

The use of simultaneous chemical precipitation in modified activated sludge systems exhibiting biological excess phosphate removal

Part 5: Experimental periods using a ferrous-ferric chloride blend

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Abstract

A blend of ferrous chloride and ferric chloride ($\text{FeCl}_2\text{-FeCl}_3$) was simultaneously dosed into an activated sludge system at pilot scale in order to test the effect on biological P removal. Additional removal due to chemical precipitation was measured as the difference in system P removal between parallel test and control systems. Both systems strongly exhibited biological excess P removal (BEPR). The extent of P release in the anaerobic reactors of the two systems was compared by mass balance, as one indicator of the relative "magnitude" of BEPR. Phosphorus fractionation of the mixed liquor also served as an indicator of the biological and chemical mechanisms. Evidence was found that the BEPR mechanism is partially inhibited by simultaneous $\text{FeCl}_2\text{-FeCl}_3$ addition, even in the absence of effluent phosphate limitation. However, the degree of inhibition was relatively low, ranging from 3 to 25% (approximately) for Fe doses in the range ca. 10 to 20 mg/l as Fe, with an average system P removal of 14 to 18 mgP/l in the control. $\text{FeCl}_2\text{-FeCl}_3$ dosing in this range was sufficient to produce additional P removal of the order of 1 to 8 mgP/l over periods of one to seven sludge ages per experimental period, depending on the experimental conditions. Sustained operation of the BEPR mechanism in the presence of $\text{FeCl}_2\text{-FeCl}_3$ was possible over a continuous period of seven sludge ages, under conditions in which effluent phosphate was at least partially limiting. Under such conditions, the chemical and biological mechanisms appear to be "disadvantaged" to approximately the same extent, as evidenced by the apparent stoichiometry of Fe:P for the chemical precipitation and magnitude of the poly P containing fractions measured for the biological mechanism. This suggested that the biological mechanism is able to compete effectively with the chemical mechanism under conditions of low reactor phosphate concentrations (~1 mgP/l orthoP) for sustained periods. However, the presence of simultaneous chemical precipitant significantly reduces the extent to which the biological P removal potential is utilised under P-limiting conditions. This could explain the difficulty sometimes reported in the control of full-scale activated sludge systems with simultaneous precipitant addition where a very low effluent P concentration (<1 mgP/l) has to be achieved.

Nomenclature

D	Delta, meaning "difference in" or "change in" (e.g. $\text{DM}_i\text{P}_{\text{rem}}$ - see also below)
AE1 or 2	Aerobic zone or reactor
Fe~P~O	Ferric phosphate/ oxide precipitate (theoretical) after ashing of ferric hydroxy-phosphate
Fe~P~OH	Ferric hydroxy-phosphate
Alk.	Alkalinity (unless otherwise stated: <i>bicarbonate</i> alkalinity)
AN	Anaerobic zone or reactor
AX	Anoxic zone or reactor
Bicarb.	Bicarbonate (or sodium bicarbonate)
COD	Chemical oxygen demand
DSVI	Dilute sludge volume index
<i>f</i>	Filtered (<i>in italics</i>)
$f\text{P}_t$	Filtered total phosphate
$f\text{P}_{t,a}$	Filtered total phosphate, anaerobic zone or reactor
$f\text{P}_{t,b1 \text{ or } b2}$	Filtered total phosphate, first or second aerobic zone or reactor, respectively
$f\text{P}_{t,d}$	Filtered total phosphate, anoxic zone or reactor

ISS	Inorganic suspended solids
$\text{M}_i\text{P}_{\text{rem}}$	Mass of phosphate removed (mgP/d)
$\text{M}_i\text{P}_{\text{rel}}$	Mass of phosphate released (mgP/d)
N_{ae}	Concentration of ammonia in the effluent
N_{ai}	Concentration of ammonia in the influent
NO_3	Concentration of nitrate
$\text{NO}_{3,a}$	Concentration of nitrate in the anaerobic zone/ reactor
$\text{NO}_{3,b1 \text{ or } b2}$	Concentration of nitrate in the first and second zone/ reactor, respectively
$\text{NO}_{3,d}$	Concentration of nitrate in the anoxic zone/ reactor
$\text{NO}_{3,e}$	Concentration of nitrate in the effluent
N_{te}	Effluent TKN concentration
N_{ti}	Influent TKN concentration
orthoP	Orthophosphate
O_t	Oxygen uptake rate (in mg/[l-h])
PCA	Perchloric acid (fractionation studies)
poly P	Polyphosphate
$\text{PO}_{4,a}$	OrthoP concentration in the anaerobic zone
$\text{PO}_{4,b1 \text{ or } b2}$	OrthoP concentration in the first aerobic (b1) or second aerobic (b2) zone
$\text{PO}_{4,d}$	OrthoP concentration in the anoxic zone
$\text{PO}_{4,e}$	OrthoP concentration in the effluent
$\text{PO}_{4,i}$	OrthoP concentration in the influent
PSTs	Primary settling tanks (or primary sedimentation tanks)
P_{ti}	Influent total P concentration
P_{te}	Effluent total P concentration

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