Iron and Manganese Removal Processes

Presentation Agenda

- Arsenic Background: chemistry and treatment options
- Treatment selection considerations
- Treatment options
  - Iron removal
- Case studies
- Conclusions

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**

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
  - Coagulation with iron coagulant
  - Iron-based adsorption media
  - Iron removal processes

Arsenic Removal by Iron

As(III) vs As(V)

As(III) is removed during iron removal and other iron-based processes, but just not as well as As(V)

As (III) Oxidation

Effective!

- Free Chlorine
- Potassium Permanganate
- Ozone
- Solid Oxidizing Media (MnO$_2$ solids)

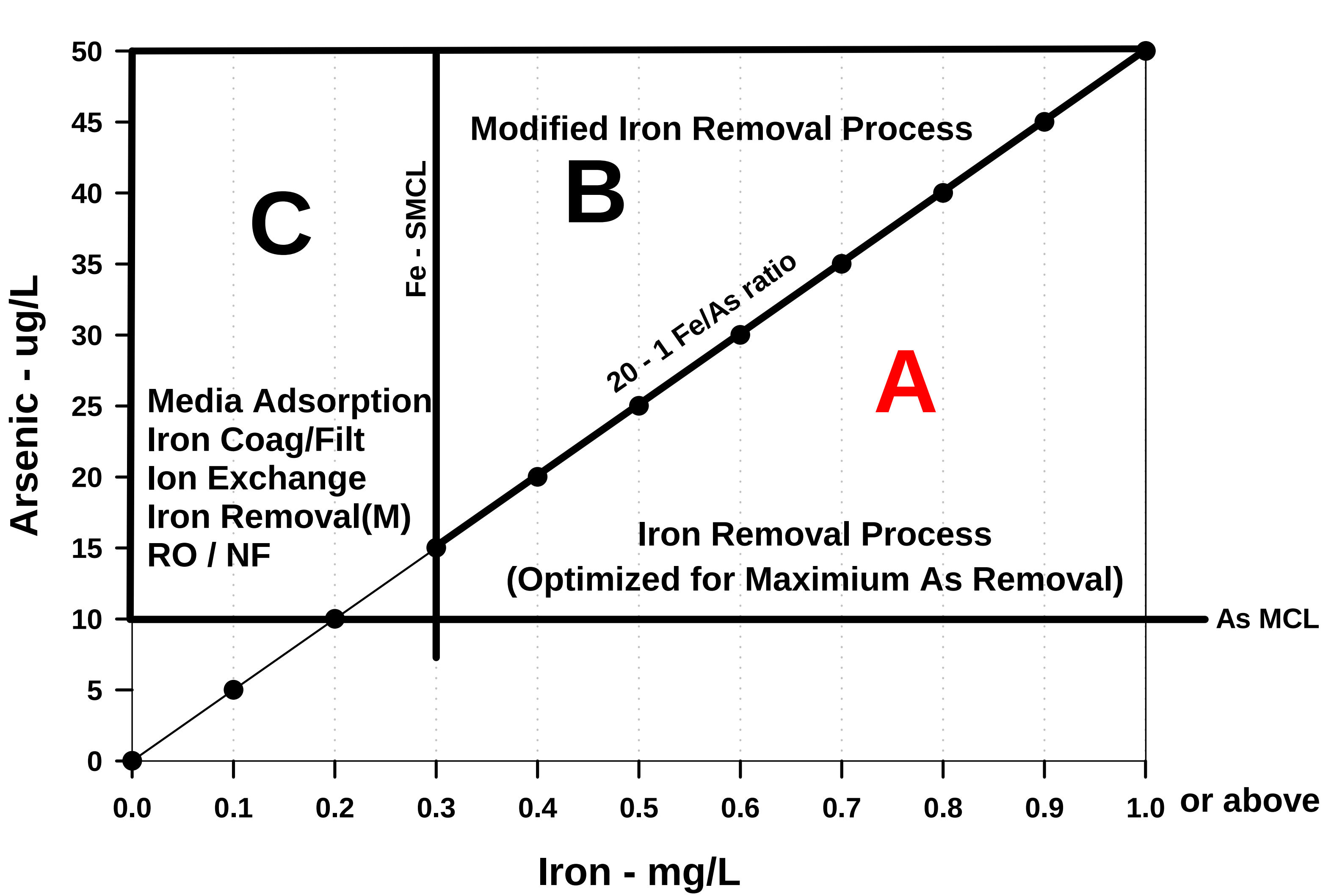
Ineffective

- Chloramine
- Chlorine Dioxide
- UV Radiation + Sulfide
- Oxygen

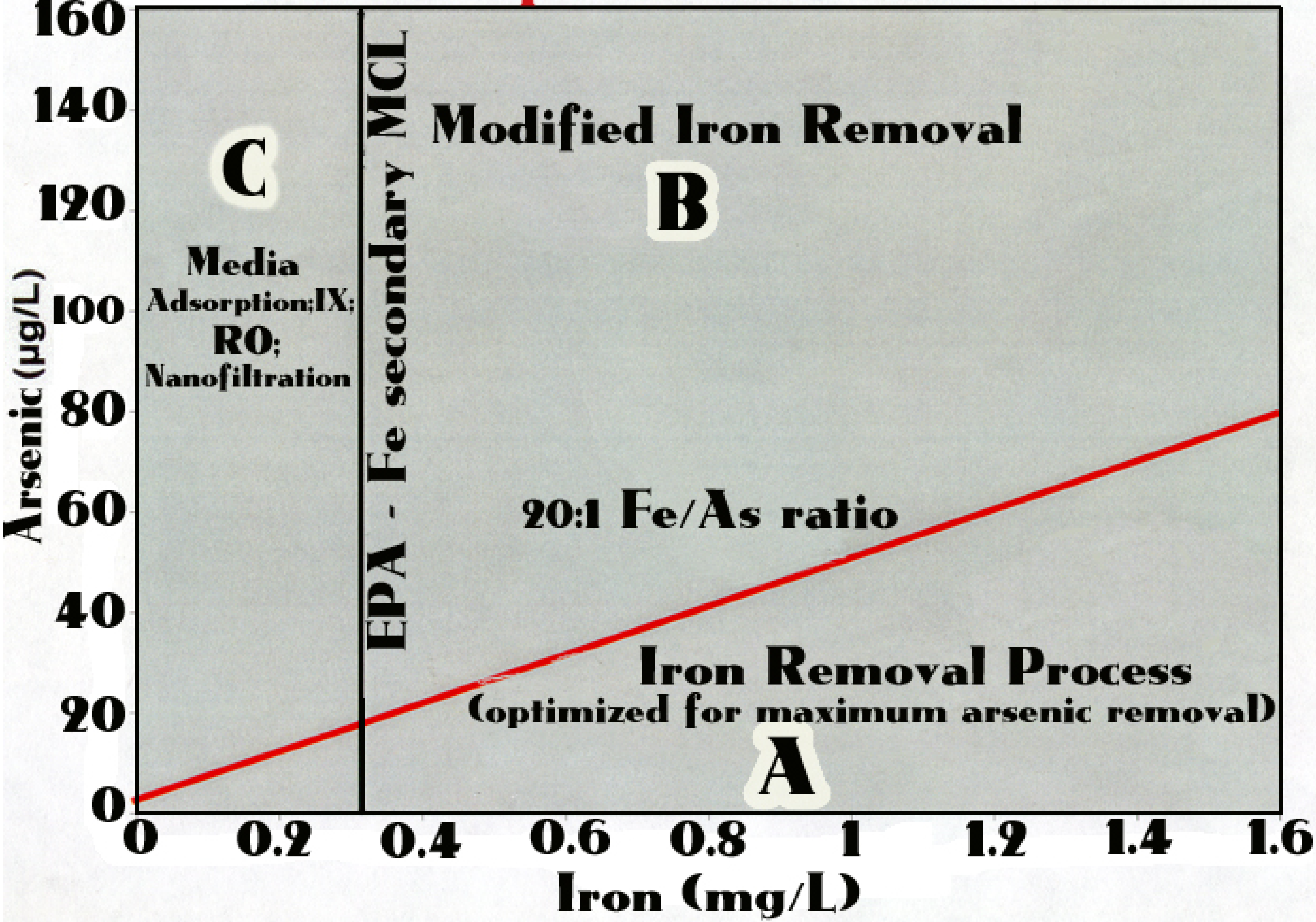
Arsenic Treatment Issues

- Treatment complexity/cost
- Pre- and Post-treatment needs
- Residuals –Disposal Issues
  – Ion exchange & RO produce liquid wastes
  – Adsorbent media produce wasted solids
  – Coagulation/filtration and iron removal processes produce solids
    - Filter backwash waste
    - Sediment in contactor (pass TCLP test)

Arsenic Treatment
Simplified Process Selection Guide



Arsenic Treatment Selection Guide as a Function of Raw Arsenic and Iron



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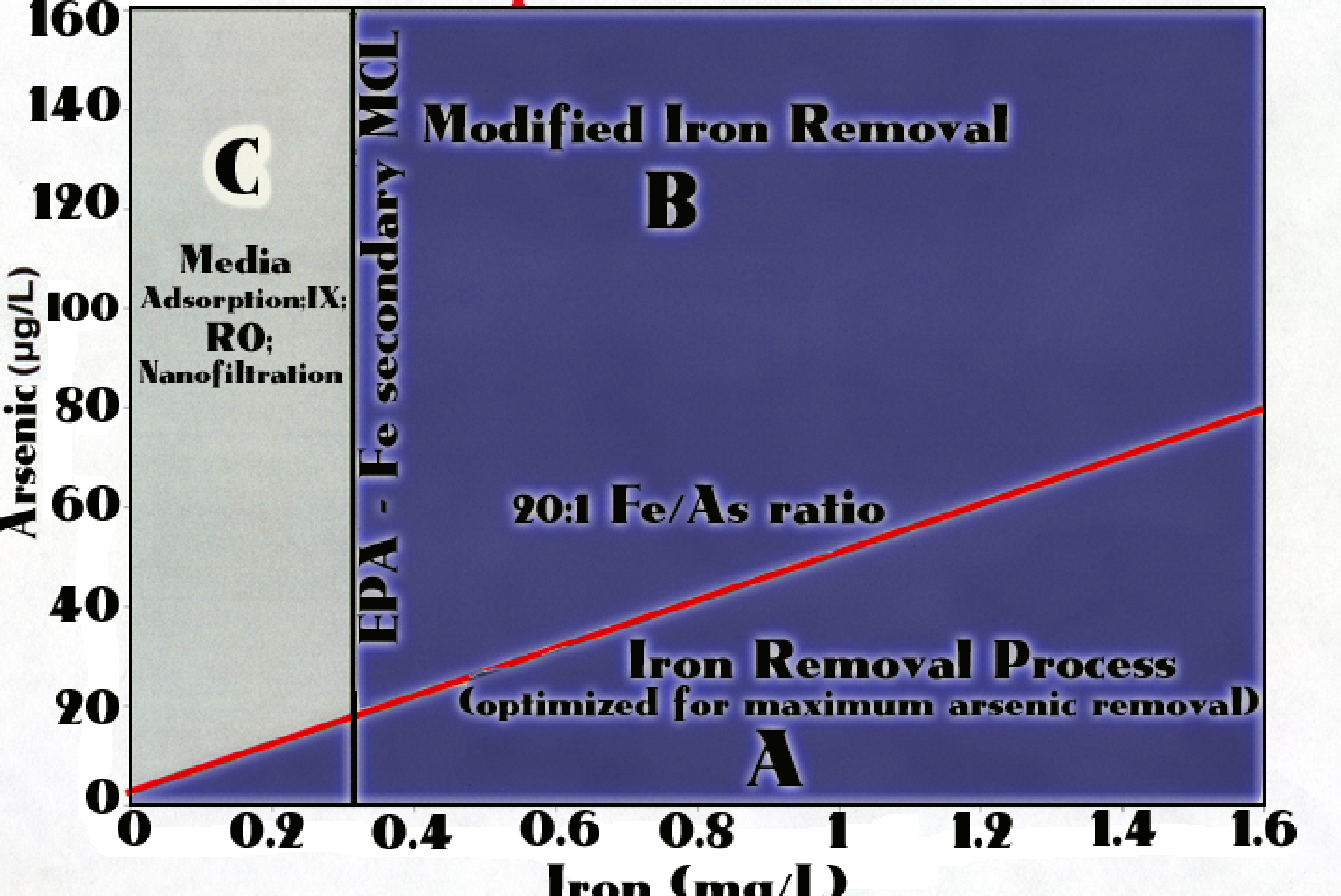

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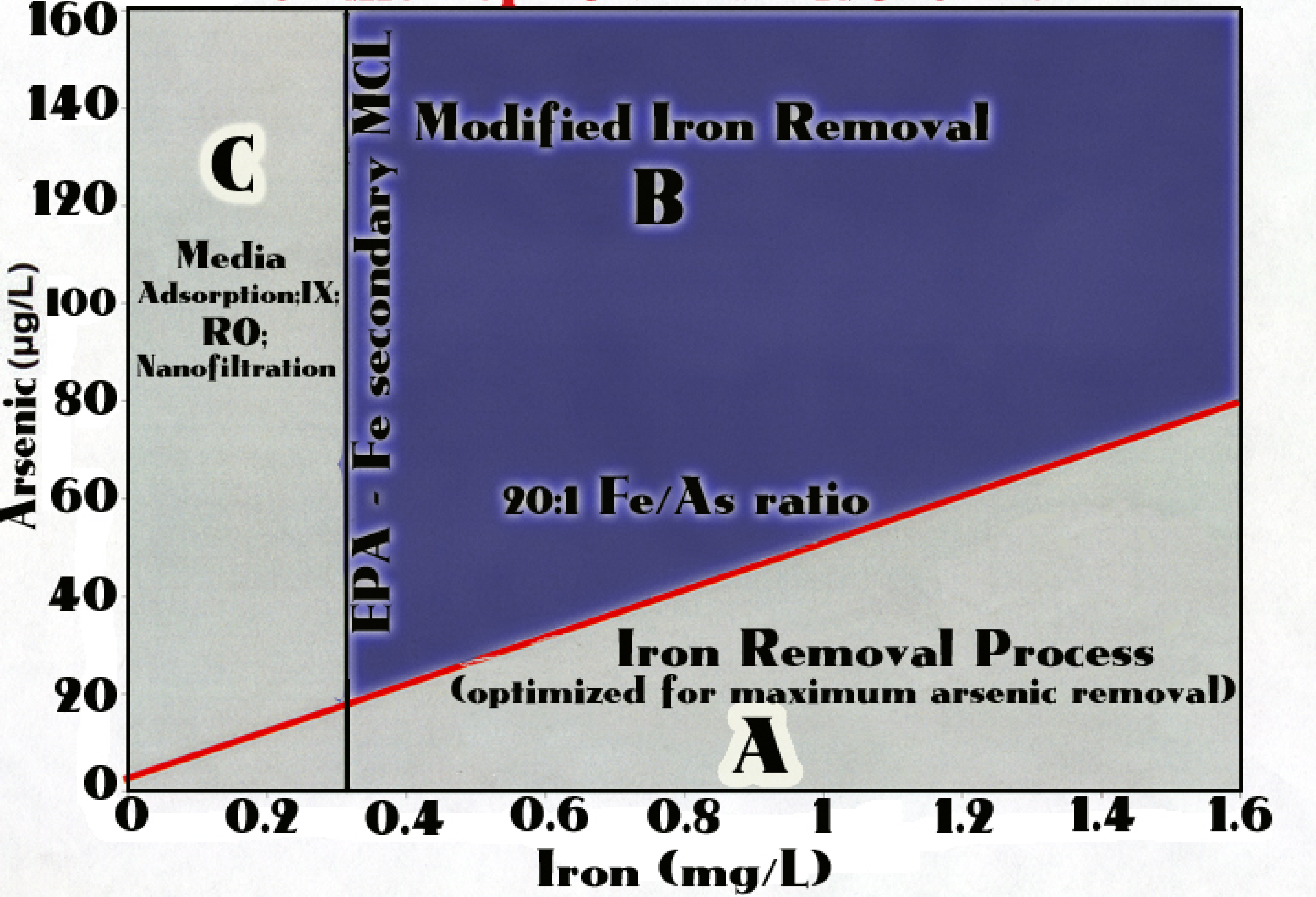
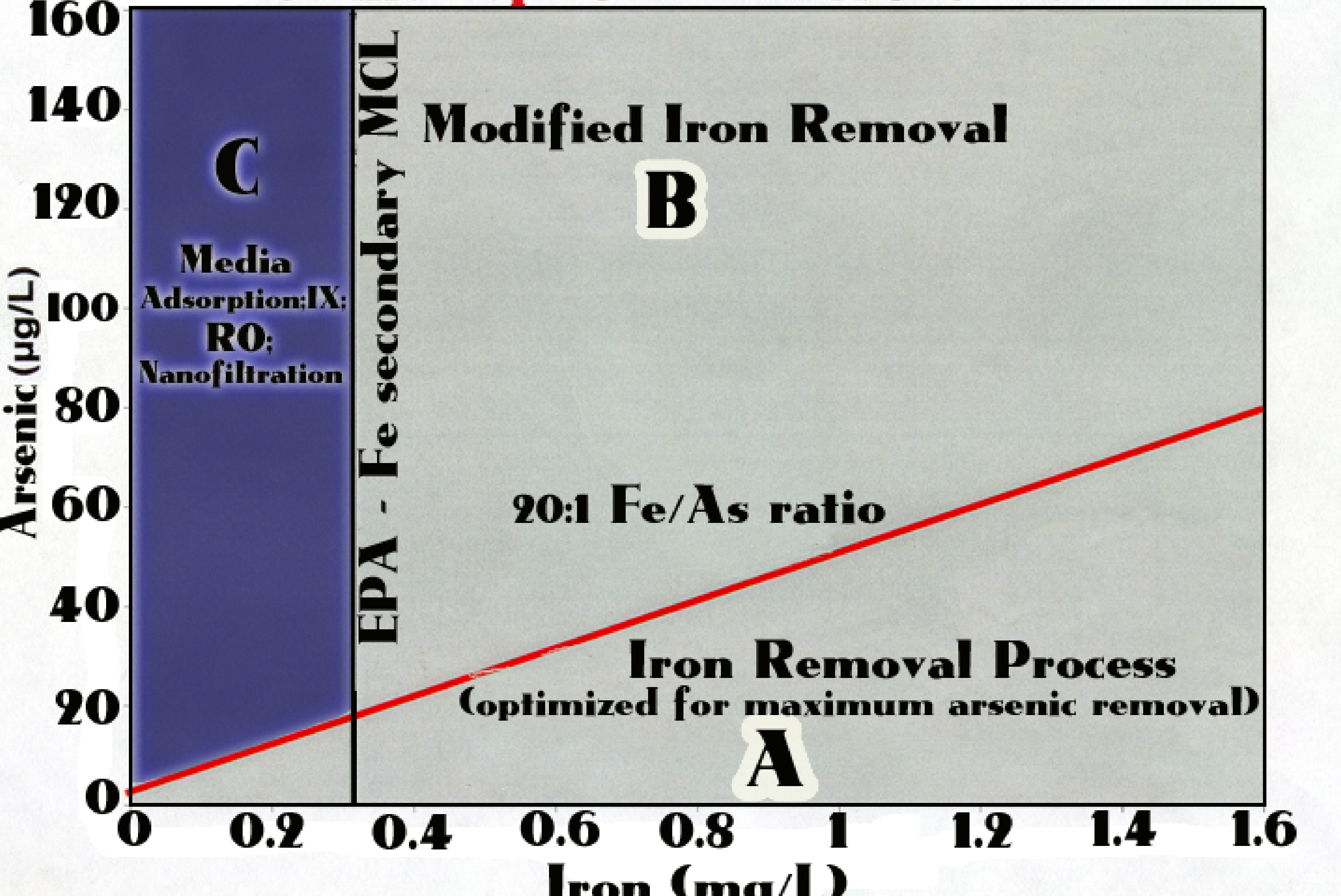


Arsenic Treatment Selection Guide as a Function of Raw Arsenic and Iron



Q: When should a stand alone AD26 System be considered vs. a two stage treatment system for arsenic?

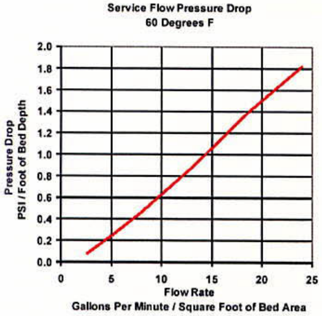
A: *The figure shown provides some guidance on the appropriate configuration for a specific water chemisty. Mainly, it wil be selected by iron and arsenic levels in the feed water. High levels of arsenic combined with high iron would favor a two stage treatment train for optimal performance to meet the Arsenic MCL. For low arsenic concentrations, a stand alone AD26 system may achieve the treatment goals. Consult AdEdge for guidance on the best approach.*

Q: Is chlorine needed for the system and does the media need replacement?

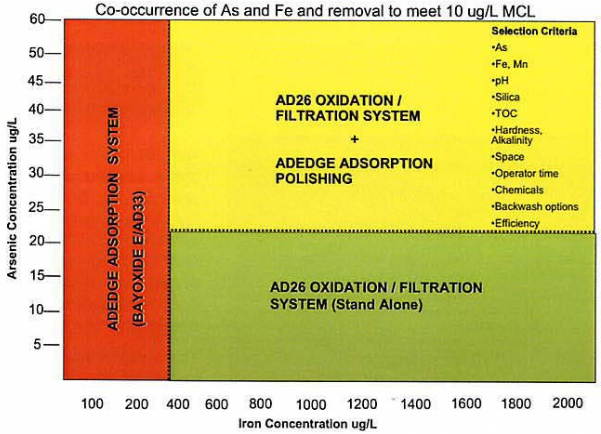
A: *A low Hypochlorite dose is recommended for optimal performance of the AD26 systems. It enhances the removal process, improves longevity, and keeps the surface of the media oxidized to prevent buildup of solids. Media life is typically 5+ years before replacement.*

Q: How do I determine the best way to achieve my treatment goals for my particular site?

A: *Begin first by obtaining a complete site specific water profile from a qualified lab. This information can then be submitted to AdEdge technical support to discuss your application, equipment sizing, and costs.*



AdEdge Treatment Selection



Operating Conditions	
pH Range	*6.5 – 9*
Treatment Goals	*< 0.3 mg/L Fe; < 0.05 mg/L Mn < 0.010 mg/L As*
Service Flow Rate	*10-12 gpm / Sq Ft*
Backwash Flow Rate	*18-20 gpm / Sq Ft*
Bed Expansion	*20-30% typical*
Pressure Drop	*< 5 psi typical across system*
Oxidant	*Hypochlorite feed for best results*
Oxidant Contact Time	*30 seconds*
Typical Oxidant Dosage	*0.5 – 2.0 ppm*
Backwash Frequency	*Site Specific (1-2X per week typical)*
Media Life Expectancy	*Site specific; typically 5+ years*

adedge
Manage the elements

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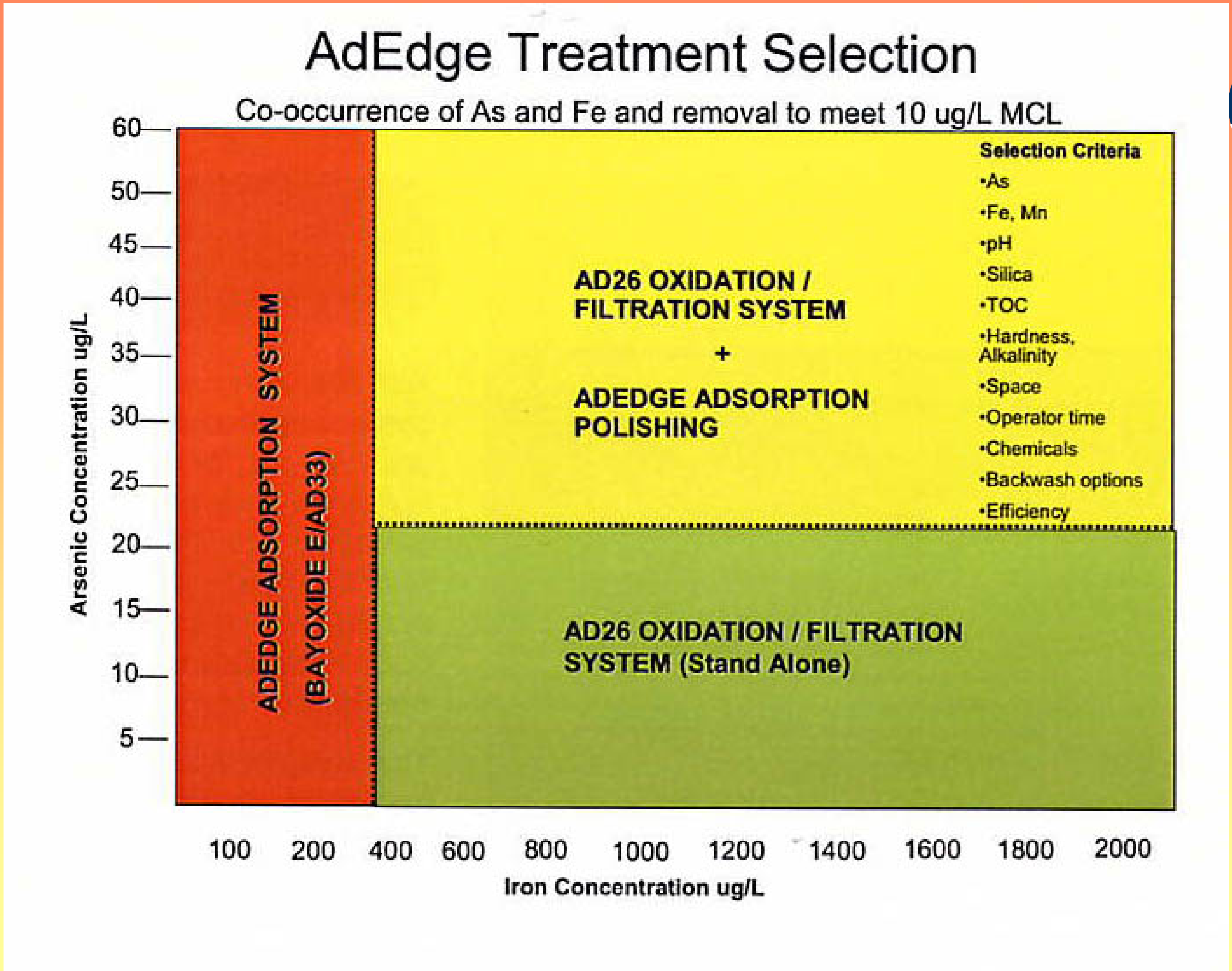

AdEdge Treatment Selection
Co-occurrence of As and Fe and removal to meet 10 ug/L MCL
Arsenic Concentration ug/L
60
50
45
40
35
30
25
20
15
10
5
ADEDGE ADSORPTION SYSTEM
(BAYOXIDE E/AD33)
AD26 OXIDATION / FILTRATION SYSTEM
+
ADEDGE ADSORPTION POLISHING
Selection Criteria
•As
•Fe, Mn
•pH
•Silica
•TOC
•Hardness, Alkalinity
•Space
•Operator time
•Chemicals
•Backwash options
•Efficiency
AD26 OXIDATION / FILTRATION SYSTEM (Stand Alone)
100
200
400
600
800
1000
1200
1400
1600
1800
2000
Iron Concentration ug/L

Arsenic Removal by Iron Removal Processes

Removal of 1 mg/L of iron

achieves

removal of 50 ug/L arsenic
(Optimized conditions and As[V])

Arsenic Removal During Iron Removal Considerations

Iron in water (>20/1 Fe/As ratio)?

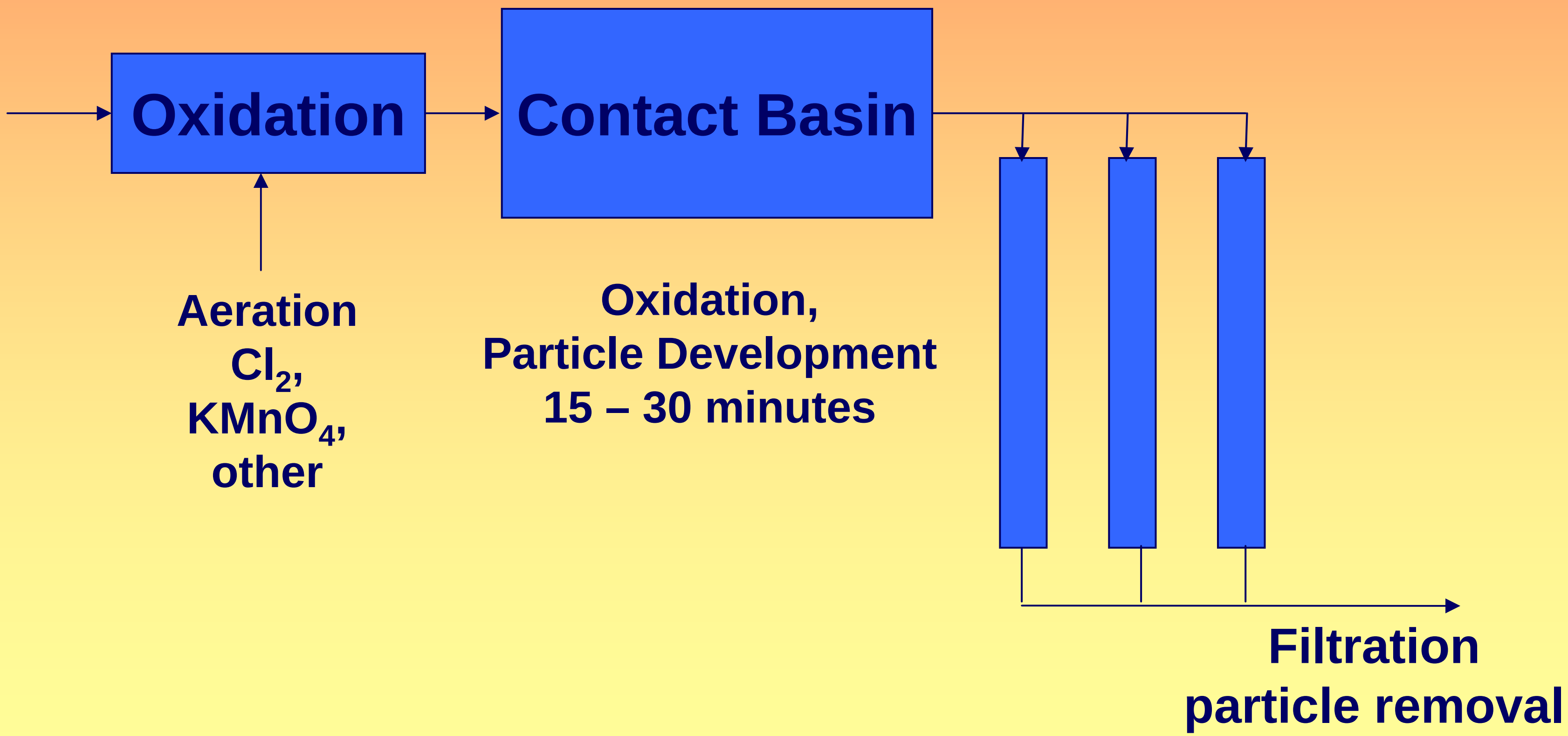
- **Form of arsenic, III or V?**

  Oxidation:
  - **Type of oxidant: oxygen, chlorine, $KMnO_4$…?**
  - **Point of application?**
- **Contact time?**
  - **Iron and As oxidation**
  - **Arsenic adsorption**
- **How can arsenic removal be predicted?**
- **Ways to improve arsenic removal during iron removal?**

Iron (and Mn) Removal Basics

$Fe\ II \longrightarrow Fe\ III \longrightarrow Fe(OH)_{3\ (S)}$

$Mn\ II \longrightarrow Mn\ IV \longrightarrow MnO_{2\ (S)}$



Iron and <u>Arsenic</u> (and Mn) Removal

$Fe\ II \longrightarrow Fe\ III$

$As\ III \longrightarrow As\ V$

Oxidation

Aeration
Cl_2,
$KMnO_4$,
other

Note: Aeration will not oxidize As III to As V

Iron and Arsenic (and Mn) Removal

Fe(III)/As particles

+

arsenic

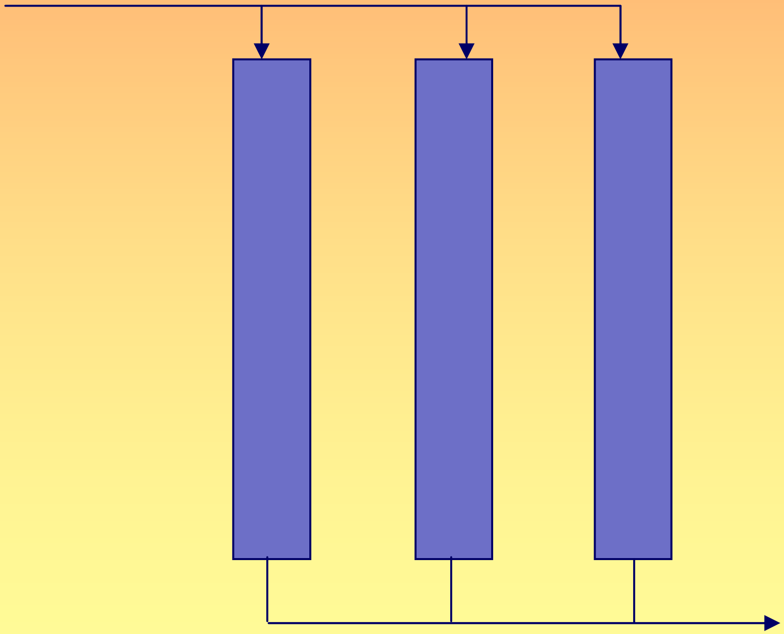
Contact Basin

Oxidation, particle development

Iron and Arsenic (and Mn) Removal

Filtration

Fe III/ As Particle Removal



Oxidant Selection

- Depends on As, Fe (and Mn)
- Aeration
  - Will not oxidize Mn II and As III (-)
  - May need contact basin (-)
  - Iron particles have less surface area (-)
  - Longer filter run lengths (+)
- Strong oxidants (chlorine, permanganate, etc)
  - Address Mn and As oxidation (+)
  - More particle surface area (+)
  - Probably no contactor needed (+)
  - Difficult to feed (-)
  - Shorter filter run lengths (-)

Assessment Tool

Jar Test

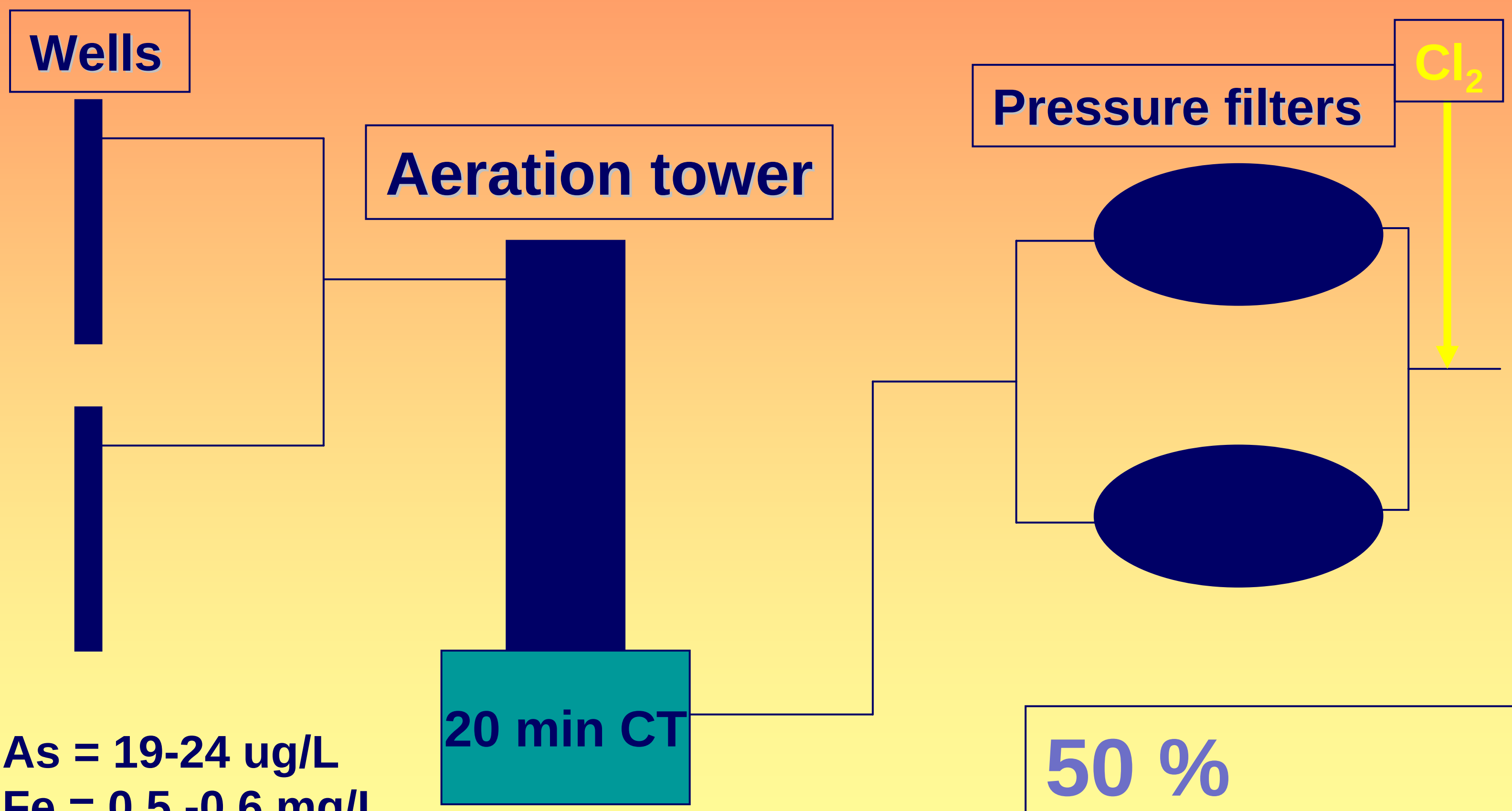
Oxidation- Point of Application

Case Study - Michigan

Parameter	Concentration
Arsenic – ug/L	19 - 24
As III	95 %
As V	5 %
Calcium – mg/L	74 - 84
Magnesium – mg/L	30 - 33
Iron – mg/L	0.5 - 0.6
Manganese –mg/L	0.02
Sulfate – mg/L	50 - 60
Silica – mg/L	12 - 13
pH - units	7.1 - 7.3

Oxidation- Point of Application

Case Study - Michigan

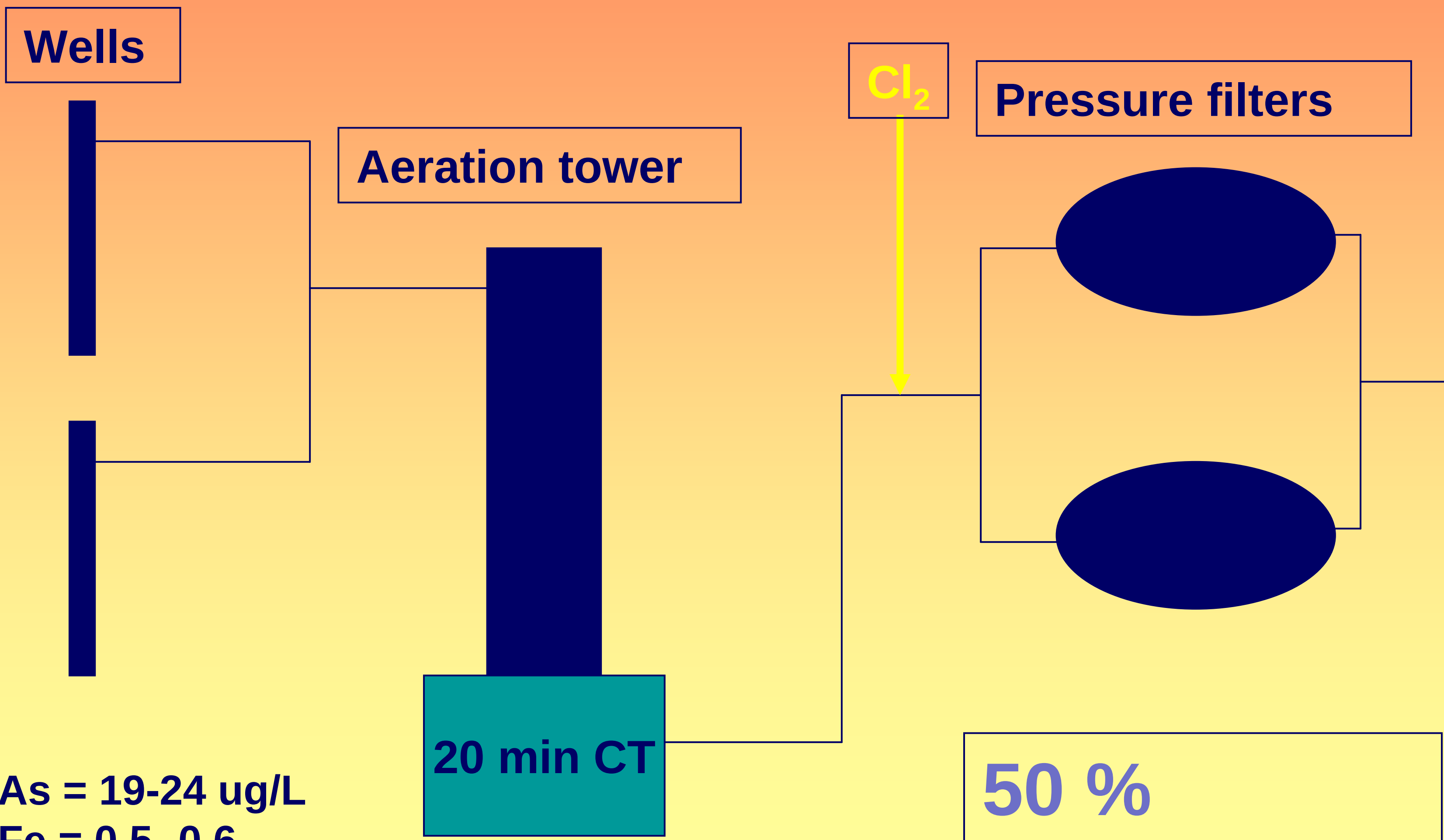


As = 19-24 ug/L
Fe = 0.5 -0.6 mg/L

50 % removal

Oxidation- Point of Application

Case Study - Michigan



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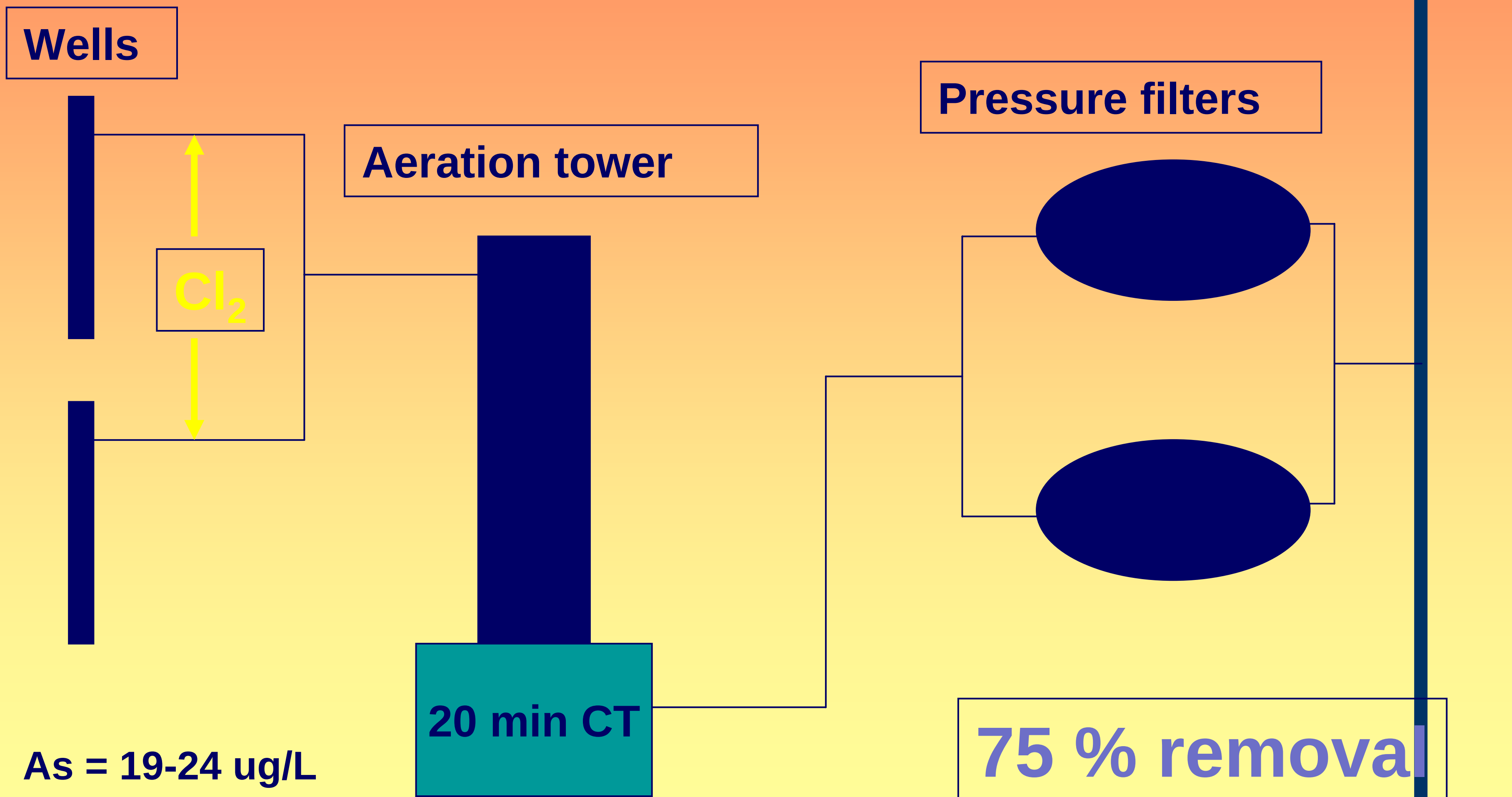

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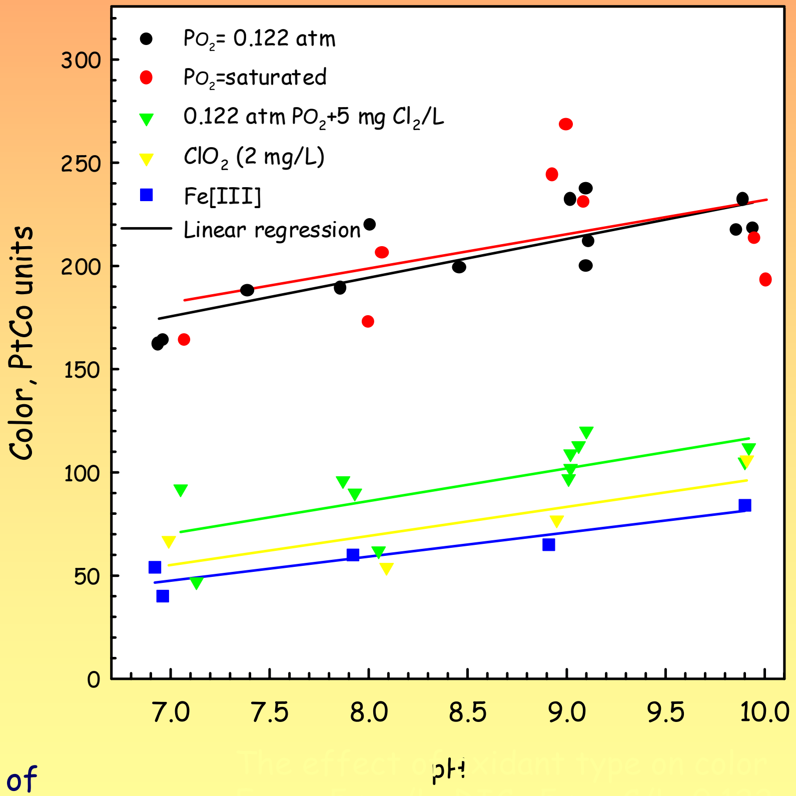
The Effect of Oxidant on Visual Properties of Iron Particles



The effect of oxidant type on the color of iron particles collected from filter backwash.

Process Modifications

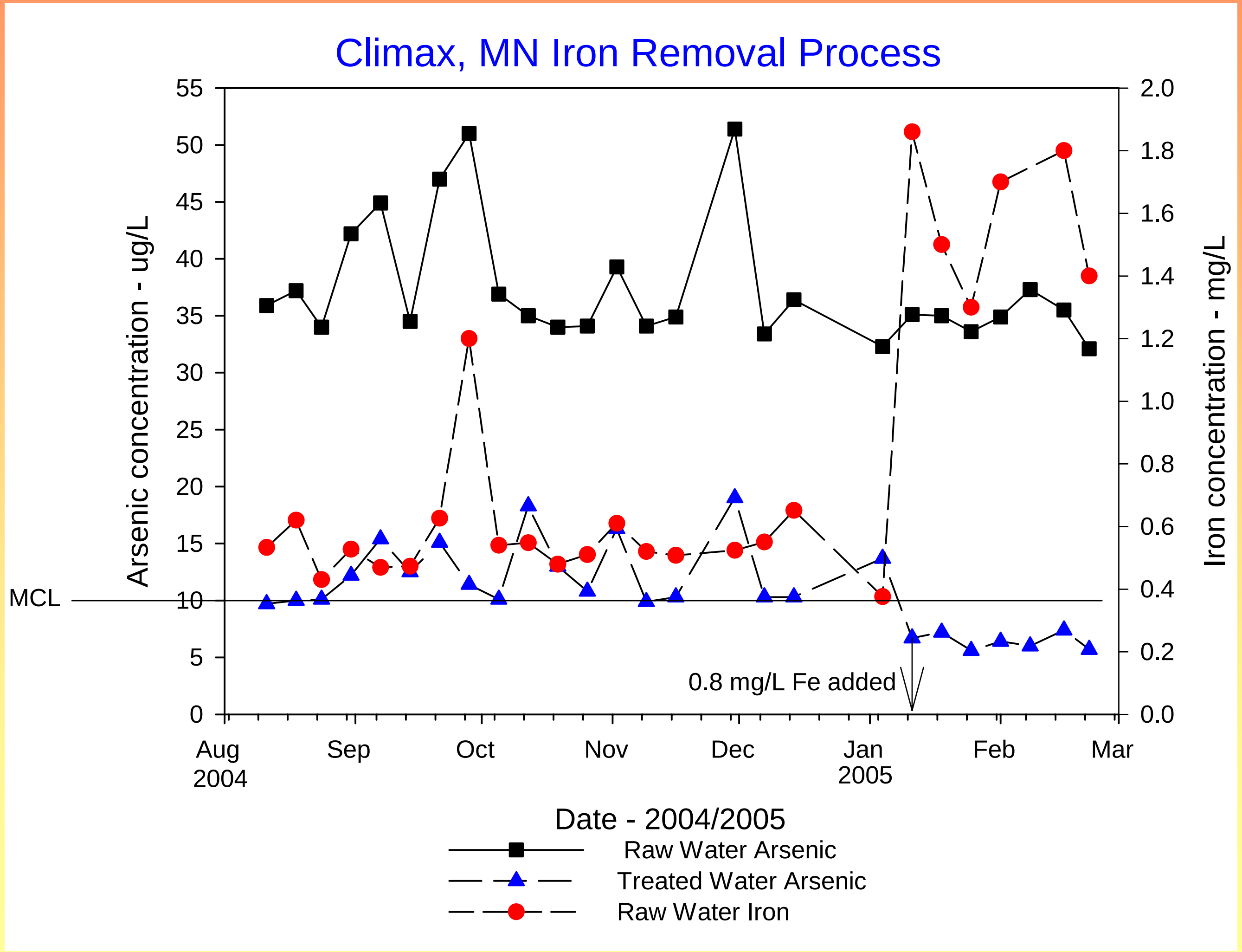
Increasing As Removal

Utility with iron removal in place or will be in place but can not meet MCL:

- Change point of oxidant addition
- Increase iron concentration
- Adjust pH
- Replace media w/ As adsorption media

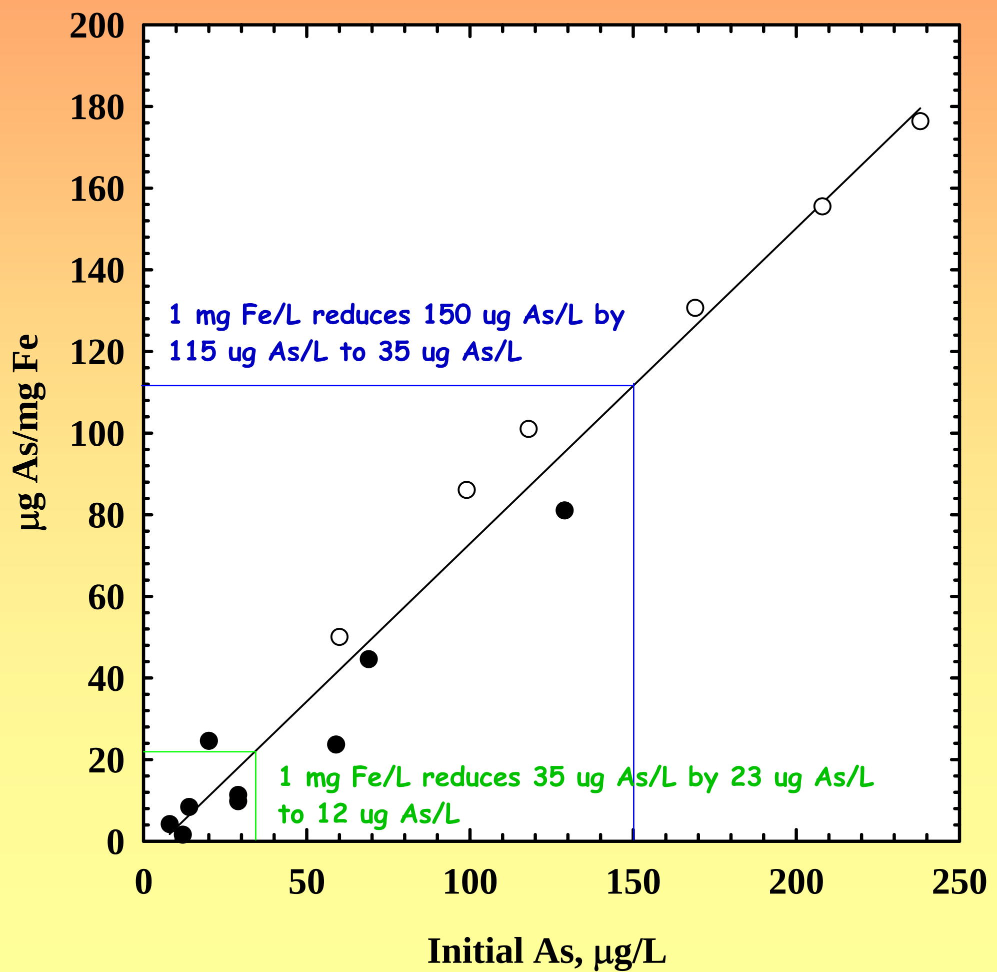
Climax, MN Iron Removal System

Climax, MN Iron Removal System



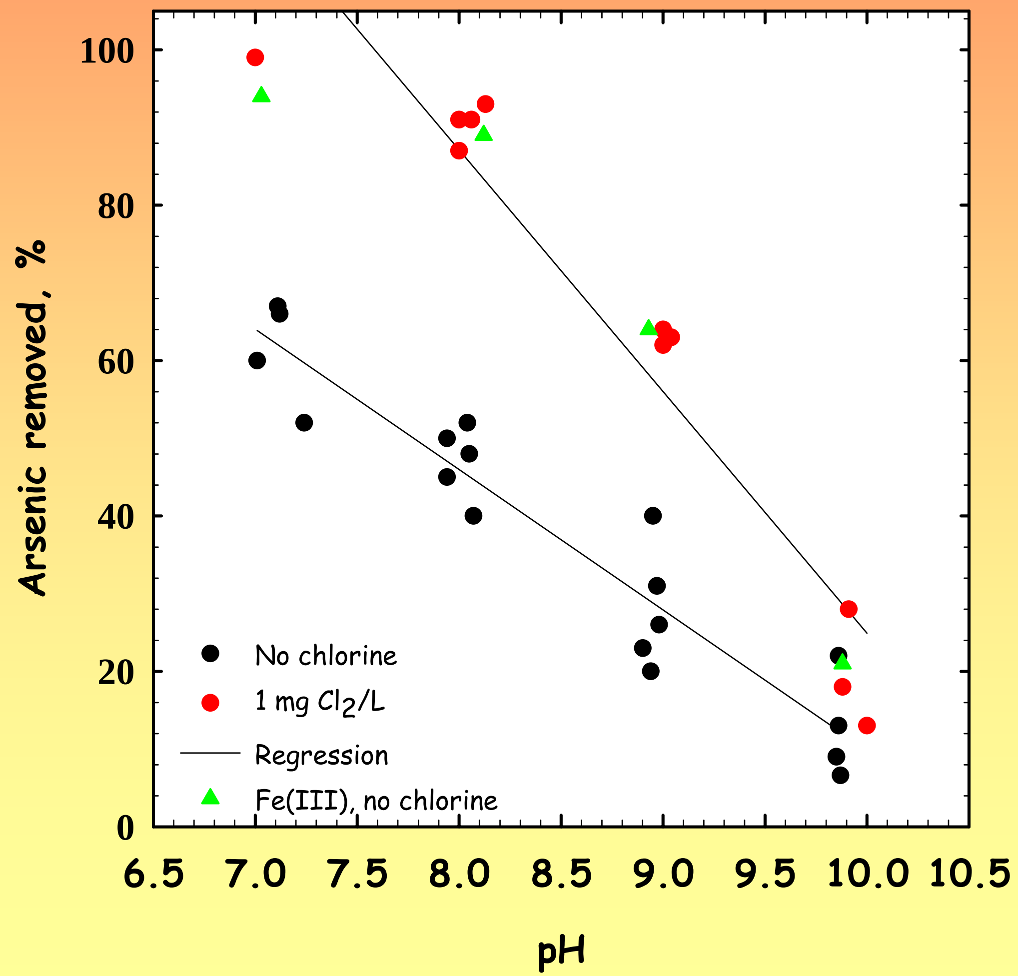
The Effect of Initial Arsenic(V) Concentration on the Capacity of Iron to Remove Arsenic

(Fe(II)init=1 mg/L, DIC=10 mg C/L, pH=8, 24^{o}C)



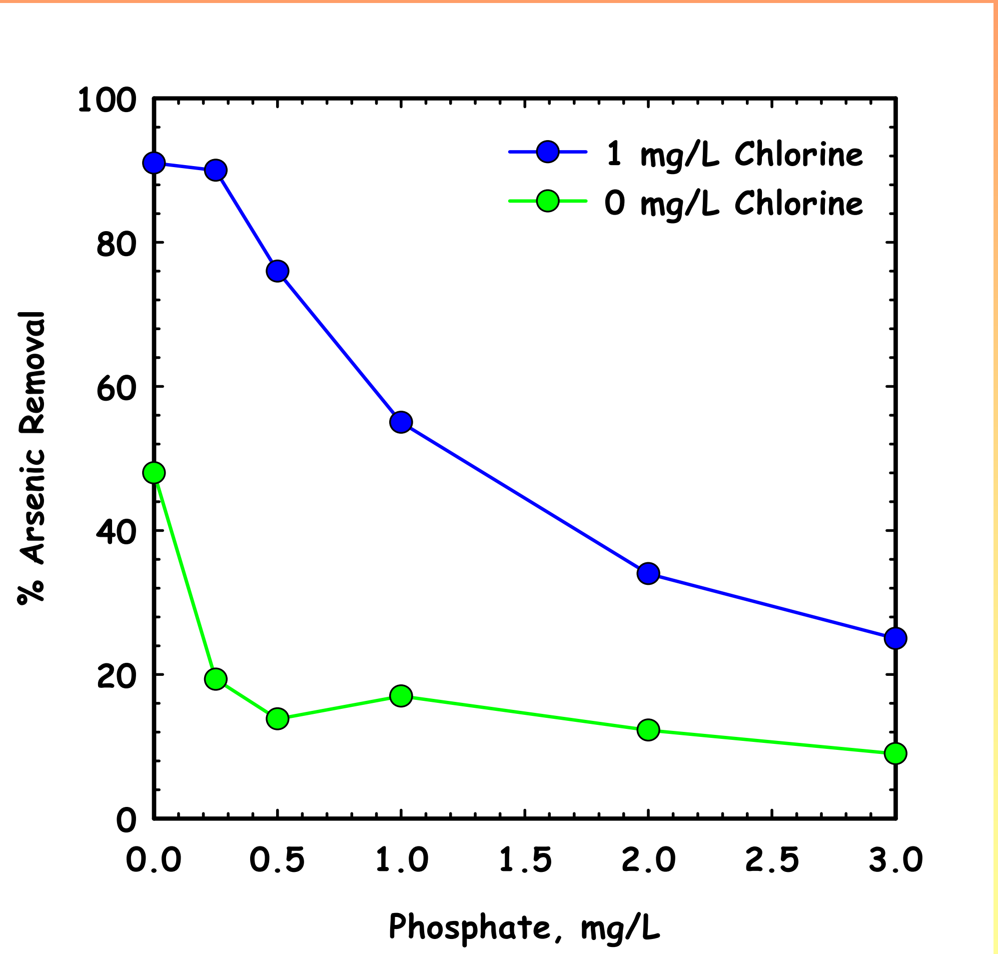
The Effect of pH, Iron and Free Chlorine on Arsenic Removal

1 mg Fe/L, 100 mg As(V)/L, 5 mg C/L DIC, PO2= 0.122 atm, 24 ^{O}C



Effect of Water Quality

1 mg Fe/L, 100 ug As(V)/L, 5 mg C/L DIC, pH=8, 24 ^{O}C

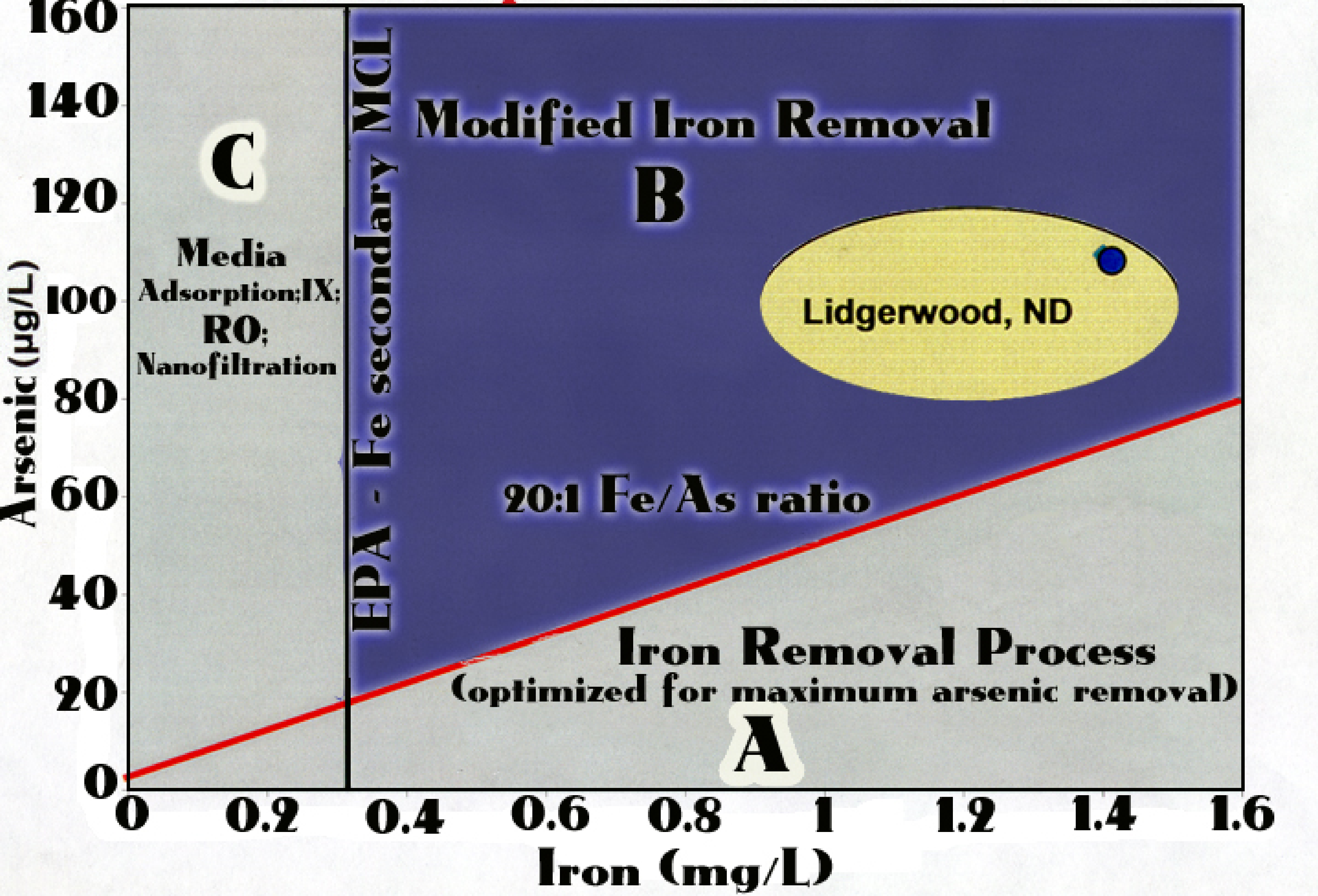


Lidgerwood, ND

Two Wells:

- **100 feet deep**
- **As Raw 135 – 150 ug/L (mostly As III)**
- **As Finished 35 ug/L**
- **Fe Raw 1.3 – 1.6 mg/L (9/11:1)**
- **Superfund site – arsenic for grasshopper control**

Arsenic Treatment Selection Guide as a Function of Raw Arsenic and Iron

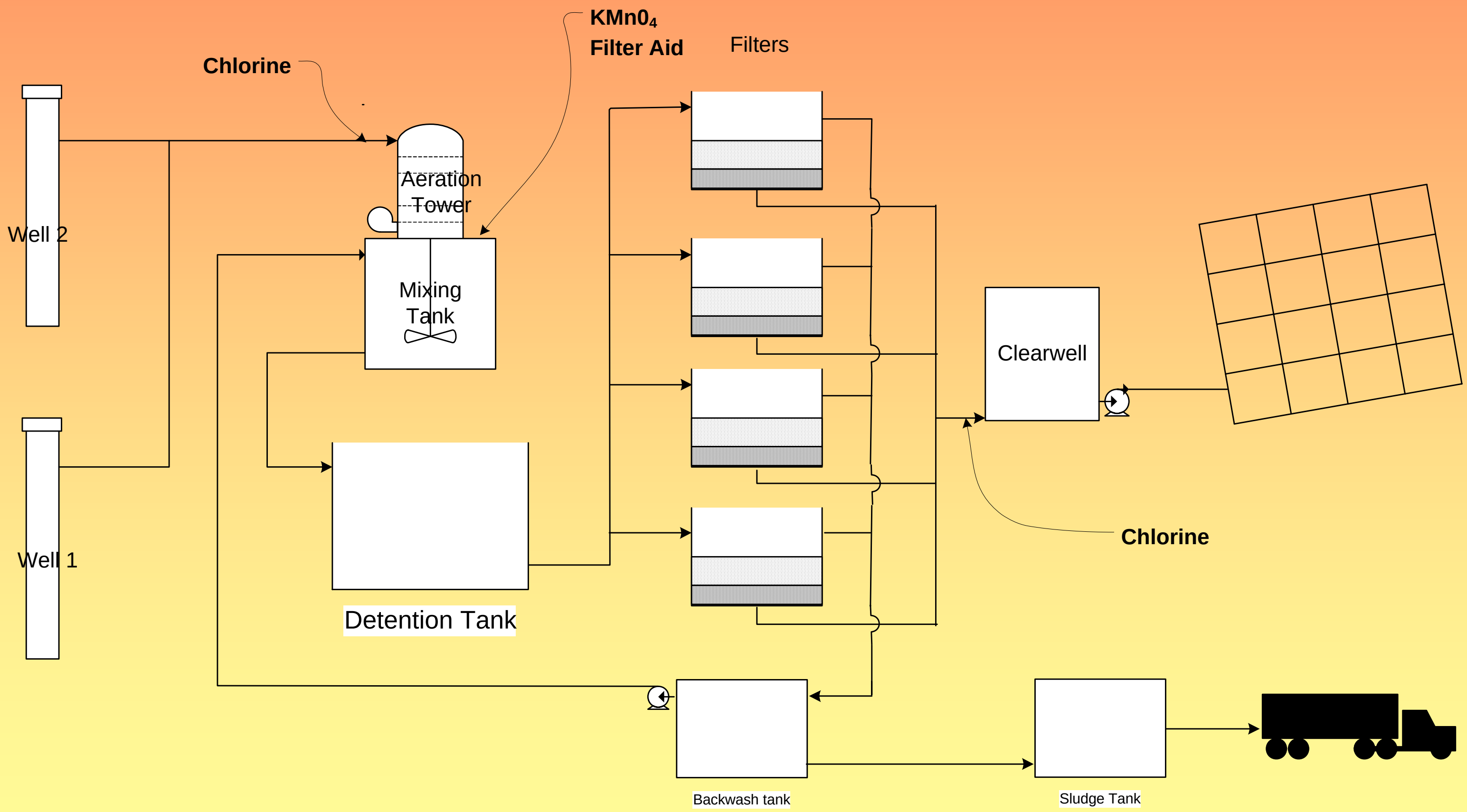


Lidgerwood, ND

Existing Treatment:

- **Pre-chlorination**
- **Aeration**
- **Oxidation – $KMnO_4$**
- **Filtration Aid – polymer**
- **Filtration – Antrasand (2 gpm/ft^2)**
- **Post chlorination and fluoridation**

Lidgerwood, ND

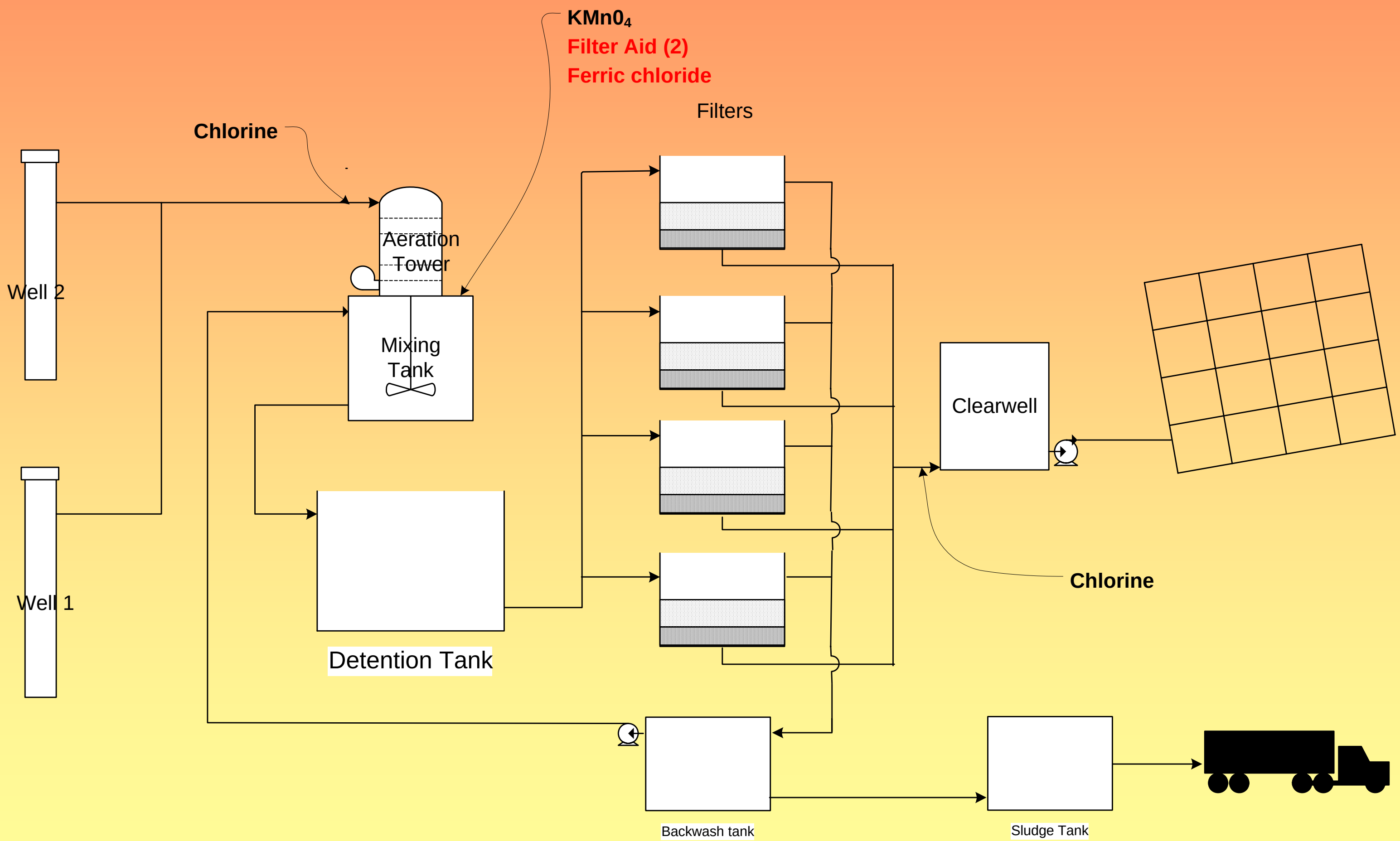


Lidgerwood, ND

EPA Demonstration Project:

- **Turbidmeters**
- **Additional polymer feed**
- **$FeCl_3$ Coagulation (~1 mg/L)**
- **As Finished 7-8 ug/L**
- **Cost - $55,740**

Lidgerwood, ND



Sabin, MN

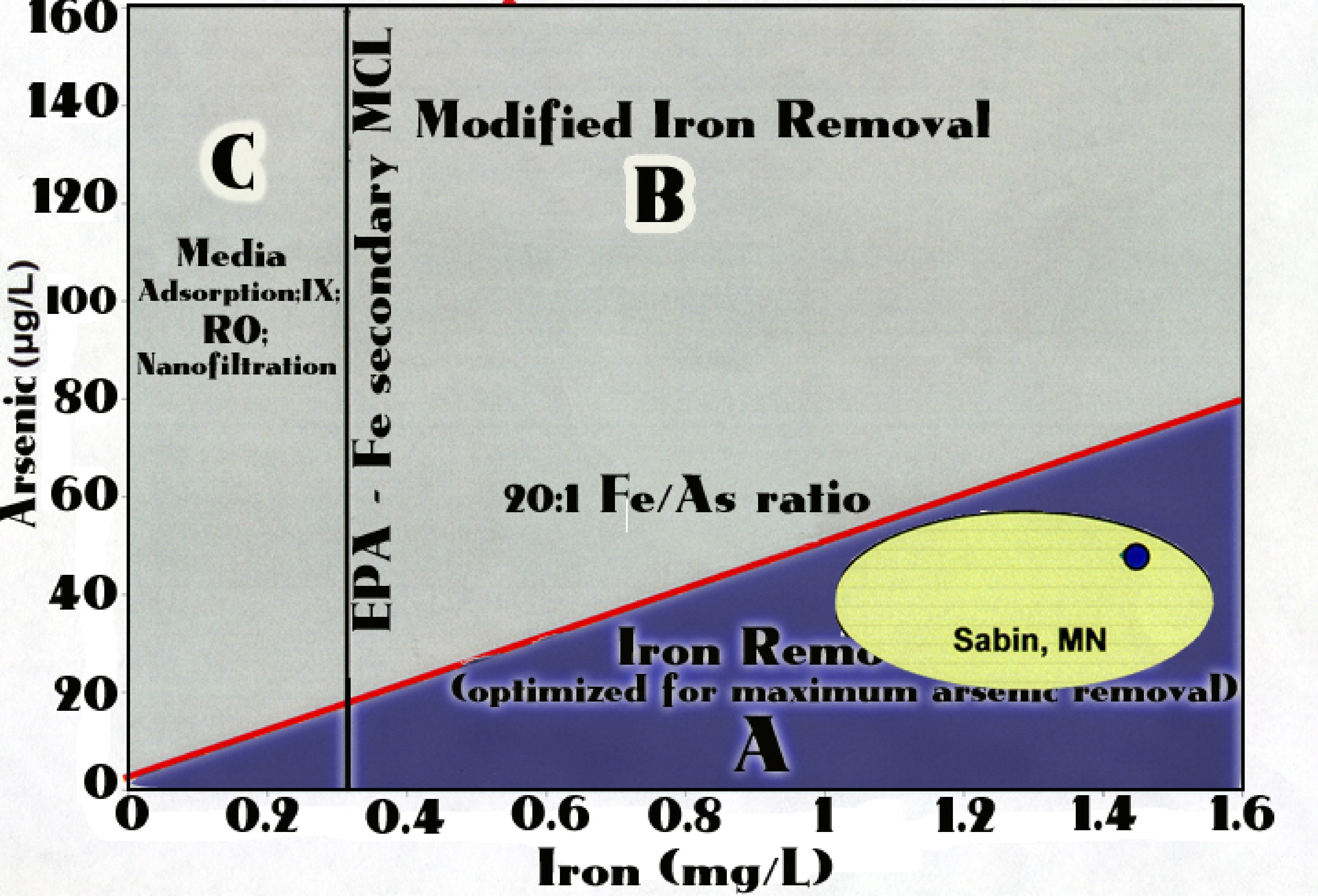
Two Wells:

•As Raw 45 ug/L

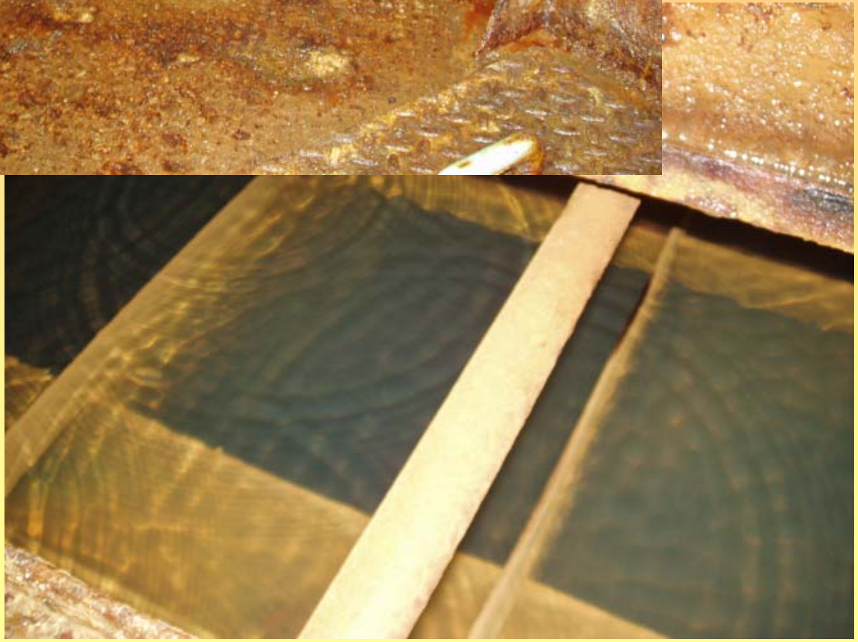
•As Finished 40 ug/L (20-25 ug/L

Plant is falling apart!!

Arsenic Treatment Selection Guide as a Function of Raw Arsenic and Iron



Sabin, MN



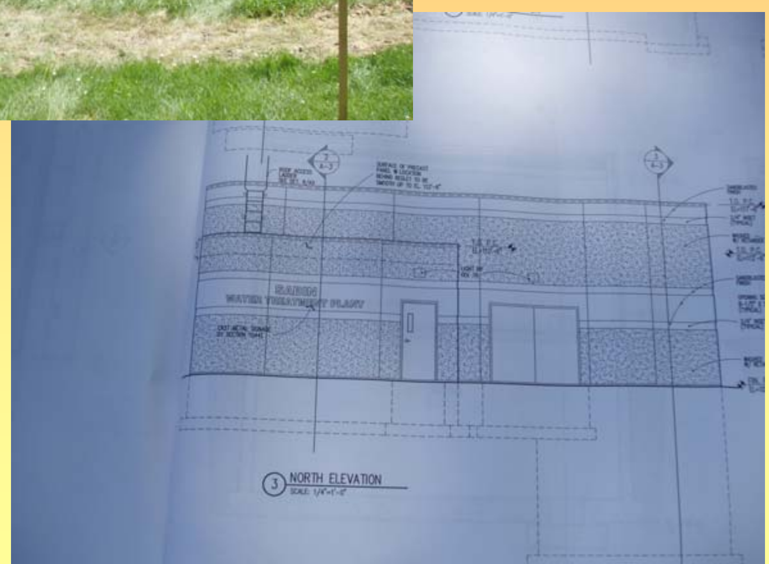
Existing Treatment:

- Chlorination
- Aeration
- Sand filtration
- Fluoridation

Sabin, MN

Major Capital Improvement:

- **Population 400**
- **$1,200,000 Total cost**
    - **$800,000 low interest loan**
    - **$160,000 grant**
    - **EPA Demonstration Project**



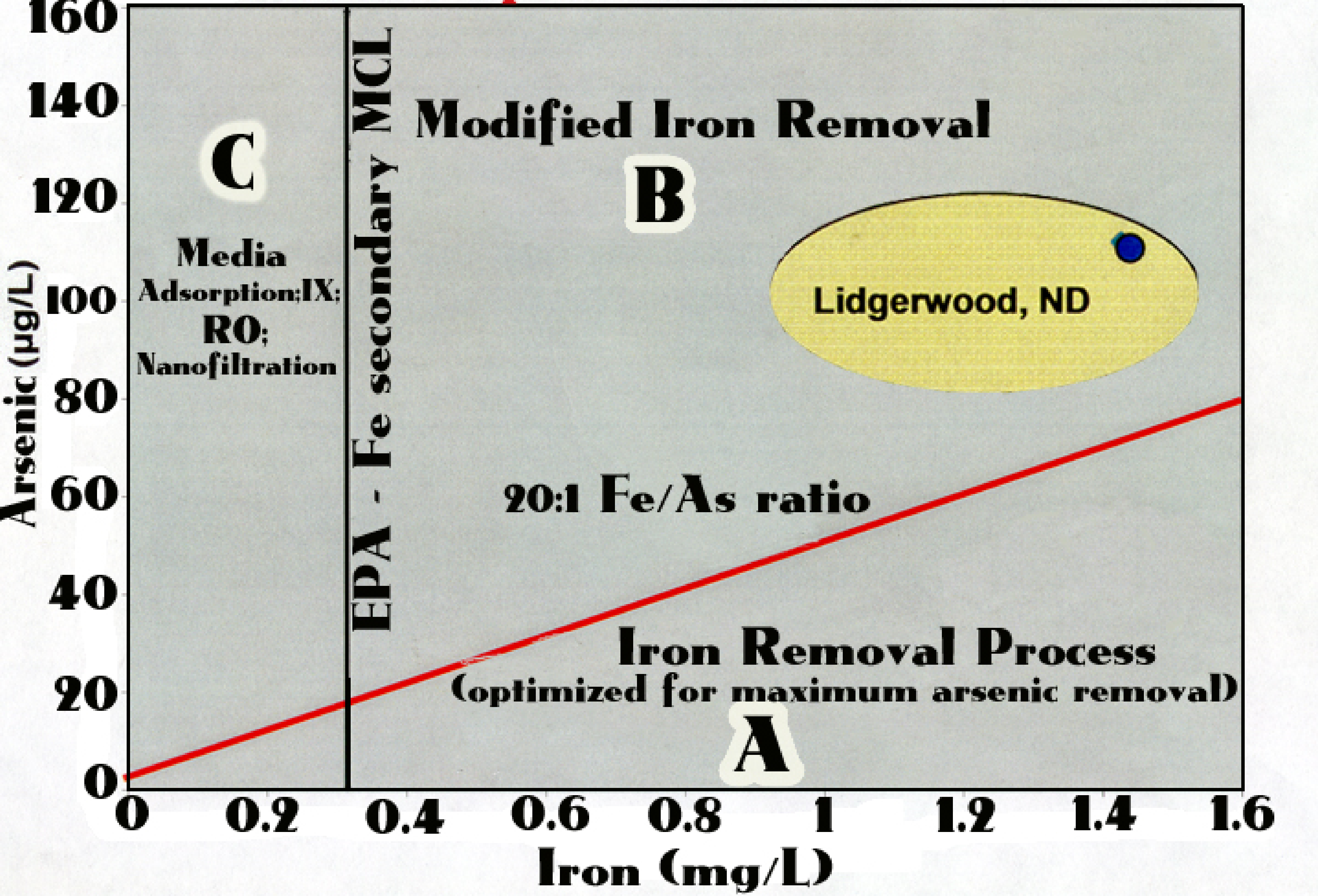
Conclusions

- Iron removal = arsenic removal
- Arsenic speciation is important
- Oxidant type is important
- Point of oxidant application is important
  - Arsenic removal impacted
  - Plant operation impacted

Thank-you

QUESTIONS TO DARREN LYTLE EPA/ORD

Arsenic Treatment Selection Guide as a Function of Raw Arsenic and Iron



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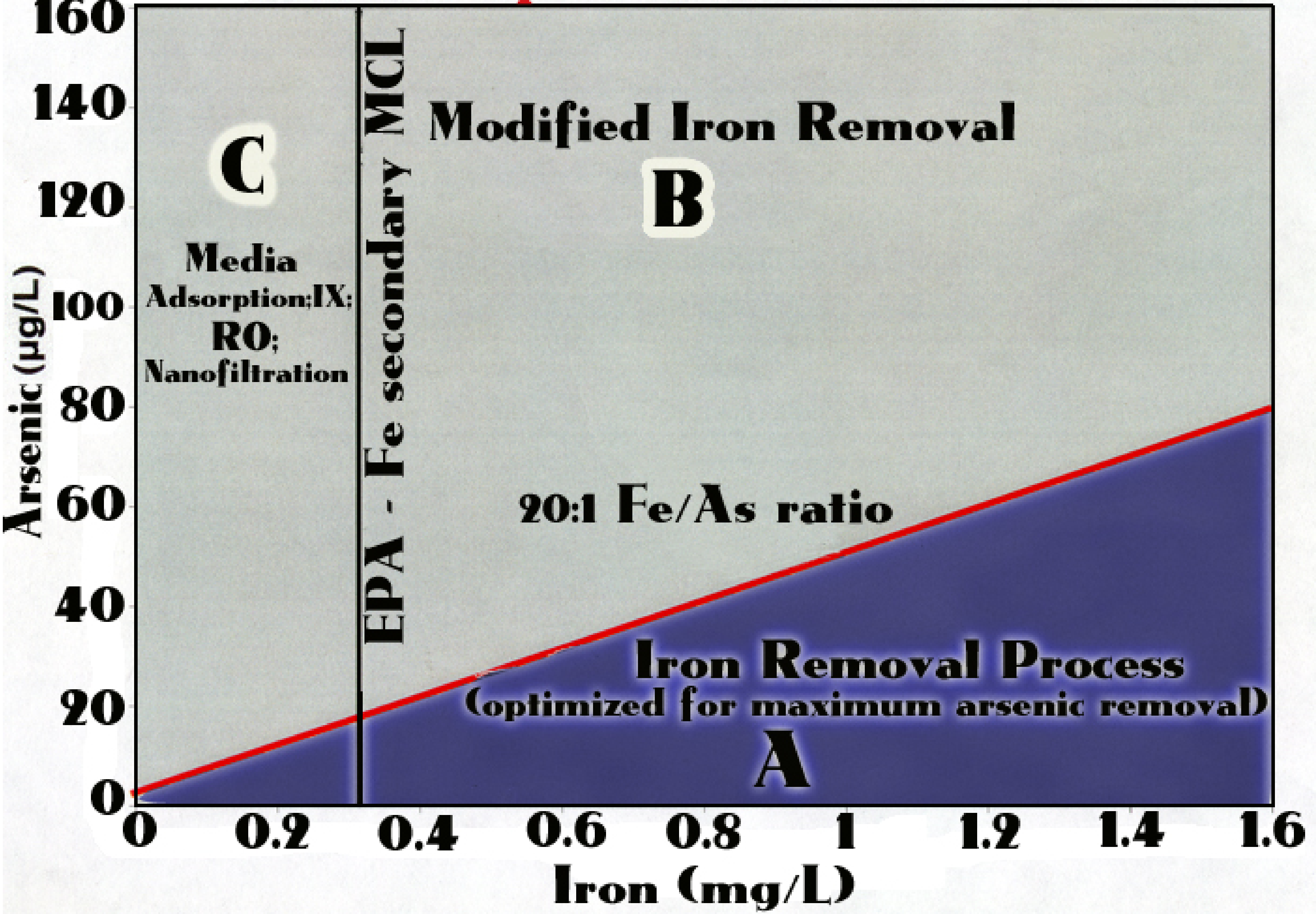

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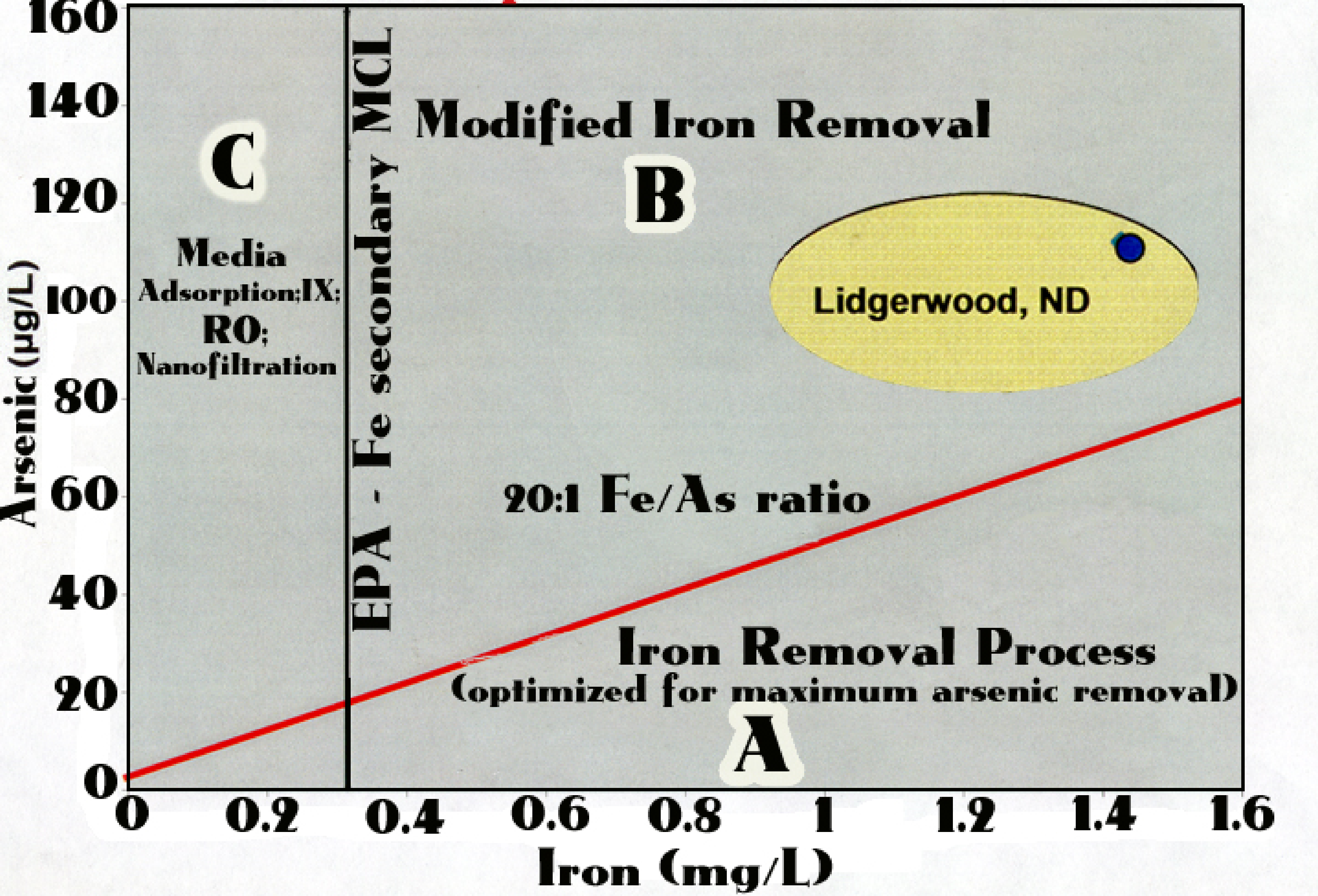

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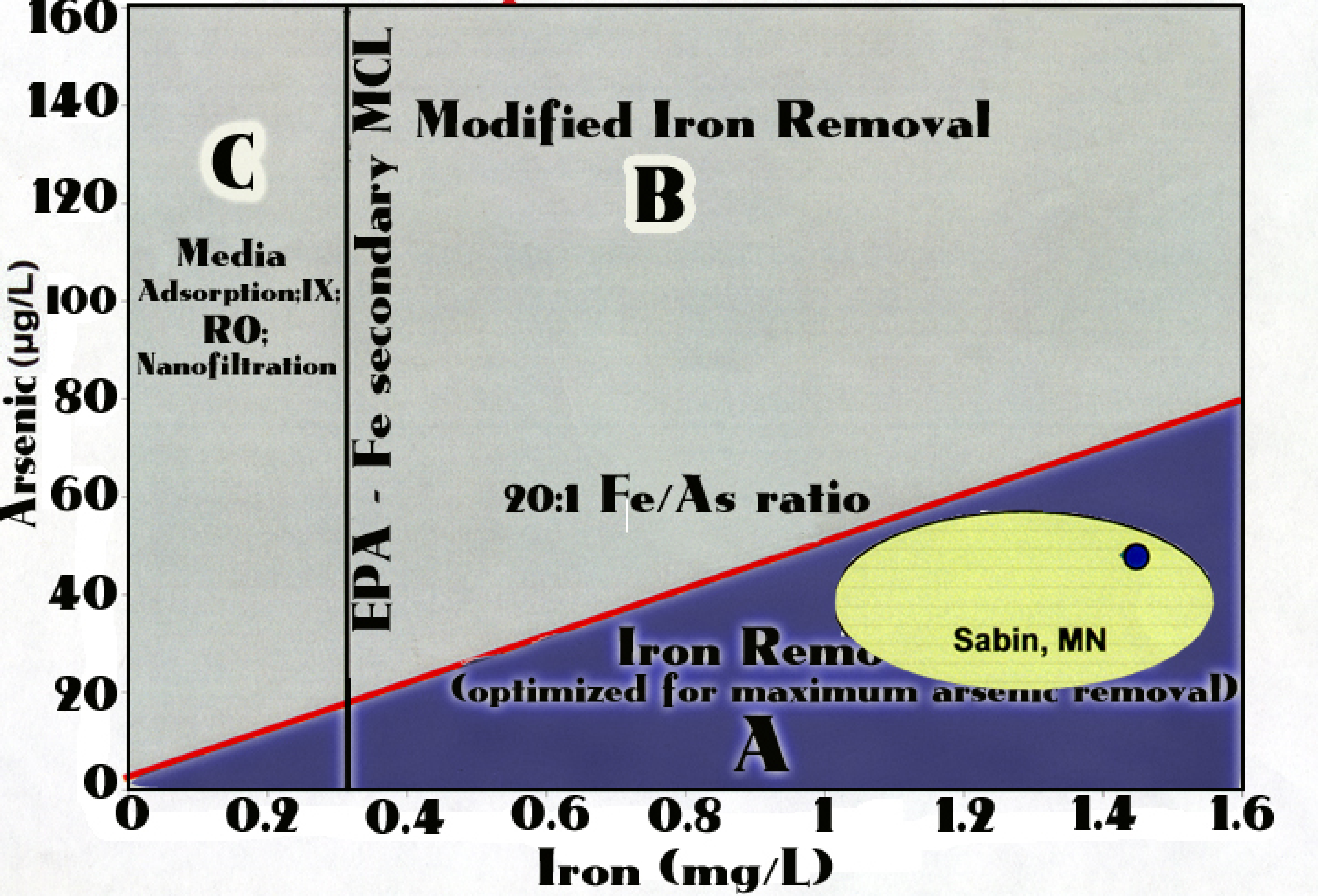

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