

# Recovery of nitrogen and phosphorus nutrients in wastewater by precipitation as struvite

Sachin Gadekar and Pratap Pullammanappallil\*  
Department of Agricultural and Biological Engineering  
University of Florida, Gainesville, Fl 32611-0570, USA

\* Author for correspondence

Tel: (352) 392 1864 ext 203

Email: [pcpratap@ufl.edu](mailto:pcpratap@ufl.edu)

## Abstract

Nutrient (nitrogen and phosphorus) removal from wastewater is an increasing challenge for wastewater treatment system operators, as regulatory authorities tighten discharge standards to avoid eutrophication problems in receiving waters. The most widely used technologies for nutrient removal include biological nitrification/denitrification for nitrogen removal and metal salt precipitation or biological treatment for phosphorus removal. Both approaches result in the nutrient being made unrecoverable as a useful product. An alternative to these conventional technologies would be the precipitation of both nitrogen (in the form of ammonia) and phosphate as struvite which is a valuable by product. Struvite recovery helps to meet legal requirements imposed on sludge disposal and reduce the area needed for wastewater disposal. Struvite is an ammonium magnesium phosphate mineral with the chemical formula  $(\text{NH}_4)\text{MgPO}_4 \cdot 6\text{H}_2\text{O}$ . It is a premium grade slow releasing fertilizer because it is sparingly soluble in water and also finds uses as a raw material in the phosphate industry, for making fire resistant panels and as a binding material in cements.

Aqueous mixtures of ammonium, phosphate and magnesium produces struvite and in addition other precipitates like magnesium hydroxide and magnesium phosphates. The extent of formation of other precipitates is determined by pH and concentration of dissolved species. To ensure that the nutrients like ammonia and phosphates are optimally precipitated, it is necessary to maintain suitable operating conditions.

In this paper we present a mathematical model for predicting struvite formation. The model considers overall mass balance for magnesium, nitrogen and phosphorus, electro-neutrality, and physico-chemical and solubility equilibrium equations to describe the system. Ionic species modeled are concentrations of  $\text{NH}_4^+$ ,  $\text{PO}_4^{3-}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{CH}_3\text{COO}^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{Cl}^-$ ,  $\text{H}^+$ ,  $\text{OH}^-$ ,  $\text{HPO}_4^{2-}$ ,  $\text{H}_2\text{PO}_4^-$ ,  $\text{MgOH}^+$ ,  $\text{MgH}_2\text{PO}_4^+$  and  $\text{MgPO}_4^-$ . In addition, concentrations of the following unionized or dissolved species are also modeled:  $\text{NH}_3$ ,  $\text{H}_3\text{PO}_4$ ,  $\text{CH}_3\text{COOH}$  and  $\text{MgHPO}_4$ (dissolved). Possible formation of five different precipitates are considered, namely,  $\text{MgNH}_4\text{PO}_4 \cdot 6\text{H}_2\text{O}$  (struvite),  $\text{MgPO}_4 \cdot 8\text{H}_2\text{O}$ ,  $\text{MgPO}_4 \cdot 22\text{H}_2\text{O}$ ,  $\text{Mg}(\text{OH})_2$  and  $\text{MgHPO}_4$ . Maple 10 was used to generate explicit expressions for concentrations of all chemical species modeled. To

solve these expressions it was then necessary to initially guess a value of the residual  $\text{PO}_4^{3-}$  concentration and subsequently iterated until this value converged.

The model was then validated using experimental data from literature as well as data from experiments carried out in our laboratory. The validated model was then simulated to determine the effect of pH and total concentrations of magnesium, nitrogen and phosphorus on yield of struvite and purity of precipitates produced. The model also calculates the amount of caustic soda required for maintaining pH. The results of these model validation and simulation studies will also be presented.

**Keywords:** Struvite, wastewater, nutrient removal, nutrient recovery, modeling

**Challenges:** Public health, wildlife health, ecosystem health and water resource sustainability

**Issues:** Nutrient enrichment of surface, ground and coastal waters