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Engelhard ARM 200 for Arsenic Removal

Thomas J. Shaniuk, P.E.
Senior Research Engineer

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Water-Water Everywhere, but not a drop of Arsenic in it

- **Arsenic Regulation / Arsenic Chemistry**
- **Adsorbent media & how does it works**
- **Engelhard ARM 200™ media**
- **Who is Engelhard ?**
- **ARM 200 Field Applications**

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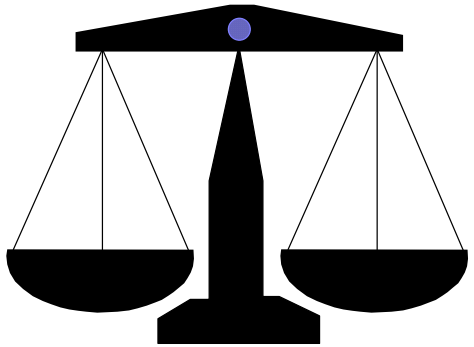
Arsenic Regulations for Drinking Water

- 1942: Public Health Service in USA establishes standard of 50 ppb As
- 1958: World Health Organization (WHO) sets 200 ppb limit
- 1975: US EPA sets limit of 50 ppb based on 1942 standard
- 1984: WHO lowers allowable concentration to 50 ppb
- 1993: WHO lowers limit again to 10 ppb
- 1995: US EPA begins to consider lowering As limit
- 1998: European Union (EU) accepts WHO guideline of 10 ppb
- 2001: President Bush signs legislation to lower limit in USA to 10 ppb
- 2003: 10 ppb becomes statutory requirement in United Kingdom (UK)
- 2006: Community Water Systems in USA must comply with 10 ppb As limit



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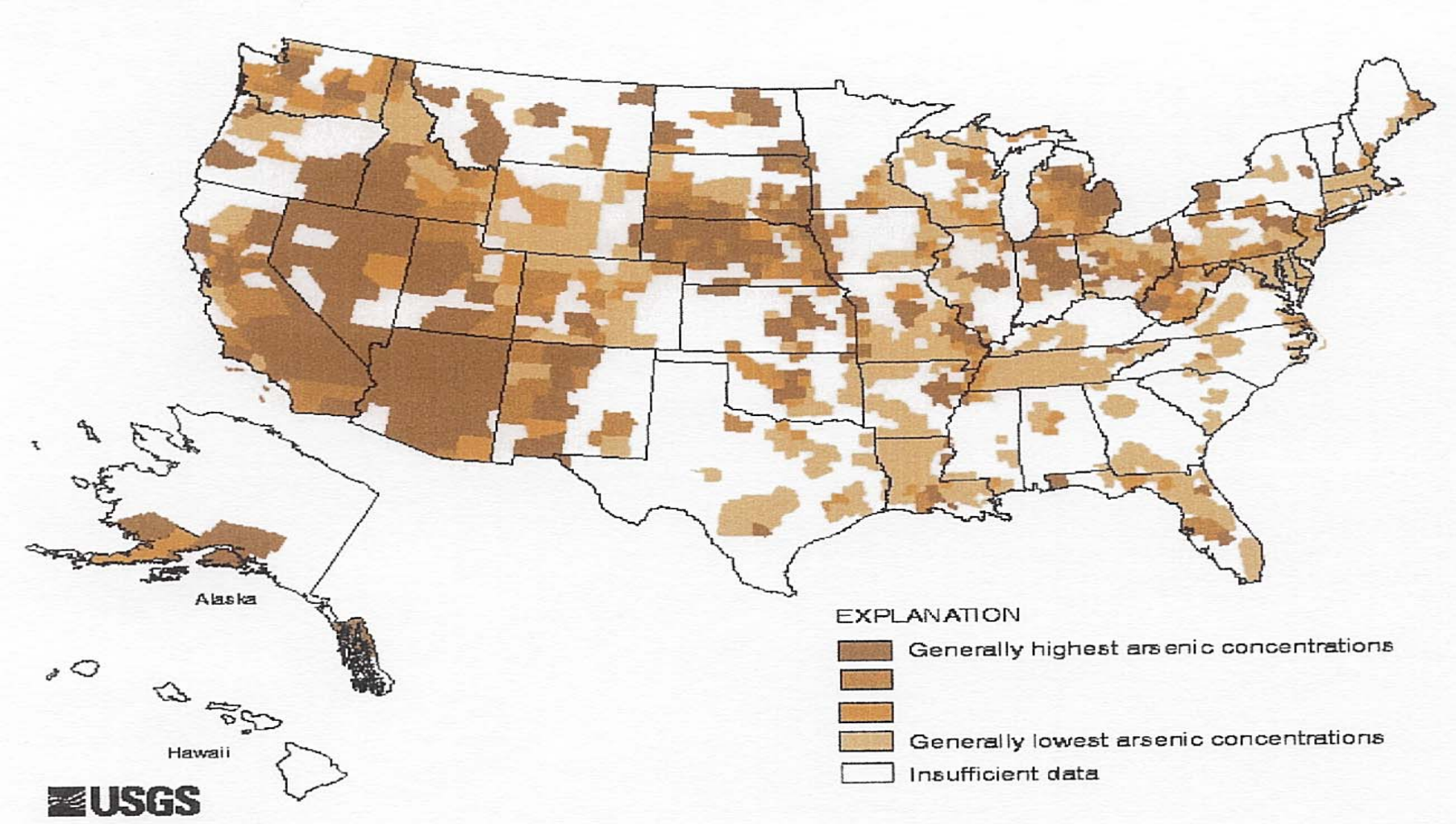
Arsenic Concentrations in groundwaters for Geographical Areas within the United States



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Arsenic Chemistry : Predominant Species

- As (III)
  - more toxic form
  - H_3AsO_3, H_2AsO_3 - , $HAsO_3$ $^{-2}$
  - found in groundwater that has not been exposed to air
  - cannot be removed by RO
  - pH not as large of a factor in adsorption
  - is a neutral species (H_3AsO_3) below pH 9.2

- As (V)
  - oxidizes to this form rather easily
  - H_3AsO_4, H_2AsO_4 -, $HAsO_4$ $^{-2}$
  - majority of arsenic in water is in this form
  - adding chlorine to water will oxidize As to +5
  - adsorption is very pH sensitive
  - exists as negatively charged ions (H_2AsO_4 -, $HAsO_4$ $^{-2}$) in typical pH range of drinking water

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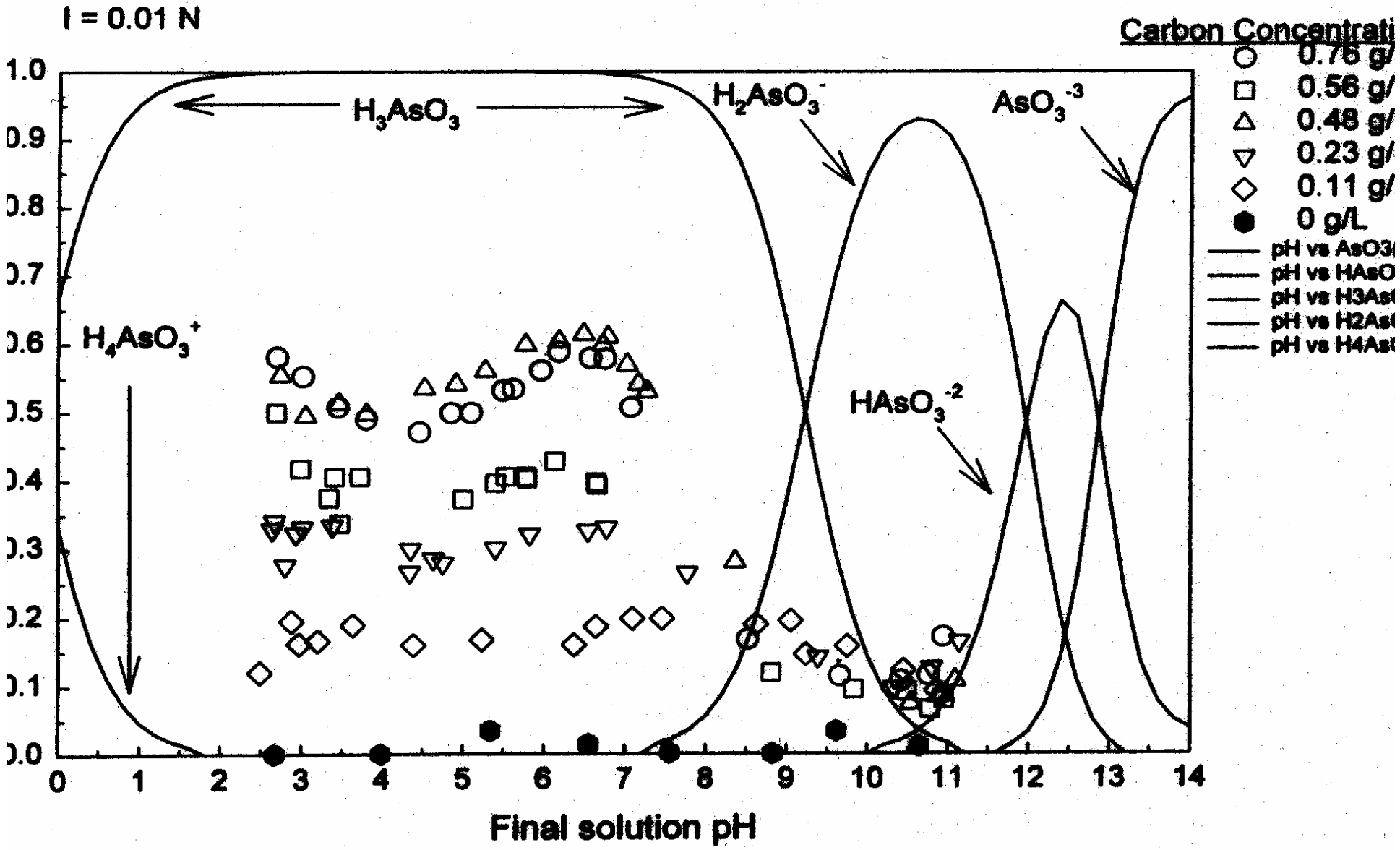
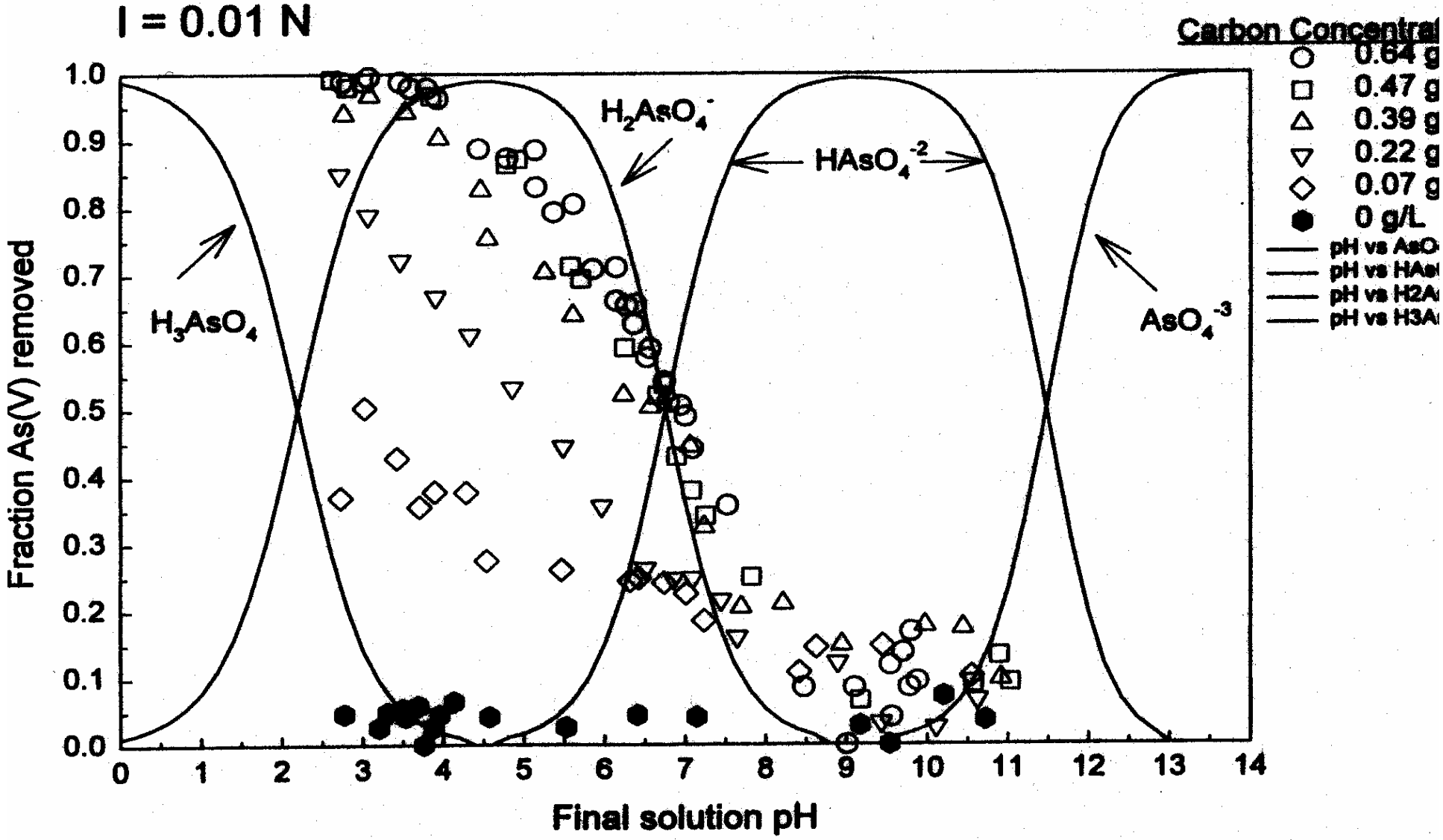

HD4000-ATC
~ 1 mg/L As(III)
I = 0.01 N
Carbon Concentrati
0.76 g/
0.56 g/
0.48 g/
0.23 g/
0.11 g/
0 g/L
pH vs AsO3(
pH vs HAsO
pH vs H3As(
pH vs H2As(
pH vs H4As(
H3AsO3
H2AsO3-
AsO3-3
H4AsO3+
HAsO3-2
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Final solution pH


HD4000-ATC
~ 1 mg/L As(V)
I = 0.01 N
Carbon Concentrat
0.64 g
0.47 g
0.39 g
0.22 g
0.07 g
0 g/L
pH vs AsO
pH vs HAs
pH vs H2A
pH vs H3A
H_3AsO_4
$H_2AsO_4^-$
$HAsO_4^{-2}$
AsO_4^{-3}
Fraction As(V) removed
Final solution pH
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Adsorption: What is it? How does it work?

- **Definition** – The action of a media in holding a soluble substance (e.g. arsenic) upon its surface

- Active sites, on a microscopic level, are located upon the surface of the media that grab onto and hold contaminants

- Adsorbent media is highly porous containing vast amounts of interior spaces that are filled with vast amounts of functional (chemical) groups that have the power to remove arsenic and other contaminants

- The media can be designed and engineered to have special properties and abilities

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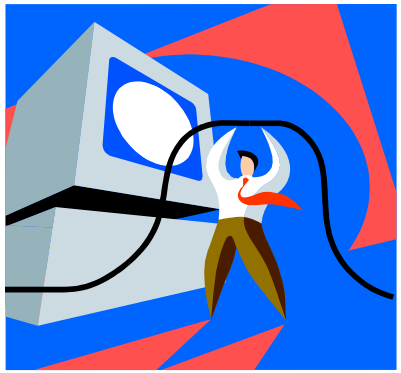
Adsorption: What is it? How does it work?

- **Adsorptive forces**
  - Electrostatic attraction
  - Formation of chemical bonds



- **Adsorbent media has a tremendous amount of porosity that creates vast amounts of interior surfaces**
  - A handful of media will contain an interior surface equal to more than 10 football fields
  - A vast number of functional (chemical) groups are present
  - The contaminants are held onto tightly by adsorptive forces

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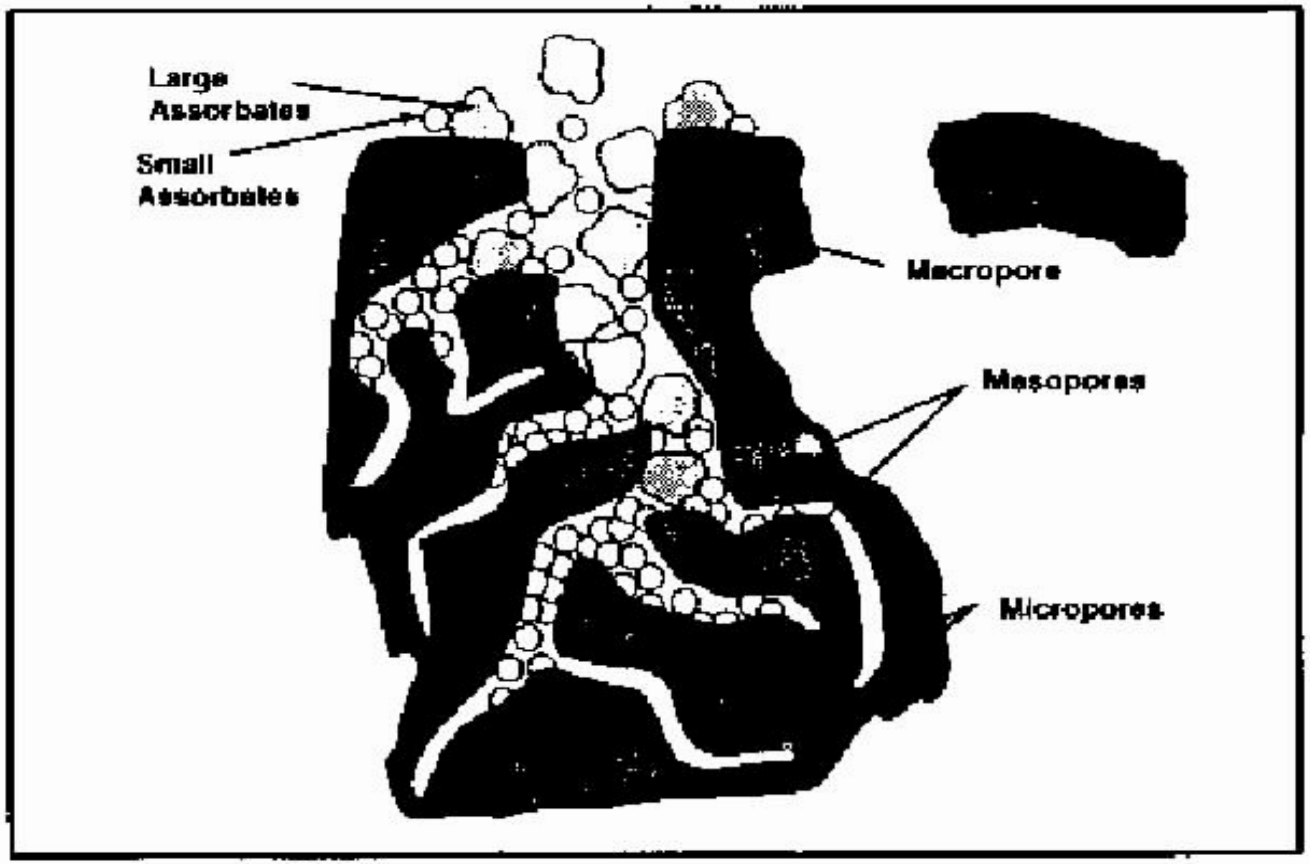
Interior Porosity of Adsorbent Media



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Arsenic removal by adsorption

- **As (III) in drinking water at pH 6 – 9**
  - Exists as a neutral ion, H_3AsO_3
  - Removed mostly by formation of covalent chemical bonds
  - Some removal by relatively neutral charged, chemical groups located on the surface of the media
- **As (V) in drinking water at pH 6 - 9**
  - Exists as a negatively charged ion, $H_2AsO_4^-$, $HAsO_4^{-2}$
  - Removed by positively charged, chemical groups located on the surface of the media
  - Some formation of covalent bonds also occur

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Engelhard ARM 200 ™ : Effective Arsenic Removal

- **Proprietary, patented, high-capacity adsorbent media**
- **Effective for both As (III) and As (V)**
  - Requires no preoxidation or pretreatment
- **Available in large granule, fine granule, or powder form for various water treatment/purification applications**
- **NSF 61 Certified**
- **Cost-effective solution for community and individual arsenic removal needs**

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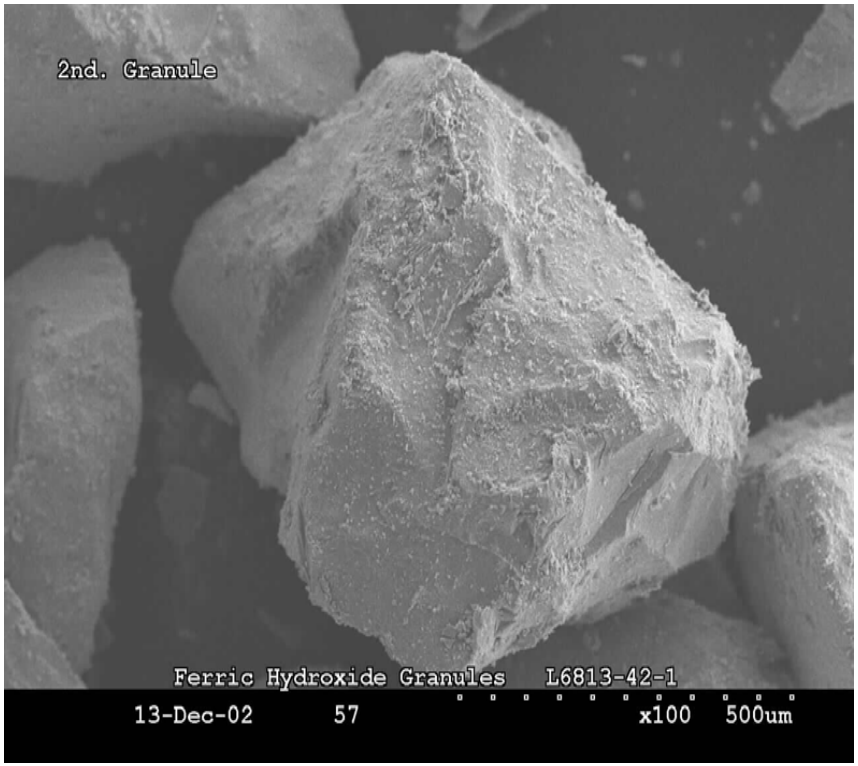
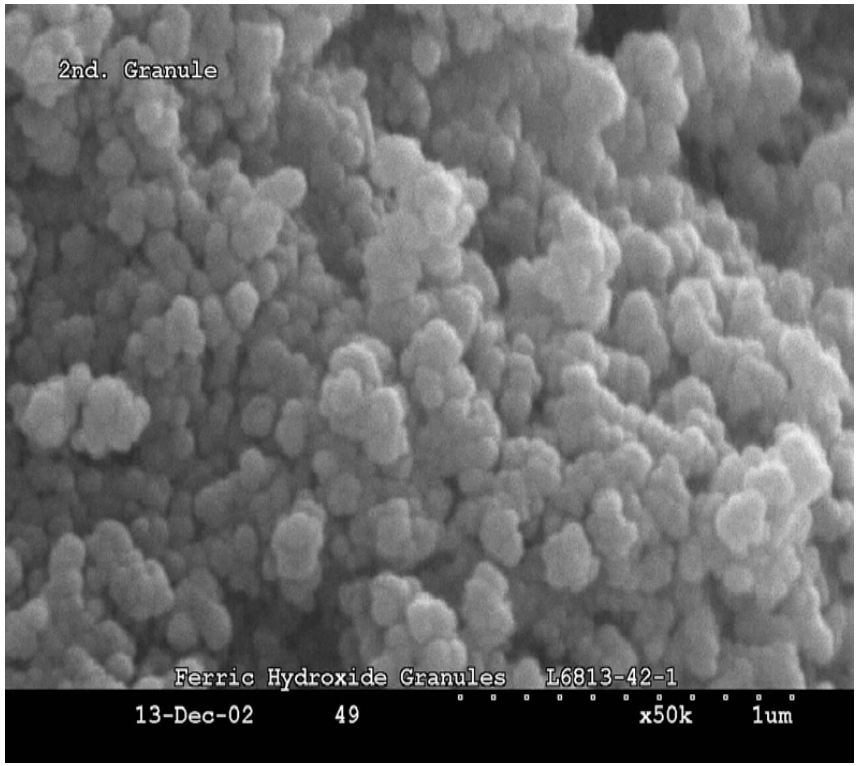
Engelhard ARM 200 ™ Surface and Materials Science

The surface of ARM 200 is a smooth granule, but as you probe deeper one can see rich texture.





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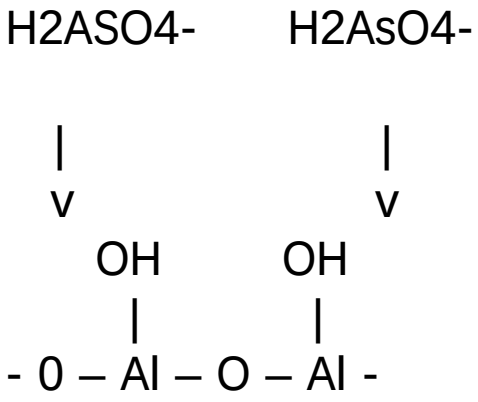
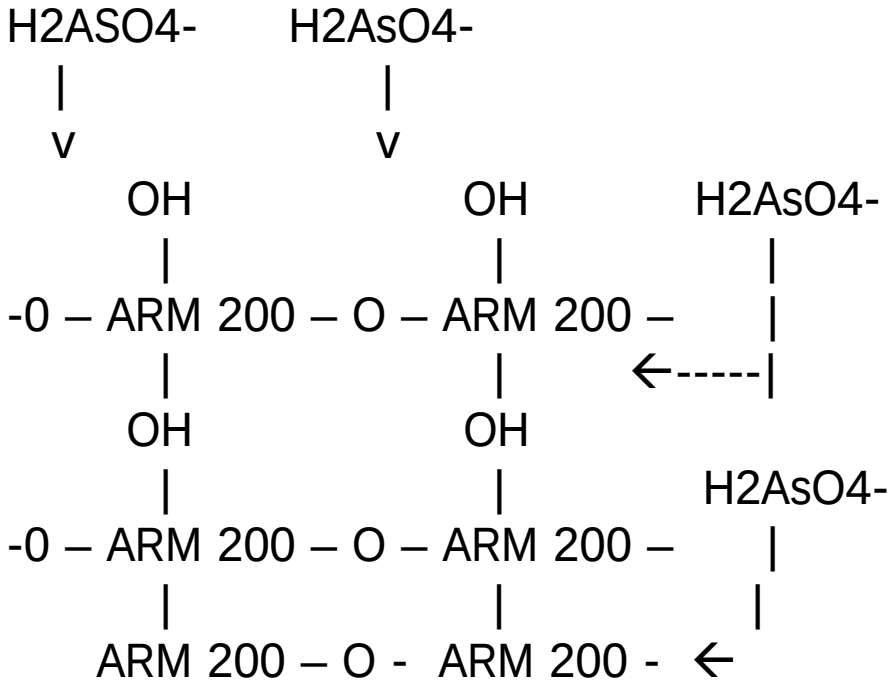
ARM 200 : very high capacity for Arsenic Removal



Adsorption is restricted to external surface sites with alumina-based media.



ARM 200 is more permeable and allows the arsenic ions to diffuse throughout the entire structure where there are more active sites available for adsorption.

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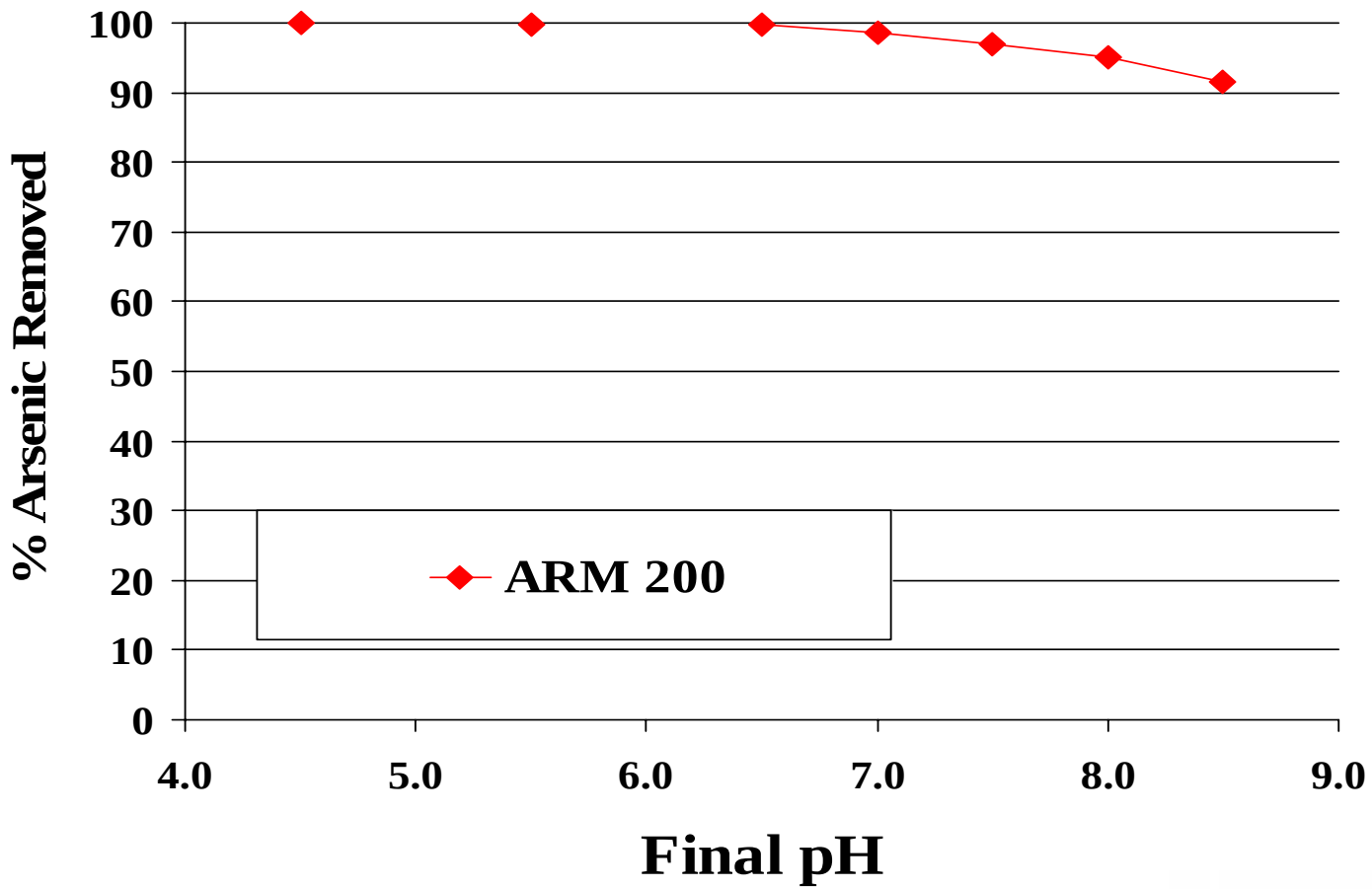
pH - Adsorption Edge Testing of ARM 200



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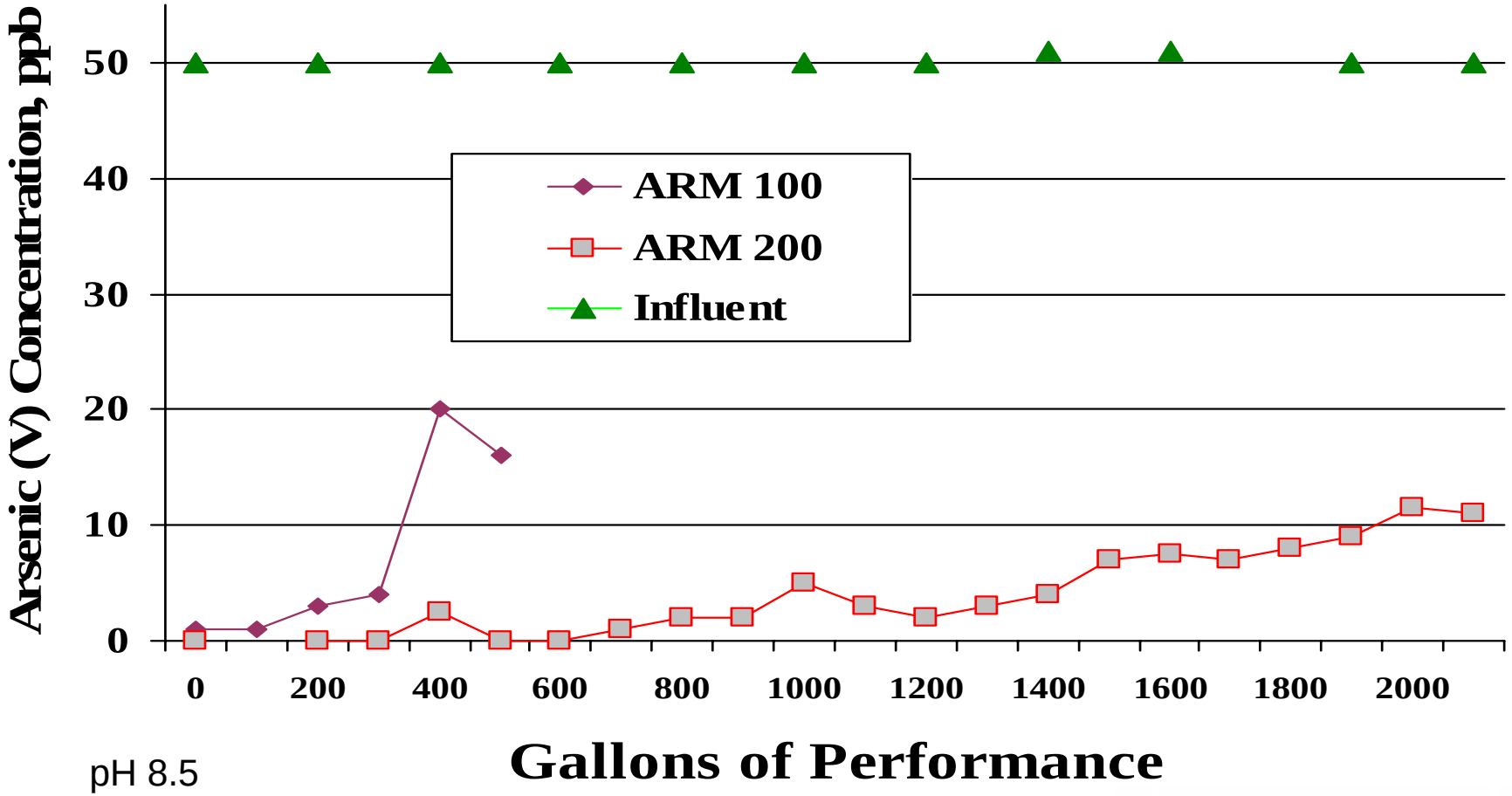
NSF53 Protocol Testing @ pH 8.5



pH 8.5

Granular media in 2.5 x 10 inch cartridge

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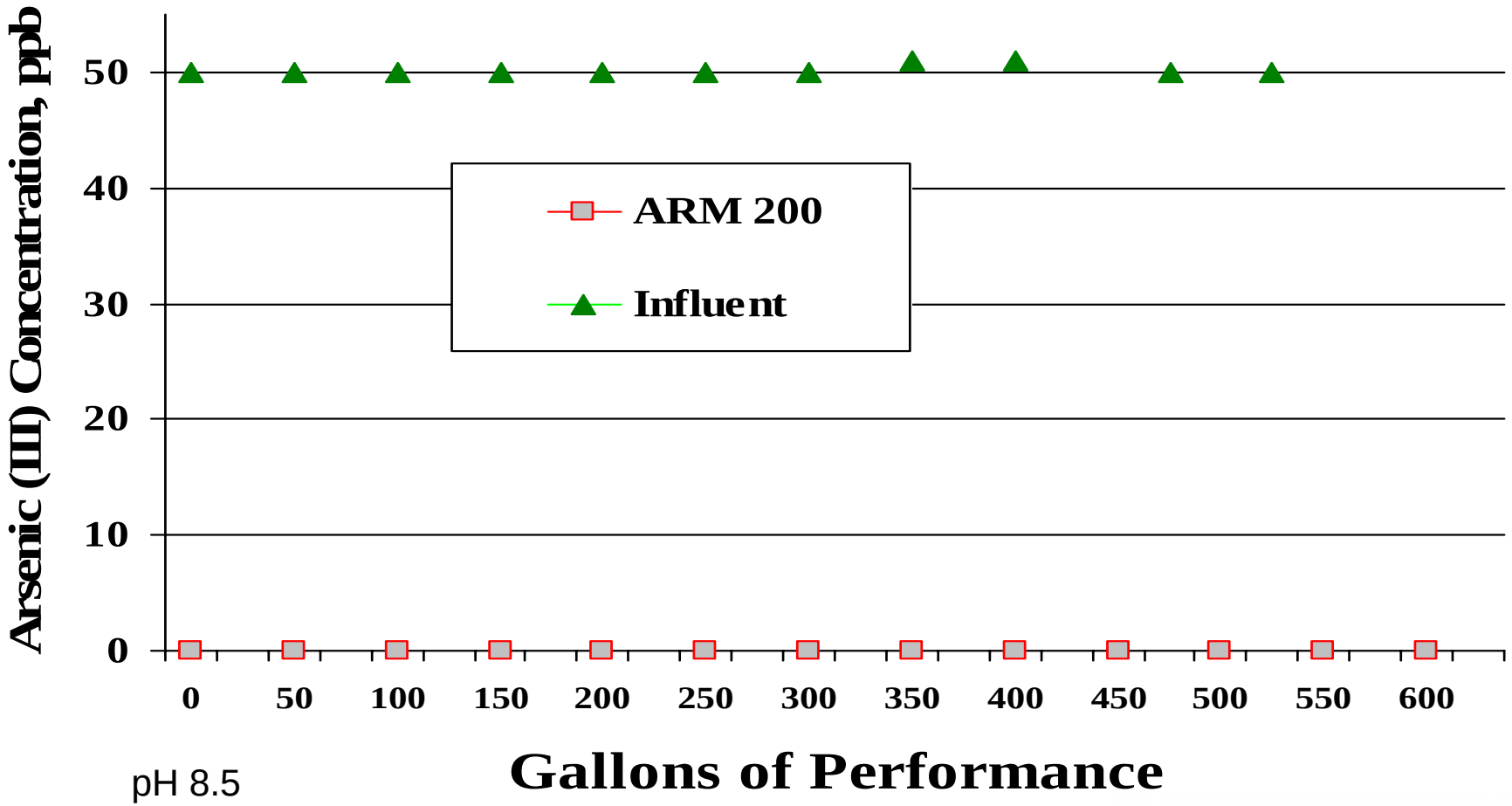
NSF53 Protocol Testing @ pH 8.5



pH 8.5

Granular media in 650 ml cartridge

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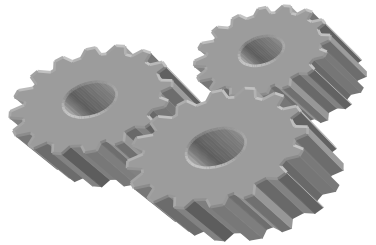
Who Is Engelhard ?

- **Large manufacturing company with global assets & resources that has exceptional expertise in materials science and surface chemistry**
  - Fortune 500 listed with $ 3.7 billion in annual sales
  - Over 100 locations across the globe; 28 R&D Centers
  - 6,500 employees
  - Over 30% of technology revenues come from new products



- Leading provider of technologies for environmental, process, appearance and performance applications
- High volume / High quality Production
  - 280 million pounds/year of FCC Catalyst for making gasoline
  - 4 billion pounds/year of Clay for paper, pigments, and fillers

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Pilot-Scale Evaluation of Adsorptive Media for Arsenic Removal

- Project run by Battelle Institute at Licking Valley School District in Newark, Ohio
- Funding provided by U.S. EPA under the Physical/Chemical R&D Support Contract (No. 68-C7-0008)
- Licking Valley School District generously allowed the use of its facilities for on-site testing since 2001
- Several adsorptive media manufacturers, distributors, and vendors provided samples
- Many Battelle staff provided field and laboratory support

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Test Conditions – Adsorption Columns

- Conditions applied to both As(III) and As(V) tests
- Media wet loaded to remove fines
- System operated under constant pressure at about 15 psi
- Bed dimension 2” diameter x 12” long
- Bed volume 620 mL
- Flowrate 125 – 135 mL/min
- EBCT 4.8 + or – 0.2 min
- No pH adjustment
- No backwash for adsorptive beds

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Sampling and Analysis

- Sampling/speciation weekly at inlet, after pretreatment (for As(V) tests only), and after each adsorption column
- Speciation for total and particulate As, As(III), and As(V); total and soluble Fe, Mn, and Al
- Metals analysis
  - EPA Method 200.8
  - Perkin Elmer Sciex Model 6000 ICP/MS equipped with a crossflow pneumatic nebulizer and an auto-sampler
  - Detection limits of 0.1, 30, 0.5, and 11 ug/L for As, Fe, Mn, and Al
- On-site analysis
  - pH, DO, ORP, and temperature using a WTW multi-340i meter

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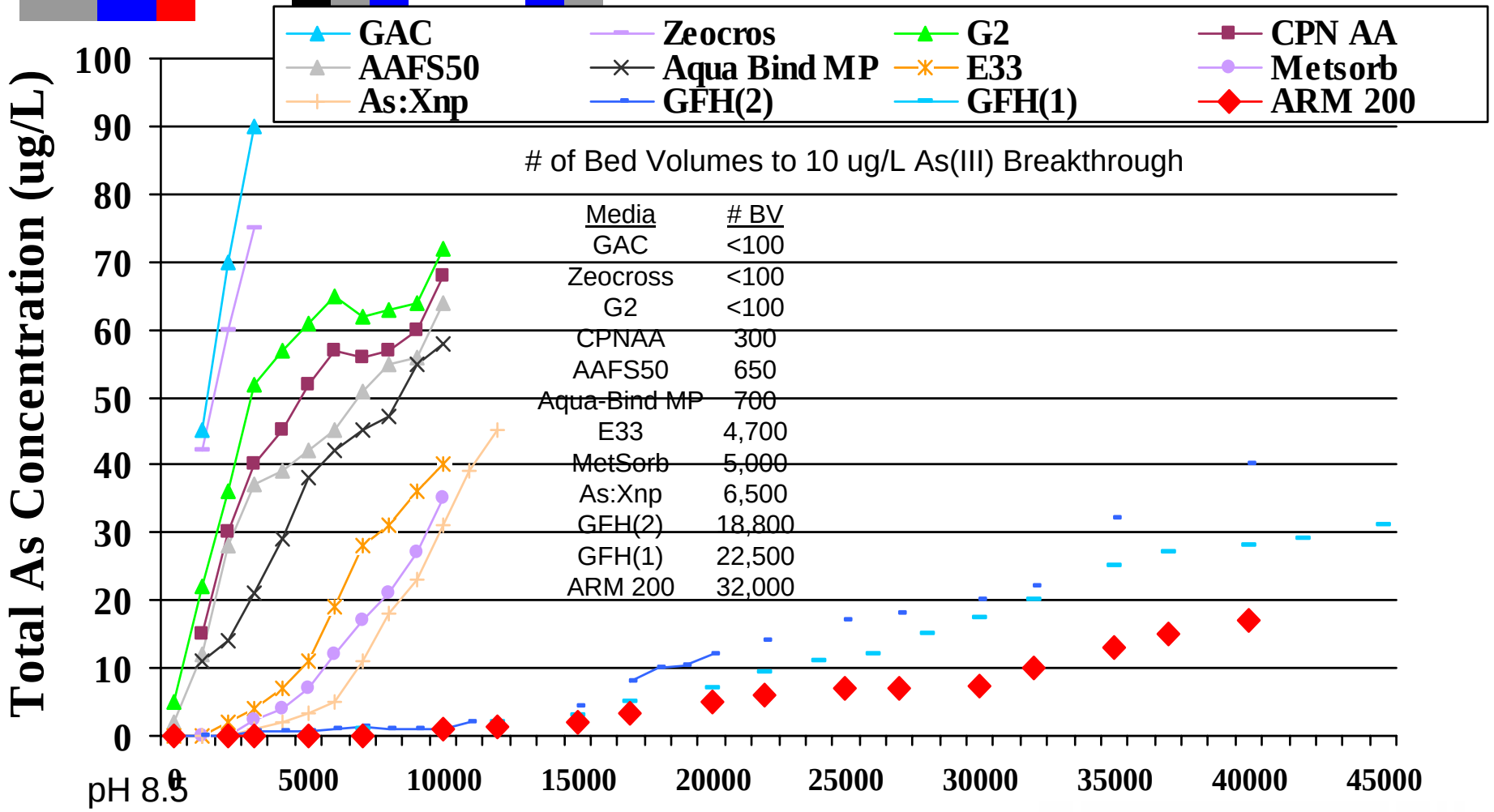
As(III) Tests: Breakthrough Curves



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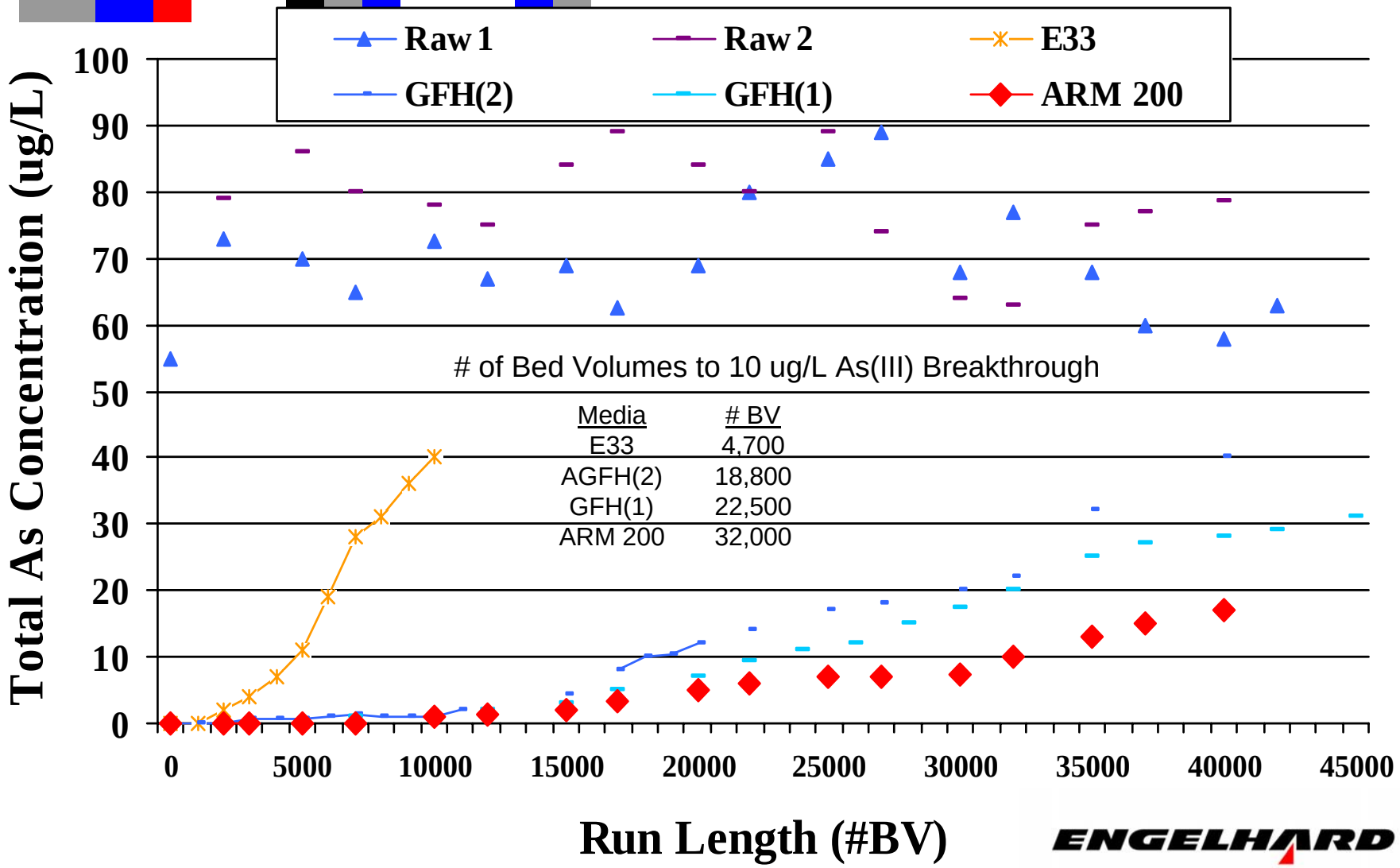
As(III) Tests: Breakthrough from E33, GFH and ARM 200



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ARM 200 Field Applications by Kinetico Inc.

- New Hampshire POE System
  - Lead/Lag w/ two (2) 12”x48” tanks – 2 ft3 media/tank
  - No pH adjustment
  - 300 – 350 ppb As inlet
  - non-detect As outlet

- Ohio POE System
  - Lead/Lag w/ two (2) 10”x35” tanks – 1.5 ft3 media/tank
  - No pH adjustment
  - 20-30 ppb As inlet
  - non-detect As outlet

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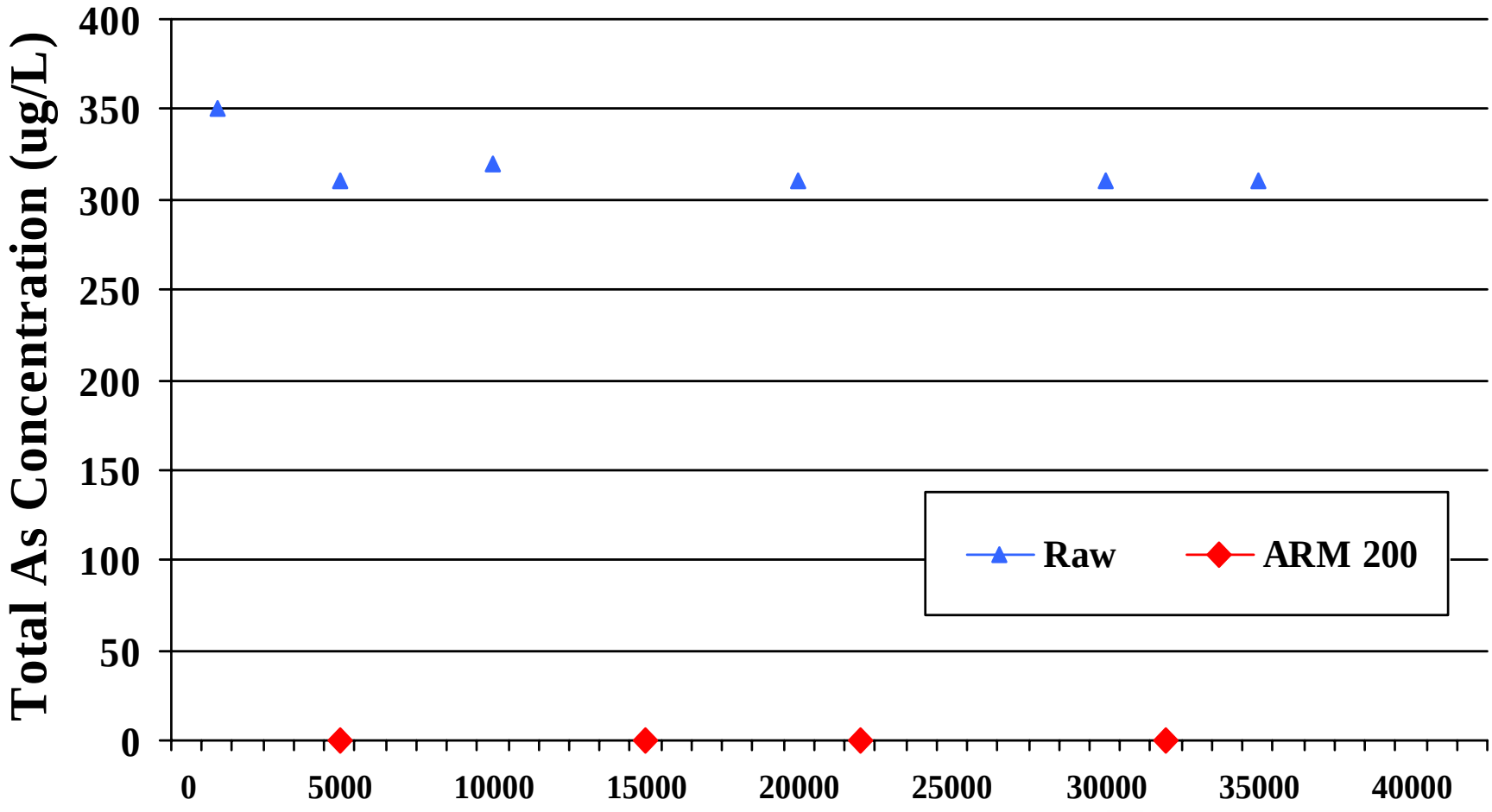
ARM 200 Field Application: New Hampshire POE



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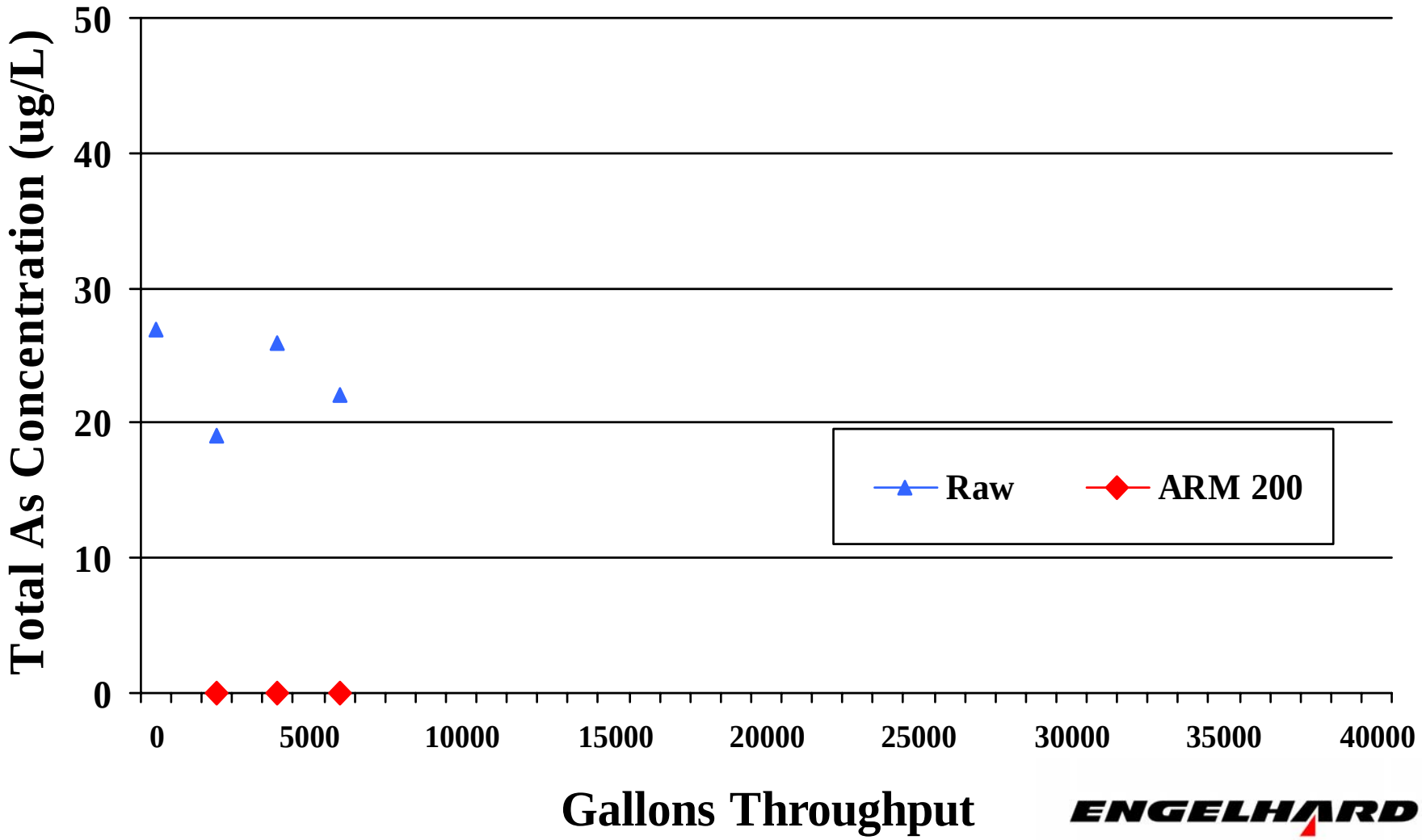
ARM 200 Field Application: Ohio POE



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Thank You

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