Arsenic contamination of groundwater is a global concern, and there is increasing interest in developing an effective treatment method to ensure safe drinking water. Adsorptive media can provide cost-effective means of lowering arsenic content to nondetectable levels without significantly altering other water quality characteristics. Selective adsorption offers simple operation, easily managed waste disposal and long-term effectiveness and sustainability.

By Stephen Wrigley & Fredrick Vance

Selecting Adsorptive Media

Adsorptive media as an effective means of arsenic removal

The performance of various types of adsorptive media is affected by water chemistry. To identify the optimum system design and predict performance, preliminary testing and modeling should be carried out.

Arsenic Removal Options

A common treatment method is the traditional pretreatment techniques of coagulation using ferric chloride followed by sand or multimedia filtration. This has a low operation cost; however, the process is rather complex.

Ion-exchange resins and reverse osmosis are not recommended for the sole purpose of arsenic removal. Though they are proven technologies, they are affected by competing ions in the water. Both generate a waste stream and are vulnerable to the presence of oxidants.

In contrast, adsorptive media such as iron-, aluminum- or titanium-based material can have a high selectivity to arsenic with less operational involvement, making it a good option for small- to medium-sized operations.

Adsorptive media may either be regenerable or nonregenerable. Regenerable media is typically iron-impregnated ion-exchange resin, which is sensitive to oxidizing environments. All media are effected by competing ions based on their selectivity toward arsenic versus other ions present. Of the nonregenerable media, alumina has been increasingly replaced by iron-based media, which offers improved selectivity and a corresponding decrease in the leaching of arsenic tending to occur at a high pH level. Lanthanum and zirconium oxides and hydroxides claim to offer further improvements over iron media; however, field data is lacking.

Titanium oxide and hydroxide media offer a proven increase in arsenic selectivity over iron or alumina and also have the highest capacity under a wide range of water chemistries. The higher arsenic selectivity translates to a lower sensitivity toward competing ions, whereas the stronger binding to arsenic means that the spent media does not have the tendency to leach arsenic.

Titanium-based media can operate over a wide range of pH conditions and it demonstrates fast kinetics. The performance characteristics of this media have been measured and evaluated in an extensive program of small column testing carried out over several years in the Dow Water Solutions laboratories.

The product used in this testing program was Adsorbsia titanium-based adsorption media, designed to remove arsenic from drinking water.

Experimentation

The columns had a nominal diameter of 0.45 in. and were 4 in. in height. A standardized synthetic water feed was used, in which competing species such as arsenic concentration, pH and silica could be varied within a constant background of common ions found in drinking water.

Capacity data was collected in equilibrium conditions, where the media was shaken in spiked water solutions for a minimum of four hours and also with dynamic column tests.

Arsenic removal was measured from waters containing up to 1.5-ppm levels, empty bed contact times (EBCT) of 15 seconds to 6 minutes, corresponding to 10 to 240 resin bed volumes per hour (BVH) and pH in the range of 5 to 9. The competing ions silica and vanadium were also added at levels up to 80 ppm and 400 ppb, respectively.

Figure 1 illustrates the impact of silica in the feedwater on the performance of iron- and titanium-based media. The feedwater contains 50 ppb arsenic at pH 6.5, running at a flow rate of 30 BVH (two-minute EBCT). Although increasing silica impacts the performance of all media, the titanium-based material demonstrates better performance, even at the silica level of 40 ppm.

Fast kinetics is a key property to allow flexibility in design. If the media is able to retain a good capacity at fast flow rates, the size of the equipment can be reduced. Optimizing the system is therefore a trade-off between system size and media service life.

One interesting finding from the column studies was that the efficiency is independent of the surface-loading rate over the range from 6 to 14 gpm/ft^2 (or linear flow rate from 15 to 35 m/hr). Figure 2 shows the results of five columns, which were

Figure 1. Impact of Silica on Operating Capacity for Titanium and Iron-Based Media

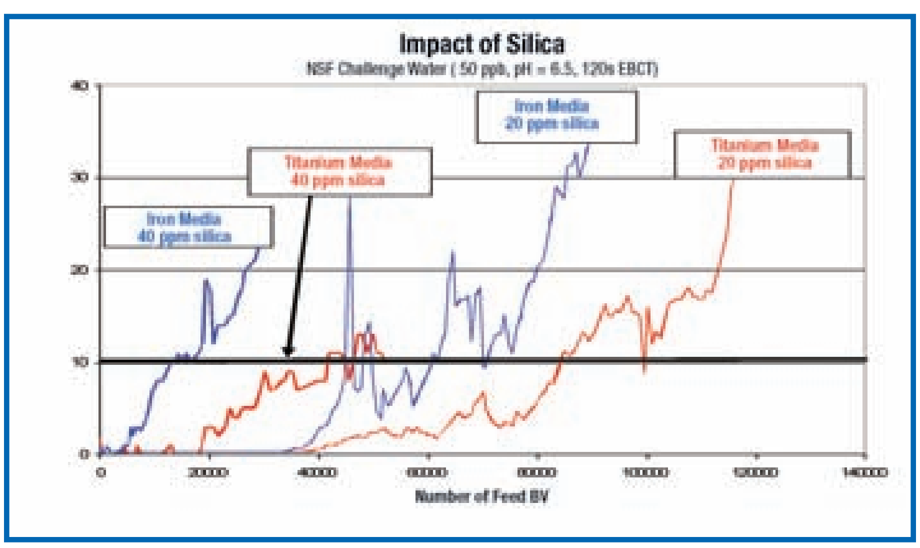
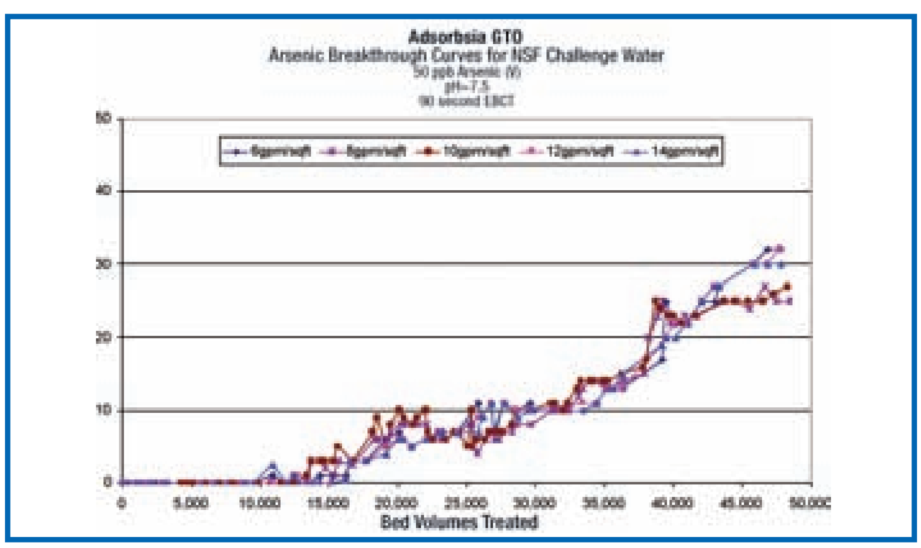


Figure 2. Independence of Efficiency from Surface-Loading Rate



run using the same water where each column was a different length. The flow rates were adjusted to keep the EBCT constant at 90 seconds (40 BVH). The figure shows that the breakthrough curves are virtually identical with the only differences between the traces accounted for by experimental error. This allows flexibility in design in terms of flow rate and bed geometry.

Modeling & Adjustment

A model has been developed to predict the performance of the titanium-based media for arsenic removal. For each experimental arsenic breakthrough profile, a sigmoid curve was fitted. The sigmoid curves were defined by three main parameters: the maximum arsenic level in the feedwater, the center of the breakthrough profile and the width expressed in bed volumes.

These parameters were then combined with the data generated from the equilibrium isotherm tests using statistical software to quantify the interactions between parameters such as water chemistry and system geometry. The model was consistent with the predictions of a Freundlich isotherm behavior and the dependence of capacity on pH was similar to that previously reported.

The impact of the parameters in the model (pH, incoming arsenic level and silica) on the performance of the titanium-based media were quantified, and the predicted throughput to a breakthrough point of 8 ppb was inversely proportional to the arsenic concentration in the feed; however, data demonstrates that the pH and silica have a more significant impact on media service life than the arsenic level.

The parameters that quantify media performance in the model are the feed arsenic level and speciation, pH, silica and other competing ions. System parameters include the flow rate, pressure drop and backwashing requirements. With these parameters, it is possible to design a plant with an optimal system layout—whether to use a single bed, a lead/lag configuration or a bypass with blending.

The performance of the media is also optimized with respect to contact time and the need for pH adjustment. The optimization is a balance between the system size and complexity, which define the capital costs and bed service life and are key to the operational costs.

The pH level has a major influence on service life, and pH adjustment should be considered when the native water has a pH>8. This can dramatically increase the bed lifetime. Titanium-based media is well suited for systems in which pH is controlled intentionally or where it may naturally drift. Even small pH increases can cause arsenic spikes in iron-based media, whereas the titanium-based media is stable. *wqp*

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