Process Selection and Operating Data for Fast-Tracked Nitrification Enhancements Utilizing Magnetite as Ballast in a Sequencing Batch Reactor

Introduction

The Smithsburg WWTP is located in Washington County, MD and is owned and operated by Washington County (County). The facility has a rated average design capacity of 0.33 mgd and treats an average of approximately 0.23 mgd. The plant utilizes sequencing batch reactor (SBR) technology and historically had provided complete nitrification and partial denitrification during warmer months, and incomplete nitrification and denitrification during winter months.

The facility had been unable to achieve the winter month reporting requirement of 4.9 mg/l effluent ammonia. In 2011, the facility was issued notification that a new discharge permit would be effective in six months requiring effluent ammonia of 2.3 mg/L in warm weather and 3.9 mg/L in cold weather.

The County recognized low temperatures, high inflow/infiltration and settleability limitations could jeopardize meeting the impending ammonia limits and retained RK&K to evaluate operational and capital improvements. Options were limited to those that could be implemented in the six-month period.

Process Evaluation

The evaluation included an analysis of influent/effluent data and plant operating conditions. Several issues critical to achieving nitrification in cold weather were identified through the evaluation including:

Influent Loadings: The facility was operating at design capacity on a loadings basis even though influent flow was 70% of design flow.

High infiltration/inflow (I/I): To treat the high flow, operations staff accelerated the cycle structure and operated with up to 19 cpd. The original design was based on 10 cpd (5 cpd per basin at 4.8 hours each). The accelerated cycle structure reduced the treatment time per day.

Inability to take a tank out of service: Any SBR upgrades that were required must be implemented while the tanks remained in service due to the nature of the two-basin SBR and to the plant operating at design capacity.

Aeration system: The cooling effect of surface aerators in combination with the cooling effect from above-grade tanks caused a wastewater temperature drop as much as 9^0 C on colder days. The low temperatures impacted the rate of nitrification requiring a longer solids residence time (SRT) to maintain nitrification. The aerators also froze periodically.

Poor Settling: The sludge volume index (SVI) was typically between 150 ml/g and 300 ml/g. This prohibited operations staff from increasing the MLSS beyond 2,500 mg/l.

The settling conditions also required an extended settling period, reducing the time available for the react phase.

The evaluation determined the limiting factor for maintaining nitrification during the winter months was insufficient biomass to provide a sufficient SRT at cold temperatures. A prioritized list of improvements was developed on the basis of an improvement having the greatest impact on promoting reliable nitrification:

Increase the MLSS within the existing reactors -providing enough biomass for the required SRT at low temperatures

Reduce the temperature loss through system - a higher temperature reduces the biomass requirement

Prevent surface freezing - an operational improvement to assure sufficient aeration

Attenuate the impact of I/I and improve settling - allows the cycle structure to be maintained with sufficient time for the react portion of the cycle

The following upgrades were identified for potential implementation within a fast-tracked schedule (4-6 months):

Utilize Evoqua's BioMag (ballasted activated sludge) technology to increase the MLSS concentration.

Replace the surface aerators with fine bubble aeration to reduce the temperature loss.

Covering the existing aerators with domes to reduce the temperature loss and provide supplemental aeration with a liquid oxygen.

Enclosing the SBR tanks in a building to reduce temperature loss.

Process Selected

The selected improvement was to utilize the BioMag technology. In November 2012, a mobile ballast feed system was used temporarily until the permanent BioMag feed and recovery system was installed. By having the ballast feed system in place by November, the facility was able to increase the MLSS concentration prior to the coldest temperatures and prevent loss of nitrification in the 2012/2013 winter.

Procurement and contract documents were prepared based on the County directly purchasing the BioMag equipment in order to expedite the equipment installation.

Discussion of Operating Data

Figure 1 depicts historical effluent ammonia and permit concentration to illustrate how often the plant would be out of compliance without improvements.

Prior to the upgrades, the MLSS typically averaged 2,700 mg/L and was limited by the SVI which averaged 200 ml/g.. Once the magnetite was added into the biological system, the MLSS was increased over 4,000 mg/L (not including the weight of magnetite). This increase is illustrated on Figure 2. Figure 3 depicts the effluent ammonia concentration for the three years' operating the SBRs with magnetite (Fall 2012-Fall 2015). With the exception of few outliers, the plant was able to achieve the effluent ammonia permit reliably for each of the three winters and effluent ammonia is considerably lower than prior to the installation of the BioMag process improvements.

Conclusions

The BioMag technology allowed for the plant to maintain both treatment trains in service and utilize a temporary feed system to meet the discharge permit through the winter months prior to the permanent feed and recovery system construction completion, which occurred in Fall 2013. After winter, and once the MLSS temperature was elevated to summer temperatures, the County was able to take one SBR offline for a few hours to install a permanent submersible pump for wasting to the magnetite recovery system provided by Evoqua.

The plant has been able to reliably achieve the effluent ammonia permit by increasing the MLSS concentration. The MLSS was increased without fear of losing solids during the decant because the low SVI observed during the daily settleability tests proved the magnetite was embedded in the biomass and helped carry it quickly to the bottom during the settle phase of the cycle. With the reliable settling, the plant was also able to revert to the original cycle structure decreasing the settling time each day and increasing the react time, further improving the nitrification process.

The plant is able to adjust the ratio of magnetite to biomass daily based on projections for I/I using the rain forecasts as well as adjusted seasonally to compensate for seasonally variable settling conditions.

As the first full-scale SBR in the world to utilize BioMag, and the first system with surface mixing and surface aeration, the system required troubleshooting during start-up. The initial addition of magnetite to the system successfully aided in the settleability of the biomass, but the surface agitation was not enough to re-suspend the biomass/magnetite combination, and more powerful mixers than originally planned were needed. Once the proper power was identified the reactor was able to be fully mixed within a reasonable amount of time after the mix phase began.

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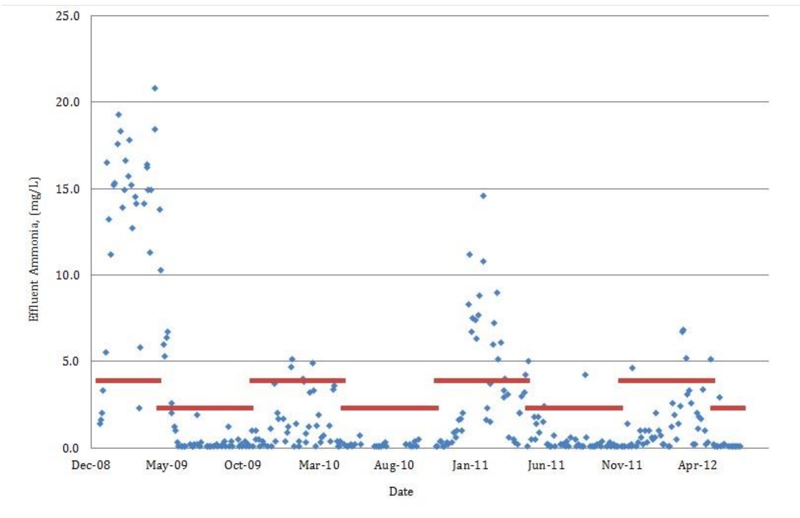
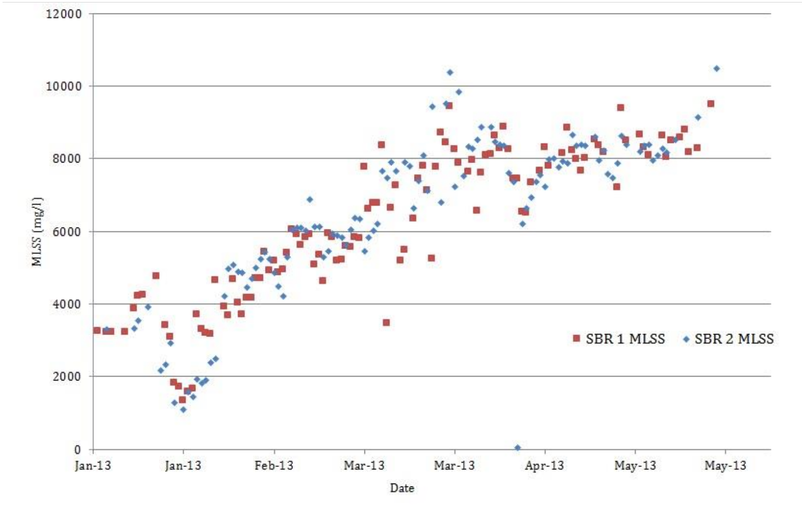
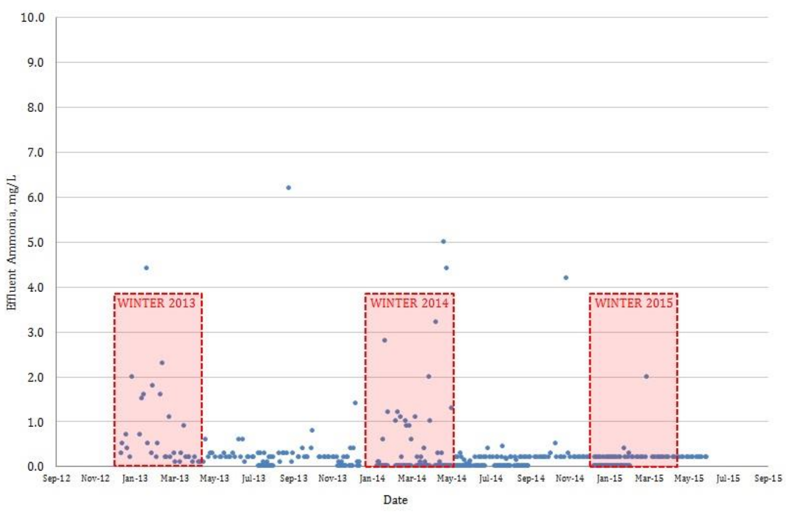



12000
10000
8000
6000
4000
2000
0
MLSS (mg/l)
Jan-13
Jan-13
Feb-13
Mar-13
Mar-13
Apr-13
May-13
May-13
Date
SBR 1 MLSS
SBR 2 MLSS


10.0
9.0
8.0
7.0
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Effluent Ammonia, mg/L
WINTER 2013
WINTER 2014
WINTER 2015
Sep-12
Nov-12
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
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Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Date