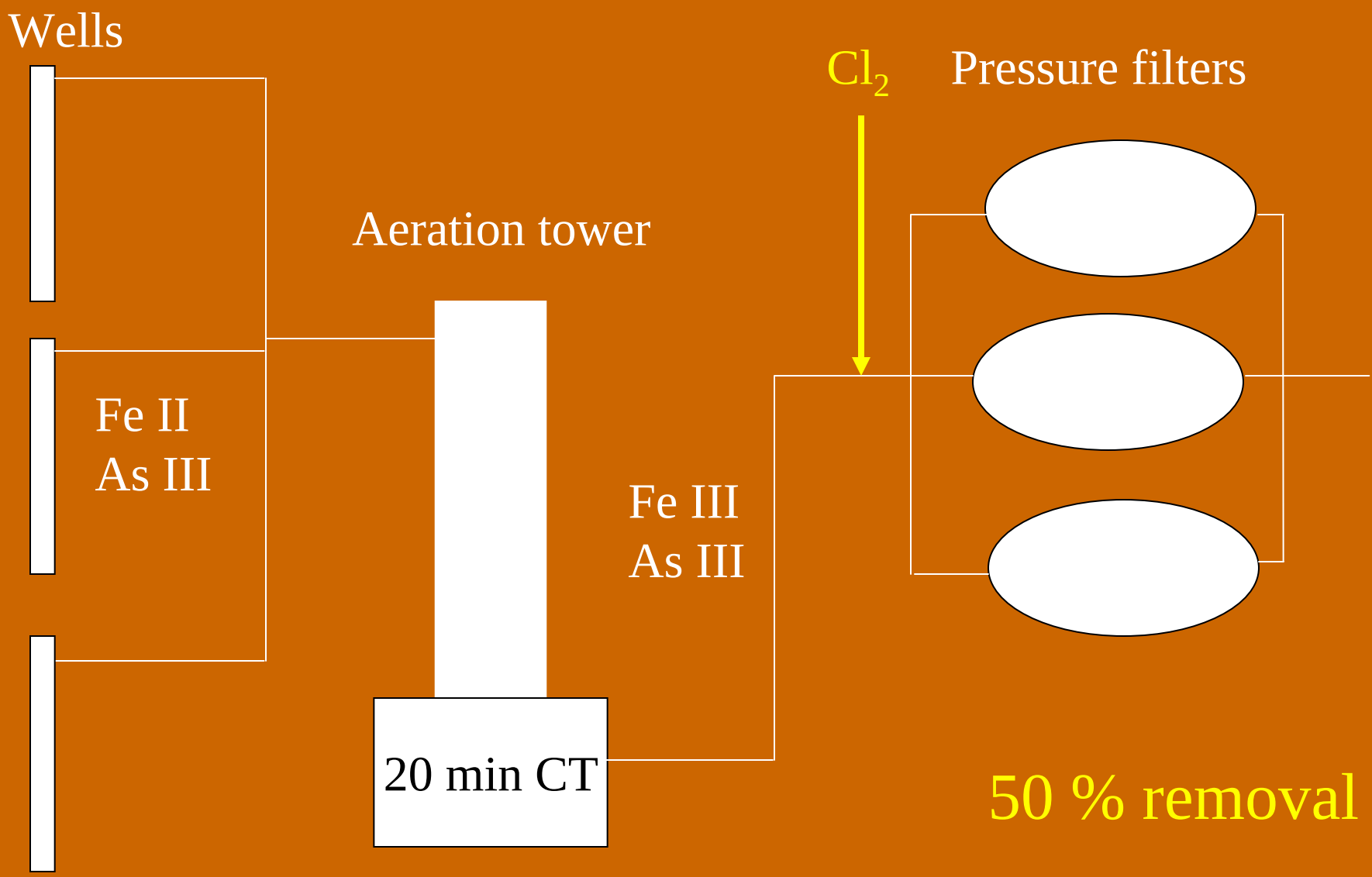
Iron concentration 0.5-0.6 mg/L

As (ug) / Fe (mg) ratio - 31 to 48

Arsenic Treatment - Process Selection Guide



Iron Removal System - Holly,MI



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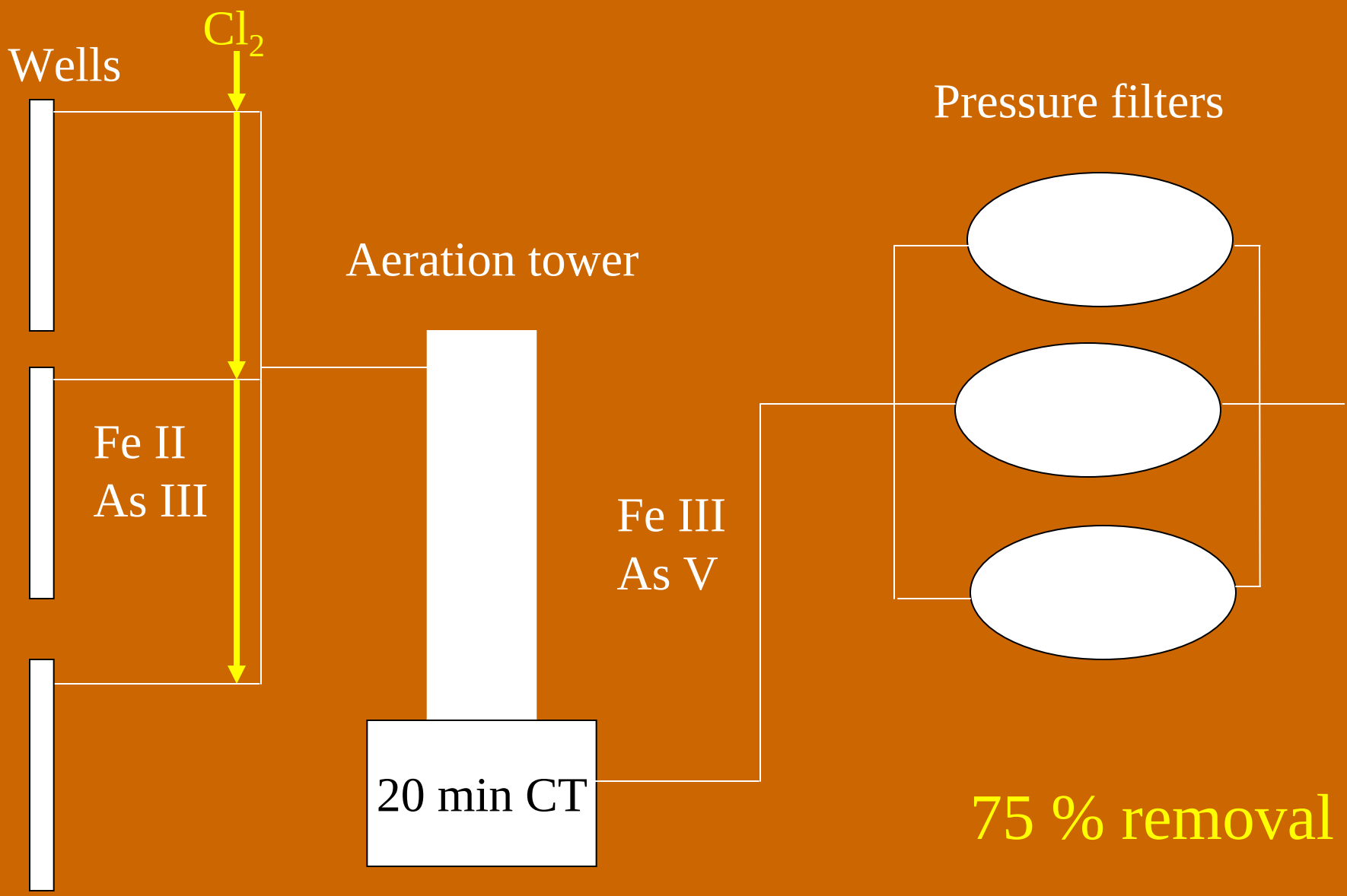
Research

Oxidize Fe II and As III at the same time!

Iron Removal System - Holly,MI




CHLORINE
SOLUTION

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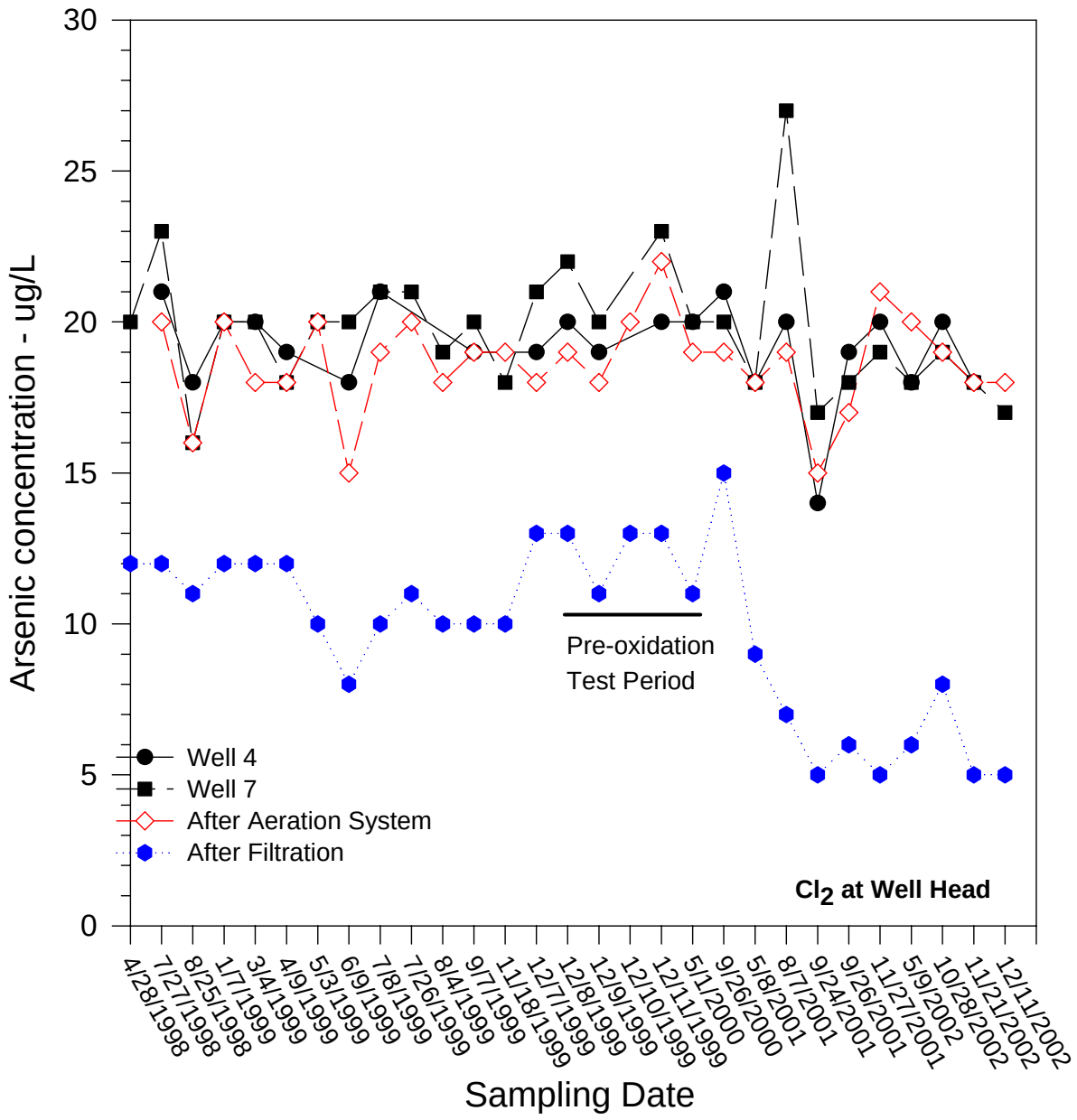
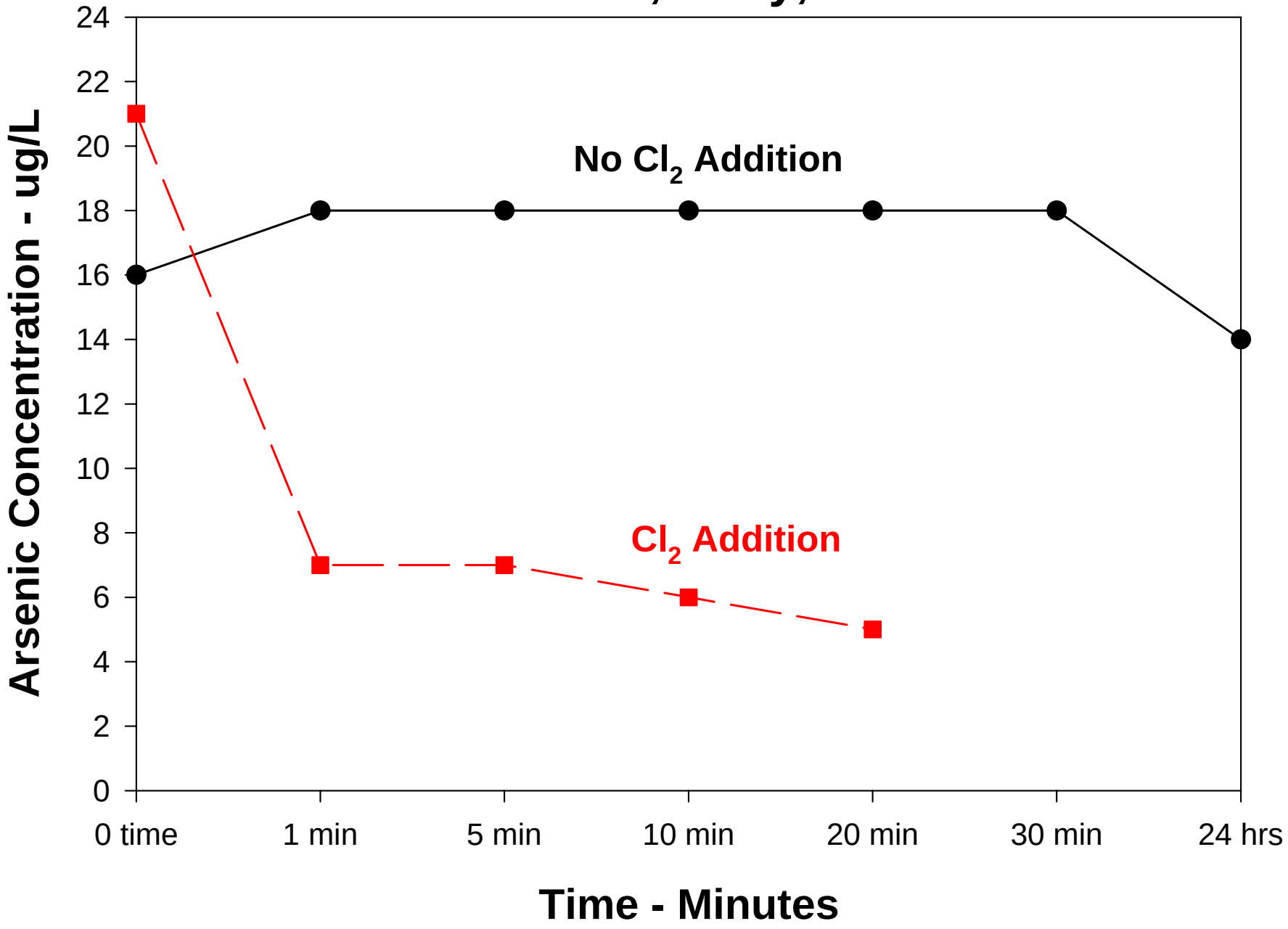
Figure 1. Arsenic Removal of Iron/Manganese Removal System, Holly MI.



Effect of System (Cl_2) Changes
(As in source water – 19 –24 ug/L)

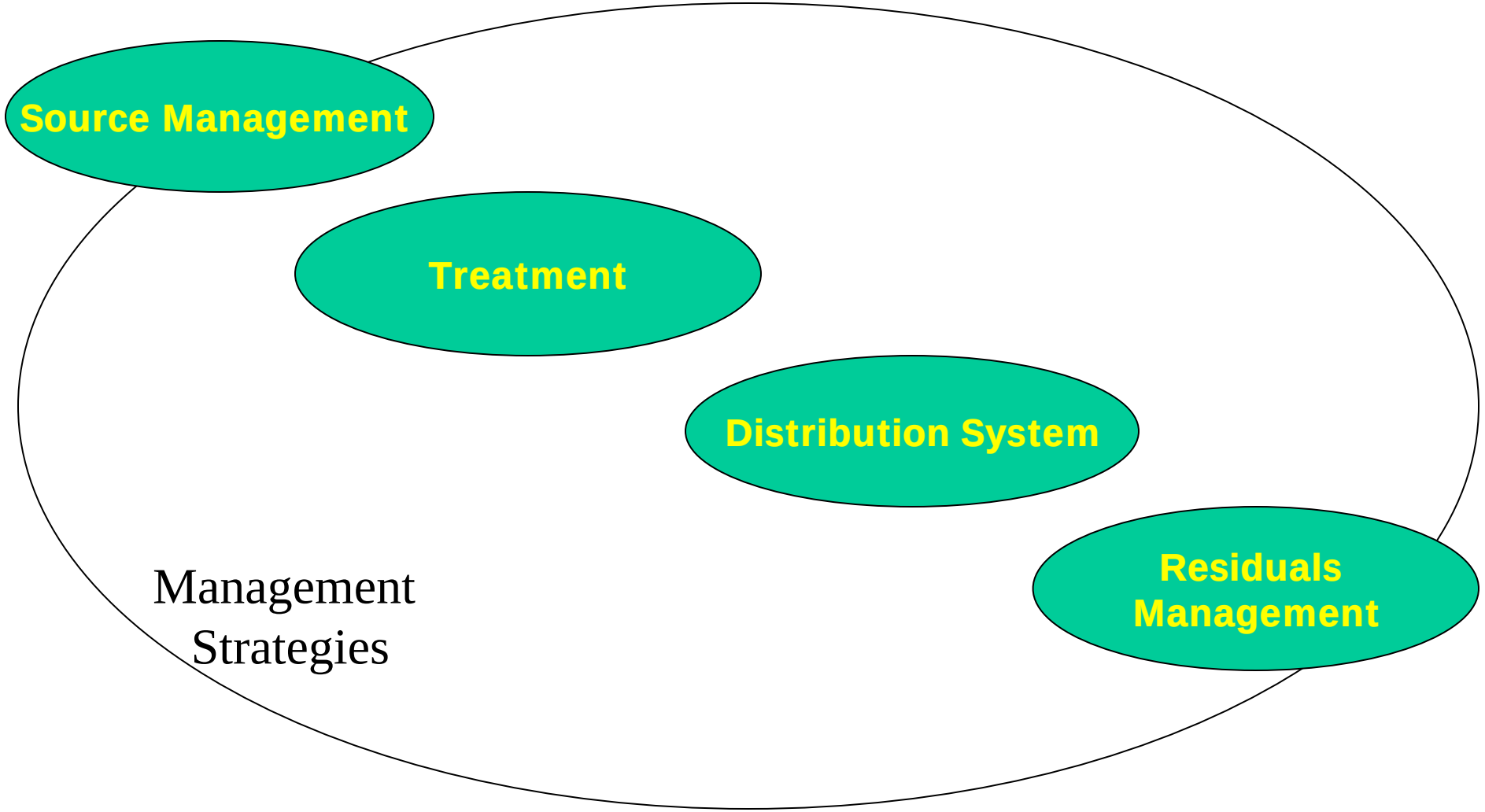
Cl point of Application	**Effluent - As ug/L**
After Filters	11 -13
Before Filters	11-13
Well head	5 - 7

Impact of Chlorination on As Removal
Jar Test, Holly, MI



Drinking Water Contaminant Management Framework

Drinking Water Contaminant Management Framework



Schmelling and Gutierrez, 2002

Arsenic Rule Implementation Research Program

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FY03 Congressional Appropriation

- $5 million for small system arsenic removal research.
- Strongly encourage use of funds for demonstrations of implementation of low-cost treatment technology.
- Report to Congress required August 15, 2003.

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FY04 Congressional Appropriation

- $5 million for small system arsenic removal research for a total of $11.7 million.
- Report to Congress required April 7, 2004.

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Arsenic Treatment Research Program

Objectives

(1) Identify and evaluate new cost-effective technologies

(2) Demonstrate/verify performance of existing and new commercially available technologies

(3) Provide technical guidance to small communities, regulators and consulting firms on selection and design of cost-effective systems to meet the arsenic MCL

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Major Elements

- Small Business Innovation Research/Science to Achieve Results
- Treatment Technology Demonstrations
- Environmental Technology Verifications
- Enhanced base research program
- Training and technical assistance

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Small Business Innovation Research (SBIR)

Purpose – Promote development of new treatment technologies

Solicitation for arsenic treatment technologies released early in 2002

Fifty proposals received for Phase I

Awarded 8 bench level studies – Phase I/II awards

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SBIR Emerging Technologies

Filtration

Sorbents (24)

Biological

Oxidation

Co-precipitation

Other

Monitoring

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Phase II SBIR Technologies

- VEETech, P.C.
  - Arsenic Removal Using a Novel Hybrid Sorbent
- ADA Technologies, Inc.
  - Arsenic Removal System for Residential Point-of-Use Applications
- Hydro Tech Engineering
  - Limestone-based Material for Arsenic Removal

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Science to Achieve Results – New Technologies

- Novel Ion Exchange Process for Selective As V Removal – Zhao
- Novel Adsorption Technology – Assaf-Anid
- Modified Natural Zeolite Selective Sorbent – Sen Gupta

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Demonstrations

- $12 - $15 million targeted to this effort
- Full-scale, long-term (1 year) in scope
- Focused on commercially ready technologies or engineering approaches
- Fill in scientific gaps

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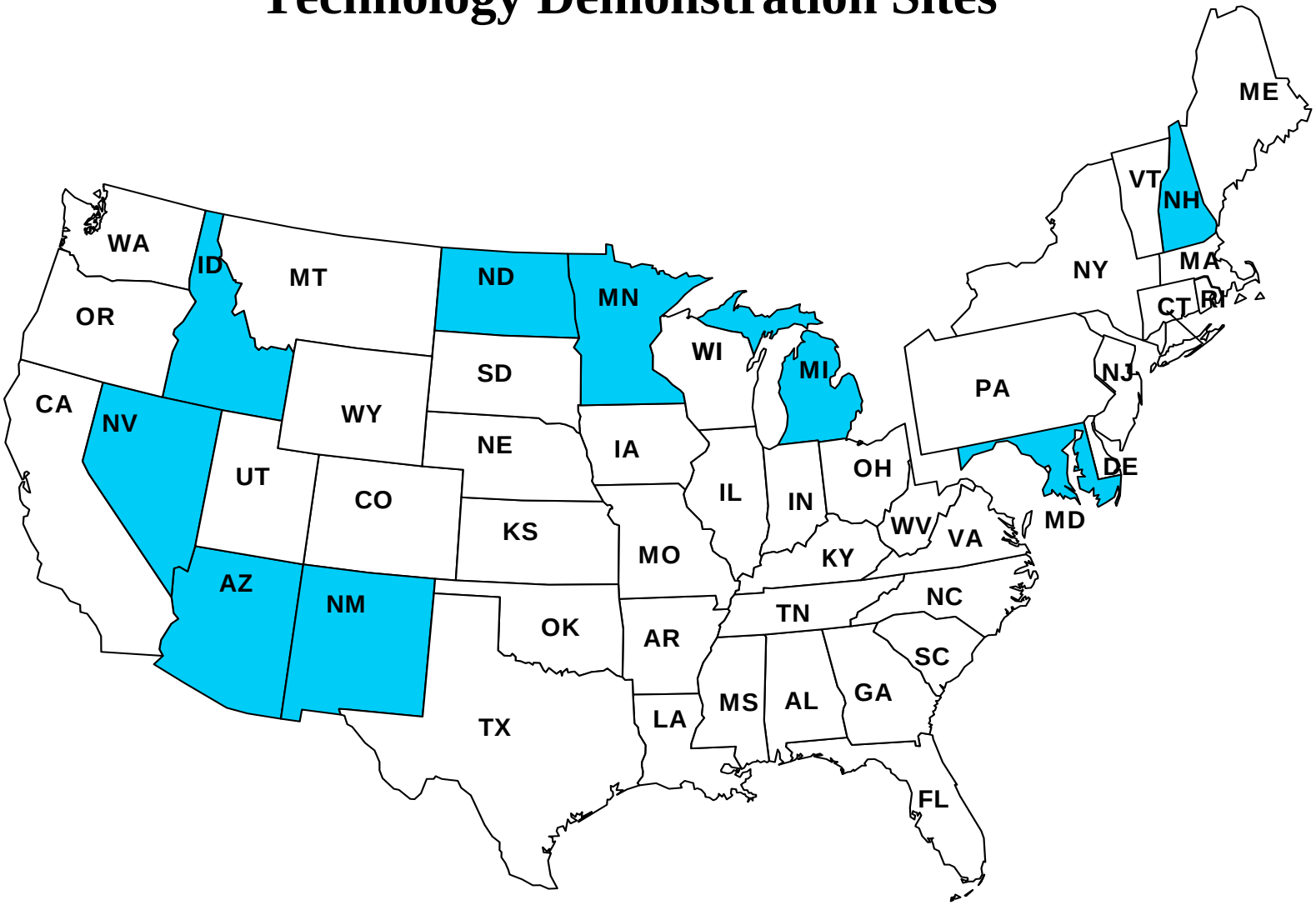
General Goals of Demo Projects

- Determine/document construction and operational costs
- Determine/document performance of the technology for 1 year in achieving compliance
- Determine operational/maintenance requirements
- Characterize residuals produced by the process
- Evaluate effectiveness of residuals disposal process

Round 1 - Arsenic Treatment Technology Demonstration Sites



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Round 1 Arsenic Treatment Technology Demonstration Sites

Site	Technology to be Demonstrated
Rimrock, AZ	AdEdge Iron Media
Valley Vista, AZ	Kinetico Activated Alumina
City of Fruitland, Fruitland, ID	Kinetico Ion Exchange
Queen Anne's Co, Stevensville, MD	Severn Trent Iron Media
Brown City, Brown City, MI	Severn Trent Iron Media
Town of Climax, Climax, MI	Kinetico Oxid/CoPrecip/Filtration
Lidgerwood, ND	Kinetico Modified Treatment
*Allenstown, NH	ADI Iron Adsorption /Regeneration
Rollinsford, NH	AdEdge Iron Media
Anthony, NM	Severn Trent Iron Media
Nambe Pueblo, NM	AdEdge Iron Media
South Truckee Meadows, Reno, NV	US Filter Iron Media

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Desert Sands MDWCA (Anthony), NM

Population served – 1,886

System flow rate (well # 3) – 320 gpm

Water quality

- As - 23 ug/L (97% As III)
- pH - 7.7
- SiO_2 - 35 mg/L
- PO_4 - < 0.10

Technology

- Media adsorption-E 33,Severn Trent
- Two 64” x 86” tanks
- 160 ft3 media (total)

Desert Sands MDWCA (Anthony), NM

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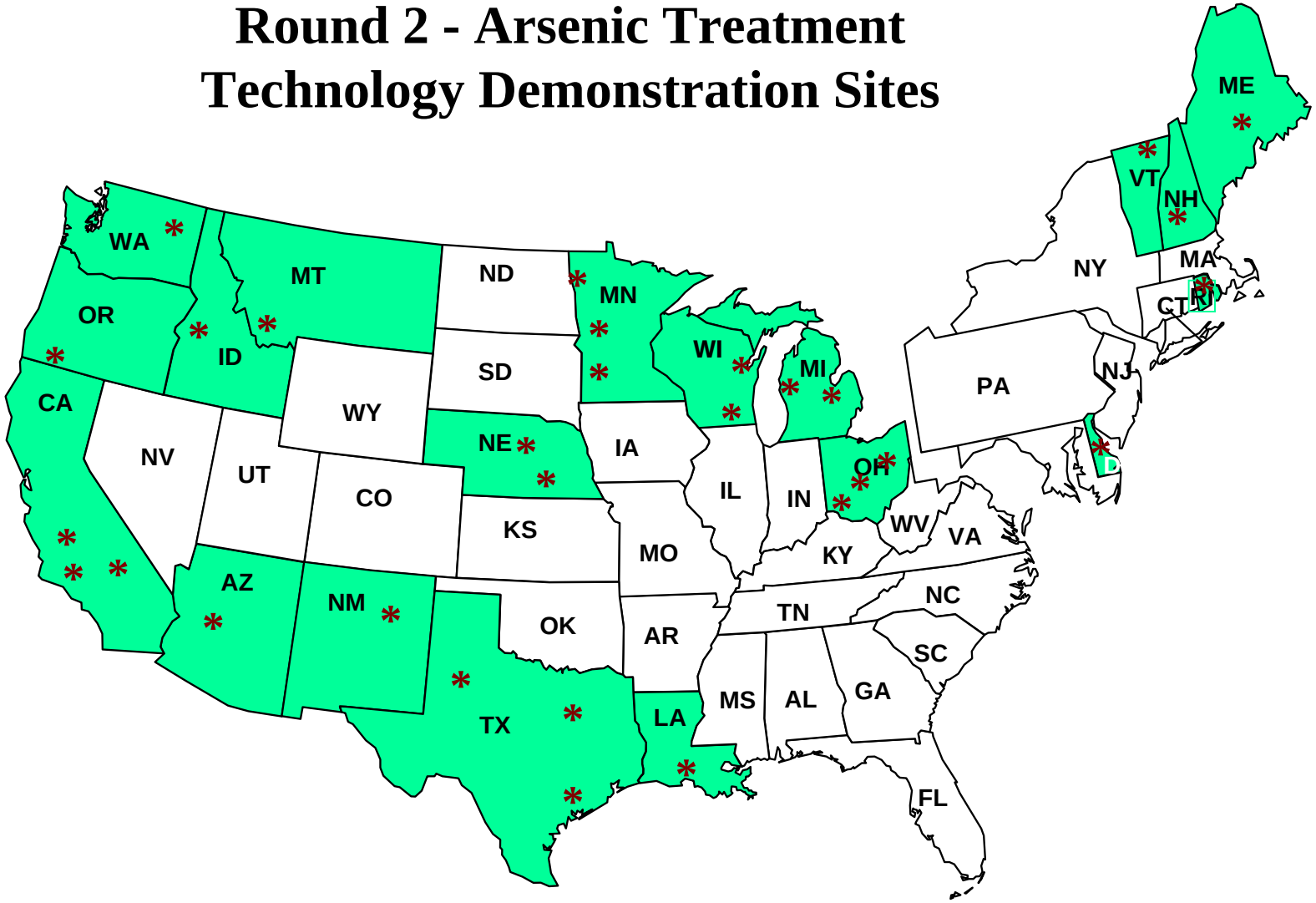
Round 2 Sites by Geographical Area

East	Central MW	Midwest	Far West
Felton, DE	Sauk Centre, MN	Breaux Bridge, LA	Susanville, CA
N. Springfield, RI	Sabin, MN*	Arnaudville, LA	Lake Isabella, CA
Goffstown, NH	Stewart, MN	Stromsburg, NE	Klamath Falls, OR
Dummerston, VT	Springfield, OH	Lyman, NE	Taos, NM
Wales, ME	Grove City, OH	Wellman, TX*	Homedale, ID
	Newark, OH	Alvin, TX	Okanogand, WA
(5)	Greenville, WI*	Bruni, TX	Three Forks, MT
	Sandusky, MI		Techachapi, CA*
	Pentwater, MI	(7)	Tohono O'odham, AZ (Sells)*
	Delavan, WI		Vale, OR
	(10)		(10)

* Site selected, but not funded in Round 1

Round 2 - Arsenic Treatment Technology Demonstration Sites



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Technologies Proposed

- *Adsorption technologies*
- Oxidation / filtration
- Iron Coagulation / filtration
- Reverse osmosis
- Ion exchange
- Process modification
- Dissolved air flotation / filtration
- Distillation

- POUs (included in above technologies)

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Round 2 – Next Steps

- Technology selection for each site – May/July, 2004
- Contracts with vendors/engineering firm – Fall of 2004
- Installation of systems – January/June, 2005

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Environmental Technology Verification Program

- Program verifies the performance of treatment technologies according to established test protocols
- Short term tests, commercial ready technologies
- NSF is EPA cooperator for drinking water verifications

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ETV Arsenic Verifications

Hydrauntics – Reverse Osmosis Membrane Element Module

Kinetico, Inc – Macrolite Coagulation and Filtration System

Koch Membrane Systems – Reverse Osmosis Membrane Module

Watermark Technologies, Coagulation and Filtration Systems

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Enhanced Base Research Program

- Treatment Optimization Studies
- Distribution System Recontamination
- Residuals Management
- Source Control
  - Hot spot location using isotope hydrology
  - Hydrogeological approach to arsenic distribution

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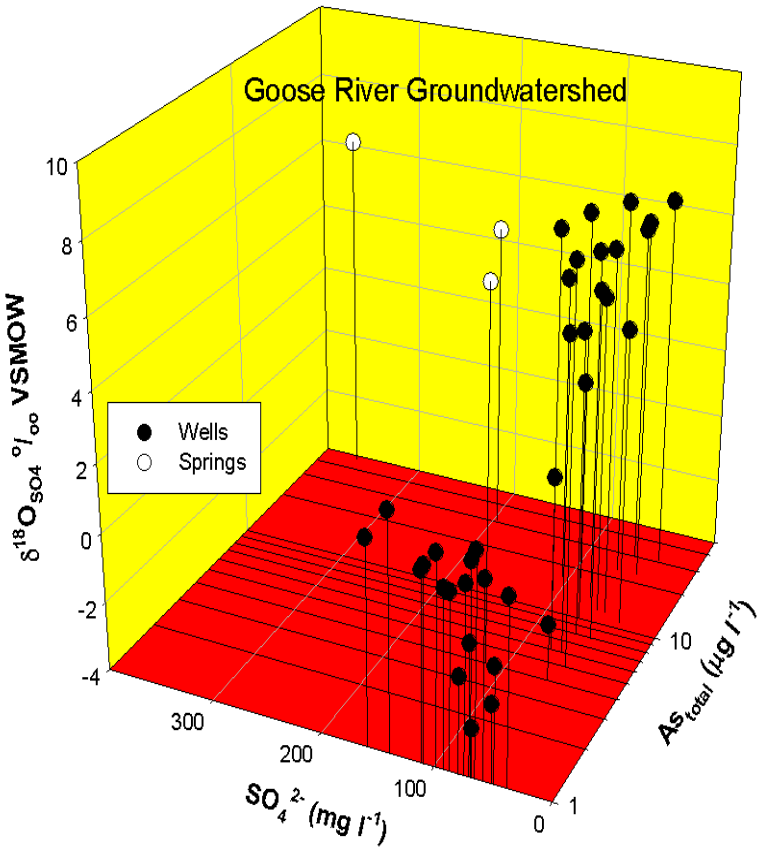
Oxidation Discriminator



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Training and Technical Assistance

- Working with the Office of Ground Water and Drinking Water
- University of Nebraska funded to investigate well pumping approach for arsenic control
- Support to State of Arizona for preparation of master plan for arsenic

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Resource Manuals Available

- Arsenic Removal from Drinking Water by Coagulation/Filtration and Lime Softening Plants
- Arsenic Removal from Drinking Water by Iron Removal Plants
- Arsenic Removal from Drinking Water by Ion Exchange and Activated Alumina Plants
- Treatment of Arsenic Residuals from Drinking Water Removal Processes
- Oxidation of As(III) by Aeration and Storage
- Laboratory Study on the Oxidation of As III to As V
- Regulations on the Disposal of Arsenic Residuals from Drinking Water Treatment Plants

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SUMMARY

- **Current technologies have capability to reduce arsenic to less than 10 ug/L, many to to 5 ug/L or less.**
- **Process modifications may help to reduce As to MCL.**

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Further Information

Website

www.epa.gov/ORD/NRMRL/arsenic/

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Thank you