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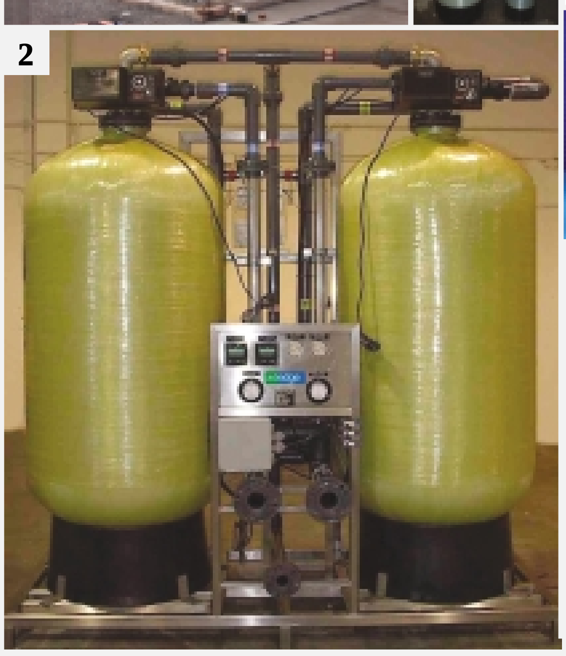
ARSENIC TREATMENT

Cross-Platform Viability of Treatment Technologies

The new maximum contaminant level (MCL) of 10 parts per billion (ppb) for arsenic presents tremendous opportunity for the water treatment industry, though for many dealers, making decisions on specific treatment options remains confusing at best. A wide range of technologies, some new and some more traditional, is being marketed and applied for arsenic treatment. Each of these technologies has specific properties impacting its suitability for any particular scale of application.

The breadth of the arsenic issue and the growing need for a diverse solution set have prompted some manufacturers to explore the boundaries of available technologies and, in some cases, extend their application into other platforms. Ferric oxide-based adsorbents, for example, have been applied in municipal systems for arsenic treatment for several years. Over the past two years, the technology has extended to point-of-entry and point-of-use applications and most recently has been proven effective in a carbon block platform.



1) A 6.0 mgd municipal ferric oxide-based treatment system.

2) Ferric oxide-based arsenic adsorption system for small water system applications.

3) Point-of-entry application for granular ferric oxide.

4) Granular ferric oxide point-of-use devices.

5) Carbon block products incorporating granular ferric oxide to achieve arsenic claim.

While rare, the ability of a single water treatment technology to perform effectively across many treatment platforms is not unique. Activated carbon is perhaps the most obvious example of a technology that has proven successful across a very wide range of application scales. Modification and engineering are, of course, required to adapt a technology to a specific scale/platform, but the engineering effort required to transition an adsorbent-based technology into other platforms often is much smaller than for other technologies.

From a technical design point-of-view, adsorbents are reasonably easy to apply as fewer factors typically impact adsorbent system performance than with other technologies. When applying adsorbents to drinking water treatment at any scale, only a handful of factors generally are considered.

- Selectivity of the particular adsorbent for the contaminant of interest
- Surface area of the adsorbent
- Adsorption kinetics
- pH of the water
- Competing species (adsorption)
- Pressure drop and occluding species
- Adsorption bed design
- Regeneration/backwashing requirements

From a pragmatic, end-user's point of view, however, most of the above are taken care of by the manufacturer's characterization and usage recommendations for the adsorption media. Consumer or operator concerns essentially can be limited to capacity/lifetime, changeout and disposal of the media.

Primarily due to their simplicity of application and operation, adsorption media have been more widely accepted and applied than other technologies. Chemical additions, feed pumps and real-time monitoring generally are not required, making operation and maintenance comparatively simple.

Expanding the application of a technology to other treatment platforms requires more than just easy application. The economics involved must be viable, as well. For example, technology costs extend far beyond, the cost/capacity ratio of media. When considering new products or applications, the practical costs of operation and maintenance, costs of data accumulation, testing and research and development, and marketing costs must be factored in to yield a realistic cost per gallon to the end user. Because of the systems' simplicity, operations and maintenance costs of adsorbent-based systems often can be kept lower than systems based on other technologies. Selection of appropriate adsorption media, which exhibit high capacity, good selectivity and few pretreatment concerns, further increases cost effectiveness. The existing knowledgebase around the application of adsorption to drinking water treatment is extensive, and because the process is fairly well understood and the application mechanics are reasonably simple, product development costs often are lower than with other technologies. In some cases such as with granular ferric oxide, the technology has been applied for years at the municipal level, giving prospective point-of-entry or point-of-use users not only a high comfort level, but a large existing base of fundamental performance data. With technologies where such history does not exist, larger amounts of fundamental research must be directed at understanding the basic technology or material in addition to research into platform-specific performance.

An existing water treatment history on other platforms also may mean that a product has third-party testing such as NSF 61 certification—a tremendous benefit both from a user acceptance and a development cost point of view.

So far, it is concluded that the success of a treatment technology extending across many platforms is reliant on ease of application and cost effectiveness of the solution. There exist some practical limitations, of course. For example, it is doubtful, for example, that even if technically possible, arsenic removal with lime-softening on a point-of-use platform would ever prove commercially viable.

Table 1 lists most of the commercially available treatment technologies for arsenic removal and outlines characteristics of each that allow suitability for various treatment platforms. Of the arsenic removal technologies listed, granular ferric oxide demonstrates one of the widest applicability profiles. A brief review of the application of the technology to each treatment platform, beginning with large municipal systems and highlighting particular strengths/weaknesses of the technology which make it suitable for each application now will be given and will use granular ferric oxide as an example.

Granular ferric oxide first was commercially applied to arsenic treatment in municipal water systems in the United Kingdom. Picture 1 shows an example of a 6.0 mgd municipal ferric oxide-based treatment system. Today, more than 500,000 people are supplied water from municipal systems using granular ferric oxide for arsenic removal. Granular ferric oxide (GFO) should not be confused with other ferric-based products. GFO is a dry material and has a ferric oxide assay of 88 percent. This material has not shown itself prone to iron bacteria growth or severe handling and pressure drop complaints due to excessive fines. The capacity of this material versus ferric treated

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adsorbents has shown significant performance differences.

As Table 1 indicates, ferric oxide also has been successfully applied to small community water systems. Because of their smaller scale and different flow requirements, small community adsorption systems require faster adsorption kinetics than do larger municipal systems, as bed contact times typically are shorter. The rapid kinetics of granular ferric oxide suit these requirements reasonably well. Unlike larger municipal systems, many small systems have no form of disinfection and, therefore, pre-oxidation of As (III) to As (V) may be considered impractical in small community systems. Therefore, the ability to remove both species with a single treatment step is more critical. While pH adjustment certainly is possible at the small water system level, it is preferable to utilize an arsenic treatment technology that does not require the added complexity and cost of pH adjustment. The broad range of pH over which ferric oxide is effective (typically 5.5–8.5) makes it an attractive solution for the small community water system platform. Picture 2 shows a typical ferric oxide-based arsenic adsorption system for small water system applications.

As a technology is extended into the whole-house/point-of-entry platform the number factors affecting suitability are further increased. Picture 3 shows a typical point-of-entry application of granular ferric oxide. Application of the media on a point-of-entry platform typically mandates even faster kinetics as available space for adsorption beds is considerably reduced. Perhaps even more importantly, the successful point-of-entry application requires that operations and maintenance by the homeowner be minimal. Point-of-entry technologies that require regeneration with chemicals or pH adjustment using acids or caustics present an unattractive level of complexity to the homeowner and increase the probability of operational problems. Media disposal also becomes even more important at the point-of-entry level. Adsorption media that bind contaminants tightly and pass the EPA's TCLP test generally are disposed of in a sanitary solid waste landfill, eliminating the costs and complexity to the homeowner of dealing with hazardous material disposal.

From a design standpoint, point-of-use platforms introduce an even larger set of challenges to an arsenic removal technology. Rapid kinetics and high capacity are absolutely critical at this scale. Dry, granular adsorbents often can be adapted to point-of-use applications relatively easily by modifying particle size. Decreasing particle size has the effect of speeding up adsorption kinetics and increasing capacity by increasing available surface area for adsorption. Trade-offs must be made, of course, as smaller particle sizes typically produce increased pressure drops. An adsorption medium also must demonstrate good handling characteristics as automated cartridge production typically requires a dry, flowable material. If a material breaks down easily on handling, it may generate too many fine particles and cause issues with plugging and pressure drop and may even result in small particles of media in the cartridge effluent. At the point-of-use scale, pretreatment ability is minimal and pH adjustment is impractical, so a technology either must be capable of "standing on its own" or working in conjunction with other, conventional point-of-use technologies. Picture 4 shows examples of granular ferric oxide point-of-use devices.

Recently, ferric oxide technology was extended into the carbon block platform. Incorporating an adsorption technology into a carbon block requires a large amount of development effort. In addition to the general point-of-use criteria discussed above, an adsorption medium must exhibit physical/chemical characteristics enabling it to be compounded into block form with other media. Formulating a carbon block often results in the obscuration of a portion of the surface area of the medium, thereby further increasing the requirements for adsorption capacity and very rapid kinetics.

Picture 5 shows recently developed carbon block products incorporating granular ferric oxide to achieve an arsenic claim.

There certainly is no requirement that a treatment technology be applicable to a wide range of platforms. Many treatment technologies perform well at specific scales or under specific conditions. Very few are capable of performing on all treatment platforms. Those that are capable of doing so typically are those that are capable of handling a broad range of water parameters; are easy to use, handle and process; demonstrate high capacities; have rapid adsorption kinetics; and can be engineered into economically viable solutions. WQP

Table 1: Arsenic Technology Application Matrix

	Activated Alumina[1]	GFH	Anion Exchange[2]	Granular Ferric Oxide	Iron Modified Alumina	RO	Manganese Greensand	Coagulation Filtration[3]
Large Municipal Systems – Commercially Available Options	X[1]	X	X[2]	X	X	X	X	X[3]
Small Water Systems – Commercially Available Options	X[1]	X	X[2]	X	X		X	X
Reduction of both Arsenic (III) and (V)		X		X			X[4]	
Complexity	Mod	Low	Mod	Low	Low/Mod	High	Mod/High	High
Operator attention and maintenance	Mod	Low	High	Low	Low/Mod	High	Mod	High
Efficient reduction of arsenic > 50 ppb		X		X		X[4]		
Non-hazardous residual disposal	X	X		X	X			
Point-of-Entry (Whole House) – Commercially Available Options	X		X[2]	X	X		X	
Reduction of As (III) without preoxidation				X				
High capacity / Infrequent replacement				X				
No regeneration or chemical use				X	X			
No concentrated residuals or waste				X	X			
Broad pH of application / reliability				X				
Disposal as non-hazardous solid waste	X			X	X			
Point of Use – Commercially Available Options	X			X	X	X[4]		
Carbon Blocks				X				
Granular Cartridges	X[4]			X	X			
Carafes/pour through devices				X				
Products Having NSF 53 Arsenic Cert.				X		X[4]		
Environmental Remediation – Commercially Available Options		X		X			X	
Industrial Wastewater – Commercially Available Options		X	X[2]	X		X[4]	X	X

notes:
1. Assumes regeneration with strong base for optimal performance at typical pH ranges.
2. Regeneration with salt and brine disposal / handling.
3. Includes various filtration media and microfiltration options.
4. Requires pretreatment / oxidation to convert As (III) to As (V) for removal.