Background Information and Cost Models used in Regulatory Development

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Drinking Water Standards in the United States & California

- Federal Government – Safe Drinking Water Act
  - USEPA, Office of Ground Water & Drinking Water
  - Direct or delegated implementation, tribal systems.
  - https://www.epa.gov/ground-water-and-drinking-water

- California Government (a primacy state) – California Safe Drinking Water Act and Related Statues
  - State Water Resources Control Board (as of 7/1/2014)
  - Division of Drinking Water (Drinking Water Program)
  - http://www.waterboards.ca.gov/drinking_water/programs/index.shtml

Water Systems subject to Safe Drinking Water Act, Statues & Regulations - Public Water Systems

- A **public water system** (PWS) is defined as a system that provides water for human consumption… to 15 or more service connections or regularly serves 25 or more people daily for at least 60 days out of the year. (A public water system can be public or privately owned.)

- A **community water system** is defined as a public water system that serves at least 15 service connections used by **yearlong residents** or regularly serves at least 25 yearlong residents of the area served by the system.

State and Federal Standards for PWS

Drinking water standards:

1. Federal regulations that California adopts and incorporates into California's regulations
2. State only drinking water regulations (MTBE, 1,2,3-TCP, upcoming: hexavalent chromium)

- To retain primacy for Safe Drinking Water Act, California must establish drinking water standards that are at least as stringent as Federal regulations

Systems smaller than PWS…

- State small water system means a system for the provision of piped water to the public for human consumption that serves at least five, but not more than 14, service connections and does not regularly serve drinking water to more than an average of 25 individuals daily for more than 60 days out of the year.
  - State Small water systems have limited water quality standard requirements and are regulated by county health departments.

- Domestic Wells – 1-4 service connections
  - Domestic wells may be subject to county requirements.

Top Water Quality Challenges for Groundwater Systems in California

- Bacteriological (well construction)
- Nitrate
- Arsenic
- Uranium
- Organic Contaminants – 1,2,3-TCP

Best Available Treatment (BAT) Technologies for Centralized Treatment

	Ion Exchange	Adsorptive Media / Activated Alumina	Granular Activated Carbon	Reverse Osmosis	Coagulation Filtration	Oxidation Filtration	Electrodialysis	Lime Softening
Nitrate	**X**			**X**			X	
Arsenic	X	**X**		X	**X**	X	X	X
1,2,3-TCP			**X**					
Uranium	**X**			X	X			X

X = BAT   **X** = most commonly used

Technologies available for Point-of-Use or Point-of-Entry Treatment

	Ion Exchange	Adsorptive Media / Activated Alumina	Granular Activated Carbon	Reverse Osmosis	Coagulation Filtration	Oxidation Filtration	Electrodialysis	Lime Softening
Nitrate				X^2				
Arsenic		X		X				
1,2,3-TCP			X^1					
Uranium				X				

X = most commonly used X^1 = most common but no certified device / POE preferred

X^2 = most common but no certified device for nitrate > 27 mg/L as N

Cost Models (1)

- Nitrate – Established by United States Public Health Service. No US EPA cost model.

- Uranium – California MCL was established in 1989, several years before US EPA established the current uranium standard.

- Arsenic – USEPA "Technologies and Costs for Removal of Arsenic from Drinking Water" – December 2000, EPA 815-R-00-0028

https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1004WDI.TXT

Cost Models (2)

- Arsenic – CA DPH "Final Statement of Reasons Arsenic Primary Maximum Contaminant Level (MCL) Revision" August 7, 2008, DPH-04-017

  https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/arsenic/DPH-17-04-ArsenicMCL-FSOR.pdf

- 1,2,3-Tricoloropropane (1,2,3-TCP) – US EPA Work Breakdown Structure
  - DDW used the WBS cost model for GAC to estimate 1,2,3-TCP treatment costs

  https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/SBDDW-17-001_123TCP_MCL_oal.html

  https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/123-tcp/sbddw17_001/tab15/15f-cem.pdf

Work Breakdown Structure Cost Model

- USEPA has developed work breakdown structure (WBS) cost models for estimating centralized treatment costs for public water systems
- WBS cost model covers flowrate from 0.030 MGD to 75 MGD (design flow) that covers a population range from 25 people to greater than 100,000 people. It is available for granular activated carbon, packed tower aeration, multistage bubble aeration, anion exchange and cation exchange treatment.

https://www.epa.gov/dwregdev/drinking-water-treatment-technology-unit-cost-models-and-overview-technologies

Hexavalent Chromium Treatment Costs

- Treatment techniques with cost information:
  - Weak Base Anion Exchange (City of Glendale)
  - Reduction Coagulation Filtration (City of Glendale)

https://www.glendaleca.gov/government/departments/glendale-water-and-power/residential-customers/water-conservation-information/hexavalent-chromium-removal-research-project

  - Strong Base Anion Exchange (Water Research Foundation) (2013) cost model:

http://www.waterrf.org/Pages/Projects.aspx?PID=4450
http://crvitreatmentcosts.com/home/

Limitations of Cost Models and Adjustments for Public Water Systems

- Broad assumptions must be used for Statewide estimates
- All sources exceeding a proposed MCL are assumed to require treatment
- All sources, based on source water type, are assumed to use the same treatment technique
- National cost models, developed by USEPA and others, may not reflect California's higher labor, materials, residuals disposal and other compliance costs
- For example, arsenic treatment residuals disposal costs were not included in the USEPA model
- Use of ENR Construction Cost Indices for updating cost estimates may not be adequate (20 cities average)

Statewide Treatment Cost Estimates for Public Water Systems

- Input required:
  - Public Water System Inventory Information
    - Water System Type, Population Served, Service Connections, Number of Active Sources
  - Occurrence Data
    - How many sources will exceed the various proposed Maximum Contaminant Levels (MCL)?
  - Treatment Techniques
    - Review of available treatment techniques that can achieve the proposed MCL reliably
    - Review of available information or model on treatment cost

Assumption for Design Flow

- Population Based
  - Design Flow = Population x 150 gpcd x 1.5 peaking factor
- Service Connection Based
  - Design Flow = Service Connection x 3.3 person per S.C. x 150 gpcd x 1.5 peaking factor
- Actual Design Flow
  - Design Flow = Actual Well Production Rate
  - The well production rate may need to be higher because of minimum fire flow requirements and the lack of storage capacity.
- Actual Design Flow will generally be higher than the estimated value that are based on Population or Number of Service Connections. The lack of information on how each water system will choose to use its sources creates a complex problem for cost estimation.

Treatment Options

- BATs or "Best Available Technologies" are technologies that have been proven effective for water systems to use. However, source water quality may impact effectiveness of a BAT.

- SSCT or "Small Systems Compliance Technologies" are specified in the Federal Safe Drinking Water Act. SSCTs must be affordable and technically feasible for small systems.

- Key Costs to consider:
  - Capital Costs
  - Operation and Maintenance Costs
    - Certified Treatment Operator, Increased Testing
    - Waste Disposal Costs – Liquid & Solid Treatment Residuals

Treatment Options (2)

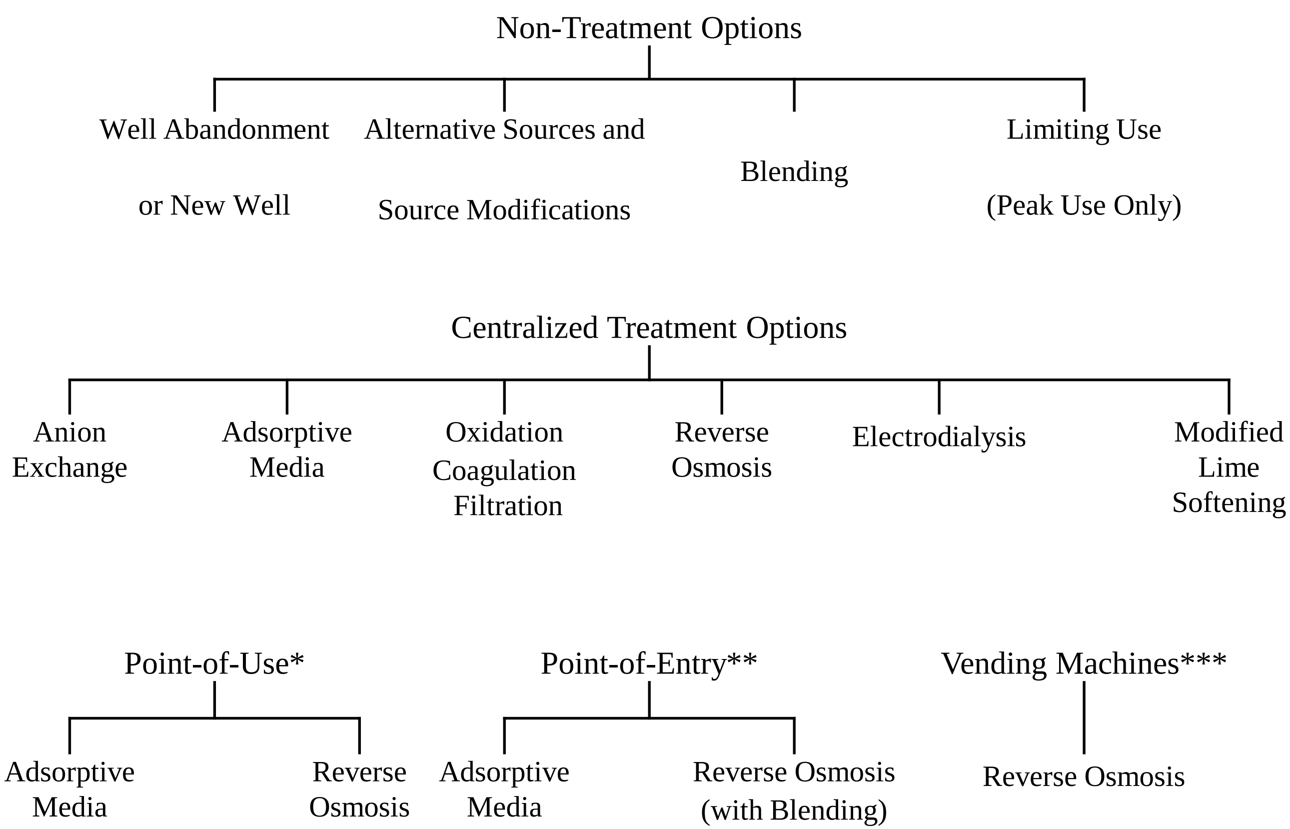
- Centralized Treatment – treating all water coming from a well

- Point-of-Entry Treatment – treating only water that enters a building for human consumption (useful for some businesses, schools (NTNC) or community water systems with a lot of outdoor water use)

- Point-of Use Treatment – treating only water that is used for drinking and cooking (useful for small community water systems and NTNC)

Preferred Treatment Options for PWS

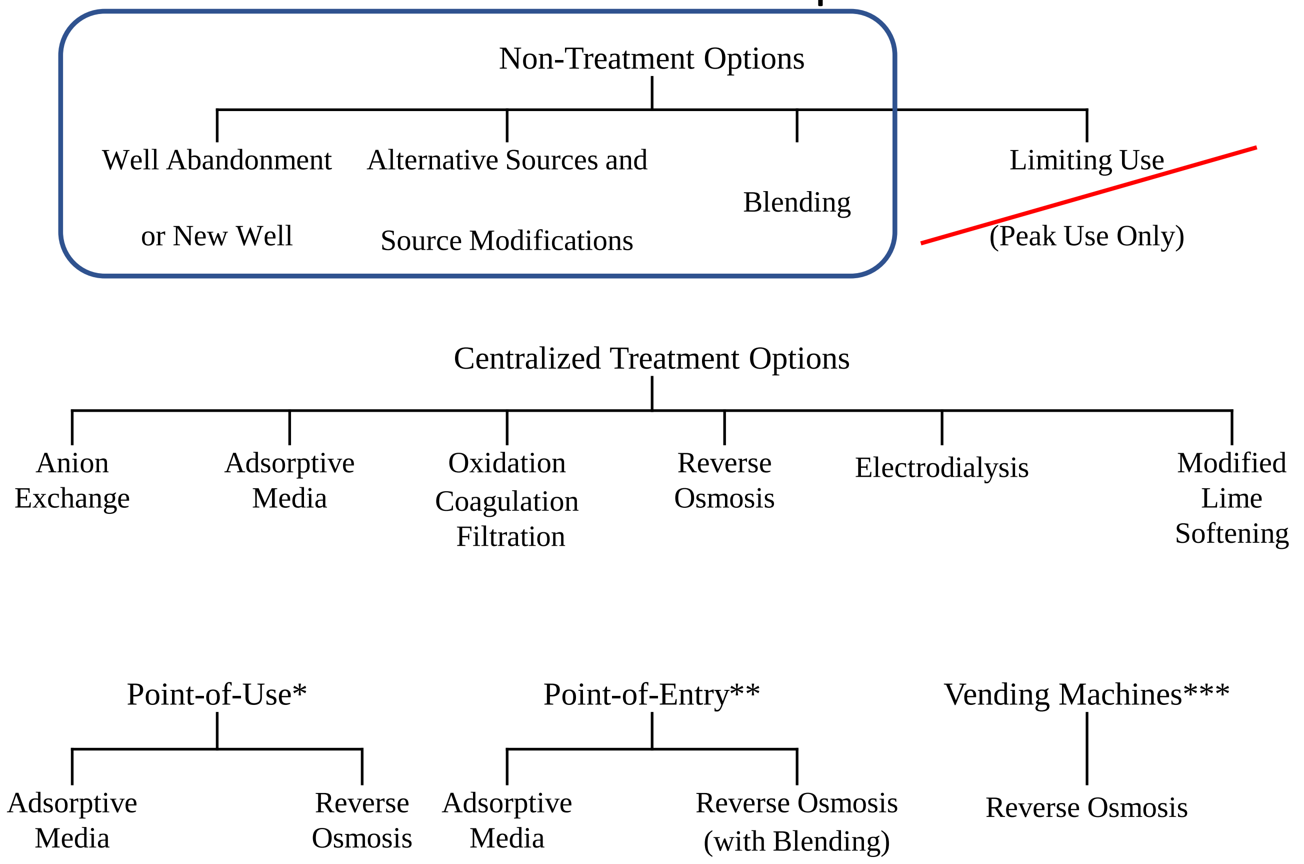
Arsenic Treatment Options



* Centralized chlorination may be required
** Site specific engineered solutions
*** Regulated by CDPH Food & Drug Brch

Preferred Treatment Options for PWS (1)

Arsenic Treatment Options



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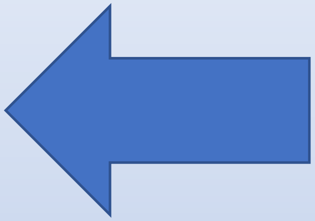
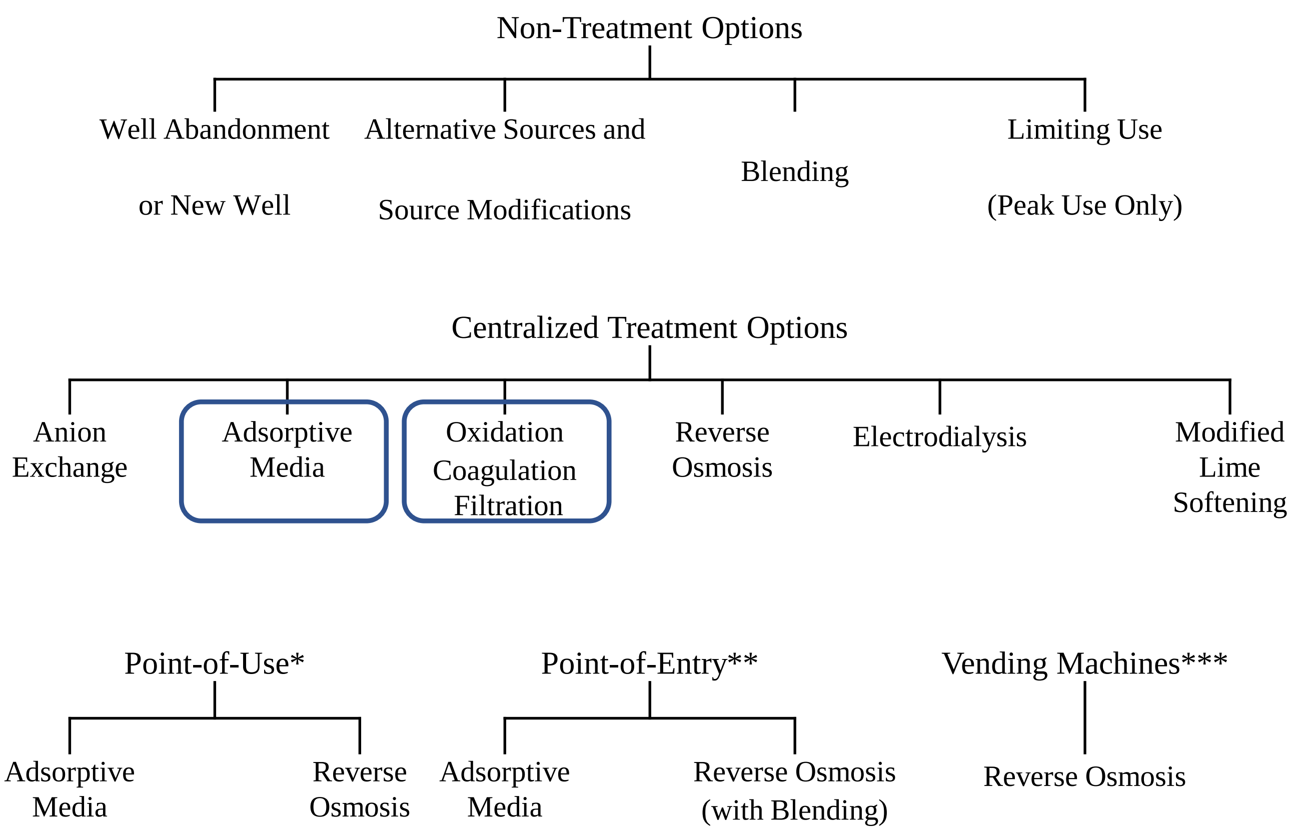
Most Preferred



Including **consolidation** with another PWS – no or lowest long-term O&M

Preferred Treatment Options for PWS (2)

Arsenic Treatment Options



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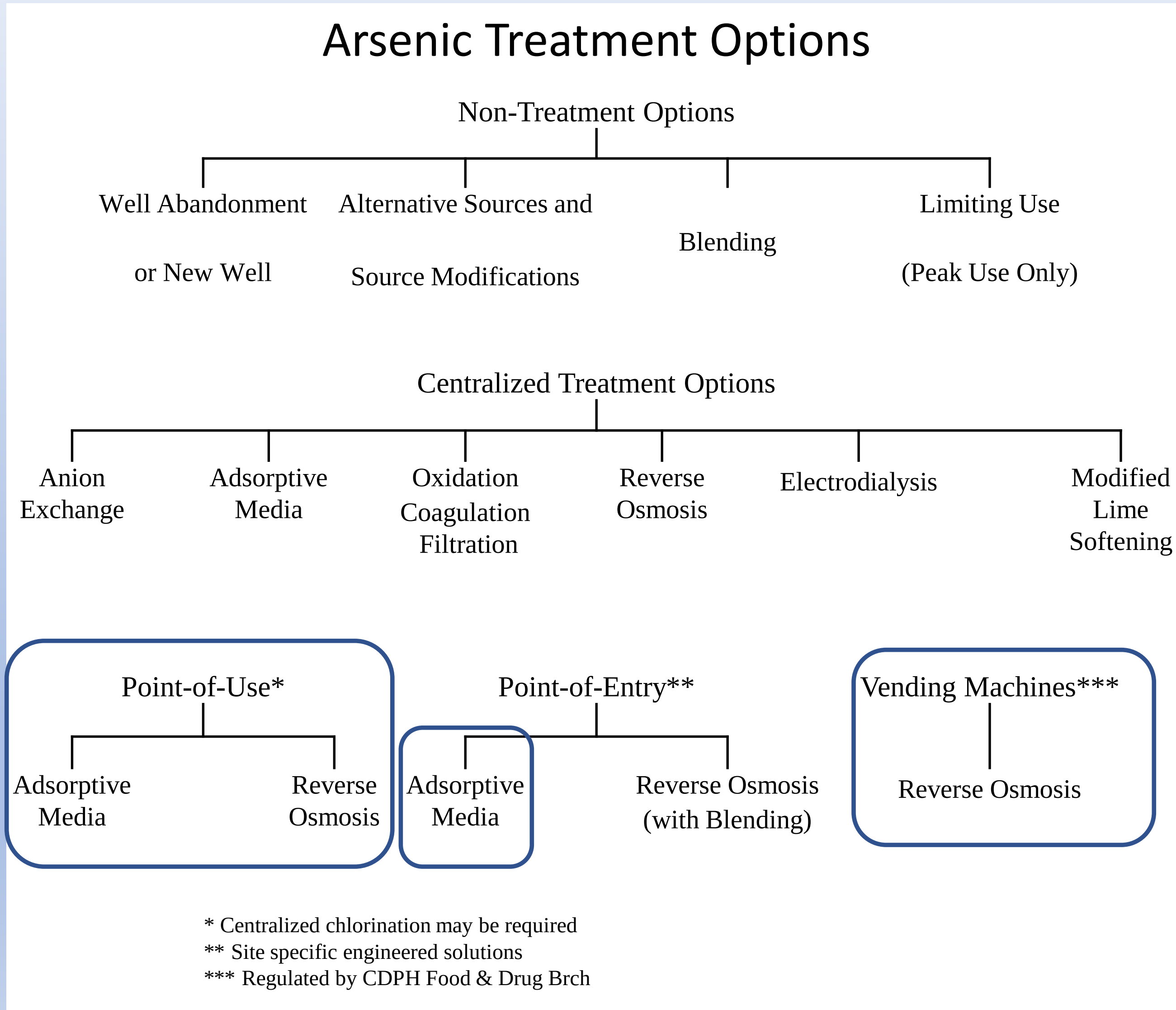
Treatment options

Cost models are developed

Treatment Options as Interim Solutions for Small PWS, State Small and Private Wells



"Interim" Treatment options

Non PWS Treatment options

Arsenic Small Systems Compliance Technologies (SSCT) 40 CFR 141.62 (d)

SMALL SYSTEM COMPLIANCE TECHNOLOGIES (SSCTS)[1] FOR ARSENIC[2]

Small system compliance technology	Affordable for listed small system categories[3]
Activated Alumina (centralized).	All size categories.
Activated Alumina (Point-of-Use)[4].	All size categories.
Coagulation/Filtration[5]	501–3,300, 3,301–10,000.
Coagulation-assisted Microfiltration.	501–3,300, 3,301–10,000.
Electrodialysis reversal[6]	501–3,300, 3,301–10,000.
Enhanced coagulation/filtration.	All size categories
Enhanced lime softening ($pH > 10.5$).	All size categories.
Ion Exchange	All size categories.
Lime Softening[5]	501–3,300, 3,301–10,000.
Oxidation/Filtration[7]	All size categories.
Reverse Osmosis (centralized)[6].	501–3,300, 3,301–10,000.
Reverse Osmosis (Point-of-Use)[4].	All size categories.

[1] Section 1412(b)(4)(E)(ii) of SDWA specifies that SSCTs must be affordable and technically feasible for small systems.
[2] SSCTs for Arsenic V. Pre-oxidation may be required to convert Arsenic III to Arsenic V.
[3] The Act (ibid.) specifies three categories of small systems: (i) those serving 25 or more, but fewer than 501, (ii) those serving more than 500, but fewer than 3,301, and (iii) those serving more than 3,300, but fewer than 10,001.
[4] When POU or POE devices are used for compliance, programs to ensure proper long-term operation, maintenance, and monitoring must be provided by the water system to ensure adequate performance.
[5] Unlikely to be installed solely for arsenic removal. May require pH adjustment to optimal range if high removals are needed.
[6] Technologies reject a large volume of water—may not be appropriate for areas where water quantity may be an issue.
[7] To obtain high removals, iron to arsenic ratio must be at least 20:1.

Note: The range of numbers provided in this table are based on the number of persons served.

Centralized Treatment vs POU

Central Treatment and Point-of-Use Units Compared

Central Treatment	Point-of-Use Units
All water treated	Treats water at the individual taps where the unit is installed
Less expensive for large communities	Can be less expensive for small communities
Capital costs very high, but equipment lasts a long time	Capital costs low, but media and membranes may require frequent replacement
Little customer involvement	Much customer involvement and support necessary
Does not require access to individual homes	Requires access to individual homes
Some technologies require a highly trained operator	Does not require a highly trained operator; maintenance can be contracted out
Waste disposal may be expensive	Waste disposal typically not a problem

<u>Key POU Considerations for PWS</u>

1. High customer acceptance with goal of full participation.
2. Routine water system personnel or contractor access to inside of customer homes for maintenance.
3. Annual monitoring of each treatment unit.

- Point-of-Use devices must be installed and maintained by public water system.
- Routine maintenance is required to ensure effectiveness.
- On-going maintenance work could potentially be contracted out.

Source: USEPA Complying with the Revised Drinking Water Standard for Arsenic: Small Entity Compliance Guidance

Disclaimer:

Photos are shown as examples and should not be considered endorsement of the products / vendors

Examples: Culligan Whole House Arsenic Reduction Filter (www.culligan.com) (left)
Multipure Aquaversa Undersink or Countertop Water Filter (https://www.multipure.com/aquaversa.html) (right)

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Examples: Watts Premier – Reverse Osmosis Treatment System (https://www.premierh2o.com/collections/reverse-osmosis?page=2)

https://www.yelp.com/biz/wps-plumbing-and-water-softener-systems-san-diego

Case Studies

- Alpaugh Community Service District
  - Tulare County
  - 392 Service Connections
  - 1026 Population Served
  - Two active wells
- Bridgeport PUD
  - Mono County
  - 258 Service Connections
  - 850 Population Served
  - Two active wells

Case Study 1 – Capital Cost for Alpaugh CSD – Arsenic Treatment

Alpaugh CSD Treatment Cost Estimates Based on USEPA Cost Equations (adjusted to 2018 dollars)

Activated alumina (Adsorptive Media)	Based on Service Connection (SC = 392)	Based on Population Served (Pop = 1026)	Based on Design Flow (Q = 0.864 MGD)
Capital cost:	$248,838.92	$201,329.09	$700,927.93
Capital cost for pH adjustment:	$82,010.83	$77,430.72	$125,593.74

Estimated Cost = $826,522

Case Study 1 – Capital Cost for Alpaugh CSD

Estimated Cost = $826,522

- Actual Bids:
  - Average of 3 bids: $3,362,045
  - Standard Deviation: $239,289 (7% deviation)
  - Winning bid: $3,089,130
  - Winning bid is substantially higher but may be caused by construction costs that are not included in the EPA model and a solar array included in the project
  - "Rough" attempt to isolate project cost
  - Adjusted project cost: $1,918,100
  - ~ 2.3 times of USEPA model's estimated cost

Case Study 2 – Capital Cost for Bridgeport PUD – Arsenic Treatment

Bridgeport PUD Treatment Cost Estimates Based on USEPA Cost Equations (adjusted to 2018 dollars)

Activated alumina (Adsorptive Media)	Based on Service Connection (SC = 293)	Based on Population Served (Pop = 2150)	Based on Design Flow (Q = 0.936 MGD)
Capital cost:	$190,836.45	$400,884.56	$757,740.88
Capital cost for pH adjustment:	$76,419.19	$96,668.54	$131,070.71

Estimated Cost = $888,811.59

Case Study 2 – Capital Cost for Bridgeport PUD

Estimated Cost = $888,811.59

- Actual Cost for Adsorptive Media
  - Actual Cost: $1,420,872
  - ~ 1.6 times of USEPA model's estimated cost
  - However, due to poor performance of adsorptive media, adsorptive media treatment plant was modified to become a coagulation/filtration system
  - Equipment from the adsorptive media system was "salvaged"
  - Direct cost comparison was not possible
  - Final contract cost: $2,786,894

Comments on Studies and USEPA model

- Limited sample size to draw any conclusion
- Cost model seems to underestimate actual costs
- USEPA construction cost estimates include: housing, electrical equipment and instrumentation, pipes and valves, labor, steel, concrete, manufactured equipment, and excavation and site work
- Construction costs do not include special site work, general contractor overhead and profit, engineering, land, legal, fiscal/admin work, and interest during construction
- Operations and Maintenance costs were not compared
- Adsorptive media for arsenic are underperforming in California due to higher natural groundwater pH

Challenges and "Total Cost" for Long Term Success

- Operator costs (labor is high to start-up, optimize and maintain water treatment facilities)
- Lack of qualified operators (to operate centralized treatment plants)
- Lack of qualified subcontractors to perform work (installation and maintenance of POU/POE)
- Small Water Systems lack someone in a "water quality manager" role to monitor treatment performance, initiate preventative maintenance and ensure compliance
- Small Water Systems also lack long-term asset management planning and resources to:
  - Replace treatment plant
  - Replace aging distribution pipes and well(s)

Acknowledgement

- Dr. Richard Sakaji

- Questions?
- E-mail: eugene.leung@waterboards.ca.gov