Arsenic Removal through Ion Exchange Iron Oxide Hybrid System

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Application Area

Arsenic contamination in potable water supplies has become a major issue in respect to human health. Arsenic in water originates from both, natural sources (geological erosion), as well as man-made pollution (e.g. mining operations that contaminate ground waters). The concentration of arsenic may reach up to 1,500 ppb in certain areas. Arsenic is known to cause damage to human health, World Health Organization (WHO) recommends a maximum contaminant level in potable water supplies of 10 ppb. Lewatit® FO 36 of specialty chemicals group LANXESS is designed to reduce the arsenic contamination in potable water supplies and meet stringent requirements of regional legislation at the same time.

Properties

Lewatit® FO 36 is based on a polymeric, macroporous, weakly basic anion exchange resin. The ion exchange resin substrate is of uniform particle size (monodispersed), and relatively small (0.35 mm bead size) in comparison to standard sized ion exchange resin particles (0.60 mm). The rigid macro pores of the resin are filled with iron oxide particles that adsorb arsenate and arsenite complexes. The ion exchange resin serves as a rigid support for the iron oxide layer and provides dimensional stability to allow packed bed column operation. The combination of the ion exchange resin and iron oxide is termed a hybrid system. The advantage of the uniform particle sized ion exchange resin is an equalised bed structure that provides a highly homogeneous flow through the bed resulting in "plug flow" adsorption. Fine beads that could cause plugging of filter collection nozzles are not present in the resin bed. The small bead size of the material results in a high specific surface area that leads to fast adsorption kinetics. ☞ **www.lanxess.in**

Functionality

The layer of iron oxide binds arsenic in a specific surface complex. It adsorbs arsenate (V-valent arsenic) as well as arsenite (III-valent arsenic). A simplified scheme of the adsorption is presented in Figure 4 [uptake of As(V)]. An equivalent reaction scheme can also be created for binding arsenite (As(III)) on the iron oxide surface. ☞ **www.lewatit.com**

Selectivity

In comparison to classical strongly basic anion exchange resins, Lewatit® FO 36 selectively adsorbs arsenic, other major ions such as

"The Lewatit® ion exchange resin for selective arsenic adsorption makes potable water safe to drink."

Country	Marginal Value (ppb)
Germany	10
EU	10
USA	10
India	50
China	10
Chile	50
Bangladesh	50
WHO Conductance	10

Figure 1: Limits of Arsenic Concentration in Potable Water

chloride, sulphate or nitrate are not bound to the resin and therefore, do not significantly influence the uptake of arsenic on the adsorber. This helps the water composition to remain constant except that arsenic is removed. Another positive effect is that arsenic, once it is adsorbed, cannot be desorbed by these competing ions. Therefore, the total capacity of Lewatit® FO 36 should be significantly higher compared to a conventional anion exchange resin.

Minor water constituents such as silicate, phosphate and antimonate can also be adsorbed by Lewatit® FO 36. If present in the water, a co-adsorption takes place and operating capacity related on arsenic may decrease.

Regeneration

As shown in Figure 4 the reaction of arsenic uptake can be reversed, meaning that arsenic can be removed from the exhausted adsorber material by regenerating it with an alkaline solution. After regeneration, the Lewatit® FO 36 may be used for another loading cycle.

Operating Capacity

The arsenic uptake of Lewatit® FO 36 depends on the concentration of arsenic present in the solution and in equilibrium with the adsorbent resin. This is presented in Figure 5, which shows the adsorption isotherm for As(V) uptake from demineralised water on Lewatit® FO 36. Under field conditions arsenic concentrations of 0.01 mg/l up to 0.1 mg/l are expected. It can be seen on Figure 5 that the equilibrium (static) uptake of arsenic in this range is 2.5-6 g of arsenic per litre of Lewatit® FO 36. Figure 6 shows the breakthrough curve of Lewatit® FO 36 under field conditions. After approximately 18,000 bed volumes of feed have passed through the filter the outlet concentration reaches 10 ppb and subsequently a gradual breakthrough of arsenic begins. Operating capacity at the breakthrough point is 1.8 g of arsenic adsorbed per litre of resin. This result was obtained with a relatively high

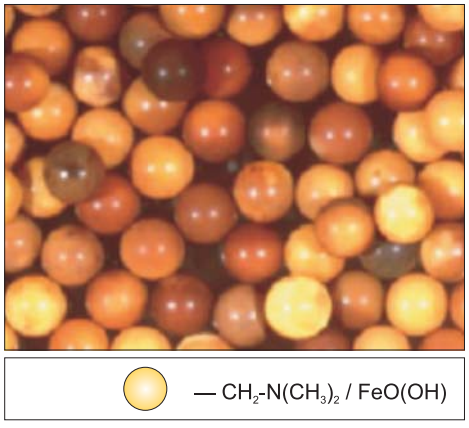

Figure 3: Chemical Structure and Appearance

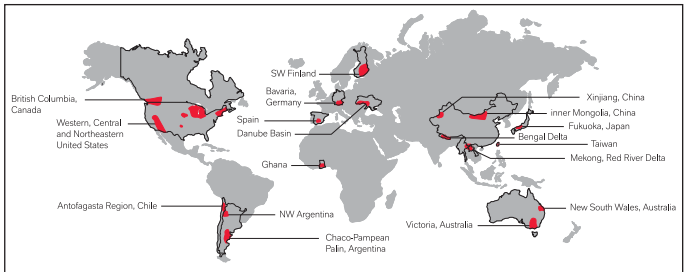

Figure 2: Major Areas of Arsenic Occurrence in the World

specific velocity of 30 BV/h. It is possible that at a velocity of 10-20 BV/h the operating capacity could be up to 30% higher. It is also possible that by using two filters in series operating capacities could increase by up to 50% by loading first column to saturated capacity while the second filter serves as a polisher.

Filter Design

Hydraulic filters with flow rates of 20 BV/h with bed depths of 1 m minimum yielded the optimal performance in our testing. The direction of flow should always be down flow. Because of the small particle size of the beads, pressure drop is higher than for conventional ion exchange systems. At 15°C the specific pressure loss is approximately 2 kPa*h/m^2. For eg, the pressure loss at a linear velocity of 20 m/h and a bed depth of 1.5 m will be 60 kPa, which equals 0.6 bar. Upstream of the Lewatit® FO 36, any suspended particles should be removed by the use of a sand filter. Inlet concentrations of <0.5 ppm of suspended solids are recommended. The feed solution should not be supersaturated with calcium carbonate. Otherwise, the column may get irreversibly plugged because of scaling. Degassing before filtration is also advantageous as bubbles of gas can accumulate in the resin bed and may negatively impact the contact between water and adsorber material. The column should be designed with a free board of 100% of the resin bed volume to allow backwash operations. The outlet tube for the backwash water should not be plugged by sieves or nozzles to allow suspended particles and broken beads to be washed out of the column. If the resin bed gets plugged with suspended solid particles in the upper layers of the resin beds, the solids can be removed by carefully back flushing of the resin bed with rinse water.

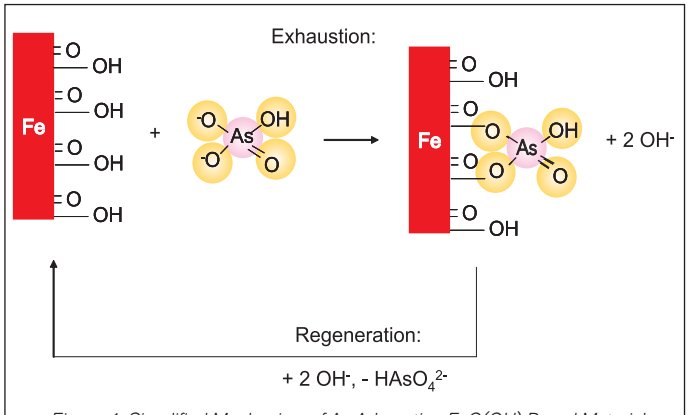

Figure 4: Simplified Mechanism of As-Adsorption FeO(OH) Based Materials

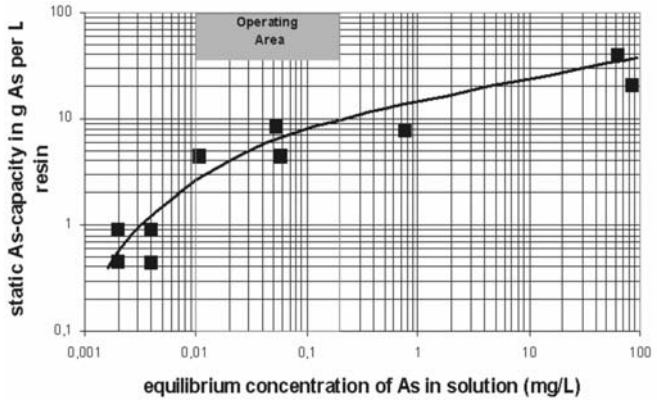

Figure 5: Adsorption Isotherm of Lewatit® FO 36: Adsorption of Arsenic is at Room Temperature from Neutral Deionized Water Containing Equilibrium Rest Concentrations of Arsenic (V) in Solution.

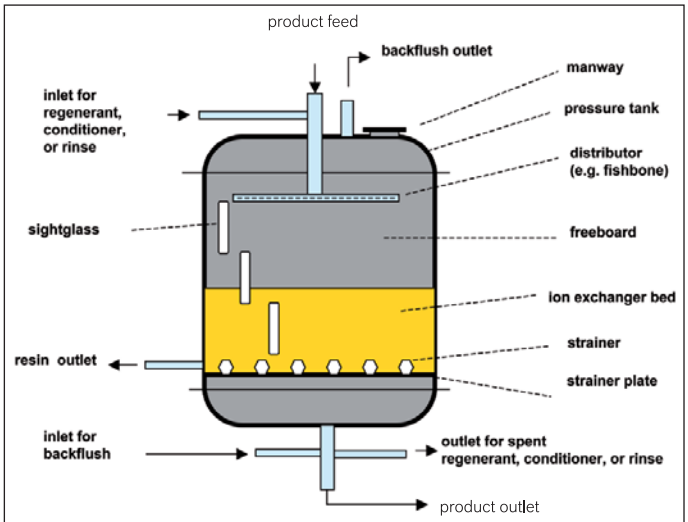

Figure 7: Main Constituents of IX-Filter Unit (Co-current Process)

The linear upward flow of backwash water should be adjusted so that at least 40% bed expansion may be achieved. The specific bed expansion factor of Lewatit® FO 36 at 20°C is 10% per m/h. Hence, the linear velocity for back flush should be adjusted at around 4-5 m/h. It should be noted that back flushing of the column will destroy the established concentration profile of arsenic load within the adsorber bed. The so called "fine purification area", a highly regenerated area of the column will be destroyed causing an increase of arsenic leakage during further operation. Thus, if backwashing has to be applied the process must be run with a second column switched in lag position. The lag column will adsorb the leakage from the lead column. The column bottom distributor plate should be equipped with strainers of 0.2 mm slit width in a density of 80 nozzles per m^2. A gravel layer with gravel stones of 0.4 mm should cover the nozzle plate so that the heads of the filter nozzles are 50 mm under the surface of the gravel layer.

Start Up Procedure

We recommend disinfecting the empty column and the connected pipe work prior to filling Lewatit® FO 36 into the vessel. After flooding the column with potable water the resin is loaded from the top. After the column is sealed, the back flush with potable water and 50% bed expansion (see above) is carried out for half an hour to wash the resin bed. After the bed has settled down, the resin is rinsed in the down flow mode with at least 20 BV of water at a velocity of 5 BV/h.

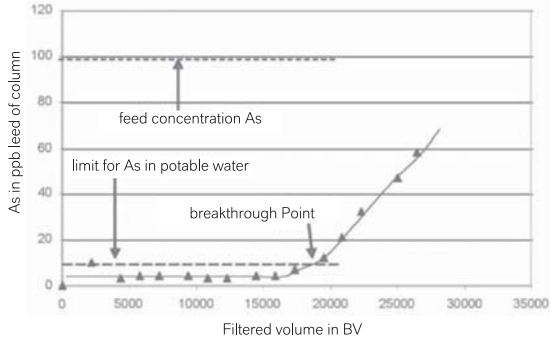

Figure 6: Lewatit® FO 36 Breakthrough Curve
Specific Velocity: 30 BV/h, feed concentration: 100 ppb arsenic V (as As) in neutral tap water 6 ppm Silica as SiO_2, 60 ppb Phosphorus, 100 ppb Fluoride, 160 ppm Bicarbonate, 50 ppm Chloride, 13 ppm Nitrate, and 43 ppm Sulfate

Regeneration Procedure

For regeneration purposes 3 BV of an aqueous solution of 2% NaOH and 3% NaCl is applied at a flow rate of 3 BV/h. Then, the resin is rinsed with 8~10 BV of water at 3~5 BV/h. The unified regenerant and the rinse water is acidified to pH 2. Then iron(III) sulfate is added followed by a neutralisation to precipitate iron hydroxide as well as iron arsenate.

The sludge is thickened, filtered and dewatered and can be disposed of according to the local regulations. In most cases discharge of the sludge on a landfill is allowed.

Disposal

Alternatively to the regeneration, the resin can be used as one-way material. By doing so, handling of arsenical solutions can be avoided and the arsenic is left stably bonded on a solid material. Disposal has to be carried out according to the local regulations. Within the EU, the exhausted material has to be disposed according to the EU regulations with the waste code 19 08 07 (saturated and exhausted ion exchange resins).

About the Contributor

With over 100 products, LANXESS offers a range of ion exchange resins that can be used as a modular system to create individually tailored solutions. The Ion Exchange Resins business unit has also made a name for itself as a developer of innovative plant engineering - for eg, modern countercurrent processes that have become the standard in industrial water treatment. Apart from providing high-performance products and processes, the Lewatit specialists also offer their customers a variety of support services. For further information please contact lewatit@lanxess.com.

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