Arsenic Treatment Alternatives

Q: How does the Capital and Operating cost of the AdEdge Packaged Granular Ferric Oxide (GFO) Adsorption Systems for Arsenic compare to other options for Small Drinking Water Systems?

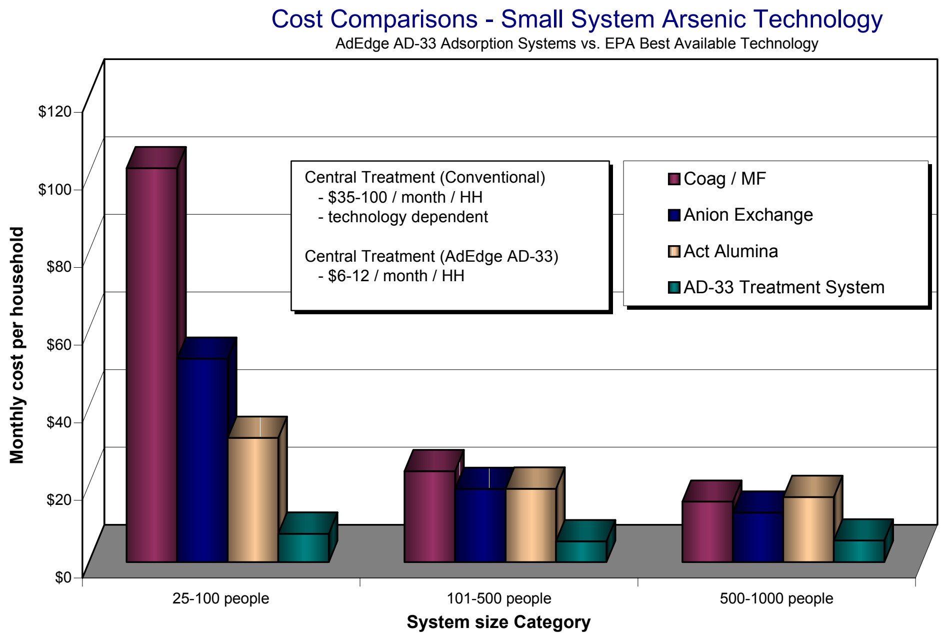
Competitive and Cost Analysis

Unit treatment costs using AdEdge's Adsorption Package Unit (APU) integrated treatment systems are significantly lower than competing technologies because:

- The GFO adsorption media (specifically the Bayoxide E33 media) is highly selective for arsenic in the presence of the other species present in high TDS water;
- The process is Simple with little operator attention required;
- The media has the highest arsenic capacity per gram than any media in the marketplace; capacity is typically 1 to 5 times higher than conventional adsorbent products, resulting in long run times and infrequent media change-out;

- Unlike other technologies such as ion exchange, the AdEdge process removes both common forms of arsenic, (V) and (III), without pre-oxidation or chemical pretreatment;
- Systems are pre-designed and packaged for simplicity and ease of installation;
- Kinetics of the media (or reaction time) to remove the arsenic is fast resulting in smaller vessels and quantity of media needed compared to alternatives;
- The spent media is non-hazardous waste and there is no need for post treatment of residuals prior to disposal; materials can be disposed in a solid waste disposal facility;
- More than 99% of the water used in the process is treated and distributed for potable consumption;
- No hazardous chemicals or media regeneration is required;
- Systems have a small footprint requiring less space than alternatives; and
- Systems are pre-engineered, pre-piped, and packaged for simple installation.

Below is a comparison of AdEdge to EPA's conventional BAT technologies for arsenic removal:



For the range of populations under consideration, the data shows that the technology lifecycle cost can be less than 50% of conventional technology, including capital and operating costs. The following table shows a qualitative comparison to conventional technologies. Each technology is discussed in detail below. However, the most important economic consideration is the simplicity of the process. When compared to all the technologies listed, this iron oxide adsorption technology is by far the simplest technology.

Technology	Process	Chemical Use	Waste Generated	Water Wasted
AdEdge E33 GFO Adsorption Process	Simple	None	Low	<0.1%
Reverse Osmosis	Moderate	Cleaning chemicals	Low	10-25%
Ion Exchange	Complex	Yes, Regeneration chemicals	High	5%
Activated Alumina	Complex	Yes, Regeneration chemicals	High	5%
Coagulation / Microfiltration	Complex	Yes, Pretreatment, Coagulants, and Cleaning agents needed	Moderate	5%

The importance of a process being simple cannot be overemphasized for small drinking water systems serving populations less than 10,000 people. In many cases, these small utilities are not accustomed to operating treatment plants and often do not have the technical staff to oversee, operate and troubleshoot a complex treatment plant. This problem becomes more acute in the situation faced by many of these utilities that have more than one well with the arsenic problem. The locations are often remote and in a community, near housing and/or recreational facilities so the technology must be simple.

Frequent visits to check the process or troubleshoot a problem are not desired. Most importantly, the labor to operate the systems must be realistically estimated and is often a hidden cost and not included in some technology provider's estimates. More frequent O&M visits to the wellhead are required and downtime for the well will occur with more complex technologies such as reverse osmosis (RO), ion exchange (IEX), activated alumina (AA) or coagulation microfiltration (CMF).

For larger municipal systems, in many cases the engineer involved has made an up front qualitative assessment to eliminate these complex technologies on that basis. While a detailed risk assessment can translate the risk of a complex technology (RO, IEX, AA or CMF) into a cost of labor and downtime, most utilities will eliminate the complex technologies based upon a qualitative engineering assessment. Other considerations by technology are discussed below:

Reverse Osmosis (RO) – RO is usually not a viable consideration due to the large waste (loss) of water (10% to 25%) except for special cases where very high Total dissolved solids (TDS) are present. Concentrated arsenic bearing wastewater (retentate) is often an issue for disposal or on-site treatment. Other important factors that make this option unattractive for small water systems are its high capital cost and relatively high operation and maintenance costs. Pre-treatment of the water is often required and is critical to effective use of RO membranes.

Ion Exchange (IX) – The anion exchange (IX) process requires a careful understanding of the water chemistry for proper application. High TDS waters would typically exclude this from consideration. This process utilizes a regenerable organic resin that is intended to be regenerated whereby the arsenic is removed from the resin by a chemical exchange process using the brine solution. The frequency of regeneration will depend on the water quality and gallons usage, but in general will be required at least weekly intervals (meaning operator involvement and potential operational problems). In addition, the IX regeneration process requires a salt brine and will generate a dilute brine waste with high levels of arsenic in a quantity equal to three to five bed volumes per regeneration. For a small water system, this waste or wastewater must be treated, transported and disposed (often as a hazardous waste) with potential long-term liability to the facility.

This potential liability as a risk factor in many cases, will eliminate this technology from consideration. In addition to the hazardous waste being generated, approximately 5% of the water processed will be wasted in the process. For many small systems with arsenic, water availability plays a key role in technology assessment. Another risk factor with IX is arsenic "spiking." If the media loads with arsenic and the regeneration is not performed in a timely manner, arsenic levels in the drinking water delivered to the system can dump or be observed in the treated water at levels higher than influent levels. If carefully operated, this can be avoided, but requires a high level of sampling frequency and operator attention for this process to work efficiently. Most small systems are electing to not use this technology option for these reasons.

Activated Alumina (AA) – There are two approaches with AA: regeneration of the AA or using it in a "throw away" whereby the spent AA is disposed. With regeneration, all the costs and complexities are similar to the IX discussion above. For the single use approach, the AA has been shown to have approximately 10-20% of the capacity of the iron-based E33 GFO media, which means that the small water system would purchase and haul 10 times the amount of media over time. In addition, there would be a significant associated increase in labor and downtime to change out the media more frequently.

Coagulation / Filtration or Microfiltration – This option most often utilizes an iron salt or coagulant to assist in arsenic removal. Ferric chloride or ferric sulfate are the most common chemicals added to the raw water to enhance arsenic removal. The capital costs are typically 1.5-3 times higher than adsorption media processes. Other means of filtration such as sand filters are available to filter the coagulated raw water, but less effective than microfiltration. The process relies heavily on proper pH, coagulant dose, proper mixing, and chemical ratios for effective removal. The main advantage often presented by technology providers for this option is lower operating costs. It is most commonly seen in the largest of arsenic applications where the economics may be more favorable for this approach.

Whether microfiltration or other specialty media filtration is used, both approaches require careful attention to coagulant mixing and dosage level, filtration performance, and processing of the sludge that will be generated. All of this makes coagulation / microfiltration a complex approach, which generally has higher labor cost and hidden costs associated with downtime. With a membrane approach, there is the additional risk associated with membrane life prediction, fouling, and output (or lack of output) during the life of the membrane. Membrane systems require chemical cleaning and associated cost. Chemicals must be transported and stored within community locations. It is estimated the membrane approach will also waste up to 5% of the filtered water for regeneration and retained water or retentate.