OPTIMIZATION OF PHOSPHORUS REMOVAL TO LOW LEVELS WITH TWO STAGE CHEMICAL ADDITION

JUREK PATOCZKA, PHD, PE; ERIC MUCHALSKI
Hatch Mott MacDonald, 27 Bleeker Str. Millburn, NJ 07041

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Introduction. Review of an EPA data base indicated that at least several dozen of wastewater treatment plants in the US presently have an enforceable total phosphorus effluent limit of less than 0.5 mg/l, with some plants facing a limit of 0.1 mg/l or less. The feasibility of achieving a potential limit as low as 0.02 mg/l has been evaluated[1] per a consent judgment. Whenever chemical addition is used as the treatment method of choice, or as a back-up for biological phosphorus removal, it is a common practice to add the chemical to the activated sludge train, most frequently to the secondary clarifier influent. For stringent phosphorus limits, such as below 0.5 mg/l, chemical addition is required as a polishing step. Under this study, a series of jar tests aimed at optimization of chemical addition for phosphorus removal to low levels was performed on samples collected from several wastewater treatment plants. Of particular interest were:

- comparison of alum and ferric in removing residual phosphorus to low levels,
- effect of staged (multipoint) chemical addition on its effectiveness,
- effect of pH on effectiveness of trace phosphorus removal.

Methodology. Chemical addition tests were performed by adding alum or ferric chloride stock solutions to 1 liter beakers, flocculating (slow mixing) samples for 5 minutes and settling for 30 minutes. Any necessary pH adjustments were made with a solution of caustic or sulfuric acid prior to initiating the settling. Where indicated, filtered samples were obtained by filtration through Osmonics MicronSep cellulosic membrane filter with a nominal pore size of 0.45 um. Where indicated, settling was aided by addition of Pollu-Treat 116 polymer, which was added at the end of flocculation period accompanied by flash mixing for 30 seconds followed by 3 minutes of additional flocculation time. Total phosphorus was analyzed by EPA method 365.1.

Alum and Ferric Comparison. Side by side tests on samples from several wastewater plants demonstrated that ferric was typically more effective than alum at the same stoichiometric excess. Figure 1 illustrates results from tests on secondary effluent from Plant A (alum previously added to the mixed liquor at full scale), where ferric lowered the filtered phosphorus concentration to below 0.04 mg/l at a lower stochiometric excess ratio than alum. Similar results were obtained with Plant

B samples (no chemical addition in full scale), with ferric achieving a lower ultimate phosphorus residual than alum (Figure 1). Theoretical considerations based on phosphate solubility in neutral pH range seem to favor alum[2]. However, factors such as presence of phosphorus in forms other than orthophosphate, presence of complexing agents and elements of adsorption removal mechanism limit the practical applicability of straight solubility considerations.

Optimization of Point of Addition. Two series of tests were performed which compared effectiveness of chemical addition in one step (to the mixed liquor) with dual point of addition, where a second dose was applied to the clarified secondary effluent. Mixed liquor sample from plant A (alum previously added to mixed liquor at full scale) was dosed with additional alum and the results contrasted with effectiveness of similar alum dosages applied to the clarified mixed liquor sample. The results (Figure 2) demonstrate that an additional, relatively small alum dose, when applied to the clarifier effluent is much more effective then the same incremental dose applied to the mixed liquor alone. While advantage of dual point chemical addition had been previously commonly recognized, these results provide its direct confirmation. This is consistent with incorporating into the mechanism of phosphate removal sorption of orthophosphate on $Al(OH)_3$, as postulated by Galernau et al.[3] Actually, a mixture of various hydrous aluminum oxides and hydroxyphosphates is probably involved[4,5]. This is further collaborated with results from this work, where phosphorus removal from various sludge processing side streams correlated quite well when modeled with Freundlich adsorption isotherms (Figure 3). Adsorption-type mechanism of phosphorus removal would clearly predict a better efficacy of two (or multi) -point chemical addition, as such staging introduces elements of counter-flow operation, which benefits effectiveness of adsorption-type processes.

Effect of pH. Optimum pH for phosphorus removal by alum or ferric salts was reported in the literature vary considerably within the moderate pH range based both on theoretical considerations and actual results [2, 6, 7, 8]. Limited results obtained to date under this study are presented in Figures 4 and 5. Figure 4, where results on primary clarifier effluent (Plant A) are reported, indicates that removal with alum is favored by more acidic pH, while for ferric the pH dependency is not pronounced in the neutral range of pH tested. For a second stage chemical addition tested on a secondary effluent from Plant B, pH dependency was not clear for alum nor ferric (Figure 5). From the results reported in this study and from the literature data, it appears that pH effects are site-

specific and in most cases are not expected to be dramatic in the neutral pH range practicable for wastewater treatment. *(Additional work in progress.)*

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Figure 1. Second Stage Phosphorus Removal at Neutral pH. Samples Previously Treated with Alum.

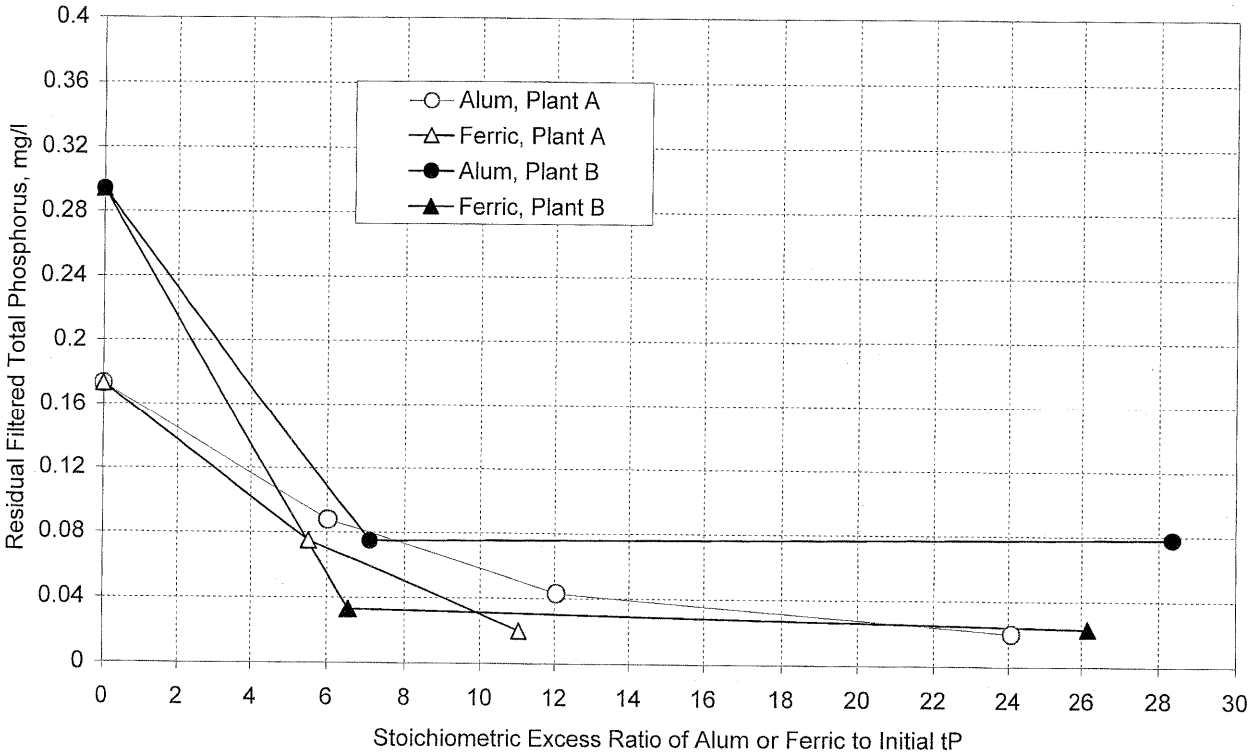


Figure 2. Comparison of Single Stage and Two Stage Alum Addition

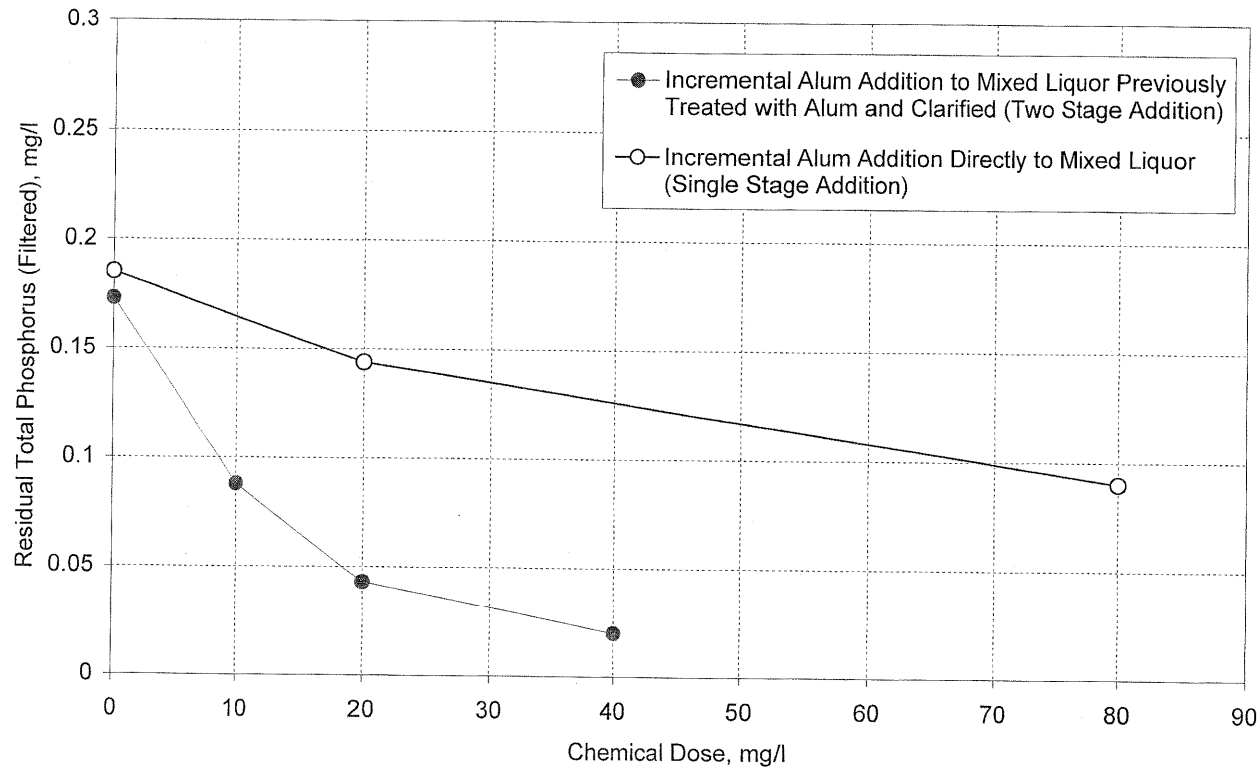


Figure 3. Phosphorus Removal by Alum (Freundlich Isotherms)

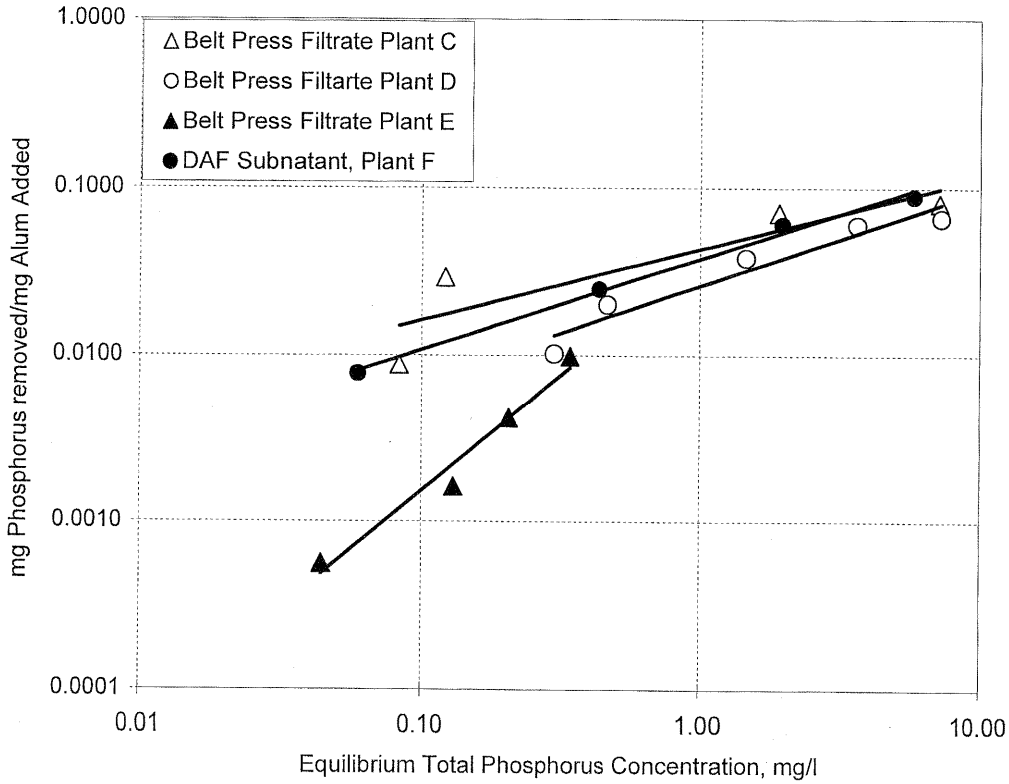


Figure 4. Effect of pH on Phosphorus Removal with Alum and Ferric from Primary Clarifier Effluent. Plant A

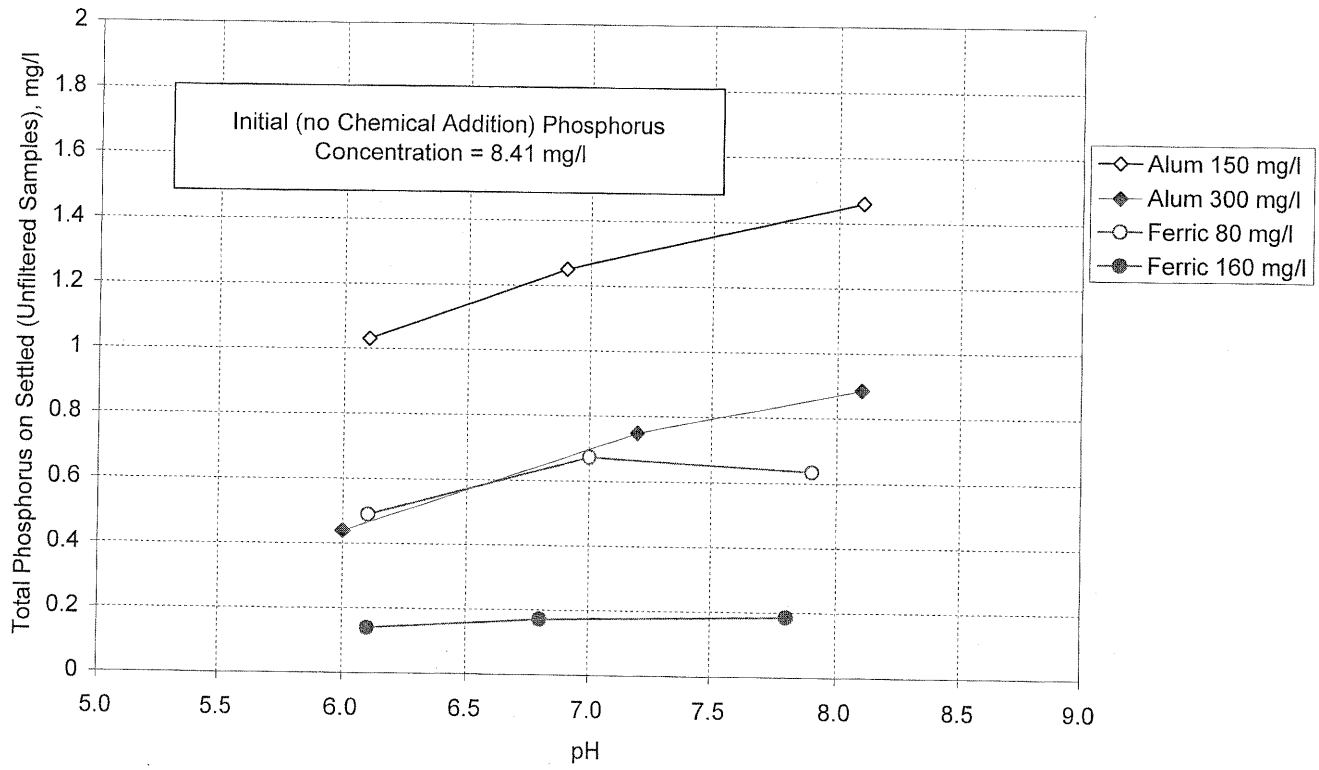


Figure 5. Effect of pH on Phosphorus Removal with Alum and Ferric from Plant B Secondary Effluent. Initial tP Concentration (unfiltered) = 0.433 mg/l.

