Polyphosphates for In Situ Uranium Immobilization

INFORMATION
Carus Corporation has a long history of developing and providing a variety of permanganate products for chemical oxidation applications. Carus is also a leading provider of phosphate products for sequestration and corrosion control. Phosphates are widely used as water treatment chemicals (dry or liquid solutions) to correct problems resulting from inorganic groundwater contaminants (iron, manganese, calcium, etc.) and also to maintain water quality (inhibit corrosion, scale, biofilm, reduce lead and copper levels). The use of polyphosphates for remediation applications is a relatively new approach but an extremely cost-effective solution for reducing the bioavailability and mobility of toxic heavy metals and radionuclides in mining tailings, soil, and groundwater.

CASE STUDY
A recent remediation effort focused on uranium immobilization using polyphosphates was conducted by Arcadis U.S., Inc. The facility is located in the Southwestern United States. Waste is disposed in a tailings pile near the site. Seepage from the tailings impoundment can result in uranium impacts to groundwater. An effective chemical mitigation includes removal from the aqueous phase via polyphosphate precipitation. This approach can be a challenge for the oxidized form of uranium (U\([\text{VI}]\)), which tends to be highly soluble under typical tailing seepage geochemical conditions. One of the remedial strategies evaluated involved the in situ precipitation of U\([\text{VI}]\) within uranyl phosphate phases. The chosen approach involved injecting soluble polyphosphate which reacts with uranium and other groundwater constituents (including calcium) to form a number of low-solubility uranium-containing phosphate phases including: chernikovite (H\([\text{UO}_2\text{PO}_4\times4\text{H}_2\text{O}\]), autunite (Ca[\text{UO}_2\text{PO}_4\times\text{xH}_2\text{O}\]), saleeite (Mg[\text{UO}_2\text{PO}_4\times\text{10H}_2\text{O}\]) and uranium-substituted calcium phosphate phases such as apatite (Ca\(_5\text{[PO}_4\text{]}_3[\text{F,Cl,OH}])\). Generation of these phosphate phases also provides a long-term barrier for uranium treatment via sorption. For this field effort sodium tripolyphosphate (STPP) and calcium chloride were injected in alternating batches over a week-long time period, without well fouling or loss of injectability. In addition, it is reported that the injected volume achieved the target radial distribution within the aquifer.

PERFORMANCE ASSESSMENT
Figures 1a and 1b provide a performance assessment summary.

![Figure 1a (left) Dissolved phosphate concentrations measured at each monitoring well post-injection](image1a)

![Figure 1b (right) Dissolved uranium concentrations and pH at downgradient monitoring wells](image1b)
The target pH for the amendment solution was 5 and a total of 63,000 liters (L) of pH-adjusted amendment solution were injected over 8 days, delivering more than 105 kilograms (kg) of STPP. The injection rate averaged approximately 23 L/min over the course of the injections. The pilot test successfully demonstrated that STPP can be used to immobilize uranium in situ in tailings impoundments, even in the extreme hydrogeological and geochemical conditions of a legacy uranium tailings impoundment. Up to 97% of uranium was immobilized and pH adjustments and phosphate concentrations were sustained long enough for precipitation with continued sustained treatment over 180 days (from 1.44 mg/L to 0.047 mg/L). Sustained treatment without rebound in uranium concentrations indicated that dissolved uranium was transported into the treatment zone from up-gradient and was immobilized by the phosphate precipitates. Most importantly, the phosphate minerals that were formed were stable and did not re-dissolve when the pore water geochemistry returned to pre-injection conditions.

CONCLUSIONS

The use of reactive chemical amendments such as polyphosphates for uranium immobilization holds great promise as a source control treatment option. This pilot test successfully demonstrated that the use of polyphosphates can be used as a cost-effective treatment option for in situ immobilization of uranium in tailings impoundments.

REFERENCES