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& Paul Sylvester



applications—arsenic removal

Multiple treatment methods and materials have been developed for the removal of arsenic from drinking water over the past decade. This development surge has been fueled by the U.S. Environmental Protection Agency's (EPA) decision to lower the maximum contaminant level (MCL) for arsenic from 50 µg/L to the new standard of 10 µg/L.

Arsenic (As) occurs naturally in water in the oxidation states +III and +V. The form of arsenic is dependent on the water chemistry and pH level, with anionic As(V) species (H_2AsO_4^- and HAsO_4^{2-}) predominating in oxygen-rich waters, and neutral As(III) (H_3AsO_3) being prevalent under oxygen-deficient conditions. It is not uncommon, however, to find both species existing simultaneously in the same water.

Accurate identification of the arsenic species is crucial when deciding on a remediation strategy. Most adsorptive media will remove both

generates large amounts of secondary waste often rendering the treatment method economically unviable. Adsorptive media, therefore, are often favored when compliance with the arsenic MCL is needed.

New Treatment Materials

Hydrous metal oxides have a positive surface charge at pH values below their point-of-zero charge pH, thus anions can be adsorbed. Key attributes of these media are listed in Table 1.

Activated alumina was initially considered one of the best available technologies for arsenic removal although it has been surpassed by several new adsorbents with greater capacities and pH tolerance. Iron oxides and oxyhydroxides have shown to have a high affinity for arsenic, and media have been developed using hydrous iron oxide as the active component for arsenic absorption.

Granular ferric hydroxide (GFH) and granular ferric oxide (GFO) are highly porous materials and have a high capacity for arsenic. Adsorption of arsenic on the hydrous metal oxides/hydroxides is generally slow and often long contact times are needed to fully utilize the high capacity of these media.

The performance of granular titanium oxide (GTO) media is comparable to many iron oxide-based media and data shows that it performs well in high-silica water, which may make it a viable single-use option for some applications.

Attempts have been made to coat or impregnate substrates such as zeolites, diatomaceous earth and sand with hydrous metal oxides to produce media suitable for column applications. Some technologies have utilized the affinity of lanthanum and cerium oxides for arsenic on such substrates although limited field data is available on its performance. A zirconium hydroxide-based media, only available in powdered form, has been incorporated into a filter cartridge to aid in operation and handling. This approach allows the use of rapid flow rates, but it may be unsuitable for large systems due to a large pressure differential across the filter bed.

Many granular metal oxide media are friable and tend to generate fines during operation, which can result in backpressure buildup during operation. This phenomenon means the media must be backwashed regularly, which adds to system complexity because the secondary waste must be treated or disposed.

A number of hybrid media have been developed to combine the affinity of the hydrous iron oxide chemistry for arsenic with the durability of a standard ion-exchange resin. Nano-sized hydrous iron oxide particles have been precipitated in a resin bead resulting in a high surface area, which ensures the rate of arsenic uptake is rapid and capacity is high. The larger the surface area exposed to the water, the more exchange sites are available to remove the arsenic.

ArsenX and LayneRT media are based on a macroporous resin (pore size >50 nm), thus exposing a larger amount of the hydrous iron oxide surface than the media based on a microporous (<2 nm) gel-type bead.

Field performance evaluations of the hybrid media have shown that the arsenic capacity and resistance to silica fouling is higher than the gel-type, bead-based media. This variation in performance is a result

Innovations in Arsenic Treatment

Hybrid media
improves
arsenic-removal
capabilities

As(V) and As(III) from water, but the capacity for the neutral As(III) species is much lower than the capacity for the anionic arsenate species. High levels of silica and phosphate are known to compete with the adsorption of arsenic and the effect of silica on arsenic capacity can become especially significant at pH values above pH 8.

Although classical coprecipitation processes are often used to treat waters with elevated arsenic concentrations, technologies relying on fixed beds of adsorptive media allow simpler engineering, lower maintenance and easier operation.

In coagulation and filtration, arsenic is adsorbed onto freshly precipitated $\text{Fe}(\text{OH})_3$ particles or flocs. The flocs can be generated either by adding ferric chloride (FeCl_3) to the water or if the water naturally contains sufficient levels of iron, arsenic can be coprecipitated with the iron using an oxidant and then filtered.

Because of the complex nature of the coagulation/filtration process, ion exchange in a simple column-tank operation can be considered as an alternative for arsenic treatment. Strong-base anion exchange resins remove arsenic from water, but due to a strong interference by sulphate and other anions, these systems require frequent regeneration, which

Table 1. Properties of Materials Used for Arsenic Removal from Drinking Water

Media	Activate Component Oxide/Hydroxide	Contact Time EBCT, min	Physical Properties
AA	Aluminum	4	Granular
GFO	Iron	4	Granular
GFH	Iron	4	Granular
G2	Iron	5	Coated granular
DE-La (NXT)	Lanthanum	4	Coated granular
Isolux	Zirconium	0.5	Powder
GTO	Titanium	2	Granular
ASM-10-HP	Iron	2	Hybrid bead
ArsenX	Iron	2	Hybrid bead
LayneRT	Iron	2	Hybrid bead

of the difference in the pore sizes of the media as well as the phase of the iron oxide.

Silica can physically block the pores of the media or restrict access to the adsorption sites and slow down the intraparticle mass transport of any species being adsorbed. The arsenic capacity has further been improved by making the structure more open, thus exposing a larger number of available iron sites where the arsenic can bind.

Advances in Physical Attributes

The robust nature of the hybrid media makes it possible for the adsorbed arsenic to be quickly and simply stripped using a caustic solution to restore the arsenic capacity. The polymeric backbone of these media makes them highly resistant to attrition, preventing them from breaking down during use or regeneration. The hybrid materials are an ideal option when reuse of the spent media is desired in order to improve the economics of arsenic removal.

It is generally not viable to regenerate granular metal oxide media, although this can be accomplished chemically. The problem is that physical attrition of the media granules during regeneration will cause particle degradation, resulting in a loss of media and an overall reduction in particle size. As a consequence, granular media are usually considered viable only for single-use applications.

Innovation & Education

Significant leaps have been made in the development of novel arsenic-removal media over the past decade, resulting in the availability of multiple technologies that have been demonstrated in the field to be effective at reducing arsenic to below the MCL. Much has been learned about water chemistry parameters, which affect the performance of these media as well as their application in the field and has helped in the development of new, improved products.

The effect of silica on arsenic adsorption, in particular, was initially underestimated and research is continuing in efforts to improve the economics of arsenic removal in high silica waters.

As the performance and properties of arsenic adsorption media have improved, some of the early products are no longer economically viable or sufficiently effective. Yet, due to the variations in media properties, water chemistries and water usage encountered at the various well sites, no single media or technology can possibly fit all situations. It is important when deciding on a treatment method to carefully consider all of these aspects collectively as it will affect the degree of success and economics of the arsenic removal. *wqp*

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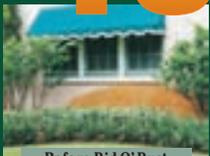
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