Assessment of Struvite Mitigation Measures for the City of Boulder Wastewater Treatment Plant Centrate Processing System

Background

The City of Boulder wastewater treatment plant has been experiencing formation and accumulation of struvite in centrate lines and process equipment downstream of its centrifuge sludge dewatering process. Struvite accumulation on pipe walls and equipment reduces capacity and fouls equipment.

Struvite ($MgNH_4PO_4 \cdot 6H2O$), a hard crystalline mineral, forms when conditions affecting solubility create an oversaturation condition. Precipitation then ensues until equilibrium conditions are reached. Conditions affecting struvite solubility include concentrations of the three constituent ions and solution pH, temperature, and ionic strength. The struvite saturation condition can be controlled by altering one of more of these conditions.

Measuring the Saturation Condition

The saturation index (SI) for struvite is a measure of the saturation condition, whether a solution is undersaturated or oversaturated, and the magnitude of that saturation condition. The SI is the logarithm of the ratio of the actual solubility product of the struvite constituent concentrations to the equilibrium solubility product. Calculating struvite solubility is a complex process because it is affected by multiple parameters. A computer model was developed to perform the equilibrium calculations based on sample data and to determine the SI for the sample.

A limited amount of sample data from the Boulder WWTP was provided for analysis using the computer model. The model output reported that the centrate was oversaturated for struvite, which is consistent with field observation of struvite accumulation.

Using the Model to Specify Struvite Control Parameters

By diluting the centrate with final effluent from the treatment plant, the struvite saturation condition can be reduced from oversaturated to undersaturated, thereby preventing struvite formation in the centrate piping and downstream process equipment. City of Boulder plant staff has demonstrated the effectiveness of dilution in preventing struvite formation and now seeks to optimize the dilution ratio.

By modeling a series of centrate dilutions for winter and summer conditions, a series of resulting SI values was developed.

Table 1. Winter Conditions (Effluent Temperature = 10°C, pH = 6.8)

Effluent to Centrate Ratio	**Saturation Index (SI)**
0	0.57
0.50	0.05
0.75	-0.14
1.00	-0.30
1.25	-0.43
1.50	-0.55
1.75	-0.65
2.00	-0.75

Table 2. Summer Conditions (Effluent Temperature = 22°C, pH = 6.8)

Effluent to Centrate Ratio	**Saturation Index (SI)**
0	0.57
0.50	-0.02
0.75	-0.22
1.00	-0.39
1.25	-0.54
1.50	-0.66
1.75	-0.77
2.00	-0.87

Staff is currently using a dilution ratio of 1.75 parts effluent to one part centrate. As the presented modeling results illustrate, the current ratio is well into the negative (undersaturated) range of SI values. The model results indicate that the effluent dilution volume can be reduced and the SI will remain negative, continuing to prevent struvite formation.

Caution must be exercised in selecting an optimum dilution ratio, one that will continue to prevent struvite formation while minimizing the pumping and use of final effluent as the dilution source. Caution must be exercised because the modeling results are based on a very limited amount of plant process data. Therefore, several critical assumptions had to be made to develop the results presented above. It had to be assumed that the centrate conditions (pH, temperature, conductance, and concentrations of magnesium, ammonia, and orthophosphate) are constant year around and are accurately represented by samples collected in May 2009. It had to also be assumed that final effluent conditions are constant year around, except for temperature, and are accurately represented by the values reported by the City for pH, temperature, conductance, and concentrations of magnesium, ammonia, and orthophosphate.

To account for normal, expected variability in centrate and final effluent water quality, a safety factor was employed in determining the recommended dilution ratios for summer and winter conditions. The recommended dilution ratios are based on achieving an SI that exceeds (-0.50), which is well into the undersaturated range. The recommended dilution ratios for winter and summer conditions are 1.50 and 1.25, respectively.

Because of the limited amount of plant data provided for this analysis and the necessary assumption that the provided data are representative of year around conditions, it is recommended that downstream processes be monitored for struvite formation after the recommended dilution ratios are implemented. Incremental adjustments can be made based on observations until optimal use of dilution resources is achieved to prevent struvite fouling.

Recommended effluent to centrate dilution ratios to prevent struvite formation:

Winter: 1.50

Summer: 1.25