

Enhanced Sludge Reduction Using External Bioaugmentation at a Full-Scale Municipal Wastewater Treatment Plant

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ABSTRACT

One of the biggest burdens facing municipal wastewater treatment plants are the expenses of hauling and disposing of residual biosolids, or sludge. In 2007, United States municipal wastewater treatment plants produced about 7.7 million dry tons of biosolids, according to sources relying on EPA estimates. Hauling costs, tipping fees and the availability of land application sites forces many administrators to search for new ways to reduce the quantity of sludge produced by the wastewater treatment process. A full-scale activated sludge wastewater treatment plant selected an emerging technology to enhance degradation of biosolids without any digestion process at the plant. The results show that using an external source of genus *Bacillus* bacteria added to the outer reaches of the sewer collection system improved operational performance at the plant and will save the municipality an estimated \$96,000 of operating expenses in the first year of treatment. This report describes the plant performance improvements, the evaluation metrics, the history and discussion of the plant process, and the environmental impacts resulting from external bioaugmentation introduced to the sewer collection system.

Keywords: bacteria, bioaugmentation, biofilm, biosolids, nitrogen

INTRODUCTION

The Farmington Water Pollution Control Authority (FWPCA) selected an emerging technology in collection system bioaugmentation to reduce sludge output. In addition to reducing sludge production, the collection system bioaugmentation program also improved other aspects of plant operation, including nitrogen removal and effluent water quality. This paper explores the effects of In-Pipe Technology's collection system bioaugmentation treatment on the Farmington wastewater treatment plant (WWTP) and the resultant operating improvements and cost savings.

1 - PROJECT HISTORY

The FWPCA WWTP treats an average of 3.9 million gallons per day (MGD) of wastewater from a number of small communities in the Farmington Valley including Farmington, Burlington and Avon. The plant discharges into the Farmington River, a tributary to the Connecticut River, which flows into Long Island Sound.

To obviate the growing nutrient enrichment problem in Long Island Sound, the Connecticut Department of Environmental Protection (CT DEP) created the Nitrogen Credit Exchange (NCE) program to control the discharge of nitrogen by assigning discharge limitations, according to plant throughput and geographic location, that incentivize municipalities throughout the watershed to improve nitrogen removal. The discharge limit for the Farmington WWTP at the time of the project startup was 203 pounds of nitrogen per day as a monthly average. The penalty for exceeding the nitrogen discharge mass limit allotted under the NCE program is the purchasing of nitrogen credits in proportion to the amount of nitrogen discharged in excess of the limit. As a participant in this program, the FWPCA paid nearly \$18,000 in nitrogen credits toward the program in 2009.

The process that the Farmington WWTP uses to treat the wastewater (a variation on the complete-mix activated sludge process) is designed for effective ammonia-nitrogen and biochemical oxygen demand (BOD_5) removal. It has no difficulties meeting the 30 mg/L BOD_5 , TSS and 7 mg/L (lowest seasonal) ammonia-nitrogen discharge limit year-round. However it is not as effective at removing the nitrate created during nitrification. The Farmington WWTP typically produced effluent water with a nitrate content of 4-6 mg/L nitrate. This is probably because the process does not have dedicated anoxic zone to facilitate more complete denitrification.

Since the NCE program took effect, the WWTP operators worked to optimize nitrogen removal by making operational changes to improve denitrification. However, the plant consistently exceeded the NCE limits for total nitrogen and was thus exposed to the additional expense of purchasing nitrogen credits. Also, because the plant does not have a dedicated anoxic zone, some denitrification

occurs in the sludge blanket within the secondary clarifiers, impairing settleability of the sludge. This condition results from nitrogen gas bubbles, produced during uncontrolled denitrification, floating the sludge in the clarifier and reducing settleability, or contributing to excess total suspended solids (TSS) in the final effluent.

The FWPCA pursued a variety of different methods to reduce the cost of biosolids disposal including anaerobic digestion, aerobic digestion and composting. However none of these options proved more cost effective for the Authority than the process of directly dewatering of waste activated sludge with the belt filter press process and disposal by incineration at nearby Hartford, Conn. The FWPCA aimed to control solids disposal costs by initiating a collection system bioaugmentation service through In-Pipe Technology Company, Inc.

In-Pipe Technology provides a service that supplies a consortium of live, facultative, heterotrophic naturally occurring bacteria into the outer reaches of the wastewater collection system. Once introduced into the collection system this treatment strategy enhances the microbial community such that the In-Pipe bacteria out compete the endemic bacteria for food and nutrients to populate and eventually thrive in the sewer environment.

The In-Pipe microbes impart treatment on the wastewater during transit in two ways: 1) converting the inner surface area of the pipe into a beneficial biofilm, similar to the biofilm present in attached growth activated sludge systems and 2) populating the bulk liquid wastewater and constantly seeding the wastewater treatment process with beneficial microbiology that are capable of nitrification and denitrification.^[1]

2 - APPLICATION OF COLLECTION SYSTEM BIOAUGMENTATION

The wastewater collection system in Farmington, Connecticut is comprised of gravity sewers, gravity interceptors and force mains feeding the WWTP. To the northwest, a long gravity interceptor collects wastewater from sections of Avon and transports it over 7 miles to the plant, intercepting small collection system basins along the way. To the southwest and to the east, a series of gravity sewer basins drain into a network of pump stations and force mains that transport the wastewater to the FWPCA WWTP.

In-Pipe completed the installation of 39 G2 dosing units in 3 separate phases over 6 weeks to allow for the gradual conversion of the collection system biofilm to the IPT biofilm. The first phase included the installation of the 13 treatment locations closest to the FWPCA WWTP. Both subsequent phases added 13 additional locations each, with

the dosing locations expanding farther out in the collection system from the plant with each phase.

Each G2 dosing unit (G2 Panel) consists of a self contained enclosure housing a battery powered solenoid pump operated by a small circuit board. The dosing panel holds a 1 liter replaceable reservoir with a 30 day supply of microbes that dispenses a preset volume of IPT microbial formula per day. The microbial formula contains the proper blend of bacteria to establish a beneficial sewer biofilm, remove fats, oil and grease (FOG), and to inhibit sulfate-reducing bacteria (SRB) in the collection system while improving treatment performance at the plant. The G2 panel is certified by the CSA as intrinsically safe and the microbial formula is proprietary to In-Pipe Technology.

The dosing panels installed in the distant reaches of the collection system provide the IPT bacteria abundant interior surface area in the collection system to form a biofilm. The vast surface area of biofilm that develops with In-Pipe treatment transforms a passive conveyance system, into a part of the wastewater treatment process.

3 - RESULTS

After 10 months of collection system bioaugmentation treatment, In-Pipe Technology reviewed the performance of the plant and compared performance with bioaugmentation to the prior 15 months of plant operations immediately before bioaugmentation. In-Pipe Technology examined influent pollutant load, pollutant removal efficiencies, effluent pollutant load, plant nitrogen balance, sludge production and collection system improvements. The results are presented below:

3.1 Influent Pollutant Load

Before bioaugmentation, the average daily influent biochemical oxygen demand (BOD_5) pollutant load was 11,711 lbs/day and with bioaugmentation, the influent BOD_5 load decreased by 4% to 11,204 lbs/day. Influent TSS before bioaugmentation averaged 14,017 lbs/day and decreased by 2% down to 13,796 lbs/day.

3.2 Pollutant Removal Efficiency

The pollutant removal efficiency of the process improved during collection system bioaugmentation. BOD_5 and TSS removal before treatment averaged 96.8% and 99.0% respectively. During treatment, the performance improved such that the plant achieved 98.0% BOD_5 removal and 99.4% TSS removal.

The BOD_5 and TSS removal performance before IPT treatment was adequate. However this result supports the claim that the constant addition of facultative, heterotrophic bacteria into the collection system enhance

	Influent			Effluent				Removal Efficiency			
	BOD ₅	TSS	NH ₃	BOD ₅	TSS	TKN	NO _X	TN	BOD ₅	TSS	TN
	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day	lbs/day
Before IPT Treatment	11,711	14,017	583	372	142	99.8	162.9	262.8	96.8%	99.0%	54.9%
With IPT Treatment	11,204	13,796	606	224	87	77.7	111.4	189.2	98.0%	99.4%	68.8%

Table 1: Comparison of Pollutant Loads and Removal Efficiencies Before and With IPT Treatment

the biological degradation of organic materials, improving the treatment process performance.

3.3 Effluent Pollutant Load

Before bioaugmentation, the daily effluent BOD₅ and TSS load averaged 372 lbs/day and 142 lbs/day respectively. After bioaugmentation, the effluent BOD₅ load decreased by 40%, to 224 lbs/day and the effluent TSS load decreased by 39% to 87 lbs day.

3.4 Nitrogen Removal

Influent ammonia load to the plant before bioaugmentation averaged 583 lbs/day which rose to 606 lbs/day with bioaugmentation, an increase of 4%. Effluent total kjeldahl nitrogen (TKN) decreased by 22%, from 99.8 lbs/day to 77.7 lbs per day with bioaugmentation. Effluent nitrate and nitrite (NO_x) averaged 162.9 lbs/day before bioaugmentation and decreased to 111.4 lbs/day with bioaugmentation. Finally, effluent total nitrogen (TN) averaged 262.8 lbs/day before bioaugmentation and decreased by 28% to 189.2 lbs/day with bioaugmentation.

The In-Pipe blend of bacteria includes Genus *Bacillus* bacteria; a classification of heterotrophic, facultative anaerobic bacteria that can grow under aerobic, anoxic and anaerobic conditions. These bacteria participate directly in the denitrification process^[1] and assist in the degradation of insoluble organic materials and break them down into readily bio-available compounds^[2] that are essential to the denitrification process.

3.5 Nitrogen Removal Efficiency

The nitrogen removal efficiency of the plant improved significantly during bioaugmentation. Before bioaugmentation, the ammonia removal efficiency of the process was 83%, according to influent ammonia load and effluent TKN load. After bioaugmentation, the ammonia removal efficiency increased to 87%. Similarly, the overall nitrogen removal efficiency of the plant, according to

effluent TN and influent NH₃, improved from 55% removal to 69% removal.

3.6 Sludge Production

The amount of sludge produced during In-Pipe treatment was significantly less than the sludge produced before In-Pipe treatment. Before treatment, the FWPCA WWTP produced an average of 75.6 dry tons of sludge per month and with IPT treatment, the plant produced 71.4 average dry tons of sludge per month, a reduction of 5.6%. Over 10 months of treatment, this added up to a reduction of over 42 dry tons of sludge and significant cost savings to the FWPCA. See Table 2 for details.

Month	Before IPT Dry Tons Sludge	With IPT Dry Tons Sludge	Dry Tons Difference
May	84.7	73.05	-11.7
Jun.	82.4	84.73	2.3
Jul.	82.2	69.72	-12.5
Aug.	68	71.35	3.4
Sept.	73.3	67.04	-6.3
Oct.	71.9	66.5	-5.4
Nov.	65	78.34	13.3
Dec.	77.2	74.67	-2.5
Jan.	77	70.27	-6.7
Feb.	74.5	58.46	-16.0
Ave.	75.6	71.4	-4.21
Total	756.2	714.13	-42.07

Table 2: Comparison of Sludge Production During Like Months Before and With IPT treatment.

Though sludge production during the 10 months with IPT treatment showed a significant decrease, the sludge production continues to trend downward as of this writing. This suggests that a greater rate of sludge reduction is likely

as treatment continues which is consistent with findings during other IPT programs.^[3]

CONCLUSION

The Farmington Water Pollution Control Authority (FWPCA) selected an emerging technology, collection system bioaugmentation, to reduce operating costs and improve the performance of the wastewater treatment process. In-Pipe provided the collection system bioaugmentation service by installing and maintaining 39 microbe dosing panels throughout the wastewater collection system. Each panel constantly dosed small amounts of IPT's proprietary blend of bacteria to the wastewater during transit to the treatment plant.

This report examines the changes in performance of the plant in an untreated condition compared to the first 10 months with IPT treatment. The primary objective of the program was to cost-effectively reduce the amount of sludge produced from the process. This objective was met with the additional benefit that many other aspects of the FWPCA WWTP process showed favorable changes during the period of time when In-Pipe was performing the collection system bioaugmentation service. The In-Pipe treatment optimizes the biology of the wastewater, the fundamental mechanism of the biological treatment process.

Sludge production decreased by nearly 6%, while the plant process performance showed marked improvement in the form of both removal efficiencies and effluent water quality. The single most significant benefit to the FWPCA, apart from reduction in sludge output, was the improvement in nitrogen removal of the process. This year, with IPT treatment, the plant is on track to purchase just \$5,000 of NCE credits as opposed to the nearly \$15,000 that the FWPCA would have spent, had WWTP performance continued at the same level it had before IPT treatment.

Further observation will provide additional understanding of the full impact of In-Pipe treatment on the FWPCA WWTP. Sludge production continues to trend downward and nitrogen levels in the plant effluent remain suppressed as treatment continues. However, the first 10 months of treatment alone show encouraging results and demonstrate that optimizing the microbiology of the wastewater in the collection system supports improvements in performance in the plant process, and ultimately our surrounding water environment.

REFERENCES

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