A MUNICIPAL CASE STUDY:

A Bioremediation Approach to Address SVI Issues and Improve System Stability

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BIOREMEDIATION AND WASTEWATER MANAGEMENT

Although it is key in activated sludge maintenance, bioremediation receives little attention in wastewater management. Bioremediation stimulates the activity of the microorganisms that convert waste into water, harmless gasses, and humus, clarifying the effluent.[1] Effective wastewater treatment relies on consistently monitored microbial activity.

F/M ratio and Filamentous Bacteria

Many wastewater facilities rely on influent for nutrients to provide a consistent food-to-microorganism (F/M) ratio. However, due to seasonal changes and community expansion, such as residential or restaurant development, many systems are impacted by fluctuations in their influent and therefore their F/M ratio. Changes in the nutritional balance of wastewater systems can determine the growth of beneficial or detrimental microbial populations. For example, filamentous bacteria dominate during a low F/M ratio. Additional high ratios of carbon and nitrogen as well as low levels of phosphorous compound the filamentous problem, which in turn increases the sludge volume index (SVI) and sludge bulking.[2]

Foaming and sludge bulking are some of the most serious operational problems encountered in activated sludge processes.[3] In contrast, stable nutrition supports a stable microbial environment, which reduces filamentous bacteria and leads to operational stability. A facility that is operationally stable can then decrease power usage, the volume of additional chemicals needed, and the outgoing waste activated sludge (WAS), which in turn reduces overhead costs.

CASE STUDY

An 8-million-gallon per day (MGD) facility in Arizona that was struggling with operational stability and, consequently, increased production costs, was tested by a third party and found to be nutrient deficient. Subsequently, to address the facility's nutrient deficiency as well as SVI and foaming issues, the facility superintendent was interested in participating in a case study utilizing BIO GENESIS® biostimulant with Micro Carbon Technology® (MCT). Results were reviewed annually over three years with variable product application dates due to periodic system stresses:

- March 13, 2014—November 26, 2014
- July 24, 2015—December 31, 2015
- January 1, 2016—May 15, 2016

At the time of the study, the facility, an activated sludge system, consisted of headworks, anoxic zone, four oxidation ditches, return activated sludge (RAS) channel, and clarifiers and sand filters to a chlorification system. (See Figure 1.) The facility pays a surcharge to send WAS offsite for tertiary handling and treatment.

Figure 1: Activated Sludge System

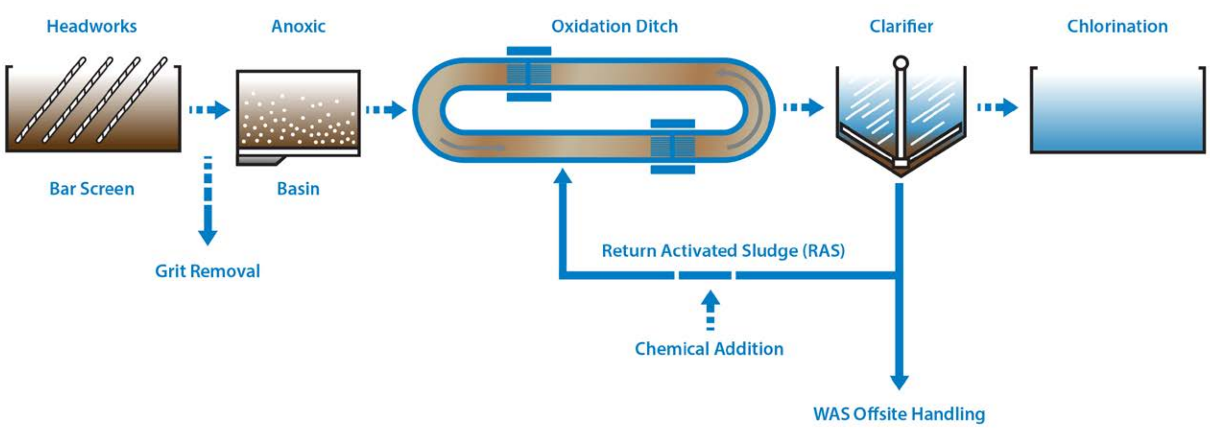

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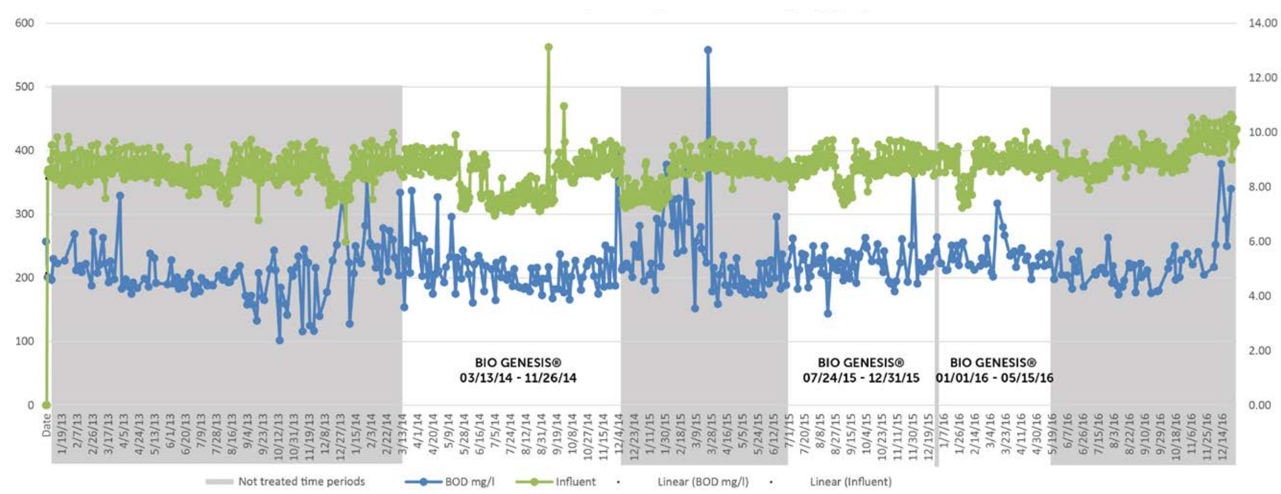
Figure 2: Influent Flow (MGD) and BOD (mg/L)



BIO GENESIS® Biostimulant with Micro Carbon Technology® Was Applied

In our analysis of the facility, we also found a history of nutrient deficiency in the wastewater. Filamentous bacteria were causing issues with settling and turbidity. Foaming was occurring not only in the oxidation ditches but in the RAS channel as well. An application program of BIO GENESIS®—a formulation of nutrients, organic acids, and natural biostimulants that balance natural microbial ecosystems—was developed using an initial shock dose of 3 parts per million (ppm) that was then optimized by using a multi-phase approach to lower the dose to approximately 1.5 ppm.

It should also be noted that, historically, the facility cleaning schedule allows one oxidation ditch to be taken off the system for cleaning per year. After addition of BIO GENESIS®, the stability of the facility's operations allowed all four ditches to be cleaned within one year during 2014.

DATA ANALYSIS

During the 3-year study (2014 to 2016), daily and monthly operational data were collected, trended, and evaluated to determine the impact BIO GENESIS® had on the system. Parameters selected for analysis included settling, nitrogen removal, power, disinfection, and WAS.

- Settling was selected due to periodic issues with settling and foaming in the system—the analysis includes SVI and settling tests.
- The facility already performed above 84% on nitrogen removal. Although significant improvements were not anticipated, the percentage of nitrogen removed was also analyzed.
- Three of the largest expenses in the wastewater facility —power, disinfection and WAS—were also selected for analysis to examine the effect BIO GENESIS® had on them.

Because of the variation of data over the 3-year study and the periodic application of the BIO GENESIS®, a statistical analysis was required to establish the product's impact on the facility.

Normality tests and an analysis of equal variances within each data set was performed by an ANOVA test. An ANOVA, or an analysis of variance, is a statistical method of analysis in which the variation in a set of observations is divided into distinct components. Once normality and equal variances were established, a variety of additional statistical tests were used to find the p-value*, or calculated probability, which is the probability of finding the observed, or more extreme results when the null hypothesis (H0) is true. The null hypothesis in the statistical analysis is that application of BIO GENESIS® made no significant difference each year. In this study, we set a 95% confidence level. If the p-value is less than 0.05, we can reject the null hypothesis. Subsequently, the data are not statistically similar, and a significant difference has been found between when BIO GENESIS® was and was not applied to the wastewater system.

** A p-value is used to weigh the strength of the data set or information against a null hypothesis.*

Normality tests and equal variances tests were performed and are summarized in Table 1. Table 2 lists the flow of statistical analysis performed for each data set (see Flowchart 1). The support data for the analysis can be found in Appendices A–C.

Table 1: Tests for Normality and Equal Variances

Year	Power	% N Removal	SVI	Disinfection	WAS
2014	normal non-equal	normal equal	normal non-equal	normal equal	normal equal
2015	normal equal	non-normal non-equal	non-normal non-equal	normal equal	non-normal non-equal
2016	normal non-equal	normal equal	normal equal	normal non-equal	non-normal non-equal

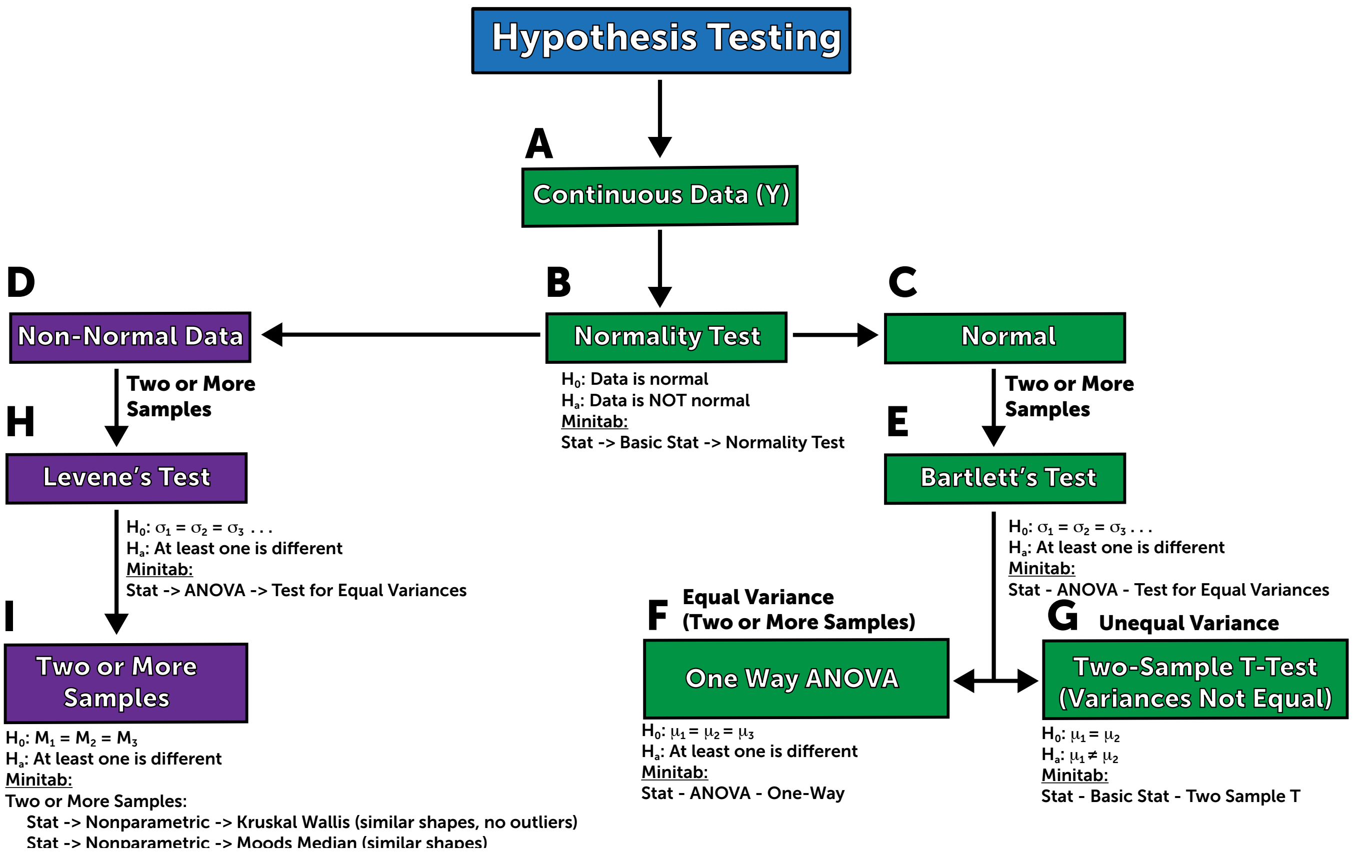
Table 2: Statistical Methodologies

Year	Power	% N Removal	SVI	Disinfection	WAS
2014	A,B,C,E,G	A,B,C,E,F,	A,B,C,E,G	A,B,C,E,F	A,B,C,E,F
2015	A,B,C,E,F	A,B,C,D,H,I	A,B,C,D,H,I	A,B,C,E,F	A,B,C,D,H,I
2016	A,B,C,E,G	A,B,C,E,F	A,B,C,E,F	A,B,C,E,G	A,B,C,D,H,I

In statistics, normality tests are used to determine if a data set is well-modeled by a normal distribution and to compute how likely it is for a random variable underlying the data set to be normally distributed.

Equal variances across samples is called homogeneity of variance. The unequal variance T-test is a way to create a confidence interval. The prime goal is not to ask whether two data sets differ, but to quantify how far apart the two means are. The unequal variance T-test reports a confidence interval for the difference between two means that can be used even if the standard deviations differ.

Flowchart 1: Hypothesis Testing Road Map

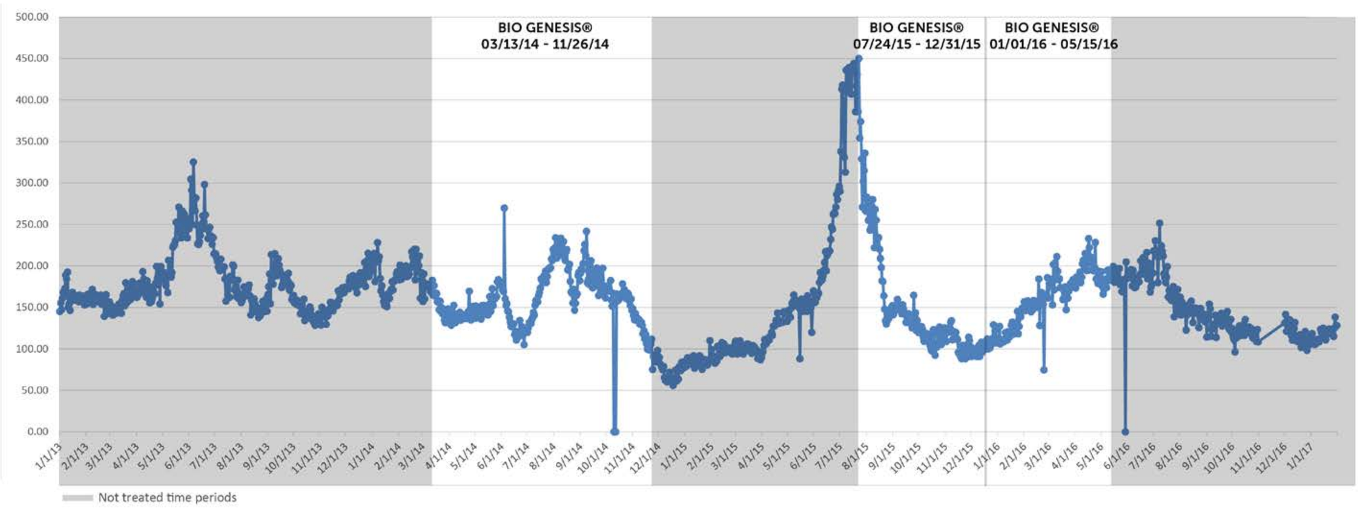


For all tests:
$P < 0.05$ Reject null hypothesis — data are not statistically the same
$P > 0.05$ Accept null hypothesis — data are statistically the same

Settling and Foam

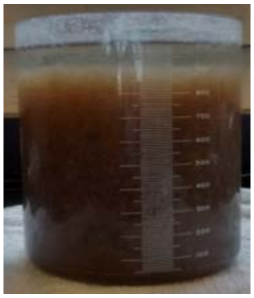
Sludge volume index (SVI) settling tests demonstrated that the facility had periodic issues with settling from 2013 to 2016. SVI is calculated by dividing the 30-minute sludge settling test by the mixed liquor suspended solids (MLSS) multiplied by 1,000. Typical SVI for this facility had been 100–200 mg/L. The most severe peak in the SVI, at 450 mg/L, occurred July 23, 2015, at which time BIO GENESIS® was reintroduced to the RAS. The SVI steadily decreased over the following week. On July 20, 2015, the 5-minute settling test showed the floc had settled to 900 ml, and to 500 ml after 30 minutes (Figure 4). Settleability testing replicated on July 30, 2015, five days after the application of BIO GENESIS®, found the floc had settled to 700 ml after 5 minutes, and to 400 ml after 30 minutes (Figure 5). It was visually noted that the foaming due to filamentous bacteria in the system had dissipated 10 days after BIO GENESIS® application.

Figure 3: Sludge Volume Index (SVI)



Sludge Volume Index (ml/g) = The 30-minute sludge settling test (ml/L) divided by the MLSS (g/L) multiplied by 1,000

Figure 4: Sludge Volume Index Test
Before BIO GENESIS® application
SVI on 7/20/2015
Settling tests were performed prior to application

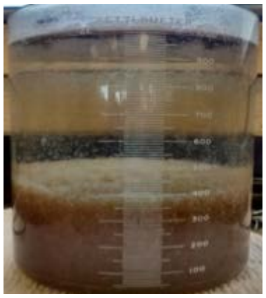


5 minutes:
SVI 900 mL.

30 minutes:
SVI 500 mL.

Figure 5: Sludge Volume Index Test
After BIO GENESIS® application
SVI on 7/30/2015
Product application was July 25, 2015

5 minutes:
SVI reduced to 700mg/L.



30 minutes:
SVI under 400 mL.

Figure 6: Oxidation Ditch With Foaming
Before BIO GENESIS® application

Figure 7: Oxidation Ditch Without Foaming
After BIO GENESIS® application

The foaming issues caused by filamentous bacteria were eliminated within 10 days of product application.

In reviewing statistical p-value data in Table 3, a significant difference was found between when BIO GENESIS® was and was not in the system. T-tests indicate mitigating factors in the system due to operations in 2015; overall however, the addition of BIO GENESIS® made significant improvement in 2014 and 2016.

Table 3: P-Values After Statistical Analysis of SVI Test Results

Year	SVI
2014	0.000
2015	0.649
2016	0.000

P < 0.05 Reject null hypothesis — data are not statistically the same
P > 0.05 Accept null hypothesis — data are statistically the same

Nitrogen removal

Because the wastewater facility was consistently achieving greater than 84% denitrification prior to product addition, total nitrogen removal and nitrate/nitrite removal were not expected to change significantly with application of BIO GENESIS®. Total nitrogen and nitrate/nitrite removal were statistically analyzed, although data were limited due to monthly data capture. The null hypothesis could be dismissed statistically for 2015 (see Table 4), which correlates with a direct impact on nitrogen removal within the system. Trending of nitrate/nitrite shows that as overall system stability improved, denitrification stabilized as well.

Figure 8: Total N Removal

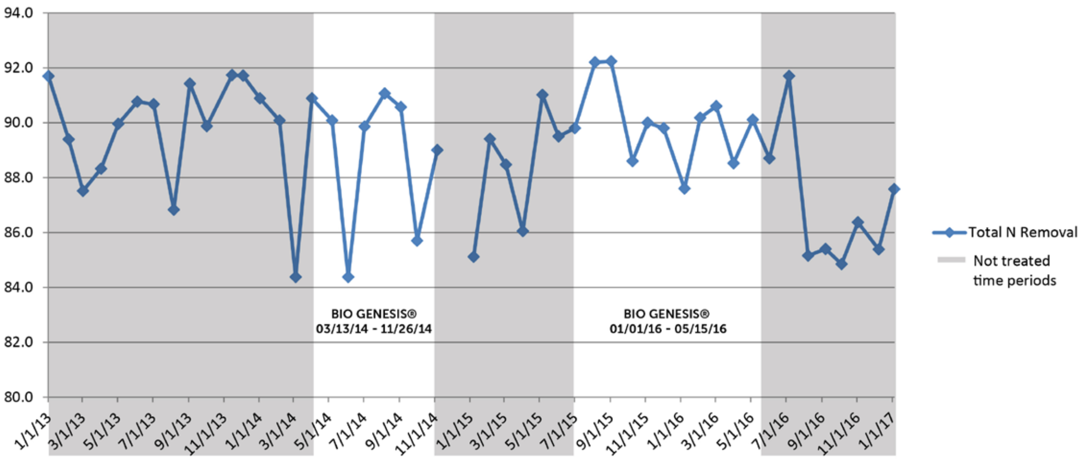


Figure 9: NO_3/NO_2 % Removal

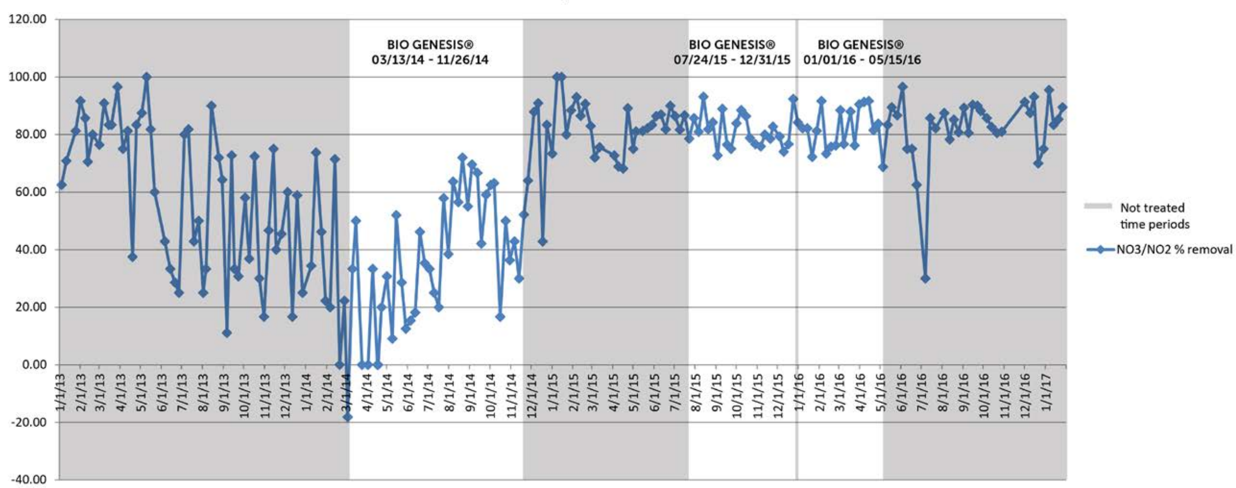


Table 4: P-Values After Statistical Analysis of Nitrogen Removal

Year	% Nitrogen Removal
2014	0.398
2015	0.021
2016	0.053

$P < 0.05$ Reject null hypothesis — data are not statistically the same
$P > 0.05$ Accept null hypothesis — data are statistically the same

Power Consumption

Power consumption was evaluated from 2014 to 2016, as power is one of the greatest expenses in wastewater treatment. During the analysis, operations made mechanical adjustments to wasting, aeration, and recirculation to manage increasing flow and BOD loading on the wastewater system. Facility operators were also actively streamlining the wastewater system, which is reflected in the overall downward trend in power usage.

Although power use increased following system shut-downs and equipment changes, overall power use steadily declined after product addition from 2014 to 2016. Statistical testing shows that p-values were less than 0.05, thus verifying that BIO GENESIS® significantly impacted power use in the system. The overhead savings influenced the facility supervisor to continue using the product. Along these lines, we can ascertain that a healthy microorganism population decreases the requirement on wastewater mechanical systems, which, in turn, lowers power requirements costs.

Figure 10: General KWH

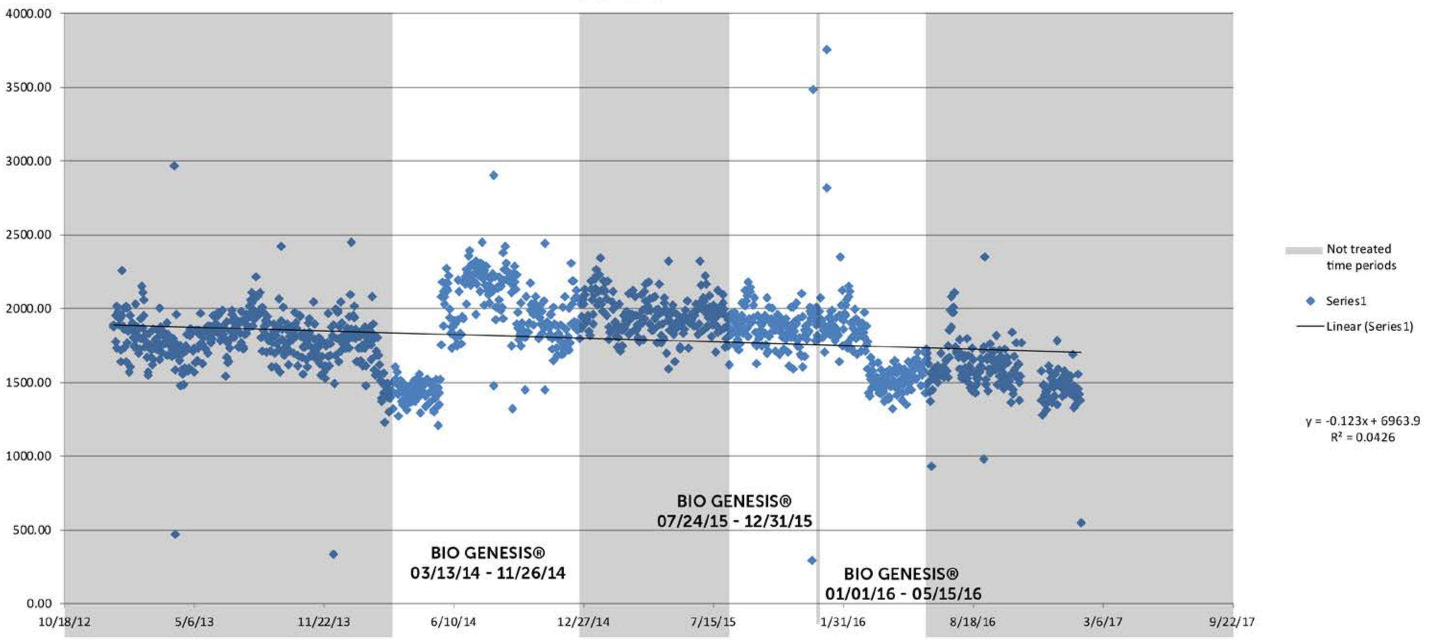


Table 5: P-Values After Statistical Analysis of Power Consumption

Year	Power
2014	0.001
2015	0.000
2016	0.000

P < 0.05 Reject null hypothesis — data are not statistically the same
P > 0.05 Accept null hypothesis — data are statistically the same

Disinfection

Effluent disinfection was reviewed as well during application of BIO GENESIS®. From 2014 to 2016, the sodium hypochlorite used for disinfection varied, sometimes greatly, from 292 gallons per day to 1176 gallons per day. Yearly totals are tabled below in Table 6.

Table 6: Disinfection in Gallons

Total	2014	2015	2016
NaOCl gallons	172,723	168,756	175,126

Due to the wide variation in sodium hypochlorite use, a statistical analysis was required to evaluate disinfection with and without BIO GENESIS®. Table 7 shows that all the p-values for disinfection were less than 0.05; accordingly, it is concluded that the application of BIO GENESIS® significantly impacted the facility's use of sodium hypochlorite, which was a cost savings for the municipality.

Table 7: P-Values After Statistical Analysis of Disinfection

Year	Disinfection
2014	0.000
2015	0.000
2016	0.000

P < 0.05 Reject null hypothesis — data are not statistically the same
P > 0.05 Accept null hypothesis — data are statistically the same

Influent vs. WAS

The municipal facility pays additional costs toward third-party processing and disposal of WAS. Between 2014 and 2016, the expansion of the local restaurant district and residential areas resulted in a steady increase of wastewater influent and WAS production. Table 8 shows yearly totals in million gallons per year (MGY) of influent and WAS and yearly percentages of influent converted to WAS. Total influent increased 12% between 2015 and 2016. However, during this same time, with the application of BIO GENESIS®, WAS increased only 2.4%.

Table 8: Influent to WAS

Year	Total Influent (MGY)	Total WAS (MGY)	WAS%
2014	3,132	168	5.37
2105	3,076	166	5.4
2016	3,446	170	4.93

Statistical analysis performed for WAS production found that the null hypothesis could be rejected for each year. Notwithstanding several external influences, application of BIO GENESIS® significantly reduced the total amount of WAS that was produced, which in turn reduced surcharges.

Table 9: P-Values After Statistical Analysis of WAS Reduction

Year	WAS
2014	0.000
2015	0.000
2016	0.000

P < 0.05 Reject null hypothesis — data are not statistically the same
P > 0.05 Accept null hypothesis — data are statistically the same

CONCLUSION

A case study using BIO GENESIS® was performed over 3 years at an Arizona municipal oxidation ditch wastewater system to address SVI and foaming issues as well as existing nutrient deficiencies. Due to the variable product application dates in response to periodic system stresses, a rigorous statistical analysis was performed to evaluate the impact of BIO GENESIS® during the 3-year period. It was found that, when consistently used, BIO GENESIS® reduced SVI and foaming issues. Application of BIO GENESIS® had an even greater impact on the reduction of power consumption, disinfection and WAS production. This translates to significant cost savings in several operational areas, including overhead costs for power, WAS treatment, and secondary products.

Citations:

1. Whitmer S., Jennings H. (2015) Micro Carbon Technology®: A Powerful and Proven Technology to Improve Wastewater Treatment Efficiency, TAPPI PEERS Conference. Available at https://imisrise.tappi.org/TAPPI/Products/15/PEERS/15Peers31.aspx

2. Marstaller T. (1992) Effect of Chlorination on Filamentous Growth and Nitrification in Batch Fed and Continuous Activated Sludge Systems, (unpublished Master of Science thesis, University of Manitoba), 16–32.

3. Yu L., Joo-Hwa T. (2001) Strategy for minimization of excess sludge production from the activated sludge process, *Biotechnology Advances*, 19:2, 97–107.

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