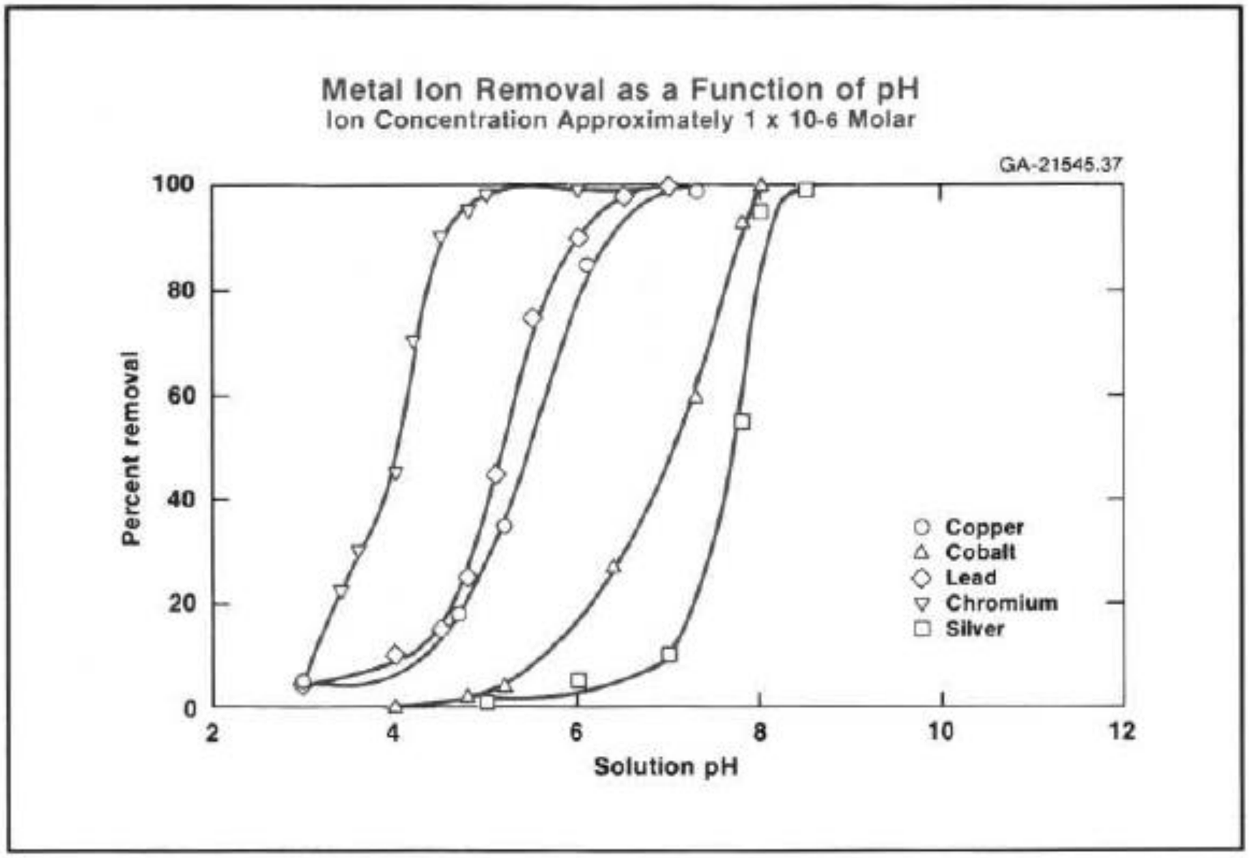
Granular Activated Alumina for Treating Waste Water Containing Metal Ions

Product Information

Riverland Industries has capabilities to manufacture a series of granular activated aluminas (GAA) as selective adsorbents for removal / recovery of metal ions. Several important process variables which influence the performance of these GAA adsorbents include: solution pH, ionic strength, and metal ion speciation.

Product Applications

The figure below contains data from Alcoa Labs (New Kensington, PA) and shows the removal of metal ions by a GAA as a function of pH.



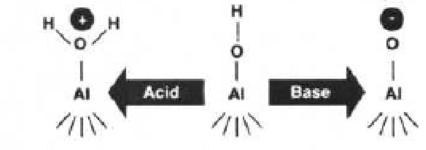
Their data were obtained under dilute solution conditions, typically: 1 gram per liter solids and 1 micromolar metal ion concentration.

There are several general rules for metal ion adsorption using GAA:

1. Anion adsorption is favored in a pH range 4 to 8; with the optimum typically pH~5.5
2. Cation adsorption occurs over a broader pH range than anion adsorption: 5 < pH optimum <12
3. Oxy-anions in solution often enhance cation adsorption.
4. Complex (e.g., chelate) formation dramatically affects selectivity and capacity for both cations and anions.

Predicting Metal Ion Removal Efficiency

Models which incorporate both alumina surface chemistry data and aqueous chemical equilibrium have been used to predict GAA treatment performance. The alumina surface is relatively easy to describe from the following picture that shows the change in speciation of an aluminum hydroxyl group reacting with both a proton and hydroxide.



Surface Sites on Alumina

From titration data, the surface changes from net positive to net negative charge around pH=8.2, aka, the pH of zero net surface charge (PZC). The number of sites which react with acids or bases determine the magnitude of the net surface charge that GAA can obtain at a specific pH. This surface charge can be associated with the efficacy of GAA in a specific application, like in the Cr(III) removal example provided below.

Chemical equilibrium models predict the solution speciation of the target adsorbates, in this case metal ions in solution, under similar conditions to the adsorbent environment. By combining the two predictions in a common model, a group at the Alcoa Lab (as reported by G.A. O'Neill, et.al, 1988 Pittsburgh Conference) showed that conditions such as pH and ionic strength can be adjusted to optimize either cationic or anionic species removal. The utility of the method is demonstrated in the Figure below for Cr(III) removal from a ground water. This figure contains the speciation of Cr(III) as determined using the equations for Cr(III) and water, and the adsorption of the Cr(III) complexes on alumina, all as a function of pH.

Chemical reactions for Chromium (III)

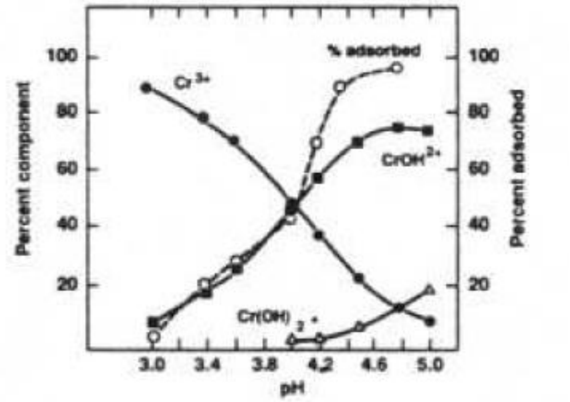
$Cr^{3+} + H_2O \rightleftharpoons Cr(OH)^{2+} + H^+$

$Cr^{3+} + 2H_2O \rightleftharpoons Cr(OH)_2^+ + 2H^+$

$Cr^{3+} + 3H_2O \rightleftharpoons Cr(OH)_{3\ ppt} + 3H^+$

$Cr^{3+} + 4H_2O \rightleftharpoons Cr(OH)_4^- + 4H^+$

$2Cr^{3+} + 3H_2O \rightleftharpoons Cr_2O_3 + 6H^+$



These plots demonstrate that adsorption of non-complexed *metal cations* from acidic solutions are not favored, electrostatically repulsive on the positive alumina surface. However, upon formation of the first Cr(III)-hydroxide complex, the surface reacts with the metal complex and adsorption occurs. Note that the adsorption pH front is predicted by solution conditions which lead to the formation of the first hydroxide complex. This work from Alcoa Labs provides good insight into the required information for designing treatment systems using GAA for metal ion removal. Water treatment strategies with GAA need to be based on the solution chemistry variables such as pH and ionic strength and include the effects of other strongly bonding ions present.