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Modernizing Water and Wastewater Treatment through Data Science Education & Research

TECH BRIEF

Data Science Summer Fellows Program 2020

Aqua-Aerobic Systems, Inc. – AquaPrime

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SUMMARY

Wastewater treatment organizations are continually developing new technologies and methods by which wastewater can be treated more efficiently. Searching for ways to decrease their environmental footprint, while increasing energy efficiency in the systems utilized by wastewater treatment facilities. *Aqua-Aerobic Systems, Inc.* is looking to do just that. Their specialized personnel has been collaborating with different treatment facilities and laboratories to experiment with their new cloth media filter technology, called *AquaPrime*. This briefing includes detailed descriptions of the facility's primary treatment, sample observation data, exploration of the data, and what was observed in the results of the statistical methods that were used.

INTRODUCTION

The first objective of this study is to determine whether the AquaPrime filter removes more solids and contaminants than the traditional clarifier in the primary stage of the wastewater treatment process.

The second objective is to find correlations between filter's online process variables and its corresponding water quality lab data. The goal here is to further investigate how to improve AquaPrime's performance and how it is impacted by process variables.

FACILITY SYSTEM DESCRIPTION

Traditionally, the primary treatment of wastewater has been achieved by a primary clarifier. A primary clarifier relies on gravity to remove solids within the wastewater. Solids either sink, creating a sludge at the bottom which is later removed, or float and are removed by an arm that skims the solids off the surface. The filter seeks to replace clarifiers in primary wastewater treatment with a smaller footprint and a consistently higher quality of effluent water.

AquaPrime uses gravity as well as cloth media filters to remove solids. Like the primary clarifier, it removes solids that have collected at both the top and bottom of the system. Both systems share the same influent water source that goes through preliminary screening to remove large objects before primary filtration. But unlike the primary clarifier, solids that neither float nor sink is collected by a cloth media filter that acts as a barrier which water permeates through as it collects solids. Treated water then flows out of the system by pipes within the disks to be further processed. These cloth media disks are cleansed through a "backwash" which removes the buildup on the filter either every 60 minutes or when it's tank reaches 10.25 feet. Then, both system's effluent water then moves on to secondary treatment. By pushing water through the filter, we expect that primary filters remove solids and biological material more effectively than a clarifier.

DATA DESCRIPTION

Data was collected from both the primary clarifier and the filter. Lab data were collected for both systems, but only AquaPrime had online sensor data. Lab data included water quality parameters taken from a variety of sample types, such as 24-hour composite samples or grab samples. Lab samples were not taken at a set frequency, though samples for the filter were more consistent and frequent than the primary clarifier. There were only two dates that contained both an influent and effluent measurement for the clarifier. Due to this issue, it was concluded that adopting the influent filter lab data for influent data for both systems was a sufficient substitution since both systems share the same original source. Finally, samples were analyzed at both Yuba City lab and BC labs. The vast majority of samples were taken to BC labs, but in some cases the same samples were taken to both labs, leaving a discrepancy in the results. Since Yuba City lab was used infrequently and gave conflicting results from BC labs, their samples were removed from this study for consistency.

Online sensor data for the AquaPrime is available at five seconds intervals from 2017 to 2019. The online data contains many process variables, such as basin level and filter mode. To compare lab results to the process variables of the online data, combining these separate datasets was necessary. This was achieved by taking daily averages of the online data. These daily averages were then aligned with their corresponding time stamp from the lab data to create a joined dataset with both online and lab results.

EXPLORATORY DATA ANALYSIS

A box plot comparison of the filter and the clarifier's total percent removal of Total Suspended Solid (TSS) and Biological Oxygen Demand (BOD) was created. These showed that AquaPrime is more consistent at reducing TSS and BOD levels than the primary clarifier. In particular, the primary clarifier could only accomplish it's best results as well as the filter's worst half of performances.

Initially, it was concluded that the filter's performance was independent of the quality of the influent water since the system seemed to be able to reduce TSS levels of all ranges with ease. After further investigation, effluent TSS levels increase by 0.5 mg/L for every one unit increase in influent TSS levels with an intercept of 33.8 mg/L ($y=33.8+0.5x$). Therefore, the filter is slightly impacted by the concentration of TSS within the influent flow.

Backwashes are essential for filter maintenance and occur frequently to prevent excess buildup and ensure water basin levels. This buildup makes the cloth filter less permeable and acts as another barrier for the water to filter through, which can be used as an advantage for treatment. However, excess buildup hinders the treatment quality of the cloth filter since excess particles will eventually stir back into the water being filtered. When the basin filter reaches maximum capacity, a backwash must be initiated to lower water levels. Therefore, the previous two variables are the limiting factors to being able to reduce the number of backwashes. Also, water used for cleaning during backwashes needs to be cycled back into the system to be taken through primary treatment, creating waste that decreases productivity when backwashes are frequent. While backwashes are essential, they can be reduced in number to promote productivity.

STATISTICAL ANALYSIS and RESULTS

Since the distributions of percentage removal of TSS and BOD were unknown, a Wilcoxon Signed Rank Test was performed. The test aimed to find a significant difference in the

percentage removal of TSS and BOD between the two primary treatment systems. The test resulted in finding there was a significant difference in the performance of the two systems, suggesting AquaPrime's pronounced superior ability to remove TSS and BOD over the Primary Clarifier (Figure 1).

Wilcoxon Signed Rank Test results: TSS		Wilcoxon Signed Rank Test: BOD	
Number of Observations	15	Number of Observations	15
p-value	<.001	p-value	<.001
95% Confidence Interval	(15.3%, 49.6%)	95% Confidence Interval	(19.3%, 51.9%)

Figure 1. Results of TSS and BOD Wilcoxon Signed Rank Test. Interpretation: with 95% confidence the true difference in median percent TSS removal between the filter and clarifier cane predicted to fall between 15.3% and 49.6%

A one-way ANOVA test was conducted to compare the filter's percent removal of water quality variables at low, medium, and high influent flow rates. The three groups were defined as "low" (mean = 286 GPM), "medium" (mean = 358 GPM), and "high" (mean = 494 GPM). The test was performed to examine TSS, BOD, and COD. The test did not provide statistically significant evidence of

One-Way ANOVA BOD Percent Removal

DF Within	DF Error	F-Statistic	p-value
2	29	5.73	0.008*

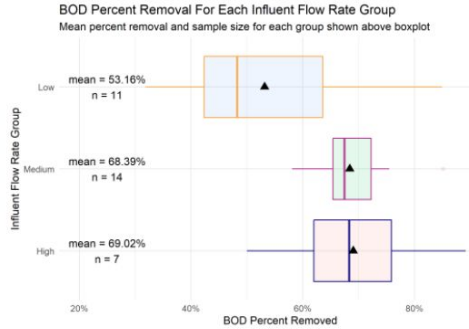

Figure 2. One-way ANOVA BOD percent removal results with corresponding box plots.

a difference between groups for TSS removal but did suggest a difference in percent BOD and COD removal. Figure 2 shows test results for BOD; COD results are similar. Further analysis of the BOD and COD ANOVA tests showed that the mean percent removal of the low influent flow group is significantly worse than the medium and high groups. (Figure 2).

The next step of the analysis was to construct a linear model to predict filter percent TSS removal using influent TSS, influent flow rate, waste flow rate, and basin pH as regressors. When the model controlled for influent TSS levels, there was no statistically significant evidence of a linear relationship between any process variables and percent TSS removal. To model BOD and COD percent removal, we used daily waste flow as the only predictor. There appeared to be a non-linear relationship in the data, so a cubic splines regression model was used with a cut point of 28,000 gallons of total daily waste flow. This cubic splines model indicated that around 60,000 gallons of daily waste flow is when BOD percent removal was optimized. By factoring in the previous ANOVA influent flow rate groups, other trends were detected (Figure 3). It can be observed that the "low" influent flow rate group corresponded to the

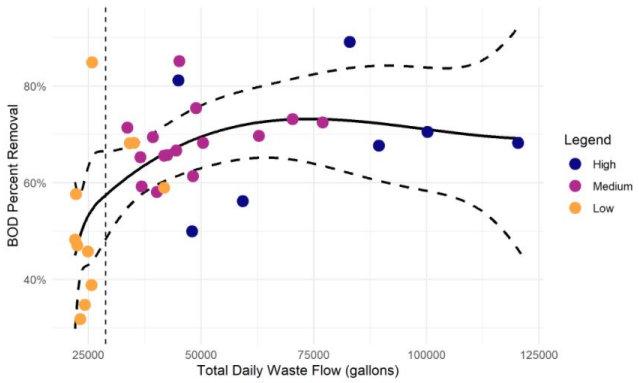

Figure 3. A cubic splines regression model of the relationship between waste flow and BOD percent removal, with a cutpoint at a total daily waste flow of 28,000 gallons.

lowest BOD percent removal, the "medium" group was associated with the optimal total daily waste flow that had dependable BOD percent removal, while the "high" influent flow group was sporadic and not very telling. Our analysis of COD followed extremely similar trends to the BOD.

CONCLUSIONS

The first goal this study sought to find significant differences in water quality improvement between the AquaPrime filter and the primary clarifier. As suggested by the Wilcoxon Signed Rank Test, the filter removes a higher percentage of TSS, BOD, and COD than the clarifier.

The other goal of this project was to find correlations between the filter's online process data to its corresponding offline data. Our modeling and testing did not show evidence to conclude that there is a relationship between percent TSS removal and process control data. However, through ANOVA testing of "low", "medium", and "high" influent flow rates, we found that influent flow rates in our "medium" and "high" categories (~350+ GPM) correspond to higher percent removals of BOD and COD. Additionally, it appears that as daily waste flow totals increase from about 25,000 gallons to 60,000 gallons, BOD and COD percent removal increases then levels off after 60,000 gallons.

To Aqua-Aerobic Systems, Inc., we recommend that further experimentation be done with the backwash cycles. This experimentation can include testing varying lengths of time between each backwash to find the most productive outcome in terms of reduced waste flow and best-improved water quality. It is the hope that this future study can account for the limiting factors, such as basin levels and particle interruption.

REFERENCES

"AquaPrime® - Aqua-Aerobic Systems | Cloth Media Filtration." *Aqua-Aerobic Systems*, © 2020 Aqua-Aerobic Systems, Inc., www.aqua-aerobic.com/filtration/cloth-media/aquaprime. Accessed 24 June 2020.

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