Production and Utilization of Polyaluminum Sulfate [Project #426]

Ordering Information:
ORDER NUMBER: 90586
DATE AVAILABLE: Spring 1994

Prepared by Brian A. Dempsey, The Pennsylvania State University

BACKGROUND
Although production of polyaluminum coagulants is increasing rapidly, these coagulants are currently produced in far fewer locations than alum. Accordingly, the transport costs associated with the purchase of polyaluminum coagulants are higher than transport costs for alum. Additionally, the raw materials and processes used in production of commercial polyaluminum coagulants are more costly than those for alum. Thus the prices for polyaluminum coagulants are typically at least two to three times the cost of alum.

APPROACH
The approach in this project was to prepare polyaluminum sulfate (PAS) on-site, with alum and caustic as the raw materials and using equipment and techniques that might easily be reproduced in a water treatment facility.

RESULTS
On-site production of concentrated and highly neutralized PAS was not feasible under the field conditions of these experiments, that is, using equipment that would be available at most water treatment utilities and using undiluted alum as the starting material. Commercial preparations of alum, PAS, and polyaluminum chloride (PAC) contain approximately 2 M total aluminum concentration. Commercial PAS and PAC typically have hydroxide-to-aluminum molar ratios of about 1.5 (i.e., 50 percent preneutralization of the acidity due to Al3+).

Although PAS was successfully prepared in the laboratory at 2 M total aluminum with hydroxy ligand number of 1.5, attempts to prepare this material in situ and at plant scale were unsuccessful. These conditions resulted in the formation of a precipitate that did not dissolve upon standing or mixing. It is likely that PAS coagulants with high concentrations and high hydroxy ligand numbers could be accomplished on-site, but the process would require the installation and testing of equipment comparable to that employed by manufacturers of coagulant chemicals.

Prior research showed that PAS coagulants with low hydroxy ligand numbers, the type that can be produced on-site, were better coagulants than alum for some raw water conditions. Accordingly, the following comments relate to the use of PAS that can be produced on-site without the use of sophisticated equipment.

Plant-scale production of more dilute and less neutralized PAS was accomplished, and production techniques were quite simple. In five test runs at Philipsburg, Pa., various formulations of PAS were prepared, stored, and pumped and injected using delivery systems intended for alum without difficulties. These tests involved PAS that was more dilute and less neutralized than commercial PAS. Coagulant dose was controlled by streaming current and flowmeter feedback to the coagulant dosing pump.

For cold waters (6°C), required doses for PAS were substantially lower than for alum. For summer conditions, the finished water quality and coagulant doses when PAS was used were comparable to results achieved with alum. These results compare very well with operating experiences with commercial polyaluminum coagulants and alum. Several utilities use polyaluminum coagulants exclusively, or to a greater extent, in winter (cold water conditions)
than in summer. Some manufacturers of polyaluminum chlorides acknowledge the relative advantages of the two coagulants for waters of different temperatures and market their products accordingly.

The relatively dilute PAS used in plant-scale tests performed well at the pilot scale, outperforming alum for most conditions. Pilot facilities were operated using minimum effective coagulant doses for synthetic raw waters. Effective coagulation was determined by decreases in turbidity, total organic carbon, and residual aluminum and by zeta potential indicating charge neutralization. A substantially lower dose of PAS (relative to alum) was required for raw water of low alkalinity and low color at 20°C. For these conditions, the PAS dose was one-fourth of the required alum dose (in terms of total added Al).

PAS worked better than alum for most other conditions, which included temperatures from 2 to 21°C, organic carbon concentrations (fulvic acid) from 0 to 1.2 mg/L, and pH values from 5.0 to 7.1. The largest differences in required dose occurred for the lowest pH values at high or low temperatures, either with or without the addition of fulvic acid to raw water. The improved performance of PAS at low pH was presumably caused by the initial presence of effective coagulant chemicals, whereas conditions had to be appropriate for the formation of effective coagulant species when alum was used.

Alum performed slightly better than PAS only for conditions of high pH (7.0) and low temperature (2°C), with or without the addition of fulvic acid. For lower temperatures, the solubility diagram for Al(OH)₃(s) shifts to higher pH values. At 2°C, the lowest solubility and the highest rate of precipitation of Al(OH)₃(s) occur at pH 7; thus, the advantage associated with the addition of preformed coagulant species is not important.

The pilot- and plant-scale performances recorded during this research project were consistent with results from previous bench-scale tests. Specifically, PAS performed best (relative to alum) for cold water conditions and for lower pH values. In some cases, the relative benefit of PAS increased when the concentration of fulvic acid (and therefore the coagulant demand) was increased. This performance was different from that observed for PAC versus alum. As shown in earlier bench-scale experiments, PAS should also be considered for raw waters where coagulant demand and pH may change rapidly because of changes in turbidity, color, or alkalinity.

PAS coagulants with low-to-moderate total aluminum and hydroxy ligand numbers were produced at plant scale. PAS coagulants with aluminum concentrations and hydroxy ligand numbers similar to commercial products were not produced successfully at plant-scale. Use of PAS coagulants with moderate concentrations and hydroxy ligand numbers resulted in decreased coagulant demand for cold waters when compared to alum. These plant-scale results were obtained for a water of low turbidity and low alkalinity. Pilot-scale tests were run on a variety of synthetic waters containing humic materials and kaolinite clay. The pilot-scale tests also demonstrated the relative effectiveness of these PAS coagulants for treatment of waters with slightly acidic pH. In addition, the PAS coagulants are well suited for the treatment of waters with rapidly varying pH or coagulant demand.