STABLE ATTRACTION: HOW TO CHEAT THE ACTIVATED SLUDGE PROCESS FOR ADDITIONAL CAPACITY USING THE MAGNETITE-BALLASTED MIXED LIQUOR PROCESS

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ABSTRACT

Utilities are often faced with addressing improvements at their wastewater treatment facilities due to a number of issues including increased growth and more stringent effluent limits. The land available for implementing facility upgrades and/or expansions may not be available leaving the utility in a challenging situation. There are a number of technologies that have gained traction to address this concern including moving bed bioreactors (MBBRs), integrated fixed film activated sludge (IFAS), membrane bioreactors (MBRs), and biological aerated filters (BAFs). An emerging technology is the BioMag system marketed by Evoqua Water Technologies.

The BioMag process provides a magnetite ballast to bioreactors for dramatically enhanced settling of biological and chemical flocs. Magnetite is an iron oxide powder with a high specific gravity that embeds within solids to enhance secondary clarification. This allows for the secondary treatment process to operate at mixed liquor suspended solids (MLSS) concentrations much higher than conventional activated sludge systems due to the enhanced setting rate of the magnetite-impregnated mixed liquor. Magnetite is recycled from the clarifiers back to the suspended growth process in the return activated sludge (RAS). Waste activated sludge (WAS) is processed for magnetite recovery using an in-line shearing mechanism to separate the sludge from the magnetite followed by a magnetic drum. Recovered magnetite from the WAS is returned to the bioreactors for reuse.

A full-scale demonstration of the BioMag process was completed from September 2009 through January 2010 at the Mystic, Connecticut Water Pollution Control Facility to verify achievement of required process performance and to test the impacts of magnetite-impregnated mixed liquor on settling, re-suspension and other mechanical aspects of successful treatment. The primary goal of the demonstration was to evaluate the potential of the BioMag process to adequately meet the facility's nitrogen removal performance goals in regards to effluent quality, mixed liquor inventory and settleability. The ability of the system to meet this primary goal was achieved and previously documented (McConnell et al., 2010).

A second important goal of the process demonstration was to evaluate certain mechanical and process impacts of the BioMag process on other treatment plant systems, e.g., aeration tank mixing, secondary clarifier capacity, and pipeline solids deposition/resuspension, such that a final installation could be designed to address these impacts. The ability of the system to meet this secondary goal was achieved and also previously documented (Moody et al, 2011).

Several full scale facilities are nearing completion or are presently in the start-up phase of the BioMag process. This paper will summarize the results of the full scale demonstration testing, preliminary results from the facility after startup of the BioMag operation, and lessons learned during the startup and early stages of full-scale, permanent operation.

INTRODUCTION

The Mystic Water Pollution Control Facility (WPCF), owned by the Town of Stonington, Connecticut, is rated at a permitted design capacity of 0.80 million gallon per day (MGD). A facilities plan in 2007 identified improvements needed to upgrade the aging facility as well as to meet an annual effluent total nitrogen (TN) limit mass load equivalent to 5.2 mg/L. At the time, the Mystic WPCF was not configured for biological nutrient removal (BNR).

The BioMag system, marketed by Evoqua Water Technologies, was eventually selected due to its attractive lifecycle cost. Other technologies that were evaluated included expanding the facility with conventional suspended growth technology, IFAS, and MBRs.

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SUMMARY OF FULL SCALE PILOT DEMONSTRATION

The BioMag process was piloted at a full-scale level from September 2009 through January 2010. The goals of the full-scale testing were to evaluate:

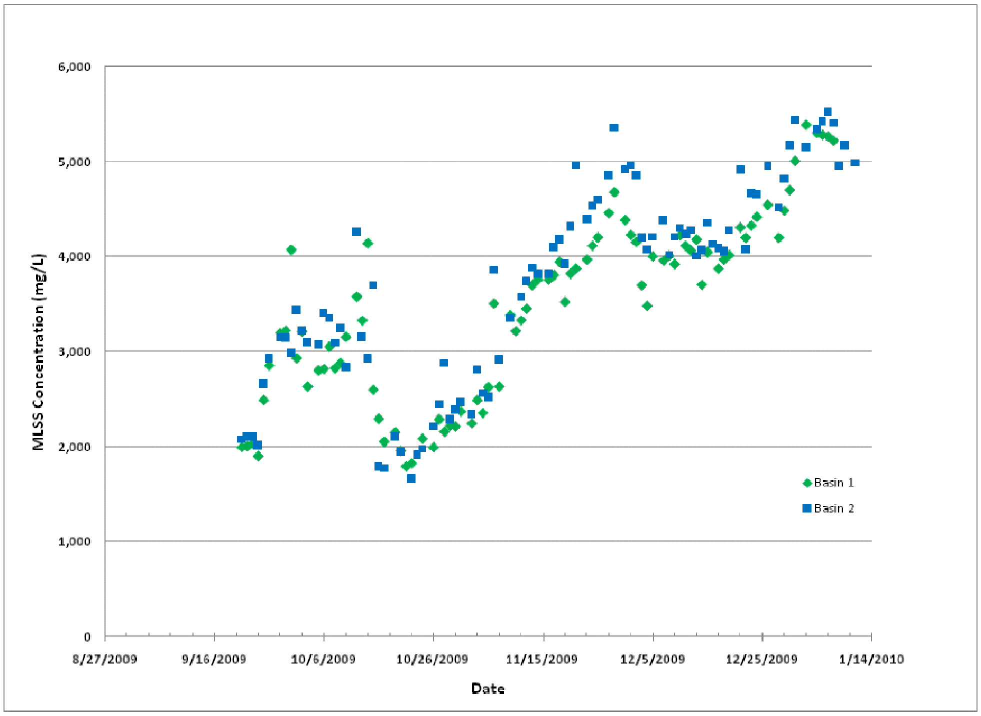
- Operations and performance of the facility to meet target performance goals of less than 10 mg/L of biochemical oxygen demand (BOD_5), 10 mg/L of total suspended solids (TSS), less than 5 mg/L of TN and less than 1 mg/L of ammonia nitrogen in the effluent.
- Impacts of the magnetite on facility equipment and piping, namely, effectiveness of basin mixing, impacts on the power draw to the chain-and-flight clarifier drives, and solids deposition in piping.

Both process trains were used for the testing due to the inability to isolate an aeration basin and a coupled clarifier to only run one train. In addition, mechanical mixers were installed in the aeration basins to keep MLSS in suspension when air was turned off to provide anoxic conditions at the facility.

Operation and Performance Goals

Figure 1 shows the increase in MLSS and solids loading rate to the secondary clarifiers during the pilot testing. MLSS values (biomass only) increased from an initial value of 2,000 mg/L up to over 5,000 mg/L. A large amount of foaming was experienced in October of 2009. Plant operations staff were required to waste a large amount of solids from the system and interim foam removal measures were taken.

Figure 1. MLSS Concentration Variation (not including magnetite) (from McConnell et al, 2010)



Figures 2 and 3 show the solid loading rate to the secondary clarifiers and the sludge volume index (SVI) of the mixed liquor. The secondary clarifiers averaged 150 kg/m^2-d (30 lb/d/ft^2) during the snow melt periods with peak days reaching over 250 kg/m^2-d (50 lb/d/ft^2). The higher than normal solids loading rates can be attributed to the SVI values of below 100 mL/g observed during the test period (with the exception for the October 2009 foaming event).

The MLSS, with the magnetite engrained in the floc, caused the solids-liquid interface in the standard SVI test to be achieved rapidly at about the 5 minute mark. Approximations for the Vesilind initial settling velocity (V_o) and hindered zone settling parameter (K) were 109 m/hr (359 ft/hr) and 0.4 L/g, respectively. The initial settling velocity results in much higher settling capacity than typical mixed liquor, about 10 times greater, resulting in additional clarifier capacity.

Figure 2. Secondary Clarifier Solids Loading Rate Variation (not including magnetite) (from McConnell et al, 2010)

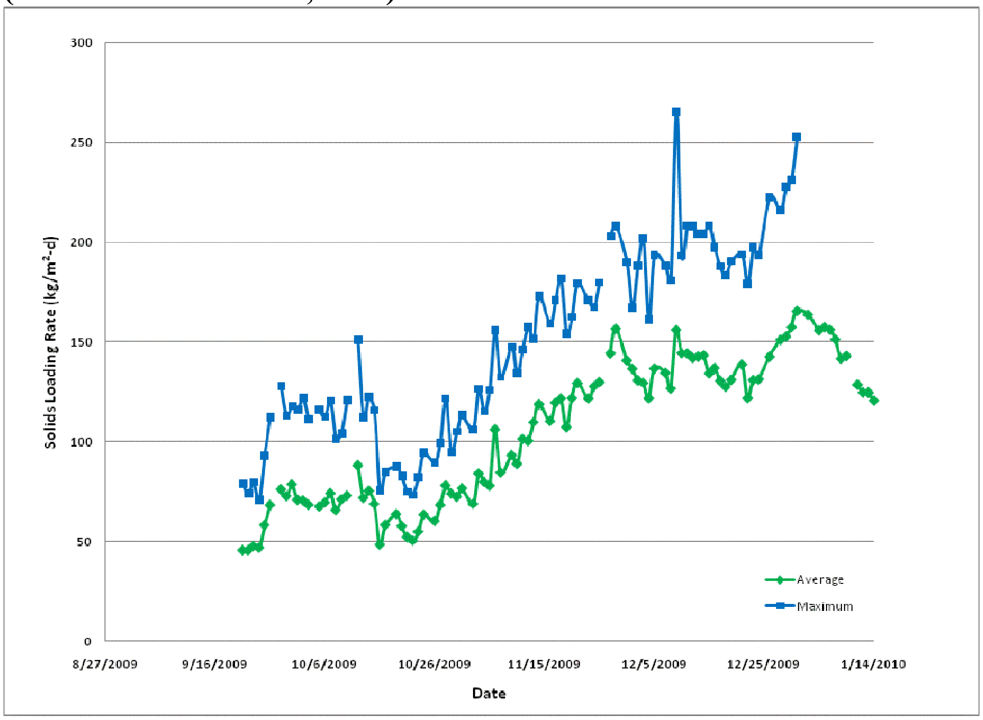


Figure 3. SVI Variation (not including magnetite) (from McConnell et al, 2010)

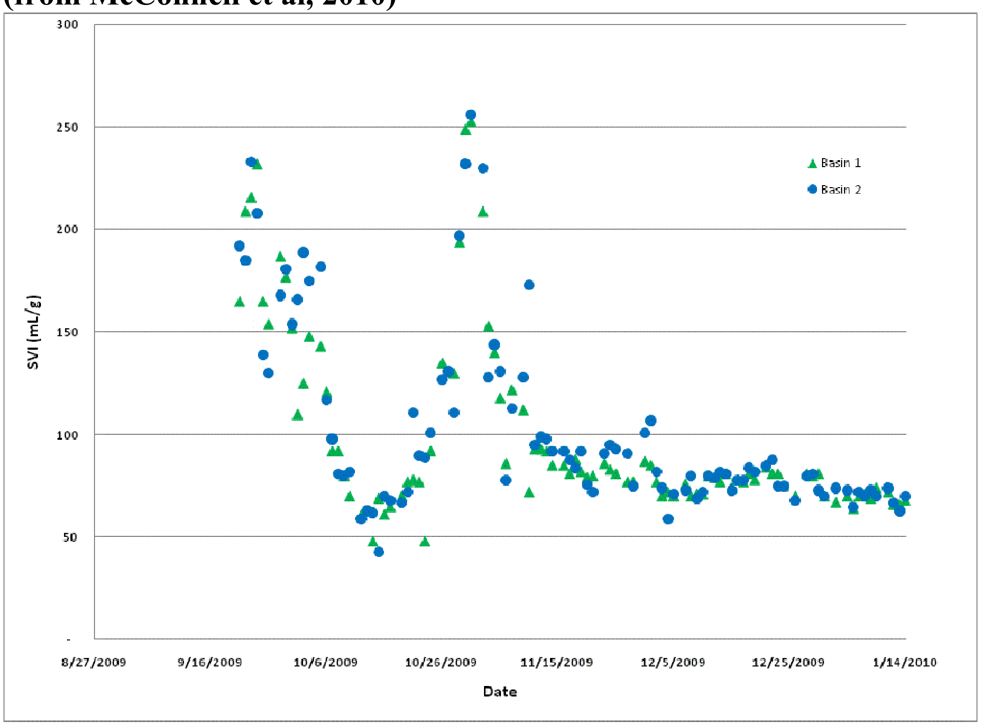
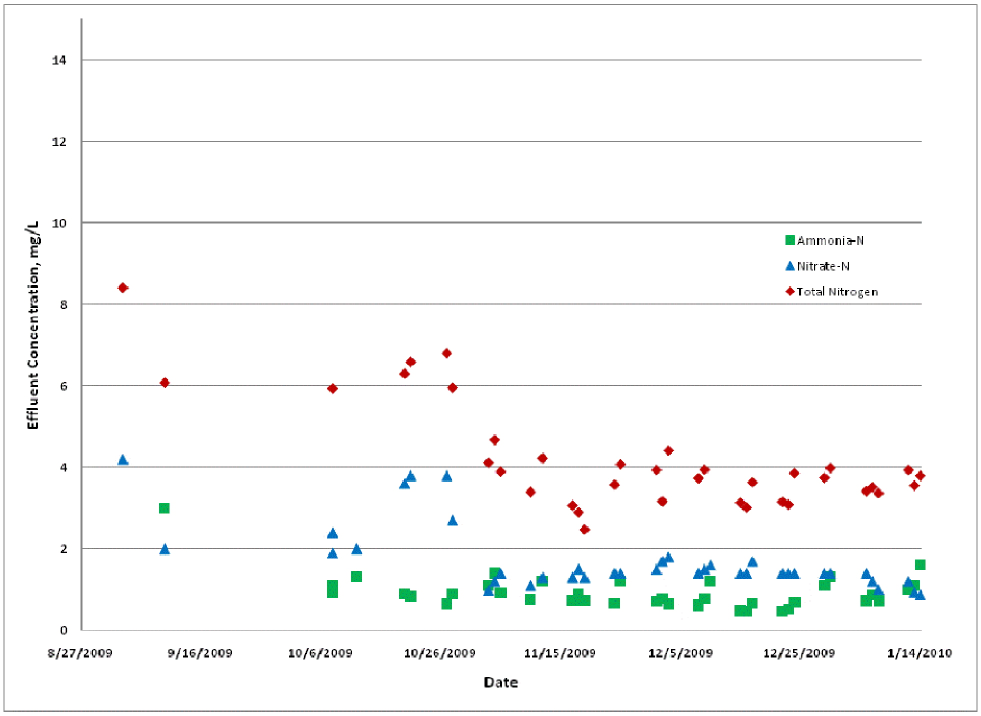


Figure 4 shows the ammonia-N, nitrate-N and TN concentration for the test period. The process basins were operated in a three hour intermittent aeration cycle with two hours being aerobic with the third hour being anoxic. The ammonia-N concentration averaged 0.86 mg/L during the while the nitrate-N concentration averaged 1.35 mg/L.

Figure 4. Effluent Nitrogen Values
(from McConnell et al, 2010)



Impacts on Equipment and Piping

As mentioned previously, the full-scale testing included use of floating mixers which were operated during the anoxic cycles. Two 5-horsepower mixers were installed in each aeration basin. The mixers were installed on the upstream and downstream ends of the basin.
TSS measurements were taken during anoxic cycles to assess the variability of the MLSS in the tanks during the anoxic cycles.

Measurements were taken with both mixers in operation and with only the upstream mixer in operation. The MLSS concentrations for the two-mixer operation, with a power input of 0.69 hp/1,000 cubic feet of volume, varied within 5 percent from top to bottom of the tank which was deemed to provide adequate mixing. One mixer operation, with a power input of .34 hp/1,000 cubic feet, showed stratification at the downstream end of the basin with concentrations 100 percent different between the upper and lower portions of the tank (6,000 mg/L at the top to 13,000 mg/L at the bottom).

Measurements were taken at the clarifiers to determine if the higher concentration of solids in the secondary clarifier affected the amp draw on the motors operating the chain-and-flight clarifiers. It was determined that there was negligible impact due to the magnetite use in the secondary clarifiers.

Testing was also done to access settling concerns in magnetite ballasted mixed liquor in process piping. Clear polyvinyl chloride (PVC) piping was connected to a submersible pump. Return activated sludge at concentrations of 0.9 to 1.1% solids (without magnetite) were pumped into the clear PVC piping. The submersible pump was shut off and the solids were allowed to settle in the pipe. After settlement, clear water was pumped through the pipe to determine the resuspension velocity needed. Testing indicated that resuspension occurred at velocities of one foot per second at a MLSS to magnetite ratio of 1 to 1. Tests were run at velocities below this value and did not show resuspension of solids in the pipeline.

Based on the results of the successful process demonstration, the Mystic WPCF was recently upgraded to a full-scale, permanent BioMag installation, configured in a four-stage BNR configuration. Initial startup of the plant occurred in late fall 2014.

PRELIMINARY RESULTS AFTER STARTUP OF BIOMAG PROCESS

An analysis of the Mystic WPCF's operational control parameters and effluent performance was done looking at data from December 2013 through February 2014 (pre-BioMag startup) and comparing to data from 2015 (post-BioMag startup). Table 1 summarizes the findings. Note that the pre-Biomag data encompasses a period when construction was occurring on site, and indicates a stressed process condition.

Table 1. Operational and Effluent Performance Parameters Pre and Post BioMag Startup

Parameter	Unit	Pre BioMag	Post BioMag
Flow	mgd	0.27	0.43
MLSS	mg/L	1136	4526
SVI	mL/g	275	104
Effluent TSS	mg/L	13	8
Effluent Turbidity	NTU	7	2
Effluent Ammonia	mg/L	8.9	0.5
Effluent Nitrate	mg/L	4.5	1.2
UV Dose	mW-s/cm2	50	149
UV Transmittance	%	49	76

Prior to the facility upgrades flow was diverted from the Mystic WPCF to a neighboring facility. The increase in flow after startup was a result of ending the flow diversion. The MLSS concentration increased roughly 400% after implementation of BioMag which allowed for more biomass inventory and increased removals of ammonia and nitrate in the effluent. The increased flow and solids loading to the secondary clarifiers did not cause a deterioration in effluent TSS and turbidity as well due to the low SVI (even though the full-scale pilot had SVIs even lower). UV transmittance increased due to the lower turbidity in the effluent, however, UV dose has increased due to intermittent difficulty in achieving the plant's disinfection limits for Enterococci.

The magnetite recovery system appears to be working well. The system is recovering roughly 95% of the magnetite in the system. Full-scale pilot testing indicated a recovery rate of 97 to 98%, which compares favorably to the results after the process was started up.

LESSONS LEARNED DURING STARTUP

The following items are lessons learned during the recent startup process that were not anticipated. These items are currently being studied further:

- Foaming has been an ongoing issue during startup. The facility is equipped with the ability to surface waste and for mechanical foam removal, and operation of these systems are required to avoid significantly excessive foam . Foam was microscopically analyzed and determined to not have an excessive count of Nocardia filaments.

- The waste activated sludge (the biomass portion) capture percentage at the rotary drum thickener is much lower than anticipated. A 65 to 75 percent solids capture rate has been experienced, causing a thinner sludge to solids handling than anticipated, resulting in increased operational time for the thickener. It is suspected that the increased solids recycle back to the suspended growth process may be a factor in seeding the process with the foam-causing bacteria instead of wasting them out of the plant.

- As noted previously the UV dose has increased significantly since BioMag was started up, to address intermittent problems with providing satisfactory disinfection. Testing is presently underway to determine the cause(s) of this unexpected issue. One theory is that large floc particles caused by polymer addition (needed for Biomag) may be shielding the Enterococci bacteria from the UV light and the dose is being increased to meet permit limits.

- Magnetite loss appears to be more than just through the magnetic drum recovery and is dependent on the loss in the scum skimmings and in the effluent stream.

CONCLUSIONS

Full-scale pilot testing and initial operation after installation of the BioMag system at the Mystic WPCP has shown increased removal efficiencies for total suspended solids and effluent total nitrogen. The ballasted mixed liquor has decreased SVI values allowing the clarifiers to effectively double the mixed liquor concentration. Some unexpected items have occurred during startup that are still being investigated and should be topics for future papers and presentations.

REFERENCES

McConnell, W., Moody, M. and Woodard, S. *Full-scale BioMag Demonstration at the Mystic WPCF and Establishing the Basis-of-Design for a Permanent Installation.* WEFTEC10 Conference Proceedings

Moody. M, Bishop, A. and McConnell, W. *Beyond Desktop Evaluation: Key Design Criteria for Mixing and Settling of Magnetite-Impregnated Mixed Liquor.* WEFTEC11 Conference Proceedings