Design Considerations to Increase Treatment Capacity with Magnetite-Ballasted Activated Sludge Facilities

Thor Young[1], Casey Whittier[2], Sam Towndrow[3]

1. GHD, Bowie, MD, United States
2. Evoqua Water Technologies, Tewksbury, MA, United States
3. Evoqua Water Technologies Pty Ltd., Sydney, Australia

1. Introduction

Magnetite ballasted activated sludge systems are growing in acceptance as a viable solution for expanding the treatment capacity of wastewater treatment plants (WWTPs). A growing installation base across the US and UK continues to prove and improve process application with many of these plants having been in operation now for over 7 years.

The magnetite ballasted process (commercially known as the BioMag® system) can double or triple the treatment capacity of an existing conventional activated sludge (CAS) process without the need for additional tankage.

This process has been found to be a cost-effective alternative for a WWTP to meet future effluent permit limits when compared to CAS processes as well as more advanced technologies such as membrane bioreactors (MBR), moving bed bioreactors (MBBR), and integrated fixed film activated sludge (IFAS).

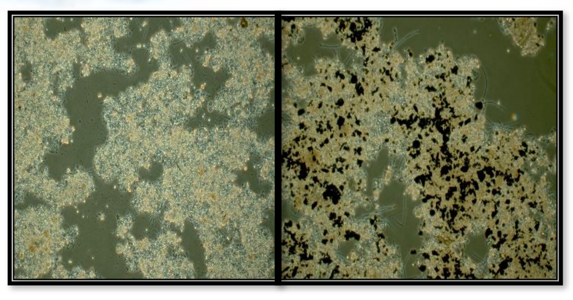


Figure 1. Magnified Images of ballasted (right) and non-ballasted (left) biological floc.

- Magnetite (Fe_3O_4) with a specific gravity of 5.2 is used to ballast biological floc
- Ballasted floc settles rapidly and reliably allowing for significantly increased mixed liquor concentrations and increased clarifier SLR and SOR rates
- Increased settling rates allow for process intensification within existing tankage making capacity available to process greater loads, increased flows, target nutrient removal or a combination of all three

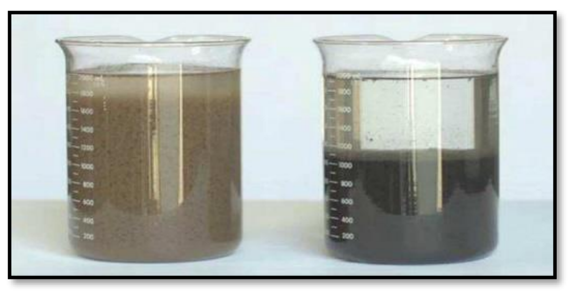
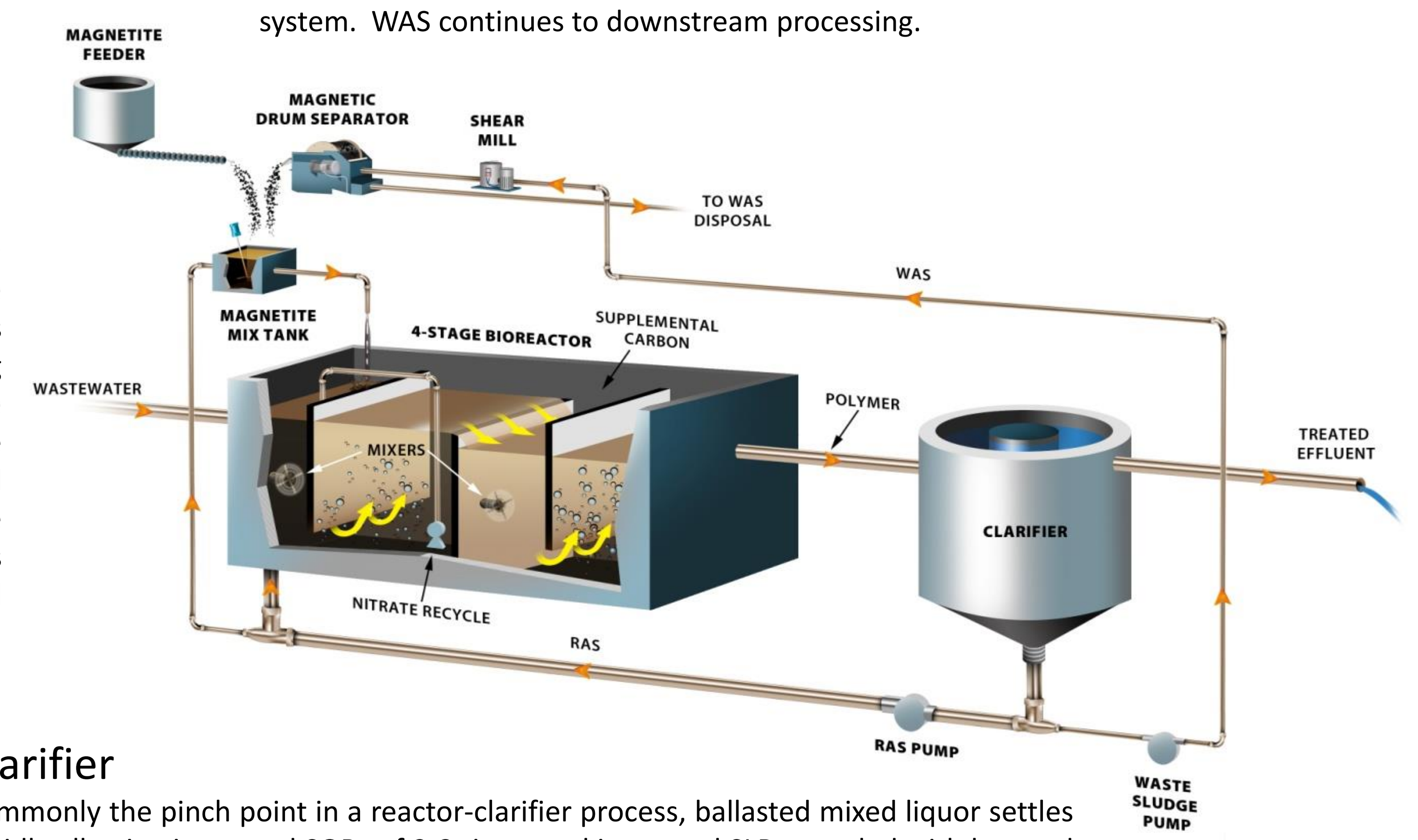


Figure 2. Non-ballasted mixed liquor (left) and ballasted mixed liquor (right) after 5 minutes settling

2. Process

Recovery and Reuse

Magnetite is continuously reused and recycled. WAS from the clarifier is pumped to the magnetic recovery drum via an inline shear mill. The shear mill is required to separate the magnetite from the biological floc. Once separated, permanent and stationary magnets inside the drum help capture approximately 95% of the magnetite for return to the system. WAS continues to downstream processing.



Bioreactor

The first step is addition of magnetite to the bioreactor. This is achieved by adding magnetite from the storage system into a side stream of MLSS, fed directly into the bioreactor where it is mixed and fully infused into the biological floc

Clarifier

Commonly the pinch point in a reactor-clarifier process, ballasted mixed liquor settles rapidly allowing increased SORs of 2-3 times and increased SLRs coupled with low and stable sludge blankets, high TSS removal and ability to manage wide swings in flow and loads

3. Application and Design

Mixed Liquor Concentration

Magnetite impregnated biological floc has a specific gravity of approximately 1.7 which dramatically increases the settling rate. Secondary clarifier loading rates can be significantly increased compared to CAS systems allowing for much higher biological MLSS concentrations in the reactor and therefore increased reactor capacity. Typically the ratio of magnetite to biological solids is 1:1 but can vary between 0.5 and 1.1 in normal operating conditions. As with MBR applications, the upper MLSS concentration is typically around 8000 mg/L due to decline in alpha beyond this point.

Clarifier Capacity with Ballasted Mixed Liquor

Typical loading rates for CAS compared to ballasted mixed liquor systems are compared in Table 1.

Table 1: Comparison of typical loading rates for secondary clarifiers for CAS and BioMag.

Activated Sludge	HLR, m³/m²/d		SLR*, kg/m²/d	
Process Description	Average	Peak	Average	Peak
Conventional	22	52	25	40
Magnetite-Ballasted	26	70	50	90
Improvement with MBAS	20%	35%	100%	125%

*The solids loading rate refers to solids without magnetite.

Even at SLRs as high as 490 kg/m²/d, the BioMag process has been demonstrated to achieve high-quality effluent (TSS and TP concentrations below 10 and 0.2 mg/L) respectively, with the addition of polymer.

Due to the high settling rate, secondary clarifiers should not be designed based on a SVI correlation such as that developed by Daigger (1995), which was originally developed for CAS processes with slow-settling MLSS. Instead, design should be based on the loading rates presented in Table 1 or statepoint analysis supported by site-specific settling column tests as described by WERF Document 00-CTS-1, example results of state point analysis is shown in Figure 3.

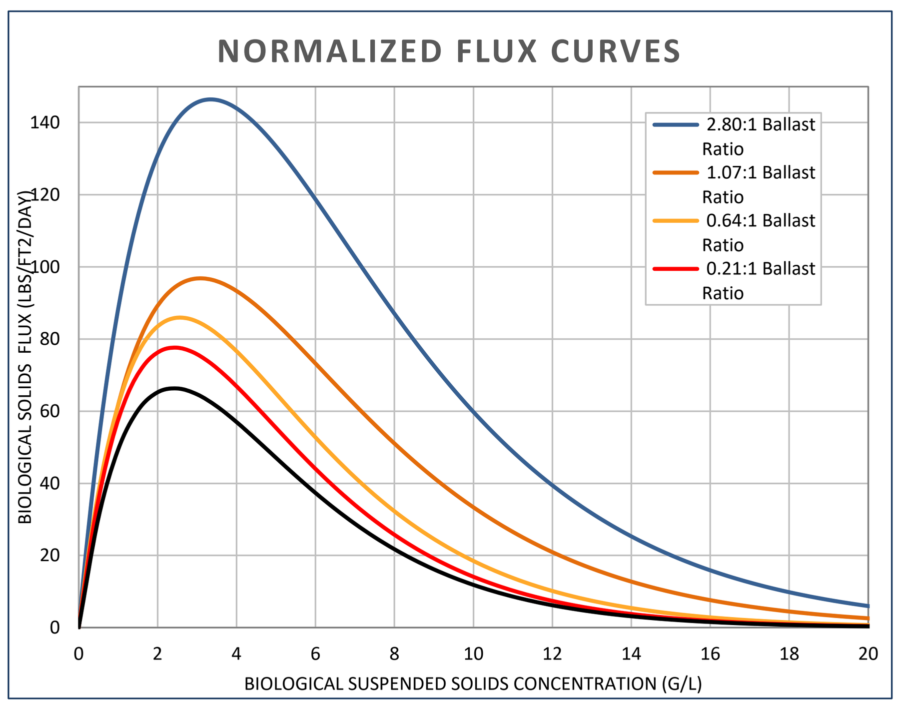


Figure 3. Example of solids flux testing results used in statepoint analysis

Sludge Withdrawal

The increased solids loading rates and enhanced settling capabilities of the process require an efficient sludge removal mechanism in the secondary clarifiers that can be precisely monitored and controlled for optimal system performance. The BioMag system process has been successfully operated with conventional rectangular clarifiers, conventional circular clarifiers, and circular clarifiers with suction manifold sludge collectors.

Aeration

When retrofitting the BioMag system, aeration and mixing energy requirements need to be carefully considered. BioMag products allows the system to operate at higher MLSS and the aeration system therefore needs to be able to meet this demand. The magnetite itself has been shown to have no impact on alpha (McKean et al. 2013). The system is compatible with a variety of aeration systems including fine bubble, coarse bubble, jet aeration and mixers with air sparge.

Mixing

A key consideration in applying BioMag is the need to prevent unwanted settling in tanks, pipes and channels. Care needs to be taken to ensure sufficient mixing can be achieved throughout the tank and may require supplemental mechanical mixing, particularly for intermittent processes or to assist with resuspension following diurnal turndowns. Similarly, in pipes and channels, minimum velocities of approximately 0.3 - 0.5 m/s are required to limit settlement.

4. Case Studies

Sturbridge

- Installation completed 2012
- Selected over MBR
- Plant expanded from 2.8 ML/d to 6.1 ML/d without additional tankage
- Improved secondary effluent quality TN<3.0 mg/L, TP < 0.2 mg/L

Installation information and images courtesy of Tighe & Bond Inc. MA, USA

Figure 4. BioMag Biological Reactors, Sturbridge

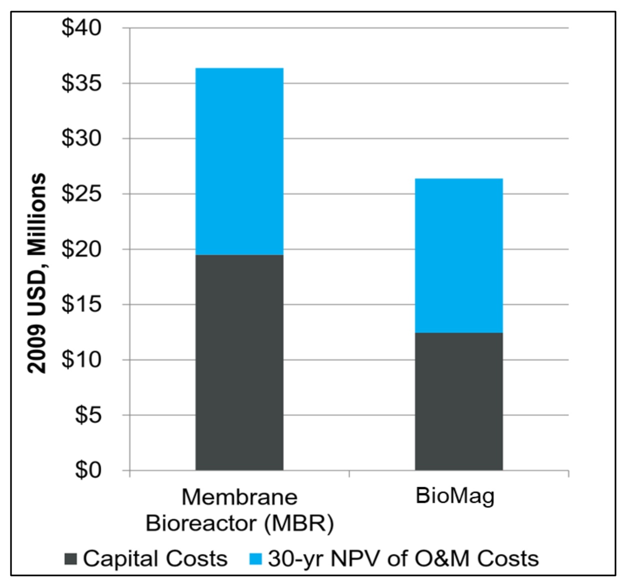


Figure 5. Cost comparison for upgrades at Sturbridge WWTP

Upper Gwynedd

- Challenge: to meet new TP limit of 0.2 mg/L, manage high wet weather peaks and avoid need for tertiary treatment
- BioMag enabled plant to almost double peak flow capacity from 45 MLD to 85 MLD

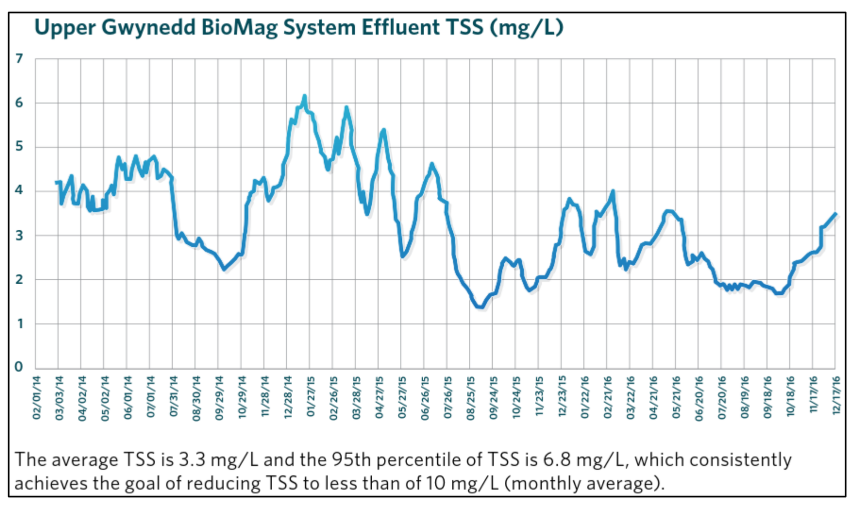


Figure 6. BioMag system effluent TSS, Upper Gwynedd

Figure 7. TowBro® secondary clarifiers, Upper Gwynedd

Plant data and image courtesy of Upper Gwynedd Township Wastewater Treatment Facility

Front Royal

- Requirement: Capacity increase and nutrient removal
- Solution: Simultaneous nitrification – denitrification (SND) process in conjunction with a BioMag system
- 75% reduction on new bioreactor and 50% reduction on new clarifiers
- No tertiary denitrification filters
- 45% capacity increase 15.1 MLD → 22 MLD
- TN < 3 mg/L and TP < 0.22 mg/L

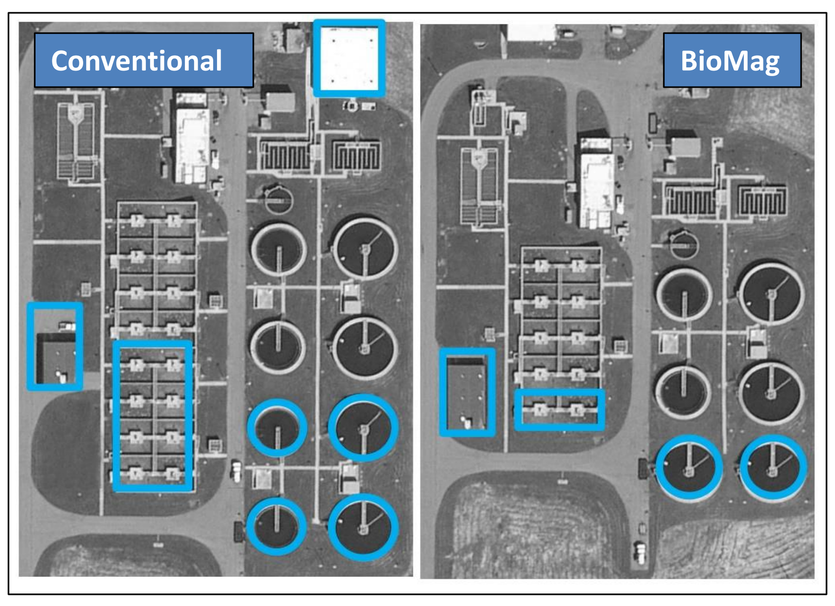


Figure 8. Comparison of conventional and BioMag system upgrade requirements, Front Royal WWTP. *Image courtesy of GHD, Bowie, MD, USA*

5. Conclusion

While many components of magnetite-ballasted activated sludge systems are similar to conventional activated sludge systems, there are several special considerations which need to be incorporated into new BioMag system installations. These include proper preliminary treatment, biological process and secondary clarification, aeration and mixing requirements, hydraulic profiling chemical addition, solids management, and magnetite feed and recovery design.

The information in this presentation is intended to serve as a guide for those interested in assessment of capacity increase potential and evaluation verses alternatives solutions. As the technology becomes more widely adapted and understood, there will be opportunities to revisit and expand these findings from future pilots, installations and operational experience, and bench-scale studies.

References: [1]Young, T; Smoot, S; VerNooy, J; Revette, J; Woods, B; Pamperin, M: (2014). "Design Considerations for Magnetite-Ballasted Activated Sludge" *Proceedings of the Water Environment Federation,* WEFTEC 2014. [2] Moody, Megan B.;Bishop, Andy; McConnell, William C: (2011), "Beyond Desktop Evaluation: Key Design Criteria for Mixing and Settling of Magnetite-Impregnated Mixed Liquor" *Proceedings of the Water Environment Federation,* WEFTEC 2011. [3] McKean, C; Redmon, D; Woodard, S: (2013). "The Impact of Magnetite Ballast on Oxygen Transfer and Alpha". *Proceedings of the Water Environment Federation,* WEFTEC 2013