



Arsenic Adsorptive Media – A Good Fit for My Water?



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Outline

- Need for Arsenic Treatment
- Options for Arsenic Treatment
- Adsorptive Treatment Options
- Working with ADSORBSIA™ Media
- Modeling Water Treatment
- Customizing Treatment for Individual Needs



The Challenge

- EPA Lowers the Arsenic Maximum Contaminant Level (MCL) from 50 ppb to 10 ppb
- Announced January 2001
- Went into effect January 23, 2006
- Affects Group A community water systems (>25 people served)
- Affects non-transient, non-community public water systems



Treatment Options

- New water source
 - Obvious choice if higher quality water is available in sufficient quantities
 - Extending a pipe may be ideal
 - High risk if quality of water source is unknown
 - Drilling a new well may be costly and not beneficial
- Blending
 - Similar risk/payoff analysis to new water source
 - Benefit is relative to quality of both waters being blended



Treatment Options

- Coagulation/Filtration for As removal
 - Low cost to operate
 - Works well where high iron levels are present
 - Provides aesthetic benefit from iron removal
 - Requires operator and/or automation equipment
 - Footprint required can be very large
 - Chemical dosing rate and pH adjustment must be tailored to specific water chemistry
 - Waste water and sludge handling may be an issue
 - Cost effectiveness questionable in low iron water
 - Effectiveness in removal to very low As levels (<5 ppb) is questionable, especially in low iron containing waters



Treatment Options

- Anion Exchange for As removal
 - “Proven” technology, i.e., familiar to water treatment engineers, owners, and operators
 - Competing ions can severely hinder effectiveness
 - Risk of eluting higher As concentration when bed is exhausted
 - Need for handling of regenerant chemicals
 - Waste water stream of 10% or more
 - Not tolerant of oxidation chemicals
- Dow Water Solutions is one of the world’s leading suppliers of anion exchange resins, but does not support this approach for As removal



Treatment Options

- Reverse osmosis for As removal
 - Can improve multiple water qualities
 - High cost to operate
 - Not effective for As(III) species
 - Waste water rate as high as 25% or more
 - Not tolerant of oxidation chemicals
- Dow Water Solutions is also a world leader in RO membrane technology, but does not support its use solely for the treatment of As.



Treatment Options

- Adsorptive media for As removal
 - Can be highly selective for As removal
 - Passive system – can have little or no user intervention
 - Waste water rates can be 2% or less
 - Versatile application to wide range of water chemistry
 - Proven performance down to non-detectable As levels
 - **Can achieve best total cost/water delivered, especially for medium to small systems**
 - Media disposal or regeneration may be an issue
 - Predicting media lifetime can be challenging with various water chemistries



Adsorptive Media Options

- Regenerable Media, e.g., iron impregnated IX resins
 - Chemically treated for media reuse, generally off-site
 - Produces secondary waste stream, which must be dealt with prior to disposal
 - Waste stream is more concentrated, producing higher arsenic concentration in solid waste
 - Regeneration schemes have not been proven for multiple reuse cycles
 - Media tracking is key
 - Avoid cross contamination
 - Accurately assess useful media life
 - Not tolerant of oxidation chemicals



Adsorptive Media Options

- Non-Regenerable Media, e.g., Al, Fe, Ti, Zr, and La oxides and hydroxides
 - Used once, then disposed
 - Waste characterization depends on media chemistry and binding with arsenic
 - In many cases, waste is considered non-toxic
 - Can pass extractive tests such as:
 - TCLP (Toxic Chemical Leaching Procedure)
 - CA WET (California Waste Extraction Test)
 - CA STCL (Solute Threshold Concentration Limit)



Non-Regenerable Adsorptive Media

- Aluminum oxide
 - Cheapest media available, with long history in water treatment
 - Binding to arsenic is weak and non-selective
 - Narrow pH window of effectiveness
 - Competing ions may render it ineffective
 - Solid waste may easily leach arsenic to landfill
- Iron oxide/hydroxide
 - Improved performance over alumina for wider range of pH and competing ion conditions
 - Leaching of arsenic is less problematic under favorable conditions
 - Can release arsenic if pH increases during operation



Non-Regenerable Adsorptive Media

- Titanium oxide/hydroxide
 - Stronger binding to arsenic than iron or aluminum oxides/hydroxides
 - No identified leaching concerns
 - Wider pH tolerance
 - Faster adsorption kinetics (10X that of iron media) allows for more flexible facility design
 - Less media and/or smaller footprint
 - Highest capacity of any known media under widest range of water chemistries
 - Least sensitive to presence of other anionic components (i.e., NO_3 , PO_4 , SO_4 , etc.)



Non-Regenerable Adsorptive Media

- Lanthanum and Zirconium oxides/hydroxides
 - Claims of high binding capacities and fast kinetics
 - Total cost of treatment remains unproven
 - Highest media costs
 - Performance has not been demonstrated in real world applications
 - Supply chain?



Working with ADSORBSIA™ Media

- A simple, passive bed of media is installed in the water system
- Equipment includes standard tanks and valves
 - Valves may be manual or automated
- No other treatment is necessary, either before or after the beds
- Media is backwashed once upon loading, then periodically as water quality dictates for solids removal, i.e., to prevent pressure buildup
 - Dow does recommend the use of particle filtration prior to the adsorptive bed when significant solids are expected



Working with ADSORBSIA™ Media





Working with ADSORBSIA™ Media

- **How big will my system be?**
 - The key to assessing your capital costs
- **How long will it last??**
 - The key to assessing your operational costs, and therefore your total cost for treated water
- Both answers depend on your system size (and specific constraints), your water chemistry, and your choice of adsorptive media
- Effective modeling is crucial for accurate system assessments
 - Media constraints such as flow rates, pressure drop, backwashing requirements, etc.
 - Effect of water chemistry such as arsenic level, arsenic speciation, pH, silica level, and other competing ions



Modeling Media Performance

- Parametric Approach – the use of general guidelines for all water systems and chemistries
 - Easy to implement
 - Accuracy and precision are unknown
- Empirical Approach – running a pilot test for each site
 - Can be very reliable if done properly
 - Can be costly and time consuming
 - Quantitative scale up can be questionable (especially for RSSCT type models)
- Semi-Empirical Approach – modeling specific system based on known parameters which effect performance
 - Fast, cost effective method
 - Requires extensive data set for accurate results



Modeling Media Performance

- Dow's Semi-Empirical Modeling Approach
 - Based on thorough understanding of equilibrium adsorption from isotherm conditions
 - Accounts for kinetic effects from hundreds of laboratory experiments under controlled conditions
 - Includes variables such as arsenic concentration and speciation, water pH, and competing ions
 - Allows for tailored system design based on customer's needs
 - Validated against "real world" water and third party testing



Modeling Media Performance

- Data base for model collected in laboratory columns using the challenge water described in ANSI/NSF standard 53.

Mg	12 ppm	SiO ₂	20 ppm
SO ₄	50 ppm	PO ₄	0.04 ppm
NO ₃	2 ppm	Ca	40 ppm
F	1 ppm		

- Challenge Water was designated by NSF to represent “typical water” and allow for “apples to apples” comparisons under controlled conditions.

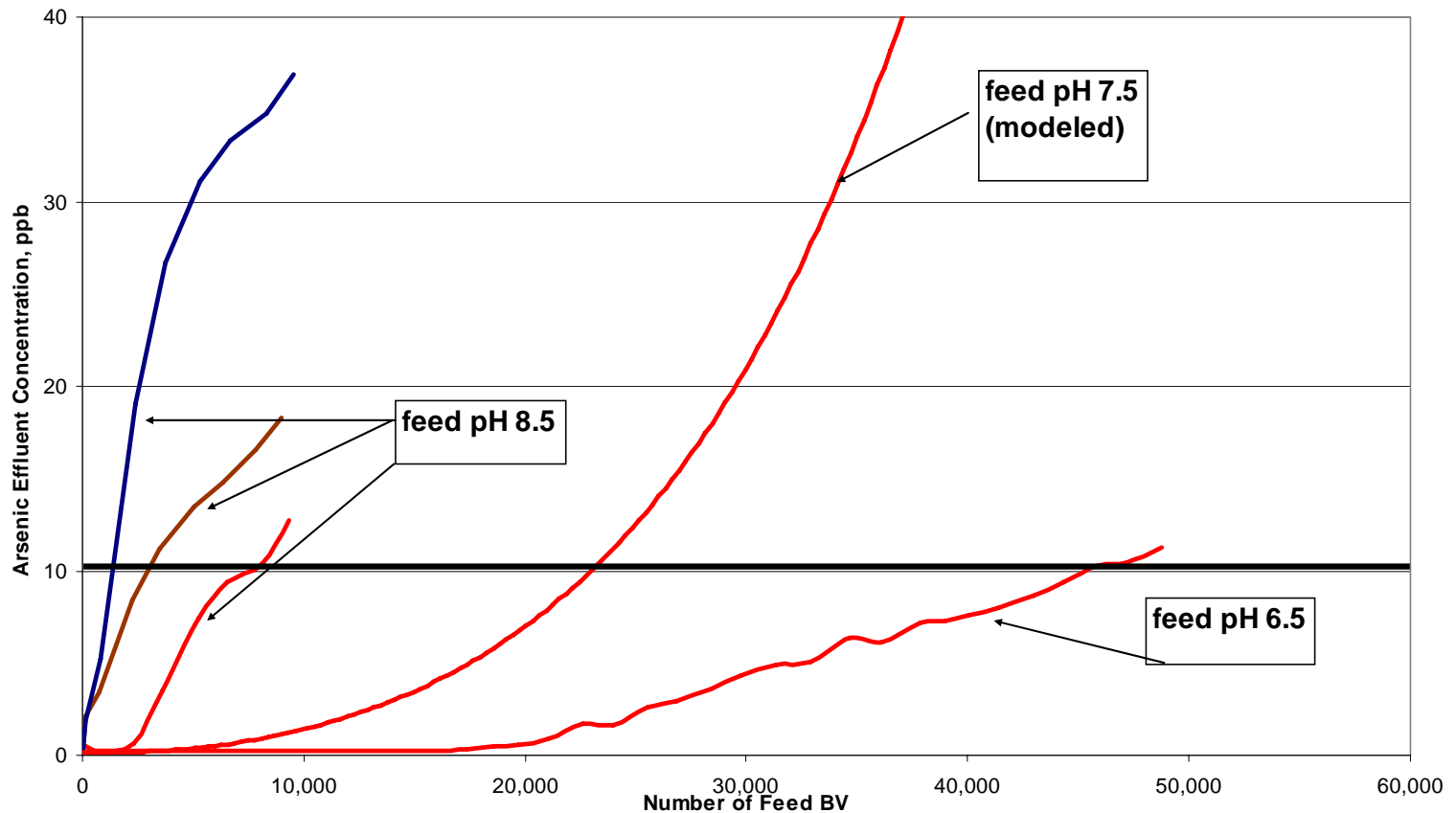


Modeling Media Performance

- Columns are 0.45 inch diameter and 4 inches in length
 - Dow currently operates 16 testing columns
- They are loaded with the commercial media
 - Media is not resized for lab evaluations
- Flow is independently controlled to each column
- Feed water can be shared across multiple columns, or used for single columns
- Pressure is monitored across each sample to validate flow conditions
- Contact times can be readily varied from 30 seconds to 5 minutes
- Loading rates of 6 to 14 gpm/ft² have been evaluated

Modeling Media Performance

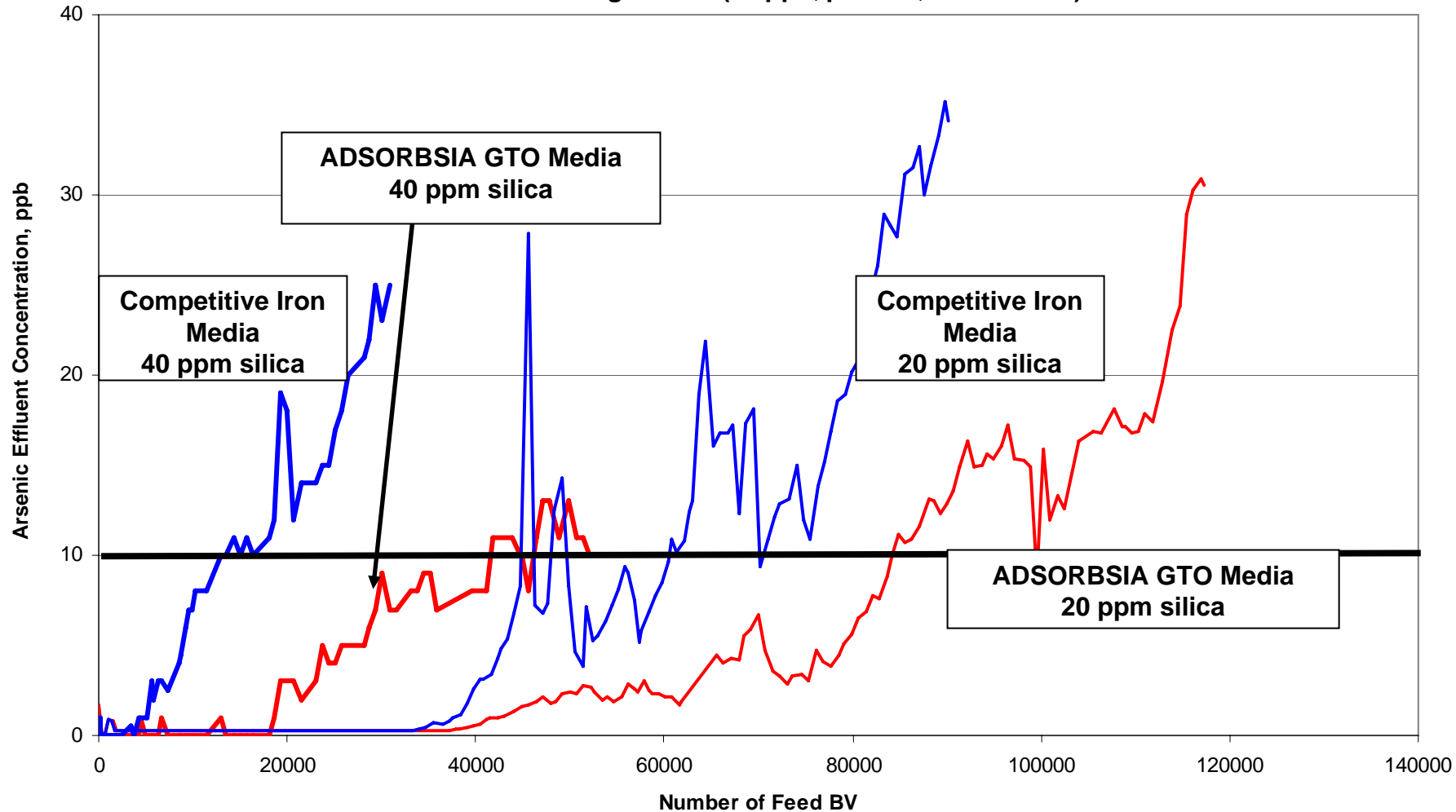
ADSORBSIA GTO media Performance at various PH NSF 53 Challenge Water (50 ppb As(V), 30 sec EBCT)



Modeling Media Performance

Impact of Silica

NSF Challenge Water (50 ppb, pH =6.5, 120 s EBCT)





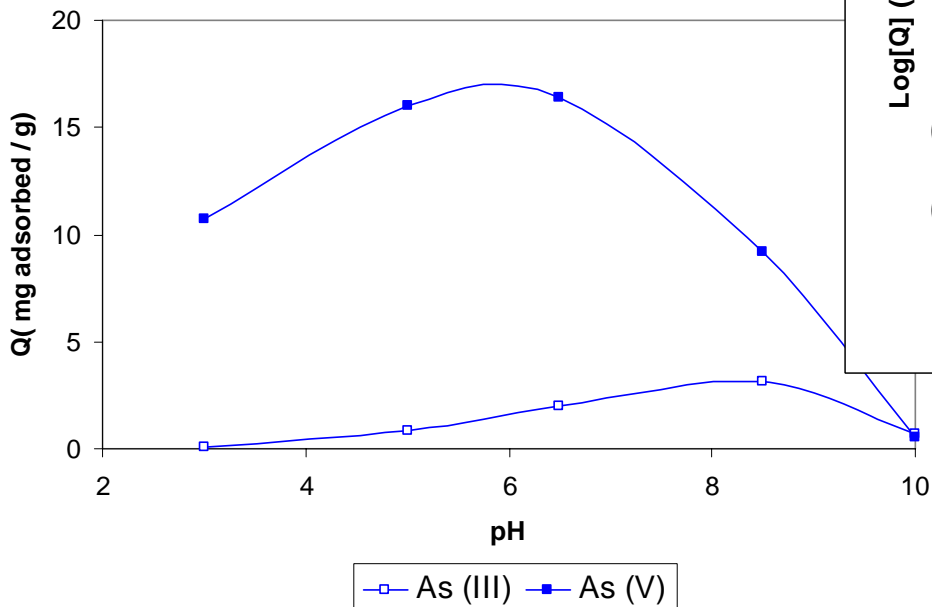
Modeling Media Performance

- Lab data provides basis for modeling predictions
- Customer supplies data needed for designing a system for their site, including, at a minimum:
 - Arsenic concentration and speciation
 - Water pH
 - Silica level
 - Maximum flow for system
 - Used to determine vessel size
 - Typical operating rate
 - Used to predict lifetime



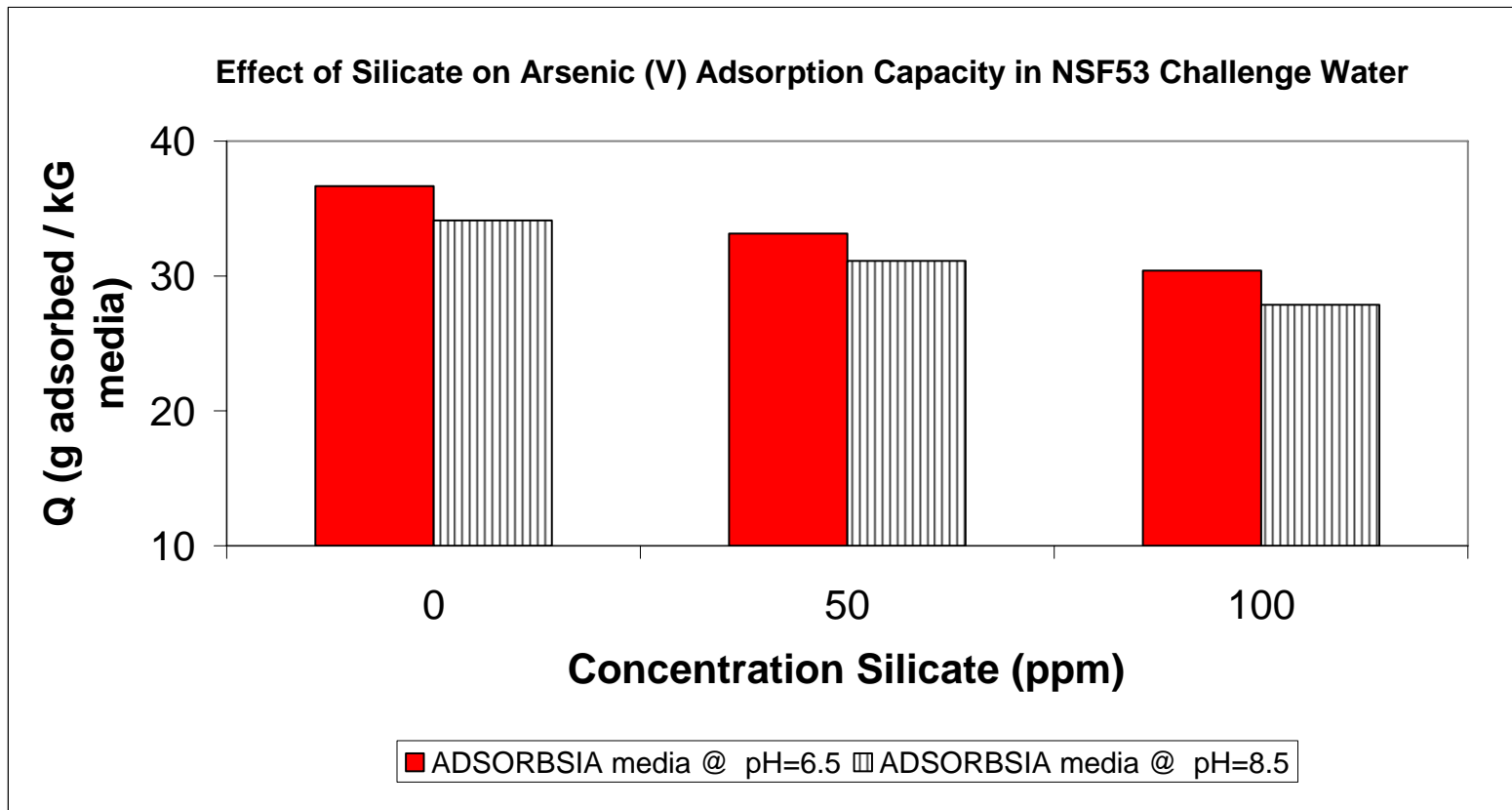
Modeling Media Performance

- Step 1: Understanding equilibrium capacity to assess ideal adsorption behavior
 - As concentration
 - As speciation
 - water pH



Modeling Media Performance

- Step 2: Adjusting equilibrium capacity to account for competing ions
 - Example: Silica

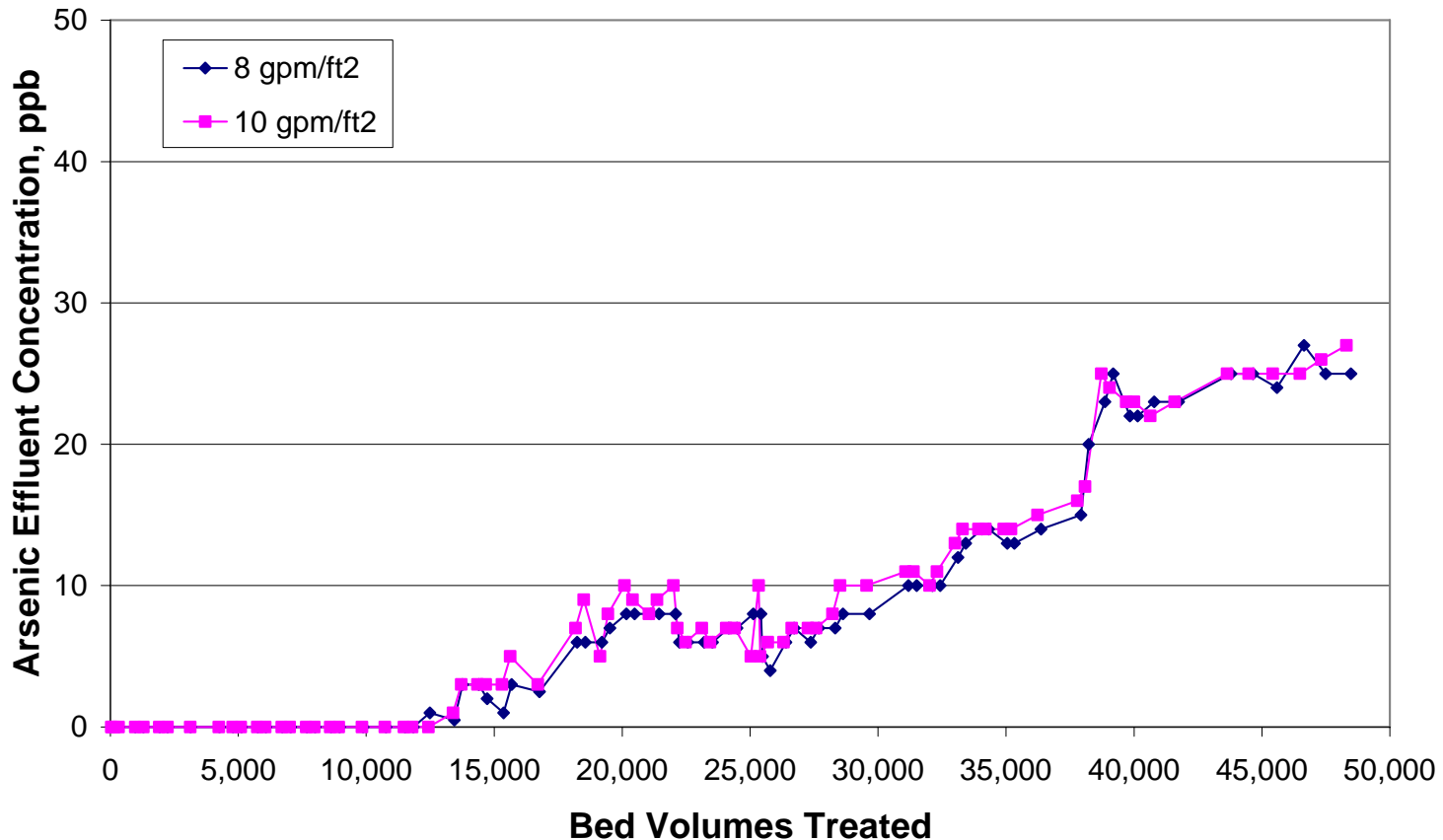




Modeling Media Performance

- Step 3: Assess dynamic conditions to determine bed utilization efficiency

Arsenic Breakthrough: NSF Challenge Water (50 ppb, pH =7.5, 90 s EBCT)





Modeling Media Performance

- Combination of equilibrium and dynamic data gives estimate of bed performance
- Model is then further refined to optimize for system configuration
 - Single bed vs. multiple beds in series (lead/lag configuration)
 - Blending options
 - Vessel sizes and desired change out frequency
- Ultimate system design is determined by customer's needs, for example:
 - Capital vs. operational costs
 - Footprint limitations
 - Running time requirements



Modeling Media Performance

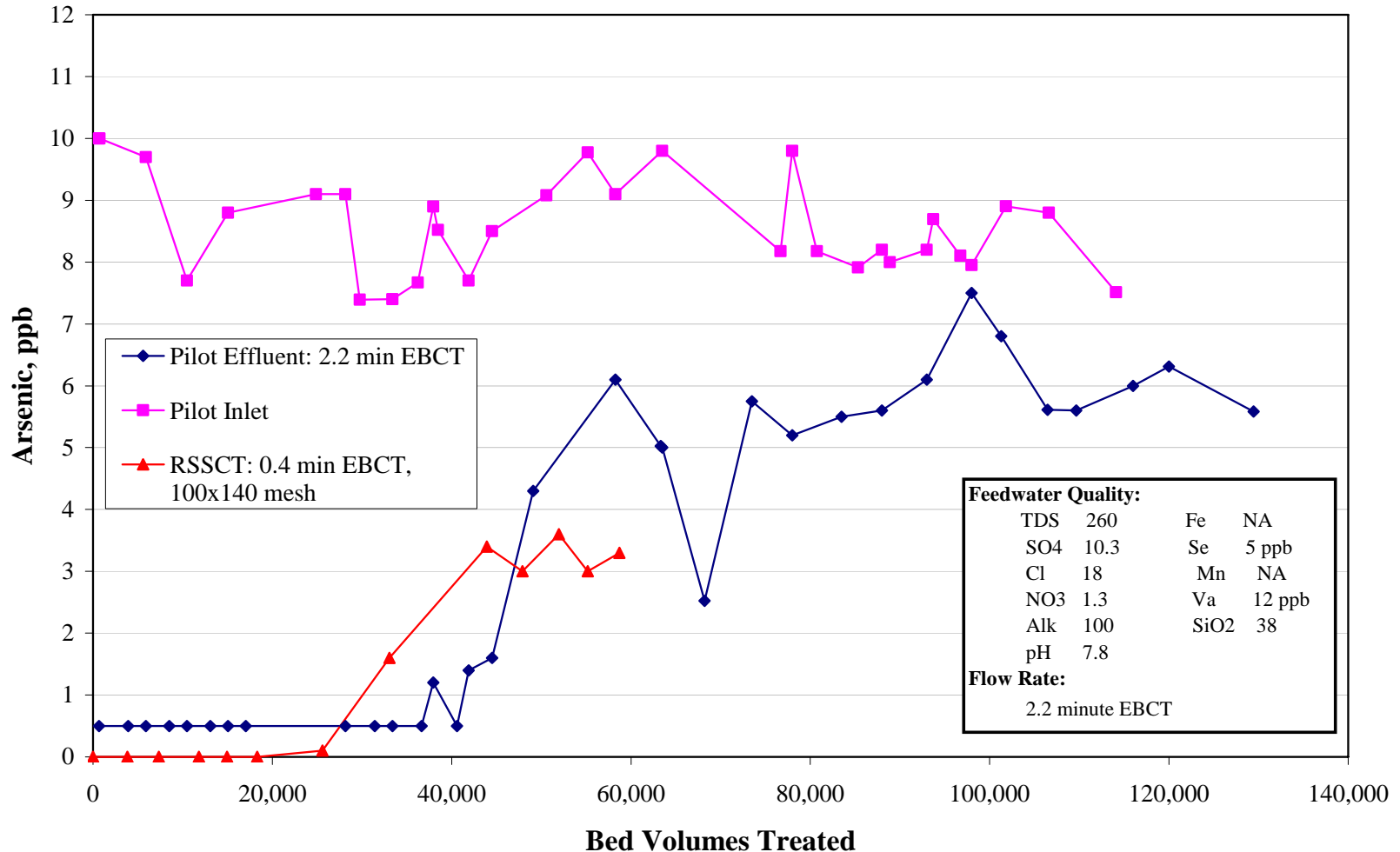
- Example: City of Phoenix pilot run by NCS consulting
 - Dow provided estimate based on inlet water quality
 - 9 ppb As in the feed water
 - pH of 7.8
 - Silica level of 38 ppm
 - Vanadium level of 12 ppb
 - Estimated bed would reach 8 ppb at 47,000 to 59,000 bed volumes
 - Bed started breaking at 40,000 bed volumes, and reached 5 ppb (50% breakthrough) around 50,000 bed volumes
 - Never actually reached 8 ppb
 - Actual breakthrough curve shown on the next slide



Modeling Media Performance

- Example: City of Phoenix pilot run by NCS consulting

Dow Media Performance at Phoenix Site



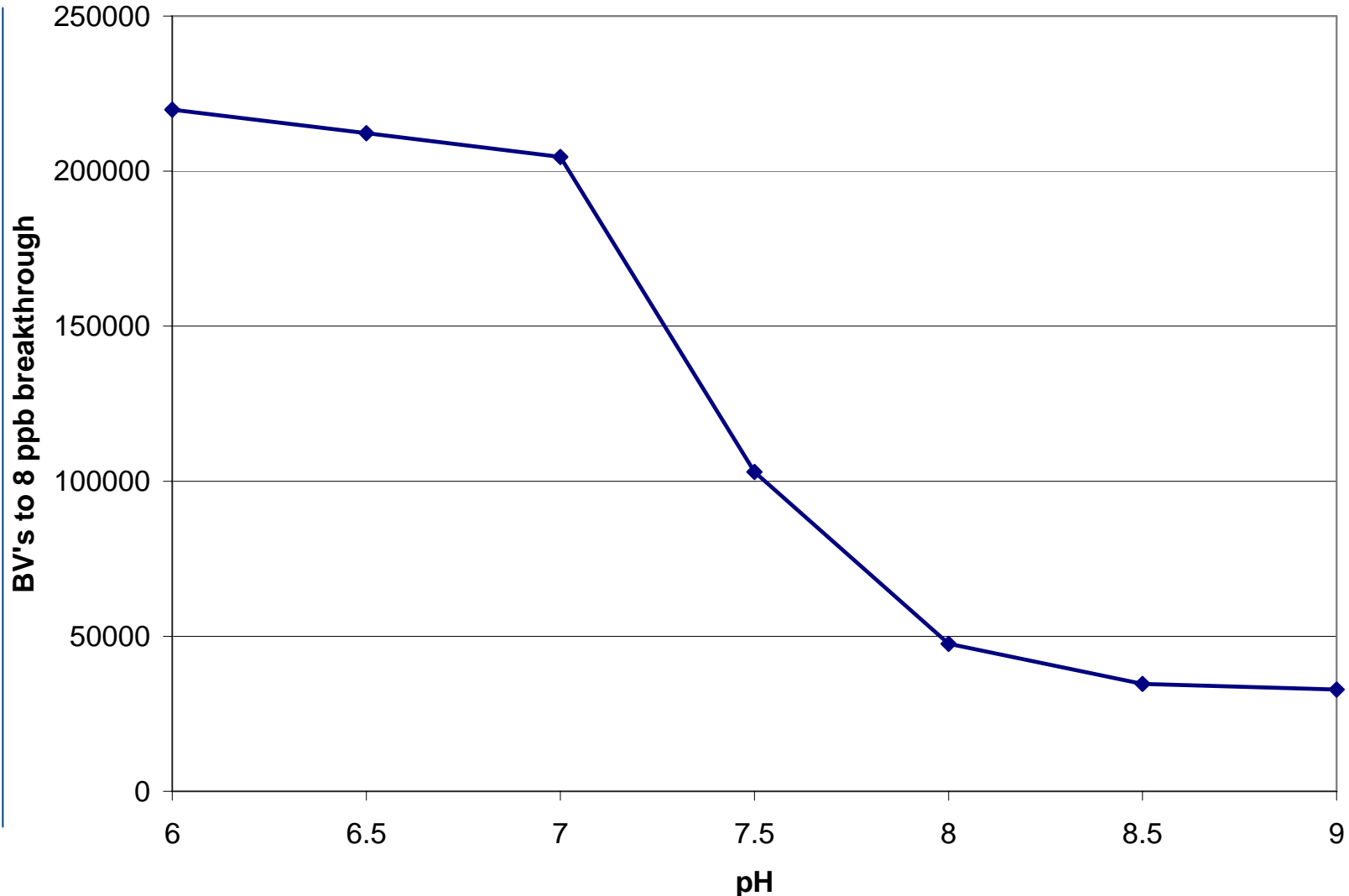


Modeling Media Performance

- Dow's Semi-Empirical model
 - Based only on customers water quality data and flow requirements
 - Provides realistic estimate for system design
 - Aids in system tailoring for unique customer needs
 - Demonstrates need to better understand interaction of variables (improved next generation model)
 - Shows important effects of several individual parameters
 - **Accurate pH and silica levels are more important in predicting bed lifetime than the arsenic level itself**

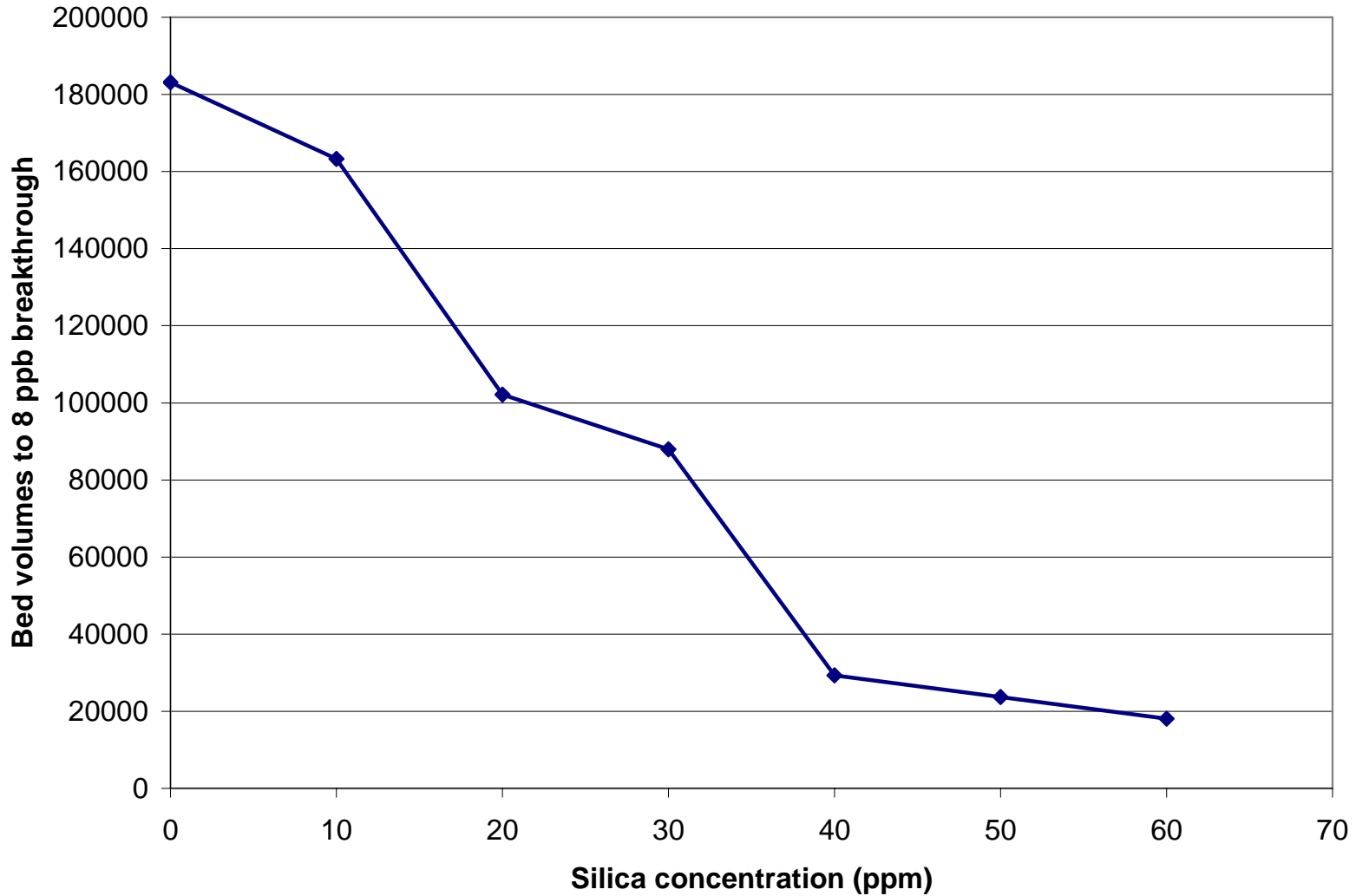


Lifetime varies by $> 4X$ with pH



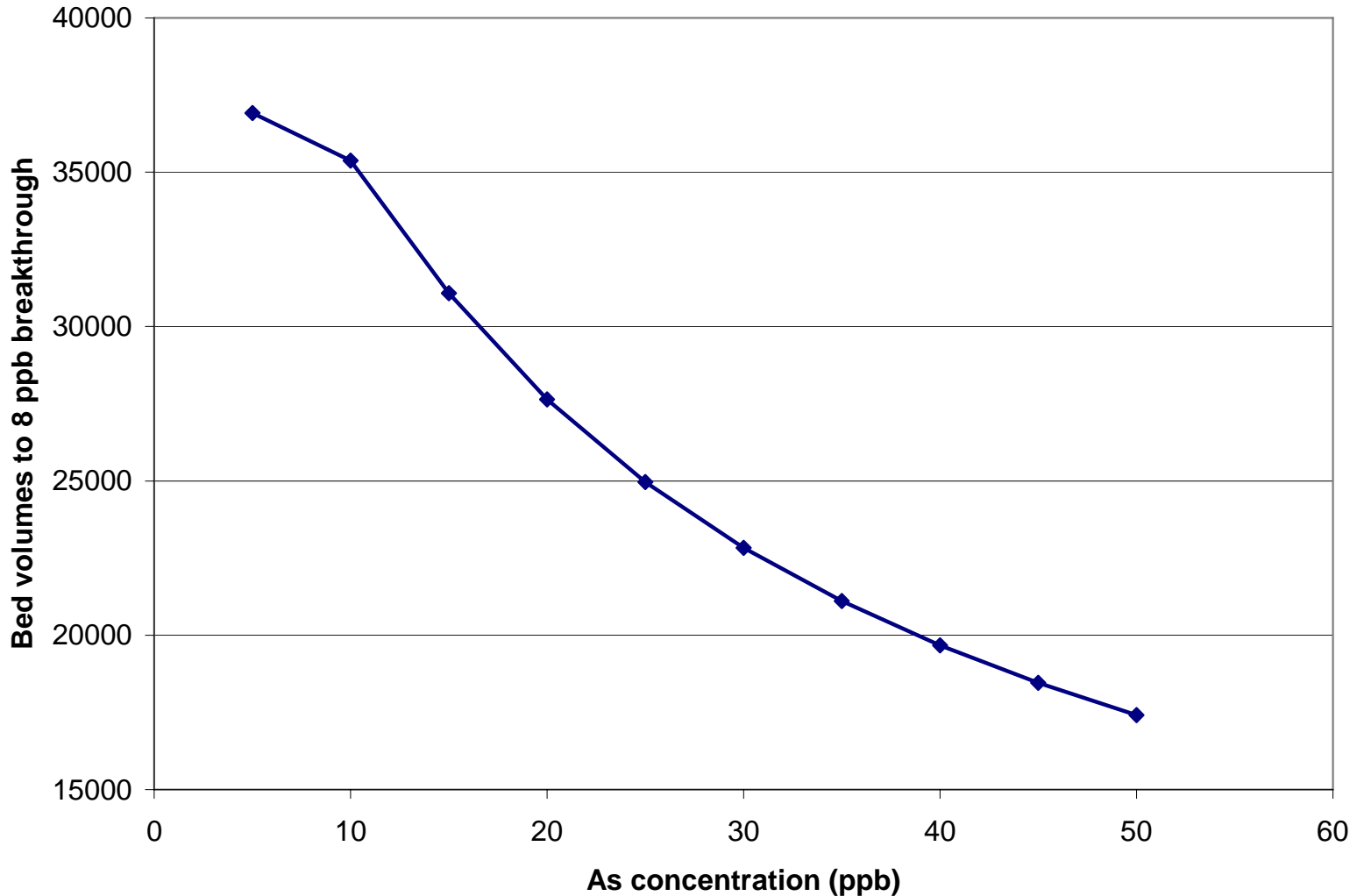


Lifetime varies by 10X with Silica





Lifetime varies only 2 to 3X with As





Customizing Performance

- Several options can be considered to improve arsenic removal performance for a given system
 - Blending of treated and untreated water
 - Using beds in series vs. a single bed
 - Adjusting pH prior to arsenic treatment
- **How do you decide what's right for you?**



Customizing Performance

- Blending treated and untreated water
 - May be appropriate when inlet water is near 10 ppb treatment threshold
 - Takes advantage of 0 ppb effluent from treatment bed for majority of bed's useful service life
 - Bed effluent must be controlled to lower level to ensure blend meets regulation
 - Example: 12 ppb inlet water
 - Blend 50:50 treated and untreated water
 - System effluent is 6 ppb for most of treatment time, i.e., when treatment bed effluent is 0 ppb
 - When treatment bed reaches 3 ppb, system effluent is still less than 8 ppb
 - Result is bed that is $\frac{1}{2}$ the size



Customizing Performance

- Using beds in series (lead/lag configuration)
 - Most useful when inlet water As is $> 2X$ regulation limit, i.e., much higher than 20 ppb
 - Lead bed is run to high level of exhaustion
 - Lag bed “polishes” water to non detect level
 - When lead bed is exhausted, media is replaced, and bed order is reversed
 - Requires additional vessel
 - Results in greater media utilization
 - Provides added measure of safety



Customizing Performance

- pH adjustment prior to arsenic treatment
 - Most useful when native water pH is high (> 8)
 - **Can dramatically increase bed lifetime, by as much as 4X**
 - Requires additional hardware and chemical dosing
 - Can be done with CO₂ or mineral acids
 - May require secondary adjustment back to native pH
 - **ADSORBSIA™ media is best suited for safe operation due to inherent pH stability of arsenic binding with titania**
 - This also holds true for natural pH fluctuations

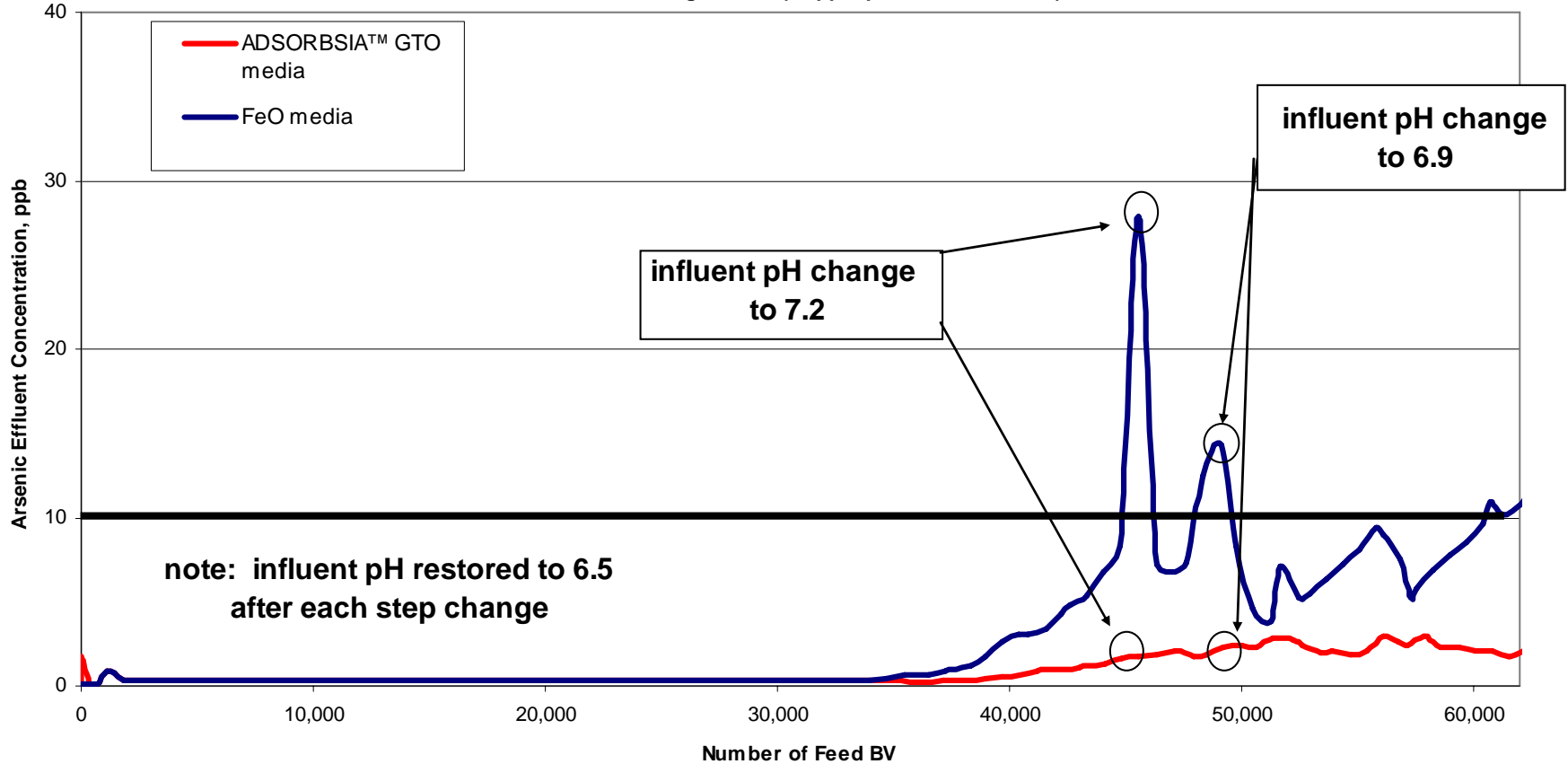


Customizing Performance



Arsenic Breakthrough Curves

NSF Challenge Water (50 ppb, pH=6.5, 120 s EBCT)





Customizing Performance

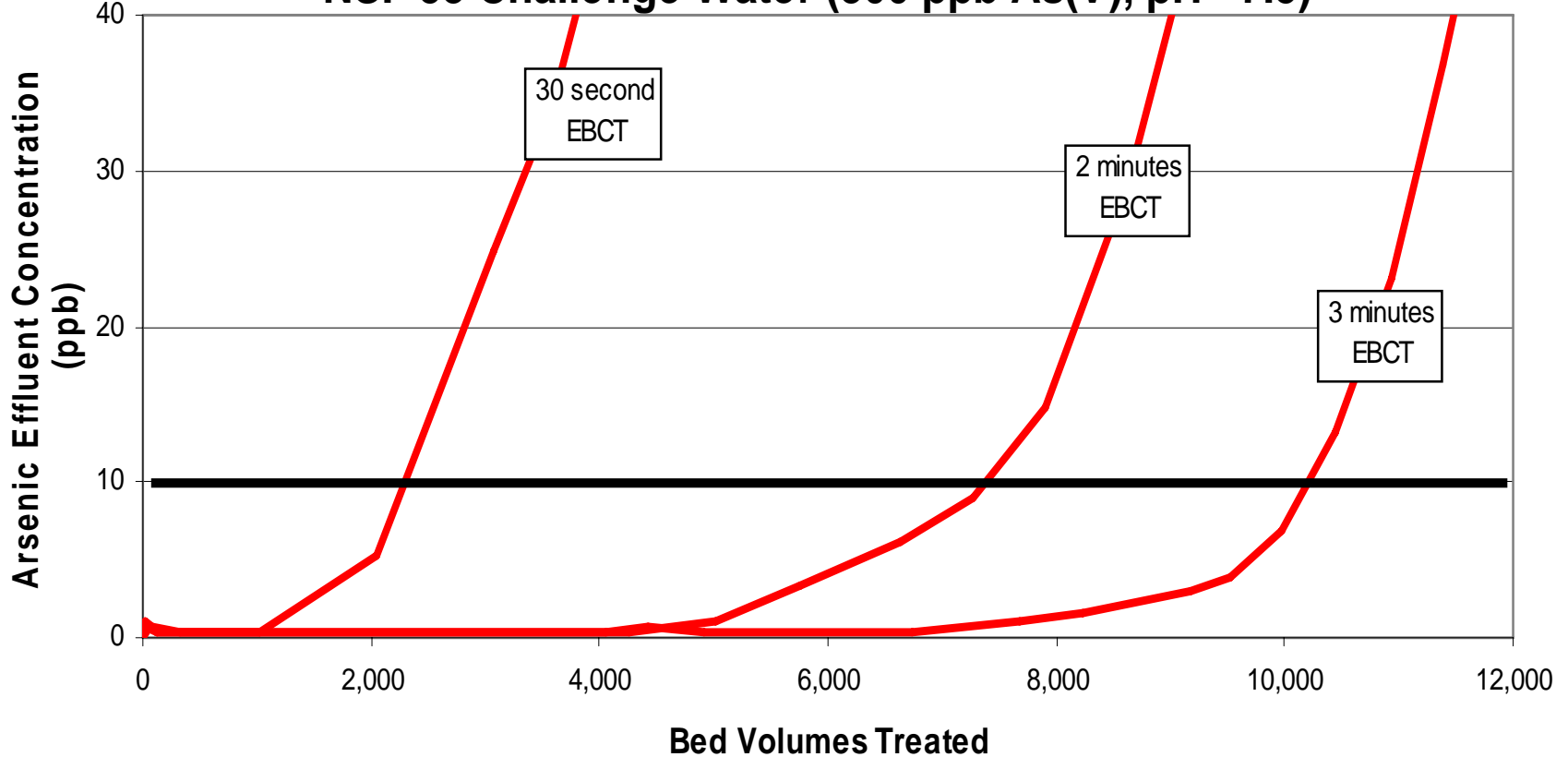
- Physical constraints of adsorptive media
 - Good system design incorporates both performance and handling characteristics of the media
 - Optimal flow rates, both for contact time and face velocity
 - Backwashing requirements
 - e.g., ADSORBSIA™ GTO™ should be backwashed at a flow rate of 6-10 gpm/ft² for proper media lift
 - Contribution and effect of pressure under flow
 - e.g. ADSORBSIA™ GTO™ contributes 1-4 psi per foot of bed depth under normal operating conditions



Fast Kinetics

Arsenic Breakthrough Curves

NSF 53 Challenge Water (300 ppb As(V), pH =7.5)





Customizing Performance

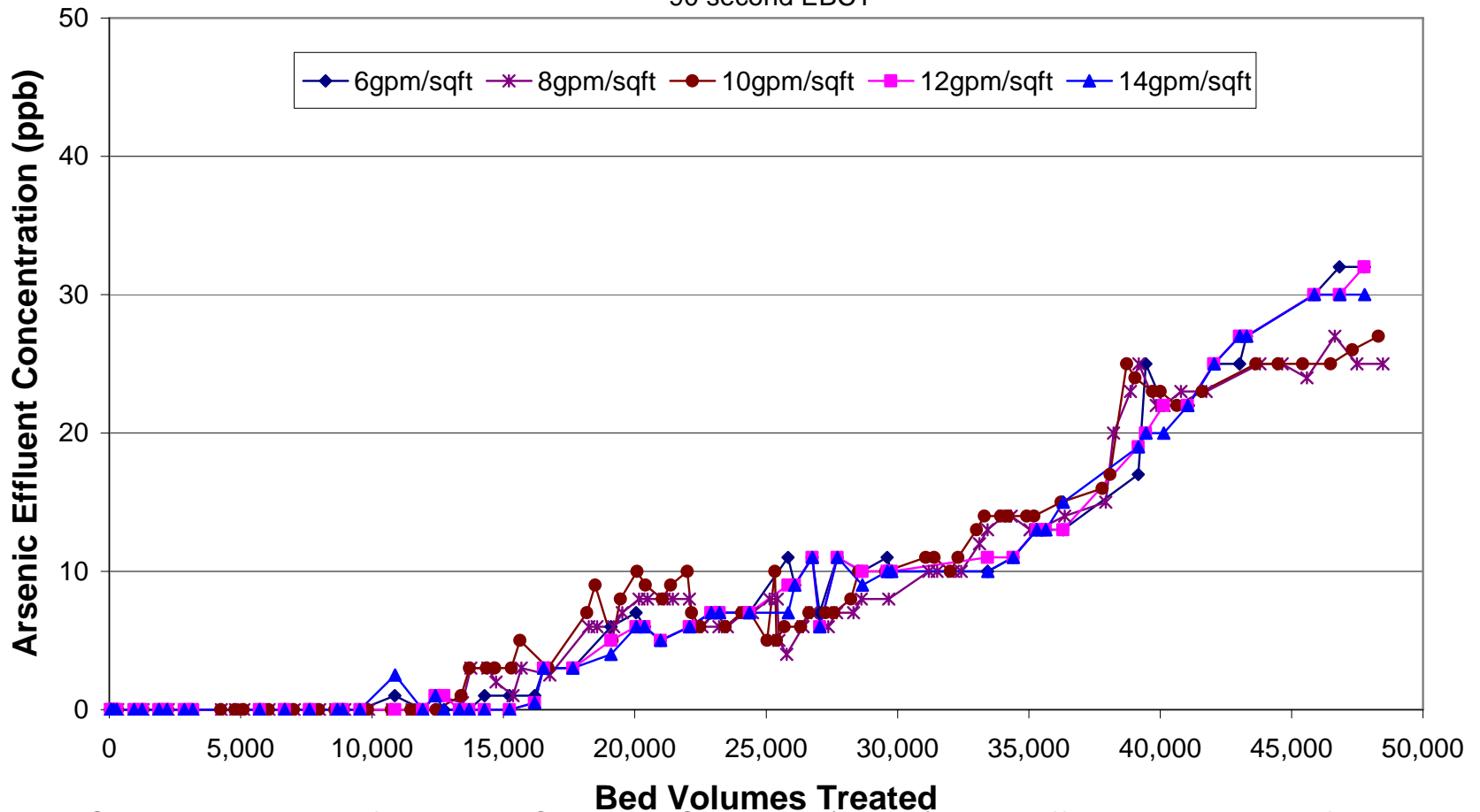
ADSORBSIA™ GTO™

Arsenic Breakthrough Curves for NSF Challenge Water

50 ppb Arsenic (V)

pH=7.5

90 second EBCT





Take Home Messages

- Adsorptive media can provide a very cost effective treatment for arsenic removal
- Knowing your water chemistry is critical for accurate system projections
 - Silica and pH play roles as or more important than arsenic levels
 - Other ions can compete as well
 - Phosphate, vanadium, and iron are known to be problematic, especially for iron based medias
- Proper media selection and good system design can greatly improve arsenic treatment performance
- Accurate system modeling is the key for a low cost design

Acknowledging Dow's ADSORBSIA™ Team



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