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

<table>
<thead>
<tr>
<th></th>
<th>Ion Exchange</th>
<th>Adsorptive Media / Activated Alumina</th>
<th>Granular Activated Carbon</th>
<th>Reverse Osmosis</th>
<th>Coagulation Filtration</th>
<th>Oxidation Filtration</th>
<th>Electrodialysis</th>
<th>Lime Softening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate</td>
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<td>X</td>
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<tr>
<td>Arsenic</td>
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<td>1,2,3-TCP</td>
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<tr>
<td>Uranium</td>
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<td>X</td>
</tr>
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</table>

X = BAT  
X = most commonly used
# Technologies available for Point-of-Use or Point-of-Entry Treatment

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<tbody>
<tr>
<td>Nitrate</td>
<td></td>
<td></td>
<td></td>
<td>X²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>X³</td>
<td></td>
<td>X</td>
<td></td>
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<td></td>
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</tr>
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<td>1,2,3-TCP</td>
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<td>X¹</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

**X** = most commonly used  
**X¹** = most common but no certified device / POE preferred  
**X²** = most common but no certified device for nitrate > 27 mg/L as N
Cost Models (1)


• 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


• 1,2,3-Tricloropropane (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/SBD DW-17-001_123TCP_MCL_oal.html

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.

Hexavalent Chromium Treatment Costs

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

Non-Treatment Options
- Well Abandonment
- Alternative Sources and Source Modifications
- Limiting Use
- Blending (Peak Use Only)

Centralized Treatment Options
- Anion Exchange
- Adsorptive Media
- Oxidation Coagulation Filtration
- Reverse Osmosis
- Electrodialysis
- Modified Lime Softening

Point-of-Use*
- Adsorptive Media
- Reverse Osmosis

Point-of-Entry**
- Adsorptive Media
- Reverse Osmosis (with Blending)

Vending Machines***
- Reverse Osmosis

* Centralized chlorination may be required
** Site specific engineered solutions
*** Regulated by CDPH Food & Drug Brch
Preferred Treatment Options for PWS (1)

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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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  - Alternative Sources and Blending
    - Limiting Use (Peak Use Only)

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

**Arsenic Treatment Options**

- **Non-Treatment Options**
  - Well Abandonment
  - Alternative Sources and Source Modifications
  - Blending
  - Limiting Use (Peak Use Only)

- **Centralized Treatment Options**
  - Anion Exchange
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- **Point-of-Use**
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Note: The range of numbers provided in this table are based on the number of persons served.
Centralized Treatment vs POU

Key POU Considerations for PWS

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

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

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

Estimated Cost = $826,522
Case Study 1 – Capital Cost for Alpaugh CSD

• 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

Estimated Cost = $826,522
Case Study 2 – Capital Cost for Bridgeport PUD – Arsenic Treatment

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

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

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