Arsenic Removal with Bayoxide® E33 Ferric Oxide Media & SORB 33® As Adsorption

De Nora Water Technologies
Agenda

• Background on Arsenic
• Arsenic Toxicity
• Sources of Arsenic
• Arsenic in Water
• Arsenic Regulations
• Arsenic Treatment Methods
• Case Study Problem and Solution:
  Hilltown Township Arsenic Removal Project
• Questions
Arsenic Background

- Natural occurring metalloid element
  - Atomic Symbol: As
  - Atomic Number: 33
  - Atomic Weight: 74.92
Arsenic Toxicity

- USEPA Group A Human Carcinogen
- Short-term (acute) and long-term (chronic) effects
- Skin, lung and bladder cancer
- Acute GI damage
- Cardiac problems
- Vomiting / diarrhea
- Dehydration
- Partial paralysis / blindness
- Hemolysis
- Vertigo
- Shock / death
Arsenic Chemistry

Arsenic found in ground waters is normally in an inorganic form as a soluble oxyanion species. It has 2 valence states, As(III) and As(V).

**“Oxidized” As(V) Oxyanion Dissociation**

\[
H_3AsO_4 \leftrightarrow H_2AsO_4^- + H^+ \quad pK_s = 2.2
\]

\[
H_2AsO_4^- \leftrightarrow HAsO_4^{2-} + H^+ \quad pK_s = 6.9
\]

\[
HAsO_4^{2-} \leftrightarrow AsO_4^{3-} + H^+ \quad pK_s = 11.5
\]

**“Reduced” As(III) Oxyanion Dissociation**

\[
H_3AsO_3 \leftrightarrow H_2AsO_3^- + H^+ \quad pH 6 - 8
\]

In waters within a natural pH range, the following species are present:

\[
H_3AsO_3, \quad H_2AsO_3^-, \quad H_2AsO_4^- \quad & \quad HAsO_4^{2-}
\]

As(III) occurs mainly under reducing conditions, e.g., in the absence of oxygen. When this water comes in contact with air, As(III) is oxidized to As(V).
Arsenic Sources in US Drinking Water
De Nora Water’s Role in Arsenic

Timeline - Lower Potable Water Arsenic Levels

Current Limit in 1990’s - 50 μg/L
1993    WHO Recommends 10 μg/L
1994    USEPA Recommends 2-20 μg/L
2000    New EC Directive
2003    UK Adopts 10 μg/L Standard
2006    USEPA Compliance for 10 μg/L MCL

Severn Trent Water

Severn Trent Services’ Sister Company
2nd Largest UK Water Company - 8 Million Customers
16 Well Water Sites with As > 10 μg/L
Total Treatment Capacity - 46.8 MGD (177 ML/Day)
No Developed Technology Selective for As Removal
As Removal – Treatment Selection

• **Adsorption**
  - Simple & non-regenerative in most cases
  - Single step process for most applications

• **Coagulation/Filtration**
  - Cost effective for large scale systems (over 4 MGD)
  - Effective for high Fe/Mn waters
  - No chemicals besides disinfection if Fe/As wgt ratio > 25

• **Reverse Osmosis**
  - Effective if other TDS must be removed
  - Won’t remove As(III)

• **Ion Exchange**
  - Good for waters with high As & pH and low SO₄ & HCO₃
  - Hybrid resins with impregnated Fe Oxide – Selective for As
  - Requires regeneration/posttreatment; won’t remove As(III)

De Nora provides As removal solutions using the most effective technology
SORB 33® - Arsenic Adsorption

**Process Features**

Removes As to <2 µg/L
Uses Granular Ferric Oxide (GFO) Adsorbent - Bayoxide® E33
High Capacity for As – Up to 4 Year Media Life
Easy Disposal of Spent Media - Passes EPA’s TCLP Test
Very Low Residuals (Wastewater)
In-line Pressure Vessel Operation - No Repumping

**System Advantages**

Low Capital & Operating Costs
Simple Process - Unattended Operation
No Chemicals for Media Regeneration
Removes As(III) - Unlike Most Other Processes
Adsorption - SORB 33® Systems

Water Flows through a bed of media

- **Pros**
  - Easy Operation
  - Little automation
  - Simple Maintenance
  - Not complex
  - Lowest Capital
  - Commonly lowest O&M

- **Cons**
  - Complex Waters
  - Low Bed volumes / Higher O&M’s

Most accepted technology

- Majority of projects in US selected adsorption
As Removal System – EPCOR: 2,400 gpm
As Removal System – Nellis AFB: 550 gpm
Adsorptive Media Pilot Testing – 3rd Party

- Breakthrough Curves – determine best performance
- 4 different medias tested at Mesa, AZ by DSWA
On-site Pilot Test Program

**Program Scope**
- Test Protocol
- 4"-∅ Clear Column with Media
- Manual Valves
- Simple Instruments
- Consistent Water Supply
- Data Collection & Monitor
- Weekly Sampling
- 2-6 Month Program
Test Evaluation – Breakthrough Curves

Breakthrough Curve Measures Media Performance - Longevity

- Arsenic effluent levels vs volume treated (“BV’s” or gallons H₂O/cu ft of media)
- As Breakthrough – Point at which media needs replacement
- The higher the BV’s to breakthrough, the lower the operating cost
Coagulation / Filtration – Omni-SORB™ Media

- **Product Composition**
  - 5% Manganese Dioxide (MnO₂) impregnated quartz (sand)
  - Non-porous blackish gray “catalytic” filtration media
  - Dense media – 88 lb/ft³
  - Screen Size – 18 x 60 mesh
  - Dustless – facilitates backwash

- **Producer**
  - Fermavi (Brazil) – Mines rich MnO₂ ore, refines into product

- **Media Life** – 9+ Years; Disposable as nonhazardous waste

- **Service Conditions**
  - Filtration rates of 7 -10 gpm/ft²
  - Backwash rates of 14 -16 gpm/ft²
Coagulation / Filtration – Omni-SORB™ Media

- Coagulation / Filtration
- Iron Removal
  - Removes Fe and Mn
  - Removes As/Fe/Mn
    - Needs high iron level
    - Fe:As -25:1 or better
- As/Fe/Mn or Fe/Mn
  - Catalyze the Fe and Mn in an oxidation/precipitation process
  - Coagulation / Filtration of Fe oxide & Mn oxide
  - Ferric chloride addition if needed
  - As adsorbed by Fe oxide
  - Backwash
Omni-SORB™ Systems

- Parallel Flow Filters
- Automated Valves
- Process Controls & PLC

Rozel, KS – 600 gpm
Fe & Mn Removal
Three 6’ Diameter Filters

Houghton, NY – 700 gpm
As Coag Filtration
Four 7’ Diameter Filters
N+1 Redundancy
Application Inquiry to Qualify the Water & Determine the Best Solution – Step 1

Site Qualification Form
- Complete & Submit
- Client & Contact Info
- Flows, contaminants & concentrations
- Pick Contaminant in Objectives to highlight key analyses

De Nora Analysis
- Conceptualize
  - Design
  - Flexibility
- Budget Proposal
  - Budget Capital
  - Budget O&M

De Nora Water Technologies
Inorganics Products
Application Inquiry – Step 2

Water Characterization

- Proprietary Model to Estimate Performance (BV’s)
- Is Water Normal Quality or is Testing Recommended?
  - Unit Operating Costs - $/1,000 gals or $/Acre-Ft
- RSSCT – Rapid Small Scale Column Test
  - 4 Week Lab Test to Quantify As Breakthrough & BV’s
  - Test Done in Tampa Lab on Client’s Well Water
- On-site Pilot Test
  - 0.5 gpm Test Program using 4”-Ø Column
  - Long Test Period to As Breakthrough

Full Scale System Design

- Adsorption Configuration: Parallel, Series, Bypass/Blend
- Pretreatment
  - Chlorination is Normal
  - pH Adjustment with CO₂ or HCl for High pH Waters
  - Fe/Mn Filtration for Elevated Fe & Mn Levels
  - H₂S Removal – Aeration, GAC, Oxidation/Filtration
- Coagulation/Filtration
  - Use High [Fe] Water to Precipitate & Filter As
  - Ferric Chloride Dosing for Very “Challenging” Waters
Sizing & Estimate Summary...

– Step 3

Process Sizes System

- Vessel Size
- Media Volume
- Performance – BV’s, etc.
- Flows Configuration
- Operating Costs: Includes annualized media replace & chemicals

Proposals Estimates Cost

- ROM or Budget
- Rough Order of Magnitude
- Issue to Client

**SORB 33® As Removal System Sizing & Estimate**

<table>
<thead>
<tr>
<th>Project Name &amp; General Information</th>
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<tbody>
<tr>
<td>Client: City of Cairo, GA</td>
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<tr>
<td>Name of Site: Test Well - 3,000 gpm</td>
</tr>
<tr>
<td>Primary Contact: Stacy G. Watkins</td>
</tr>
<tr>
<td>Engineer: Watkins &amp; Associates</td>
</tr>
<tr>
<td>Op Factor: 7.1 Hrs/Day or 29%</td>
</tr>
<tr>
<td>0.0% Bypass</td>
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</tbody>
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<table>
<thead>
<tr>
<th>System Design</th>
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<tbody>
<tr>
<td>SORB 33® Model No: EAS-9014</td>
</tr>
<tr>
<td>Adsorber No &amp; Size:</td>
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<tr>
<td>System Footprint: 96'L x 16'W x 14'H</td>
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<tr>
<td>Flow Configuration: Series</td>
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<tr>
<td>Adsorptive Media: Bayoxide E33 Granules</td>
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<tr>
<td>Media Quantity: 89,268 lbs (40.48 MT)</td>
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<tr>
<td>Backwash Volume: 21,970 gals/vessel</td>
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<tr>
<td>pH Adjustment: pH Adjust from 8.1 to 7.1</td>
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<tr>
<td>CO2 Flow: 207 scfh</td>
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<tr>
<td>Annual Usage: 60,640 lbs CO2</td>
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<table>
<thead>
<tr>
<th>System Configuration</th>
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</thead>
<tbody>
<tr>
<td>Well Pump</td>
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<tr>
<td>pH Adjust</td>
</tr>
<tr>
<td>CO2 Handling &amp; Feed</td>
</tr>
<tr>
<td>NaOCl ICI Cl2 Storage &amp; Feed</td>
</tr>
<tr>
<td>Not In Scope Of Supply</td>
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<tr>
<td>Disinfection</td>
</tr>
<tr>
<td>SORB 33® Adsorber</td>
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<tr>
<td>E33 Media</td>
</tr>
<tr>
<td>To Train 1</td>
</tr>
<tr>
<td>E33 Media</td>
</tr>
<tr>
<td>To Train 2 &amp; 3</td>
</tr>
<tr>
<td>To Storage or Distribution</td>
</tr>
<tr>
<td>Treated Water</td>
</tr>
</tbody>
</table>

**Budgetary Capital & Operating Costs**

- Annual O&M Costs: $168,400 per Yr or $118 / Acre Ft
- Total Water Volume Treated: 1,684 Million Gallons

**Special Notes**

- No PO4, SiO2 or V Assays
- Increased As to reflect pilot

Issued: 04-Jun-14 MAL: Y13 Proposal No. 36066
Media Replacement & Disposal

Media Removal
- DNWT subcontractors
- Vacuum removal or vactor truck
- Fill rolloffs or sacks
- TCLP analysis – verify media is non-hazardous

Media Replacement
- Gravity fill - 52 ft³ sacks
- Hydraulic fill - eductors
Hilltown Township Well No. 2

Hybrid Fe/Mn Filtration & As Adsorption

- Well No. 3 – 300 gpm
- Multiple Contaminants
  - Arsenic – 15 ppb
  - Iron – 250 ppb
  - Manganese – 110 ppb
- Aside from As removal, needed to remove Fe & Mn
  - Black & red water issue
- Hybrid design – 1 OmniSORB filter & 2 Sorb 33 adsorbers
  - Oxidize & filter all of the water to remove Fe & Mn
  - Treat 50% of filtered water through adsorption
  - Bypass and blend remainder
- System in service for over 10 years
  - Bayoxide E33 lasted 7 years before replacement
Hilltown Township
Hybrid Fe/Mn Filtration & As Adsorption
Questions?

De Nora Water Technologies
1000 Cliff Mine Rd, Suite 600
Pittsburgh, PA 15275

T: +1 412-788-8300
F: +1 412 788-8304
E: info@denora.com
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