IMPROVED TREATMENT PLANT PERFORMANCE THROUGH PRETREATMENT IN THE COLLECTION SYSTEM USING PATENTED IN-PIPE TECHNOLOGY

Final Report

Prepared for

THE NEW YORK STATE

ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

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Contract No. 8772

March 23, 2012

NOTICE

ABSTRACT

In this study, the effectiveness of In-Pipe Technology (IPT) for improving wastewater influent characteristics, wastewater effluent quality and reducing treatment plant costs was demonstrated at two small sewer districts, one domestic (Sewer District #20 – Leisure Village) and one industrial (Sewer District #18 – ITT), in Suffolk County, Long Island, New York. The effectiveness of IPT was evaluated relative to performance without IPT, designated as either "Pre-IPT" or "Post-IPT" since IPT fully utilizes the existing sewer infrastructure and extends the waste treatment boundary layer out from the wastewater treatment plant (WWTP) to include the sewer system.

In the Leisure Village WWTP, the influent biological oxygen demand (BOD), total suspended solids (TSS) and total Kjeldahl nitrogen TKN load to the WWTP With-IPT compared to Pre-IPT treatment decreased by 13% from 454 lbs/day to 397 lbs/day, 13% from 485 lbs/day to 424 lbs/day, and 5% from 116 lbs/day to 110 lbs/day, respectively. The effluent BOD, TSS, and TKN loads With-IPT compared to Pre-IPT treatment decreased by 17% from 41 lbs/day to 34 lbs/day, 30 % from 20 lbs/day to 14 lbs/day, and 15% from 5.6 lbs/day to 4.75 lbs/day, respectively. Electrical energy consumption in the equalization (EQ) tank and Sequencing Batch Reactor (SBR) treatment during Post-IPT operation compared to With-IPT treatment increased by 14% from 230 kWh/day to 262 kWh/day and by 23% from 307 kWh/day to 377 kWh/day, respectively.

In the ITT WWTP, influent BOD, TSS and TKN loads to the WWTP With-IPT compared to Pre-IPT treatment were decreased by 32% from 967 lbs/day to 655 lbs/day, 36% from 834 lbs/day to 533 lbs/day and 23% from 52 lbs/day to 40 lbs/day, respectively compared with Pre-IPT treatment. The effluent BOD, TSS and TKN load decreased by 44% from 70 lbs/day to 39 lbs/day, 30% from 20 lbs/day to 14 lbs/day, and 33 % from 7.9 lbs/day to 5.3 lbs/day, respectively. Energy consumption was not evaluated for the ITT treatment plant.

During the demonstration, IPT improved the raw wastewater characteristics, reduced influent loads to the treatment plant, improved effluent quality, reduced electrical energy usage, and reduced sludge production without additional energy input or capital expansion.

Key Words:
IPT Bioaugmentation, Compliance, Energy Reduction, Facultative, Nutrient Removal, Nitrogen Reduction, Sewer, Treatment Improvement, Wastewater.

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SUMMARY

Suffolk County has significant concerns about the effluent nitrogen that is discharged by the 180+ small Sanitary Treatment Plants (STPs) that are distributed throughout the county. Growth and development has created a very large number of STP's using primary ground discharge through effluent seepage beds of sand filter infiltration basins. Because most of Suffolk County gets their drinking water from a 'sole source aquifer' under Long Island, there was a growing concern for the effluent nitrogen load discharged into these basins. Most of the 180+ STPs have a State Pollution Discharge Elimination System (SPDES) discharge limit of 10 mg/L for effluent nitrogen. Many of these facilities are beyond their planned design life, many face costly upgrades, and most are at the SPDES permitted capacity for treatment.

The Leisure Village WWTP was permitted for 0.3 MGD and utilized a Sequencing Batch Reactor process. The effluent nitrogen limit was a daily average of less than 10 mg/l. Due to the way the treatment plant was constructed with a side water depth of 10 feet rather than the more acceptable design of 12 feet, it was historically difficult to maintain 3,000 mg/L mixed liquor suspended solids (MLSS) for effective nitrogen removal in cold weather. A new mechanical and control equipment upgrade was planned to overcome operational problems. In contrast, the ITT Plant serviced an industrial park with wastewater pollutant concentrations two to four times (2-4x) higher than typical domestic wastewater. The current plant was designed to treat 0.25 MGD. Due to capacity constraints, a new, larger facility was designed that will be capable of treating 1.65 MGD.

The New York State Energy Research and Development Authority implemented the In-Pipe Technology (IPT) bioaugmentation program for improving wastewater influent characteristics, wastewater effluent quality and reducing treatment plant costs including energy consumption at two small sewer districts, one domestic (Sewer District #20 – Leisure Village) and one industrial (Sewer District #18 – ITT), in Suffolk County, Long Island, New York. The goal was to use IPT treatment to improve the characteristics of the influent wastewater going to these plants. The hypothesis was that with improved influent wastewater characteristics, these smaller facilities might be able to avoid challenges of upgrading the plant. In addition to the capital cost savings and reduced aeration electrical requirements, reduced waste sludge production was also expected as an additional IPT benefit thereby reducing the plants' operating costs and environmental impact.

The IPT bioaugmentation process consists of the continual addition of high concentrations of select, facultative, symbiotic, spore-forming, naturally-occurring, non-pathogenic bacteria at multiple points located in the outer reaches of the wastewater collection system in order to, (1) grow throughout the surface of the sewer pipes and thereby dominate the sewer biofilm with beneficial bacteria, (2) improve the ability of the sewer biofilm to degrade the organic material, and, (3) take advantage of the retention time of the wastewater within the sewer allowing the added bacteria additional time to degrade the waste.

In the Leisure Village collection system, influent BOD, TSS and TKN loads at the WWTP With-IPT treatment compared to Pre-IPT decreased 13% from 454 lbs/day to 397 lbs/day, 13 % from 485 lbs/day to 424 lbs/day, and 5% from 116 lbs/day to 110 lbs/day, respectively. In the ITT collection system, influent BOD, TSS and TKN loads With-IPT treatment compared to Pre-IPT decreased 32% from 967 lbs/day to 655 lbs/day, 36% from 834 lbs/day to 533 lbs/day and 23% from 52 lbs/day to 40 lbs/day, respectively. IPT's robust and highly adaptive bacteria are continually added to the wastewater collection system in high concentrations. Consequently, they grow, modify the indigenous sewer biofilm, and dominate the sewer biofilm thereby establishing a beneficial microbial population in the biofilm. Indigenous fecal bacteria are not efficient in processing the complex wastewater organics whereas the IPT heterotrophic bacteria are specifically selected because they are able to more effectively degrade the complex wastewater organics.

Electrical energy cost savings were achieved with IPT bioaugmentation treatment. During Post-IPT operation compared to With-IPT operation at Leisure Village, energy consumption in the EQ tank and SBR increased by 14% from 230 kWh/day to 262 kWh/day and by 23% from 307 kWh/day to 377 kWh/day, respectively. IPT heterotrophic bacteria are facultative anaerobes and do not require the presence or absence of dissolved oxygen (DO) or other electron acceptors in order to function. However some portion of this energy reduction could be attributed to process related operational changes that were carried out by the County plant personnel. Because a significant amount of the organics and nitrogen are transformed in the sewer, it functions as a very effective pre-treatment step with dominant IPT bacteria present. IPT achieved energy savings at Leisure Village by, (1) reducing aeration in the EQ tank to lower the dissolved oxygen (DO) level, (2) reducing the SBR aeration cycle time (fill/react + react) from approximately 144 minutes/cycle to an estimated 115 minutes/cycle, and, (3) operating the aerated digester in a facultative mode (without aeration).

Although operational changes were made to save energy costs, improved effluent quality was always achieved in both plants due to the presence of IPT bacteria throughout the process. The effluent BOD, TSS, and TKN loads at Leisure Village WWTP With-IPT compared to Pre-IPT decreased 17% from 41 lbs/day to 34 lbs/day, 30% from 20 lbs/day to 14 lbs/day and 15% from 5.6 lbs/day to 4.75 lbs/day, respectively. The effluent BOD, TSS and TKN loads from ITT WWTP With-IPT compared to Pre-IPT decreased 44% from 70 lbs/day to 39 lbs/day, 30% from 20 lbs/day to 14 lbs/day, and 33% from 7.9 lbs/day to 5.3 lbs/day, respectively.

The results of this study confirmed that the patented IPT treatment develops the collection system into an active part of the wastewater treatment process by extending biological treatment from the plant into the sewer collection system. Utilizing miles of existing sewer pipe, IPT converts the passive sewer system into a significant treatment operation. Performance in the collection system provides increased additional capacity within the plant, forestalls costly upgrades, and extends the life of the existing infrastructure.

INTRODUCTION

GENERAL DESCRIPTION OF THE IN-PIPE PROCESS

The IPT process consists of continual addition twenty-four hours per day, seven days per week (24/7) of high concentrations of facultative, symbiotic, spore-forming, naturally-occurring, non-pathogenic bacteria to the wastewater collection system to reinforce the natural biological processes. IPT bacteria are specifically selected and formulated to effectively degrade a wide variety of organic compounds normally found in domestic wastewater. IPT standard domestic formulations are adjusted to target specific biodegradable compounds found in industrial wastewater streams.

The IPT process adds bacteria to the outer reaches of the wastewater collection system in order to, (1) grow throughout the surface of the sewer pipes and thereby dominate the sewer biofilm with beneficial bacteria, (2) improve the ability of the sewer biofilm to degrade the organic material, and (3) take advantage of the retention time of the wastewater within the sewer to allow the added bacteria additional time to degrade the waste.

In-Pipe G2 Dosing Panel

IPT bacteria are compatible with all wastewater treatment processes because they are facultative in nature and do not require the presence or absence of dissolved oxygen (DO) in order to function. Because IPT bacteria are continually added to the wastewater collection system in high concentrations, they modify and dominate the indigenous sewer biofilm. Indigenous fecal bacteria are not as efficient in processing the wastewater whereas the IPT bacteria are specifically selected because of their ability to more effectively degrade the wastewater organics. Moreover, IPT microbes contribute to the nitrification and denitrification processes and contribute to overall nitrogen removal from wastewater.

Moreover, IPT bacteria have a broad temperature operating range compared to indigenous fecal bacteria that are adapted to human body temperature. The modification of indigenous (non-beneficial) biofilm bacteria through the addition of large quantities of IPT bacteria, and the resulting vastly increased organic material degradation rates results in a decrease in the amount of organics and nitrogen in the treatment plant influent.

In addition to the positive effects of the reduction in influent organics and nitrogen, the IPT process vastly increases the total quantity of active and beneficial bacteria entering the wastewater treatment plant. The very large increase in active, beneficial biomass entering the plant reduces the time required within the treatment process for carbon and nutrient removal. This increase in the amount of influent bacteria is achieved through transformation of waste products within the wastewater collection system and assimilation into additional beneficial bacteria, and results in a net reduction of the total carbon and nitrogen loads to the plant. Also, with the dramatic increase in the proportion of facultative bacteria with IPT treatment relative to non-IPT treated sewage, there is better utilization of available oxygen. Lower oxygen demand resulting from a reduction in influent organics and nitrogen combined with increased efficiency of oxygen utilization due to a higher proportion of aerobically capable bacteria enables an overall reduction in oxygen delivery demands.

BIOCHEMISTRY & METABOLIC PRODUCTS

In-Pipe Technology introduces *Bacillus* bacteria at strategic locations throughout the sewer collection system that modify the existing biofilm in accordance with an engineered plan. The *Bacillus* formulation contains facultative anaerobes that grow under anaerobic conditions either with nitrate or nitrite as the electron acceptor, in aerobic conditions by respiration with oxygen as the final electron acceptor, or by fermentation (Ye, 2000). Respiration is the process in which nutrients are converted into useful energy in a cell. Fermentation differs from respiration in that it uses carbohydrates as the electron acceptor rather than molecular oxygen (Gerardi, 2006).

Through the continuous injection of IPT at each dosing location, the *Bacillus* bacteria dominate in the sewer biofilm. As a result, more reactions occur in the sewer biofilm and contribute to increased metabolism of wastewater compounds within the sewer that are more efficient at degradation of organics than the bacteria that are present in natural, untreated conditions (Gerardi, 2006). IPT bacteria inoculate the raw wastewater, and consequently the treatment process mixed liquor, with bacteria that are inherently more suited to the conditions in the collection system than the bacteria that exist there in untreated conditions. The IPT bacteria accelerates the transformation and assimilation of waste compounds in a variety of dissolved oxygen conditions including low oxygen levels and anaerobic sections of the collection system and the sewer biofilm. Carbon transformation under low oxygen and anaerobic conditions yields less biomass per pound of carbon transformed. Each pound of organic material transformed in the sewer during transit reduces the net sludge production at the treatment plant. This conversion involves two distinct processes, namely the conversion of TSS into a soluble format that bacteria can uptake and metabolize and the actual transformation of the soluble material into beneficial bacteria, water, carbon dioxide, and nitrogen gas.

The *Bacillus* bacteria present in the IPT formulation include common heterotrophic soil bacteria. These bacteria have many desirable qualities that can enhance biodegradation of wastewater including production of enzymes to break down slowly biodegradable materials (cellulose, starch, etc.) thereby making them more bio-available allowing transport into the cell as smaller molecules for use within the cell. Examples of some of the enzymes produced by the soil bacteria contained in the IPT formulation include: amylase, cellulase, chitinase, maltase, mannanase, xylanase, proteases, lipase, nucleases and phosphatase. When nutrient limitations become too severe for the maintenance of the IPT bacterial cells, these spore-forming bacteria begin to cannibalize other cells and feed off of the resulting solubilized nutrients to delay sporulation. If pushed beyond this stage, these bacteria are capable of going dormant by sporulation which results in a resting state where they can remain inactive for an extended time until favorable conditions for metabolism return.

As R-strategist organisms, IPT bacteria are the first organisms to grow and multiply based on the nutrients available to the microcosm. *Bacillus* species are cannibalistic, which allows them to extend substrate utilization such that organic carbon, including consumption of the prokaryotic solution within cell membranes of other life forms, is converted with a low biomass yield and simultaneous decrease of net biosolids produced per pound of Chemical Oxygen Demand (COD) removed.

By-products of the activities of the IPT bacteria are similar to by-products produced by bacteria within the untreated environment of sewers and at the treatment plant, except IPT bacteria are incapable of generating hydrogen sulfide (H_2S) and methane (CH_4) because they simply do not have the genes required to produce these gases as by-products. During respiration (aerobic growth or growth with an alternate electron acceptor), various carbon sources are catabolized by IPT bacteria through glycolysis which generates adenosine tri-phosphate (ATP) to be used for energy within the cell and various precursor metabolites leading to pyruvate. Many of the metabolites generated in the glycolytic cycle are used by other metabolic pathways in order to provide important molecules that the cell needs to grow and reproduce. Many of these bacteria have been shown to have a mixed-acid fermentation profile which results in the release of a mixture of organic acids and carbon dioxide (CO_2). Fermentation products in common gram-positive facultative *Bacillus* include such compounds as acetate, acetoin, lactate, succinate, and 2,3-butanediol to name a few. This pathway is also used by many of the enteric bacteria such as *Escherichia*, so the addition of IPT bacteria does not drastically change the profile of by-products except for no production of H_2S and CH_4.

GENERAL DESCRIPTION OF THE WASTEWATER TREATMENT PLANTS

LEISURE VILLAGE PLANT DESCRIPTION

The Leisure Village WWTP is permitted for 0.3 MGD and utilizes a Sequencing Batch Reactor (SBR) process. The effluent nitrogen limit is a daily average of less than 10 mg/l. Due to the way the treatment plant was constructed with a side water depth of 10 feet rather than the more acceptable design of 12 feet, it has been historically difficult to maintain 3,000 mg/L mixed liquor suspended solids (MLSS) for effective nitrogen removal in cold weather. The Leisure Village WWTP consists of the following unit processes:

- Rotary Screen

- Aerated equalization tank, 115,000 gallons
- Sequencing Batch Reactor, 2 tanks x 165,000 gallons each
- Aerobic digestion, 96,000 gallons

Using available collection system maps and based on average per residential unit wastewater production of 90 gallons per day, the estimated sewer retention time from the furthermost dosing locations to the Leisure Village treatment plant is 1.82 hours at the average daily flow and 0.91 hours at peak flow. Dye tests performed by the Suffolk County Department of Public Works on Thursday, October 26, 2006 between the hours of 11:00 AM to 2:00 PM determined a retention time of 0.75 hours at a preliminary dosing point upstream from the furthermost dosing location. These retention times are within the acceptable ranges for In-Pipe treatment.

ITT PLANT DESCRIPTION

The ITT plant services an industrial park with wastewater pollutant concentrations two to four times (2-4x) higher than typical domestic wastewater. The current plant is designed to treat 0.25 MGD. The ITT facility consists of the following unit processes:

- Aerated equalization, two-stages, 108,000 gallons total
- Rotating Biological Contactors (4), operated in series, 12' diameter x 25' long
- Final clarifiers (2): diameter 20', depth 10'
- Denitrification filters (4): 94" x 61" x 186"
    - Media (from bottom) 18" of 15-20mm; 12" of 3.5-7.0mm; 12" of 3.0-3.5mm; 36" of 2.5-3.0mm
- Aerobic digestion: 35,100 gallons

Using available collection system maps and based on the flow rate information provided, the total estimated sewer retention time from our outermost dosing locations to the ITT treatment plant is 2.89 hours at average daily flow and 1.28 hours at peak flow. These retention times are within the acceptable ranges for In-Pipe treatment.

PERFORMANCE EVALUATION

Because the IPT process fully utilizes the existing sewer infrastructure and extends the treatment out from the plant to include the sewer collection system, the impact of IPT must always be evaluated relative to performance without IPT, e.g., "Pre-IPT" or "Post-IPT". It is not possible, for example, to isolate a treatment line within the plant to compare against an untreated control because IPT treatment in the collection system significantly changes influent wastewater characteristics, impacting all the parallel trains within the plant, including the 'control', thereby eliminating the ability to define a 'control' train.

A comparative analysis of Pre-IPT historical performance data to performance data With-IPT was performed at Leisure Village. Given the nature of the variability of wastewater, the plant operational parameters were not changed. The solids retention time (SRT) and MLSS concentration, where applicable, remained constant throughout the project. Efficiencies were calculated to measure IPT's impact on energy consumption within individual plant processes. Twelve (12) months of data Pre-IPT and eighteen (18) months of data With-IPT were obtained in order to account for seasonal changes in wastewater temperature, loads, flows, etc. The report also includes six (6) months of additional Post-IPT data to measure the reversion from IPT's impact across individual plant processes and to provide a more in-depth analysis of efficiency improvements once IPT bacteria are no longer added to the collection system. This Post-IPT process, after IPT treatment is discontinued, is referred to as "reversion" to the uncontrolled Pre-IPT conditions. The timeline for full reversion is difficult to quantify and is dependent on several factors including wastewater characteristics, retention time, temperature, and collection system configuration. At the Leisure Village plant, the analysis compared the EQ tank and SBR aeration blower energy use With-IPT to Post-IPT as no Pre-IPT energy data was available.

Influent and effluent flow rates, BOD, TSS and TKN values were calculated based on monthly averaged values. In most cases, the sampling interval was every 7 days and samples were analyzed by the Suffolk County laboratory. Electrical energy use in the EQ tank and SBR was calculated as the % reduction in the kWh/day used. The reduction in sludge production was calculated as % reduction in dry lbs/day sludge produced and was then converted to energy savings.

LEISURE VILLAGE PLANT (SEWER DISTRICT #20)

IPT TREATMENT AT LEISURE VILLAGE

In-Pipe treatment in the Leisure Village collection system included the installation of ten (10) G2 dosing units at engineered locations under manholes at the farthest reaches of the network. Each

G2 unit dispensed approximately 32 milliliters of IPT microbial solution per day, on a fixed rate, around the clock basis. This amounted to the addition of approximately 0.1 milliliters at each location every five (5) minutes. This provides 288 distinct microbe additions per day at each of the locations. This dosing strategy added a total of about ten (10) liters of solution throughout the month, into the monthly wastewater volume of about 7.5 million gallons. In-Pipe's field service technician performed monthly service visits, inspected the condition of the collection system and treatment plant, and refilled the bottles with a new liter of microbial solution.

IPT IMPACT ON LEISURE VILLAGE TREATMENT

INFLUENT FLOW RATE

Figure 1 represents the influent flow rate for the three (3) year study period. The influent flow rate to the Leisure Village treatment plant during this study period did not change significantly. The overall mean value for the flow rate and % change in flow rate is listed in Table 1. The seasonal flow rate was compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT for the Jul-Dec period. The Jul-Dec period was selected for comparison as only Jul-Dec period Post-IPT data was available. There was no change in flow rate during Jul-Dec period throughout the three year study period (Table 1).

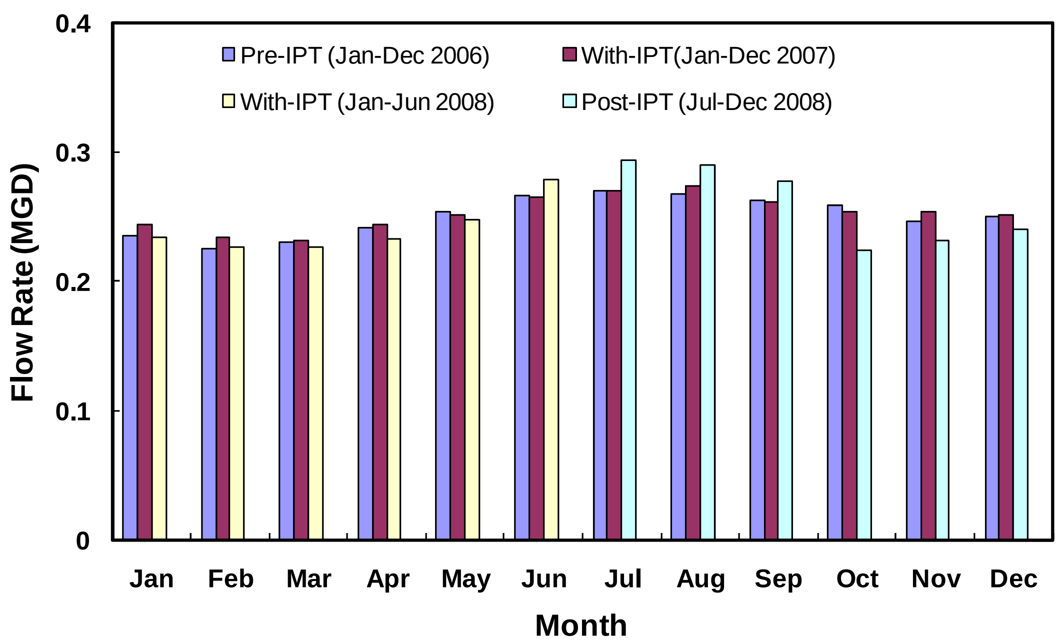

Figure 1: Monthly average influent flow rate to the Leisure Village plant over three year period

INFLUENT BOD LOAD

Figure 2 shows that influent BOD values decreased With-IPT implementation compared to Pre-IPT and Post-IPT plant performance. The overall influent BOD decreased ~13% With-IPT bioaugmentation compared to Pre-IPT treatment (Table 2). After reversion from IPT bioaugmentation, the BOD values increased ~10% (Table 2). This implies that indigenous microbial activity was less efficient than the activity during the IPT bioaugmentation period and increased BOD values were observed. The seasonal BOD load was compared to explain the seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT during the Jul-Dec period. This comparison result shows that BOD value decreased with IPT bioaugmentation and reversion from IPT results increased influent BOD load (Table 2). Since there was no significant change in flow rate during the Jul-Dec period throughout the 3 year study period (Table 1), the decreased BOD is the result of IPT bioaugmentation. Please note the values reported in December 2007 do not correspond to any failure of the IPT program. All G2 units functioned properly as documented on the Field Service Reports. However, only two samples were taken during this month which may have influenced the reported performance during the month of December 2007.

Flow rate (MGD)	**Pre-IPT Jan-Dec 2006**	**With-IPT Jan 2007-Jun 2008**	**Post-IPT Jun-Dec 2008**
Mean	0.251	0.249	0.260
Standard deviation	0.015	0.016	0.031
N (sample size)	12	12	12
Parameter	*% change*		
% Change With-IPT vs. Pre-IPT	-0.8		
% Change Post-IPT vs. With-IPT	4		
Seasonal performance analysis			
Parameter	*Flow rate (MGD)*		
Pre-IPT (Jul-Dec 2006)	0.26		
With-IPT (Jul-Dec 2007)	0.26		
Post-IPT (Jul-Dec 2008)	0.26		
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	0		
% Change Post-IPT vs. With-IPT	0		

Table 1: Leisure Village wastewater influent flow during three (3) year study period

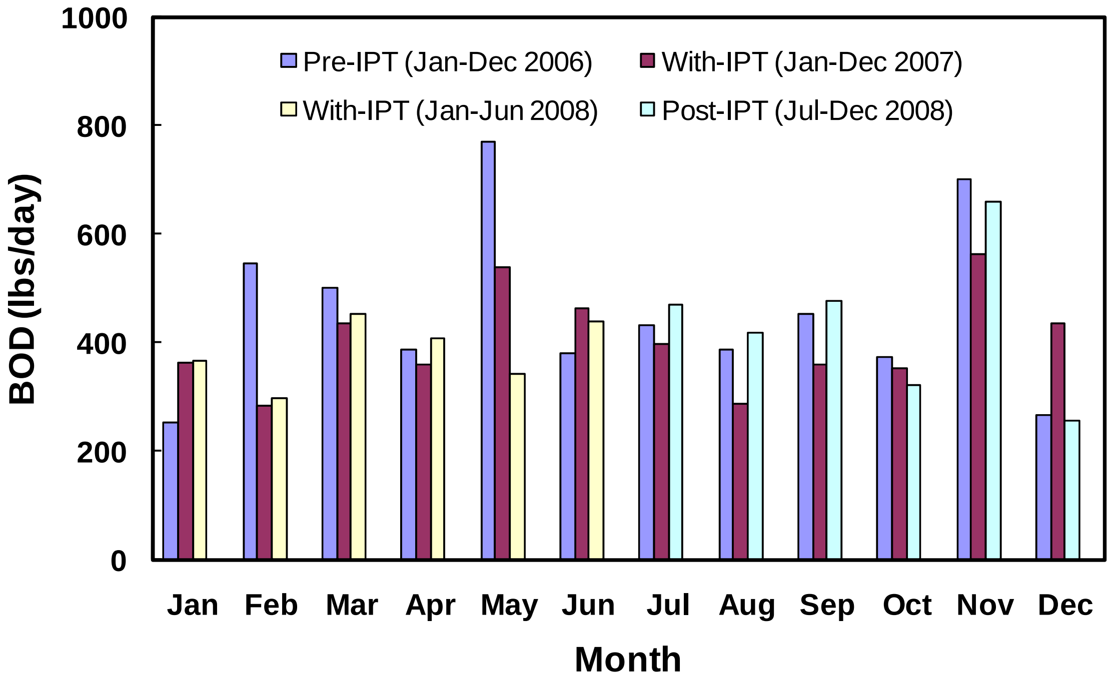

Figure 2: Monthly average influent BOD value over three year study period

Parameter	Overall Performance Analysis		
	BOD (lbs/day)	TSS (lbs/day)	TKN (lbs/day)
Pre-IPT (Jan-Dec 2006)	454	485	116
With-IPT (Jan 2007-Jun 2008)	397	424	110
Post-IPT (Jul-Dec 2008)	435	510	119
% Change With-IPT vs. Pre-IPT	-13%	-13%	-5%
% Change with Post-IPT vs. With-IPT	10%	20%	8%
Seasonal Performance Analysis			
Parameter	*BOD (lbs/day)*	*TSS (lbs/day)*	*TKN (lbs/day)*
Pre-IPT (Jul-Dec 2006)	436	510	119
With-IPT (Jul-Dec 2007)	400	420	123
Post-IPT (Jul - Dec 2008)	435	510	119
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	-8%	-17%	-3%
% Change Post-IPT vs. With-IPT	9%	21%	3%

Table 2: Leisure Village wastewater influent BOD, TSS and TKN comparing Pre-, With-, and Post-IPT treatment

INFLUENT TSS LOAD

Figure 3 shows that Influent TSS values decreased With-IPT implementation compared to Pre-IPT and Post-IPT plant performance.

The overall influent TSS decreased ~13% With-IPT bioaugmentation compared with Pre-IPT treatment (Table 2). After reversion from IPT bioaugmentation, the TSS values increased ~20% (Table 2). This implies that indigenous microbial activity was less efficient in degrading Leisure Village domestic wastewater than during the IPT bioaugmentation period. The seasonal comparison result shows that TSS value decreased With-IPT bioaugmentation ~17% and reversion from IPT results increased ~21% TSS load (Table 2).

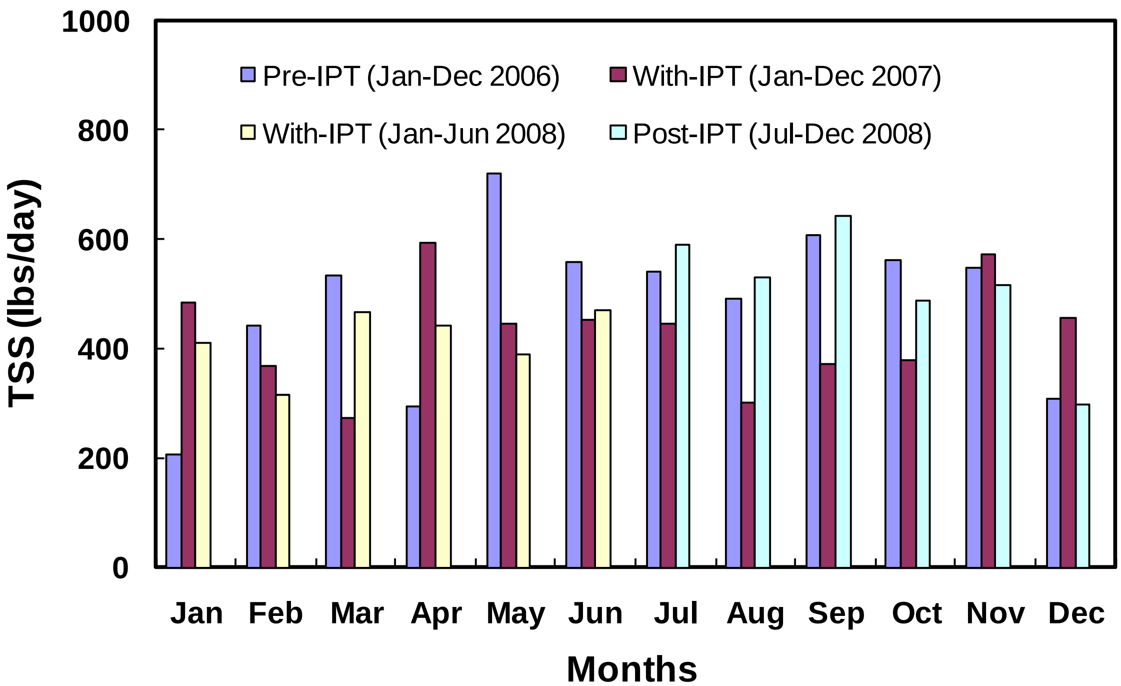

Figure 3: Monthly average influent TSS value over three year study period

INFLUENT TKN LOAD

Figure 4 shows that influent TKN values decreased With-IPT implementation compared with Pre-IPT and Post-IPT plant performance. The overall influent TKN decreased ~5% With-IPT bioaugmentation compared with Pre-IPT treatment (Table 2). After reversion from IPT bioaugmentation, the TKN values increased ~10% (Table 2). The insignificant reduction of TKN could be the result of anaerobic collection system conditions where oxidation of NH_3 was not achieved. The seasonal TKN load was compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT during the Jul-Dec period. This comparison shows that TKN values decreased With-IPT bioaugmentation and reversion from IPT results increased TKN load (Table 2). Since there were no significant changes in flow rate during the Jul-Dec period throughout the three year study period (Table 1); the decreased TKN is the result of IPT bioaugmentation.

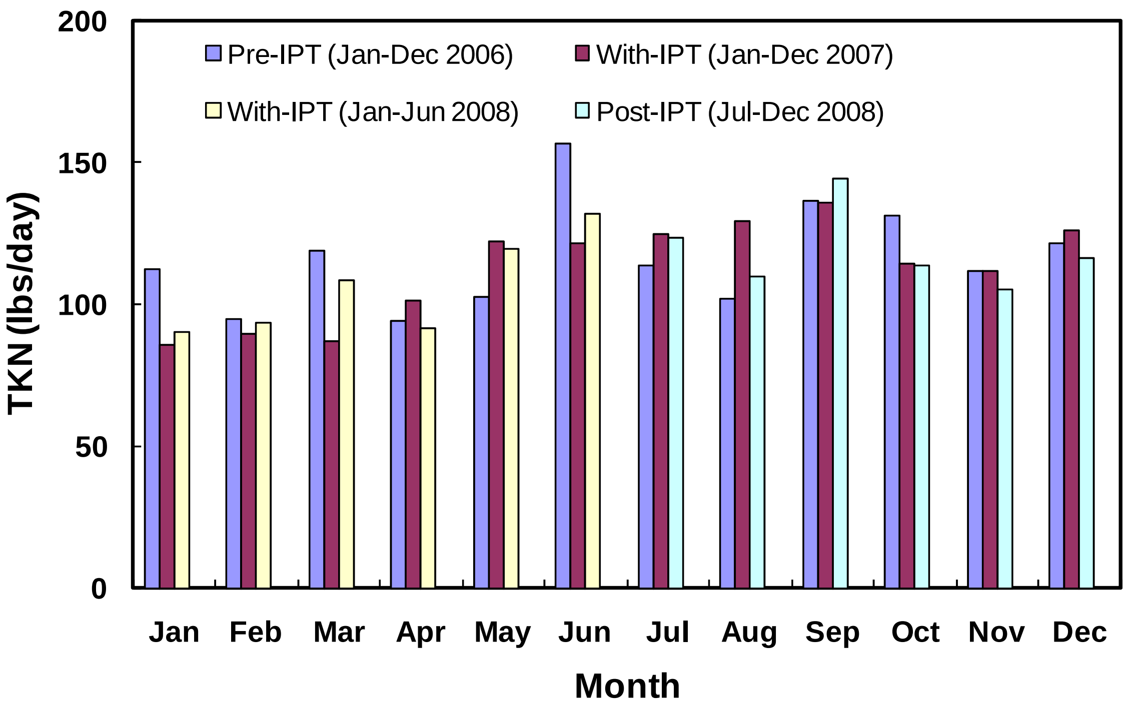

Figure 4: Monthly average influent TKN value over three year study period

EFFLUENT BOD, TSS AND TKN

Effluent BOD, TSS and TKN values are summarized in Table 3. Implementation of IPT bioaugmentation did not result in any negative impact on plant performance and in fact, enhanced the effluent quality. The effluent BOD, TSS and TKN values decreased With-IPT compared to Pre-IPT by 17%, 30% and 15%, respectively. Reversion from IPT bioaugmentation increased effluent BOD, TSS and TKN values by 9%, 114% and 14%, respectively. These results demonstrate that IPT microorganisms were actively working throughout the processes during bioaugmentation. The higher percentage increase implies IPT microbes were a significant part of the overall process. The seasonal effluent BOD, TSS and TKN loads leaving from the plant were compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT Jul-Dec period. This comparison also shows that, BOD, TSS and TKN values decreased significantly With-IPT bioaugmentation 44%, 60% and 32% respectively and reversion from With-IPT resulted in remarkable increases in effluent BOD, TSS and TKN loads 76%, 186% and 27% respectively (Table 3). Since there was no plant operational change except turning off the air blower (SRT and MLSS remains constant throughout the three year study period), the improved effluent quality is the result of IPT bioaugmentation due to IPT microbes being present in large numbers which are highly cable of removing BOD, TSS and TKN. Turning off the air blower to save the electrical energy did not result in an adverse impact on the plant performance as IPT microbes are robust and highly adaptive under aerobic, anoxic and anaerobic condition.

Parameter	**Overall Performance Analysis**		
	BOD (lbs/day)	TSS (lbs/day)	TKN (lbs/day)
Pre-IPT (Jan-Dec 2006)	41	20	5.6
With-IPT (Jan 2007-Jun 2008)	34	14	4.75
Post-IPT (Jul-Dec 2008)	37	30	5.4
% Change With-IPT vs. Pre-IPT	-17%	-30%	-15%
% Change Post-IPT vs. With-IPT	9%	114%	14%
Seasonal Performance Analysis			
Parameter	*BOD (lbs/day)*	TSS (lbs/day)	TKN (lbs/day)
Pre-IPT (Jul-Dec 2006)	38	26	5.6
With-IPT (Jul-Dec 2007)	21	10.5	4.25
Post-IPT (Jul-Dec 2008)	37	30	5.4
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	-44%	-60%	-32%
% Change Post-IPT vs. With-IPT	76%	186%	27%

Table 3: Leisure Village wastewater effluent BOD, TSS and TKN comparing Pre-, With-, and Post-IPT treatment

ELECTRICAL ENERGY REDUCTION

Energy savings can be realized with IPT treatment as the modified microbiological population allows operating the plant by changing various processes without negatively affecting the plant performance. The process changes could be the elimination of specific processes and/or improve process conversions. Since there was no historical data for kWh use prior to IPT installation, the kWh use during IPT treatment was the baseline and was compared with the Post-IPT kWh data. The kWh use was recorded by the plant operator in the log for the last 6 months of the IPT treatment (Jan-Jun 2008) and Post-IPT data was recorded for the 2.5 months after the termination of IPT treatment (Jul-Sep 2008). To account for the seasonal effect, the kWh use was compared between May 2008 and Sep 2008 (With-IPT: May-Jun 2008; Post-IPT: July-Sep 2008).

The daily average kWh use in EQ tank was 230 kWh/day With-IPT treatment and 262 kWh/day after reversion from the IPT treatment. Figure 5 shows the daily kWh use in EQ Tank with and without IPT treatment. The kWh use increased approximately 14% during the Post-IPT operation.

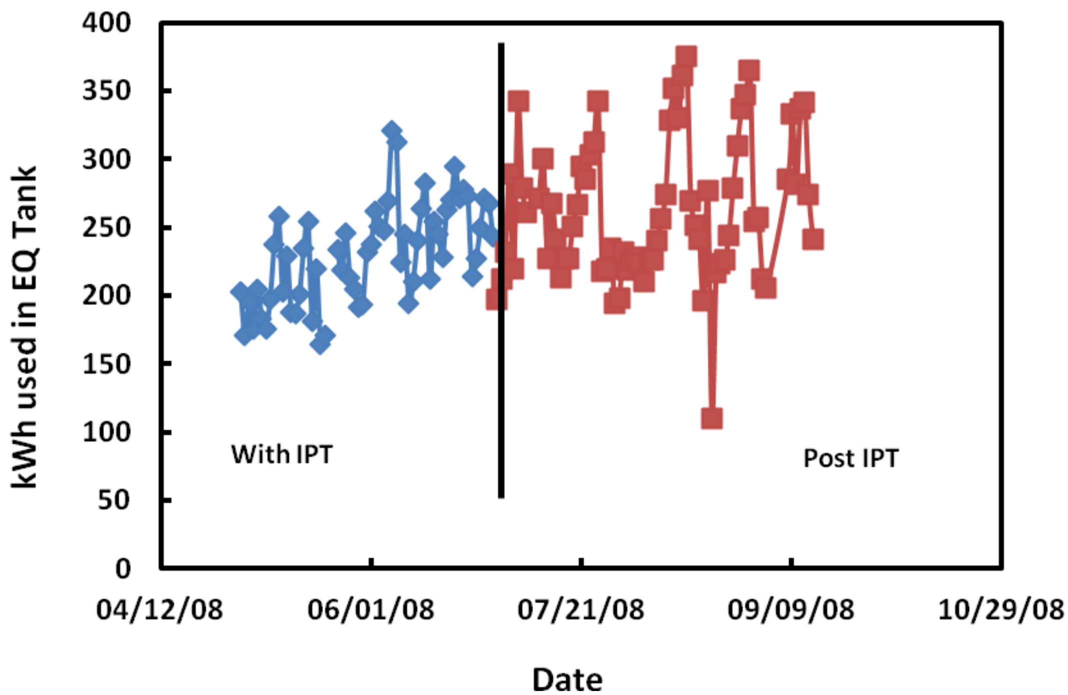

Figure 5: The daily kWh use in EQ Tank With-IPT and Post-IPT treatment.

The daily average kWh use in SBR was 307 kWh/day With-IPT treatment and 377 kWh/day after reversion as Post-IPT treatment. Figure 6 shows the daily kWh use in SBR With-IPT and Post-IPT treatment. The kWh use increased approximately 23%.

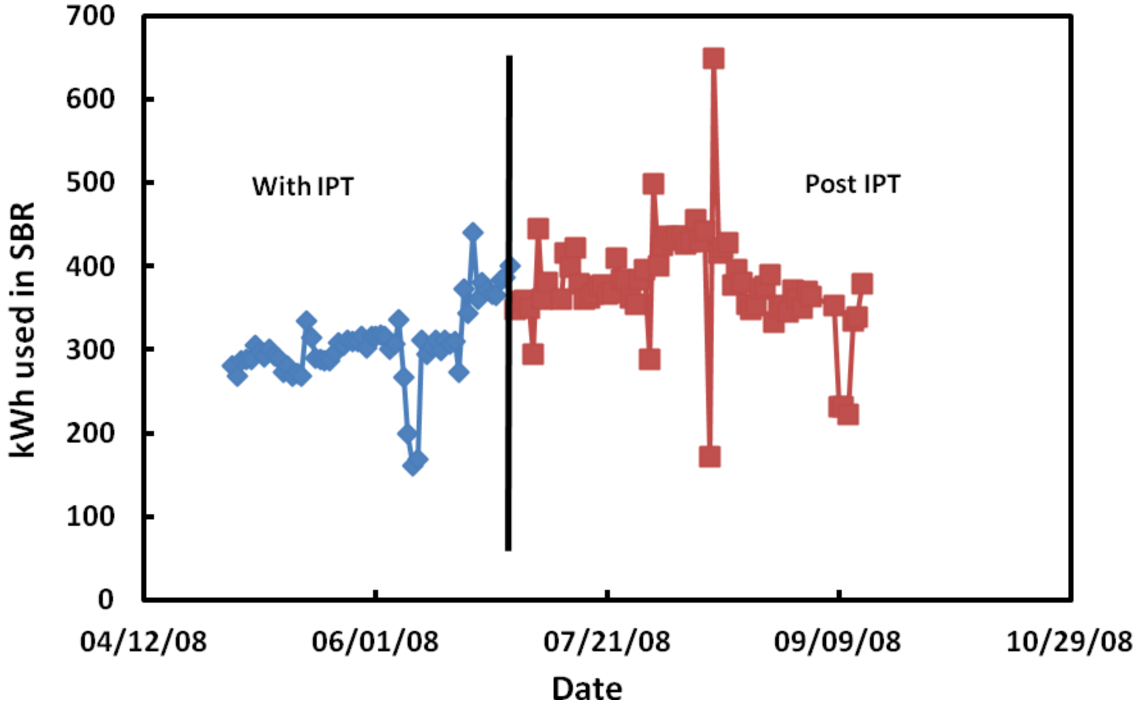

Figure 6: The daily kWh use in SBR With-IPT and Post-IPT treatment.

The influent BOD and TKN after reversion from With-IPT treatment increased ~15-20% (based on BOD & TKN removal during May-Jun 2008 and during Jul-Sep 2008). Therefore, the theoretical demand calculation predicts an increase requirement of ~15-20% kWh use after the reversion from With-IPT. The plant data provided to IPT showed 23% (SBR) and 14% (EQ Tank) increases (Jul-Sep 2008) in kWh use after the reversion from IPT treatment. One operational change was made during IPT operation without affecting the plant performance. The aeration cycle was reduced by 30 minutes/cycle (from 144 minutes/cycle to 115 minutes/cycle) enabled by the improved microbiology consortium and the resulting high oxygen utilization efficiency. An increase in cycle time would require more kWh to achieve the desired performance during Post-IPT.

By applying the results of the project, we attempted to quantify the energy, environmental, and economic benefits to treatment facilities in Suffolk County. We conducted a blower demand analysis based on decreased influent load relative to blower size and horsepower demand. The blower demand analysis calculated 8.1% reduction in O_2 requirement (Pre-IPT vs. With IPT) and a drop in required horsepower from 66 HP to 61 HP, not sufficient for a reduction in installed HP. This is projected to save Leisure Village $3,942 annually in kWh usage (5HP x 0.75 kW/HP x 24 hr/day x 365 day/yr x \$0.12/kWh) running at lower rpm and kWh use. Detailed calculations are shown in Appendix A3.

SLUDGE PRODUCTION

Lastly, the significant presence of IPT bacteria in the sludge allowed the aerated digesters to be operated in the facultative mode, thereby saving a significant amount of electrical energy and resulting in a large reduction in sludge production. The facultative mode of operation involves turning off the air to the digester, with only intermittent use for periodic mixing. With a single blower providing aeration for the EQ and digester through a common air header, direct measuring of EQ tank and digester process energy efficiencies was not possible. If the facility had a dedicated blower for the digester it is estimated to require approximately 15 HP motor, allowing a projected savings of about 93,000 kWh per year (15 HP x 0.75 kW/HP x 24 hr/day x 95% reduction x 365 days/year). In addition, the sludge hauling operated under an independent contractor not by Suffolk County (see Appendix A2). There was no financial incentive for the contractor to reduce the volume of liquid sludge hauled. Dry pounds of sludge produced decreased by 10% (Table 4).

Parameter	Dry Sludge Produced (lbs/day)
Pre-IPT (Jan-Dec 2006)	282
With-IPT (Jan 2007-Jun 2008)	255
Change With-IPT vs. Pre-IPT	-10%

Table 4: Sludge production in Leisure Village wastewater treatment plant

ENERGY & ENVIRONMENTAL IMPACT

A reduction in 27 pounds/day of sludge generation will save approximately 9.0 Million BTU (MBTU)/yr in Diesel #2 fuel consumption and will save 1,554# CO_2/yr generation. The detailed calculations are shown in Appendix A4.

ITT PLANT (SEWER DISTRICT #18)

IPT TREATMENT AT ITT PLANT

In-Pipe treatment in the Sewer District #18 collection system included the installation of six (6) G2 dosing units at engineered locations under manholes at the farthest reaches of the network. Each G2 unit dispensed approximately 32 milliliters of IPT microbial solution per day, on a fixed rate, around the clock basis. This amounted to the addition of approximately 0.1 milliliters at each location every five (5) minutes. This provides 288 distinct microbe additions per day at each of the locations. This dosing strategy added a total of about six (6) liters of solution throughout the month, into the monthly wastewater volume of about 4.2 million gallons. In-Pipe's field service technician performed monthly service visits, inspected the condition of the collection system and treatment plant, and refilled the bottles with a new liter of microbial solution.

IPT IMPACT ON ITT PLANT TREATMENT

INFLUENT FLOW RATE

Figure 7 represents the influent flow rate for the three (3) year study period. The influent flow rate to the ITT treatment plant did not change significantly. The overall mean value for the flow rate and % change in flow rate is listed in Table 5. The seasonal flow rate was compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT for Jul-Dec period. The Jul-Dec period was selected for comparison because only the Jul-Dec period Post-IPT data was available. There was a minimal change of ~4-5% in flow rate during the Jul-Dec period throughout the three year study period (Table 5).

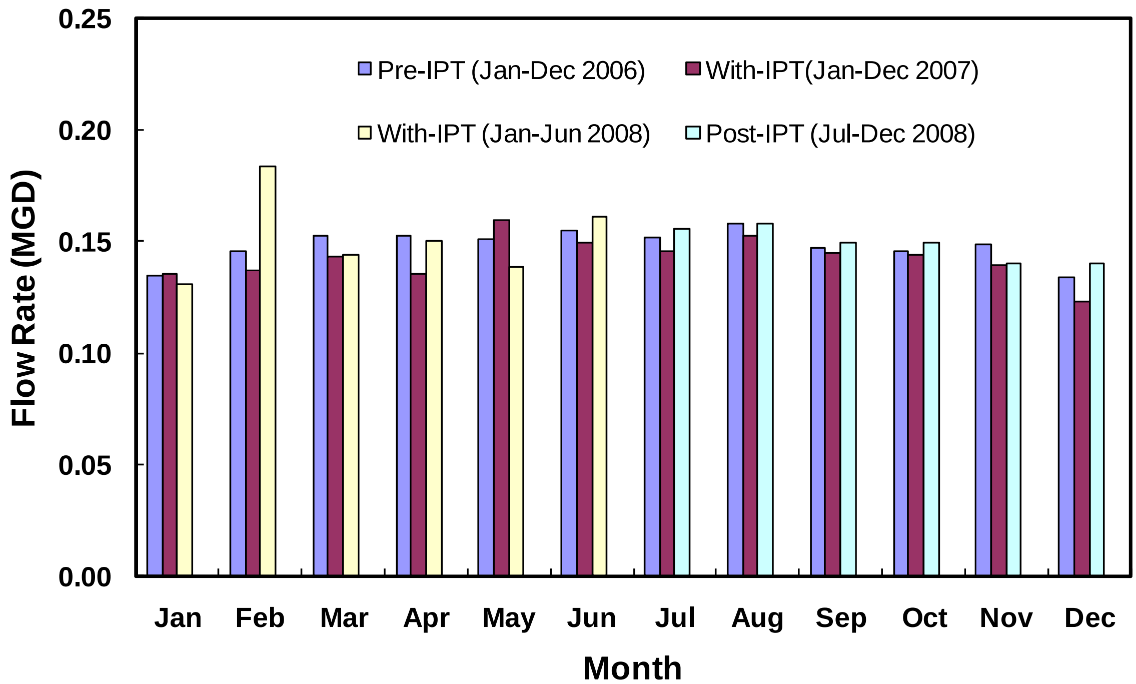

Figure 7: Monthly average influent flow rate to ITT treatment plant over three year study period

INFLUENT BOD LOAD

Figure 8 shows that influent BOD values decreased With-IPT implementation compared to Pre-IPT and Post-IPT plant performance. The overall influent BOD decreased significantly ~32% With-IPT bioaugmentation compared to Pre-IPT treatment (Table 6). After reversion from IPT bioaugmentation, the BOD values increased ~96% (Table 6). This implies that indigenous microbial activity was less efficient than during the IPT bioaugmentation period and increased BOD values were observed. The seasonal BOD load was compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT, and Post-IPT during the Jul-Dec periods. This comparison shows that BOD values decreased with IPT bioaugmentation and reversion from IPT resulted in increased BOD loads (Table 6). Reversion from IPT treatment increased BOD significantly ~78%. This is because of the indigenous microbes' limited ability to degrade mixed wastewater in contrast to IPT microbes, which have a high capability to degrade complex wastewater.

Flow rate (MGD)	Pre-IPT Jan-Dec 2006	With-IPT Jan 2007-Jun 2008	Post-IPT Jun-Dec 2008
Mean	0.148	0.145	0.149
Standard deviation	0.007	0.01	0.013
N (sample size)	12	12	12
Parameter	*% Change*		
With-IPT vs. Pre-IPT	-2		
Post-IPT vs. With-IPT	2.7		
Seasonal performance analysis			
Parameter	*Flow rate (MGD)*		
Pre-IPT (Jul-Dec 2006)	0.148		
With-IPT (Jul-Dec 2007)	0.142		
Post-IPT (Jul-Dec 2008)	0.149		
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	4		
% Change Post-IPT vs. With-IPT	5		

Table 5: ITT wastewater influent flow to ITT plant during three year study period

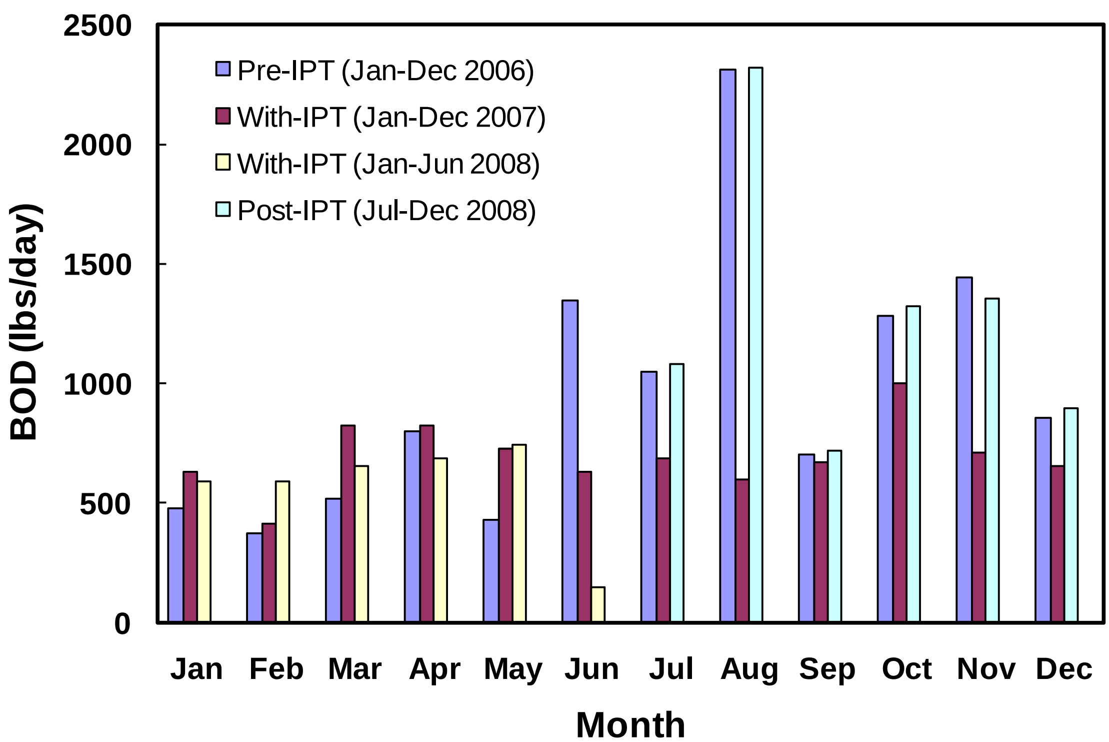

Figure 8: Monthly average influent BOD value over three year study period

Parameter	Overall Performance Analysis		
	BOD (lbs/day)	TSS (lbs/day)	TKN (lbs/day)
Pre-IPT (Jan-Dec 2006)	967	834	52
With-IPT (Jan 2007-Jun 2008)	655	533	40
Post-IPT (Jul-Dec 2008)	1,281	1,288	62
% Change With-IPT vs. Pre-IPT	-32%	-36%	-23%
% Change Post-IPT vs. With-IPT	96%	142%	55%
Parameter	*Seasonal Performance Analysis*		
Pre-IPT (Jul-Dec 2006)	1,276	1,276	62
With-IPT (Jul-Dec 2007)	721	560	49
Post-IPT (Jul-Dec 2008)	1,281	1,288	62
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	-43%	-56%	-19%
% Change Post-IPT vs. With-IPT	78%	130%	27%

Table 6: ITT influent BOD, TSS and TKN comparing Pre-, With-, and Post-IPT treatment

INFLUENT TSS LOAD

Figure 9 shows that influent TSS values decreased With-IPT implementation compared to Pre-IPT and Post-IPT plant performance. The overall influent TSS decreased ~36% With-IPT bioaugmentation compared with Pre-IPT treatment (Table 6). After reversion from IPT bioaugmentation, the TSS values increased ~142% (Table 6). This indicates that indigenous microbial activity was less efficient than during the IPT bioaugmentation period and increased TSS values were observed. The seasonal TSS load shows that TSS values decreased with IPT bioaugmentation and reversion from IPT results increased TSS loads (Table 6). Reversion from IPT treatment increased TSS significantly ~130%. This result also shows that the indigenous microbes are less capable of using mixed wastewater in contrast to IPT microbes which have a high capability to degrade complex wastewater and solubilize complex compounds to smaller molecules allowing the soluble smaller molecules to be used by the indigenous and IPT microbes present in wastewater. Consequently, reduced TSS loads were achieved during IPT bioaugmentation.

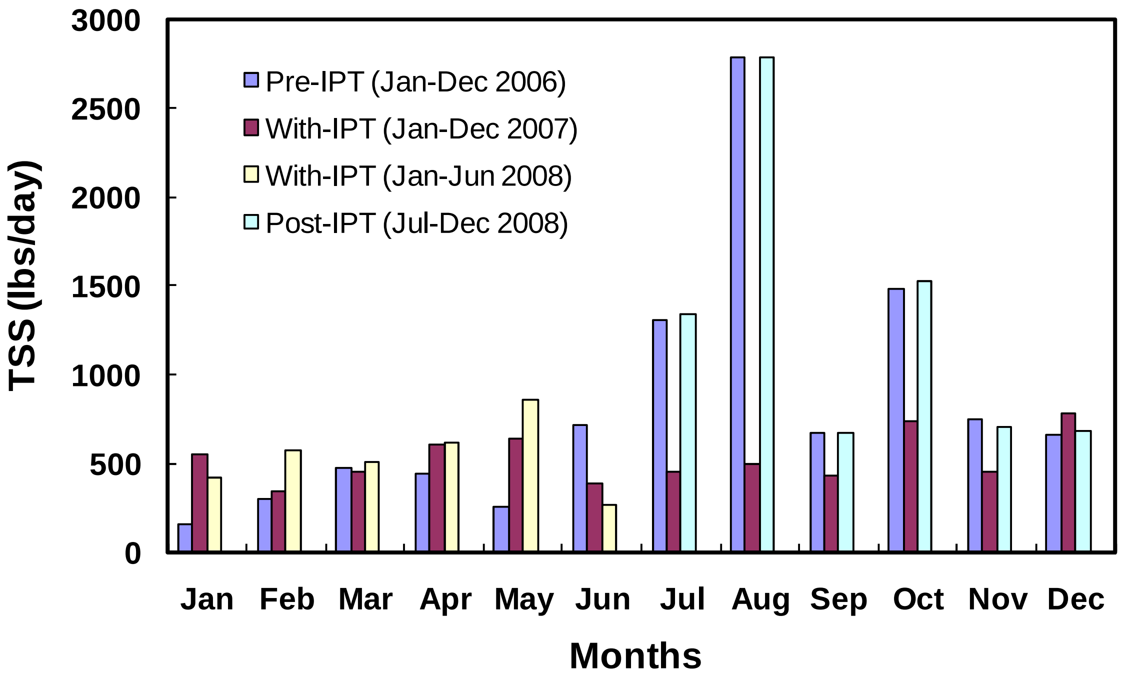

Figure 9: Monthly average influent TSS value over three year study period

INFLUENT TKN LOAD

Figure 10 shows that influent TKN value decreased With-IPT implementation compared to Pre-IPT and Post-IPT plant performance. The overall influent TKN decreased ~23% With-IPT bioaugmentation compared with Pre-IPT treatment (Table 6). After reversion from IPT bioaugmentation, the TKN values increased ~55% (Table 6). The significant reduction of TKN could be the result of aerobic/anoxic conditions in the collection system where oxidation of NH_3 was not achieved. The seasonal TKN load was compared to explain seasonal impact on IPT performance by comparing Pre-IPT, With-IPT and Post-IPT during the Jul-Dec periods. This comparison shows that TKN values decreased with IPT bioaugmentation and reversion from IPT treatment resulted in increased TSS loads (Table 6). Reversion from IPT treatment increased TSS significantly ~27%. This result also shows that the indigenous microbes are less capable of using nitrogen compounds.

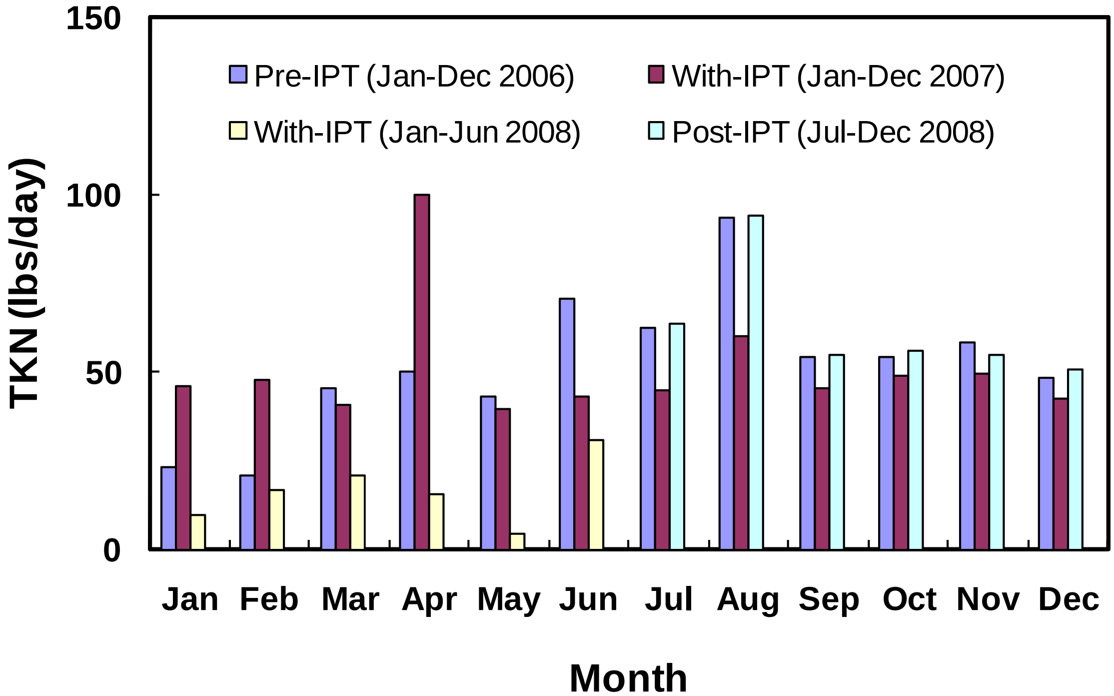

Figure 10: Monthly average influent TKN value over three year study period

EFFLUENT BOD, TSS AND TKN

Effluent BOD, TSS and TKN values are summarized in Table 7. Implementation of IPT bioaugmentation did not result in any negative impact on plant performance and in fact, enhanced the effluent quality. The effluent BOD, TSS and TKN values decreased With-IPT compared to Pre-IPT by 44%, 30%, and 33%, respectively. Since, there were no operational changes except turning off the air blower (SRT and MLSS remains constant throughout the 3 year study period); the improved effluent quality is the result of IPT bioaugmentation. Turning off the air blower did not result in an adverse impact on the plant's performance as IPT microbes are robust and highly adaptive under aerobic, anoxic, and anaerobic conditions. Reversion from With-IPT bioaugmentation increased effluent TSS value by 7%. However, effluent BOD and TKN values continued to decrease after reversion from IPT. This could be due to the stable IPT biofilm developed in the RBC units. Biofilms are more resistant to change in environmental conditions (for example, wastewater inflow shock) except unusual pH and temperature changes. They can continue to grow, multiply and degrade the wastewater. However without the continued addition of IPT, the highly efficient biofilm will slowly be replaced with indigenous bacteria and the metabolic rates will slow down with time and revert to the Pre-IPT rates. The seasonal effluent

BOD, TSS and TKN load leaving the plant shows that TSS loads decreased significantly with IPT bioaugmentation and reversion from IPT resulted in increased effluent TSS loads (Table 7). However, BOD and TKN values increased during IPT bioaugmentation but decreased after reversion and the possible reasons are explained above.

Parameter	**Overall Performance Analysis**		
	BOD (lbs/day)	TSS (lbs/day)	TKN (lbs/day)
Pre-IPT (Jan-Dec 2006)	70	20	7.9
With-IPT (Jan 2007-Jun 2008)	39	14	5.3
Post-IPT (Jul-Dec 2008)	21	15	4.2
% Change With-IPT vs. Pre-IPT	-44%	-30%	-33%
% Change Post-IPT vs. With-IPT	-46%	7%	-21%
Seasonal Performance Analysis			
Parameter	*BOD (lbs/day)*	*TSS (lbs/day)*	*TKN (lbs/day)*
Pre-IPT (Jul-Dec 2006)	21	16	4.1
With-IPT (Jul-Dec 2007)	27	13	4.4
Post-IPT (Jul - Dec 2008)	21	15	4.2
Season (Jul-Dec)			
% Change With-IPT vs. Pre-IPT	28%	-19%	7%
% Change Post-IPT vs. With-IPT	-22%	+15%	-5%

Table 7: ITT wastewater effluent BOD, TSS and TKN comparing Pre-, With-, and Post-IPT treatment

ELECTRICAL ENERGY REDUCTION

Another objective of this project was to determine potential future capital and operating cost reductions for the planned new wastewater treatment facility to be constructed for this Sewer District #18. Due to uncontrollable situations the electrical energy reduction efficiency was not evaluated for this project; however the data generated is used to project future potential energy savings (see Appendix A1 and A5).

SLUDGE PRODUCTION

Lastly, the significant presence of IPT bacteria in the sludge allowed the aerated digesters to be operated in the facultative mode, thereby saving a significant amount of electrical energy and resulting in a reduction in sludge production. Dry pounds of sludge produced decreased by only 3% (Table 8) (see Appendix A2).

Parameter	Dry Sludge Produced (lbs)
Pre-IPT (Jan-Dec 2006)	637
With-IPT (Jan 2007-Jun 2008)	619
% Change With-IPT vs. Pre-IPT	-3%

Table 8: Sludge production in ITT wastewater treatment plant

ENERGY & ENVIRONMENTAL IMPACT

A reduction in 18 pounds/day of sludge generation will save approximately 2.1 Million BTU (MBTU)/yr in Diesel #2 fuel consumption and will save 355# CO_2/yr generation. The detailed calculations are shown in Appendix A6.

CONCLUSIONS ON PROJECT PERFORMANCE

The goal of this study was to evaluate the effectiveness of In-Pipe Technology (IPT) for improving wastewater influent characteristics, wastewater effluent quality and reducing treatment plant costs including the total energy required for treatment. This was demonstrated at two small sewer districts, one domestic (Sewer District #20 – Leisure Village) and one industrial (Sewer District #18 – ITT), in Suffolk County, Long Island, New York.

The IPT study demonstrated that:

1. Influent BOD, TSS and TKN loads to the wastewater treatment plant decreased during the IPT study period.
    a. The influent BOD, TSS and TKN loads to Leisure Village WWTP were decreased by 13% from 454 lbs/day to 397 lbs/day, 13% from 485 lbs/day to 424 lbs/day, and 5% from 116 lbs/day to 110 lbs/day, respectively.
    b. The influent BOD, TSS and TKN loads to the ITT WWTP were decreased by 32% from 967 lbs/day to 655 lbs/day, 36% from 834 lbs/day to 533 lbs/day, and 23% from 52 lbs/day to 40 lbs/day, respectively.
2. The air to the EQ tanks and digesters was turned off to save to save electrical energy consumption at the WWTP and effluent quality was improved.
    a. The Leisure Village WWTP effluent BOD, TSS, and TKN loads were decreased by 17% from 41 lbs/day to 34 lbs/day, 30 % from 20 lbs/day to 14 lbs/day, and 15% from 5.6 lbs/day to 4.75 lbs/day, respectively.
    b. The ITT WWTP effluent BOD, TSS and TKN loads were decreased by 44% from 70 lbs/day to 39 lbs/day, 30% from 20 lbs/day to 14 lbs/day, and 33% from 7.9 lbs/day to 5.3 lbs/day, respectively.
3. Electrical energy consumption was reduced by turning off the air to the EQ tanks and digesters during the IPT study.
    a. Electrical energy consumption in Leisure Village WWTP EQ tank and SBR treatment increased during Post-IPT operation compared to With-IPT treatment by 14% from 230 kWh/day to 262 kWh/day and by 23% from 307 kWh/day to 377 kWh/day, respectively.
    b. The electrical energy reduction was not evaluated for ITT WWTP (See Appendix A1). However Brake Horsepower calculations for air used in the EQ tank based

on the reduced influent load With-IPT indicate a 29.5% decrease in O_2 demand and a drop in required horsepower from 79HP to 56HP. This is projected to save ITT $18,133 annually in future kWh usage upon completion of a new aerated activated sludge plant.

4. Sludge production was reduced during IPT bioaugmentation. Dry weight sludge production was reduced 10% at the Leisure Village WWTP and 3% at the ITT WWTP. These reductions provide annual savings of 9.1 MBTUs and 1,550# of CO_2 for Leisure Village WWTP and 2.1 MBTUs and 355# of CO_2 for ITT WWTP. These savings are calculated only for liquid sludge transportation to Bergen Point WWTP for further dewatering and disposal. The reduction in sludge production was not fully realized during the IPT study (see Appendix A2).
5. IPT bioaugmentation did not result in any adverse impacts to the WWTP effluents. Seasonal performance data showed reduction in influent load and enhancement of effluent quality during IPT bioaugmentation.
6. Reversion from IPT bioaugmentation significantly increased the influent (BOD, TSS and TKN) loads and increased effluent loads (BOD, TSS and TKN) leaving from the plant, i.e., decreased effluent quality.

The IPT bacteria enhance the microbial community in the collection system so that more reactions occur in the sewer biofilm that contribute to increased metabolism of wastewater compounds within the sewer. This study confirmed that In-Pipe Technology develops the collection system into an active, beneficial part of the wastewater treatment process by extending treatment from the treatment plants into the sewer collection system. The reduction in the influent carbon and nutrient load at the treatment plant significantly reduces the total kWh required to treat wastewater. Transformations in the collection system provide increased additional organic capacity within the plant, forestall costly upgrades, reduce the operating costs for treatment, and extend the life of the existing infrastructure through suppression of hydrogen sulfide formation. In-Pipe Technology offers a sustainable solution to collection system and wastewater treatment plant challenges without additional energy input, operating cost, or capital expansion.

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APPENDIX

A1

The digester and EQ tank operate on the same blower at Leisure Village. Manual operation was necessary to reduce air delivery and was originally planned to control the blowers. After offering to install a timer, SCDPW rejected this plan due to potential operator error that might have caused odor complaints. Aeration reduction was initially tested in May 2007, but concerns of spiking effluent ammonia eliminated this schedule even though effluent ammonia levels did not increase. Operators at Leisure Village keep the air delivery high in the EQ tank for increased nitrification. The ITT plant experiences significant problems due to shock loads from industrial contributors. Due to the small footprint at the plant and short retention time in the sewer, the EQ and digester operations were non-negotiable for reduced air delivery. As with Leisure Village, ITT was to utilize an air flow meter to track pounds of oxygen supplied per day. The goal was to assume no difference in process oxygen transfer efficiency between Pre- and With-IPT treatment. Since there is no direct air flow measurement, we were to assume the blowers deliver the rated air flow (scfm) irrespective of the age and condition of the blowers. However, the meter purchased by SCDPW was damaged prior to installation and never replaced during the life of the project. No direct measurements were taken. However brake horsepower calculations based on the reduced influent loads at the ITT plant With-IPT resulted in a 29.5% reduction in O_2 requirement in the EQ tank (Pre-IPT vs. With IPT) and a drop in required horsepower from 79HP to 56HP. This is projected to save ITT $18,133 annually in future kWh usage (23HP x 0.75 kW/HP x 24 hr/day x 365 day/yr x $0.12/kWh) utilizing an aerated activated sludge process. The detailed calculations are shown in Appendix A5.

A2

Sludge hauling is a separate contract for SCPDW and independent of WWTP operator control. For both plants, the number of hauling trips was not adjusted during the life of the project. SCDPW attempted to control the contractor in order to eliminate one trip per week as the percentage of total solids decreased during IPT treatment. This was not accomplished and sludge hauling occurred at the same schedule, which was every day at ITT and 3 days a week at Leisure Village.

A3

Actual O_2 required (AOR) (Pre-IPT) = $[(BOD_{in}-BOD_{out}) + 4.6 \cdot (TKN_{in}-TKN_{out})]/24$ = 38.4 lbs/hr

Actual O_2 required (AOR) (With-IPT) = $[(BOD_{in}-BOD_{out}) + 4.6 \cdot (TKN_{in}-TKN_{out})]/24$ = 35.3 lbs/hr

Reduction in O_2 requirement (With-IPT vs. Pre-IPT) = 8.1%

Standard Actual Oxygen Required (SAOR) = $(AOR \cdot (Cs \cdot \theta^{20-T}))/(\alpha \cdot \beta \cdot (Cs-Co))$

Where,

θ is temperature correction factor = 1.024

T is temperature = 17 ^{o}C

Co = 2 mg/L

Cs = Saturation oxygen concentration = 9.02 mg/L

α = 0.8 and β = 0.95

SAOR (With-IPT) = 64.1 lbs/hr

SAOR (Pre-IPT) = 69.7 lbs/hr

For coarse bubble diffuser (confirmed by operator during IPT plant visit), O_2 transfer rate = 0.8-2.0 lbs O_2/HP $\cdot$ hr (Using an avg 1.4 lbs O_2/HP $\cdot$ hr in HP calculation)

HP required (With-IPT) = SAOR/O_2 transfer rate = 45.8 HP

HP required (Pre-IPT) = SAOR/O_2 transfer rate = 49.8 HP

Assume 75% blower efficiency (blower efficiency = 0.75; Blower efficiency for diffused aeration systems (typ. range 0.7-0.9)

Actual blower HP required Pre-IPT = 66 HP

Actual blower HP required With-IPT = 61 HP

[1. USEPA (1989), Design Manual - Fine Pore Aeration Systems. Center for Environmental Research, Cincinnati, Ohio. 2. Metcalf & Eddy (1991), Wastewater Engineering: Treatment Disposal Reuse 3rd Ed]

A4

A reduction in 27 pounds/day of sludge generation will save approximately 9.0 Million BTU (MBTU)/yr in Diesel #2 fuel consumption-

27 dry weight pounds/day x 365 days/yr = 9,855 dry weight pounds sludge reduced

9,855 dry weight pounds/yr @ 2.5% solids in liquid sludge = 394,200 pounds reduced

394,000 pounds / 8.34 #/gallon = 47,266 gallons reduced

47,266 gallons / 5,000 gallons per truck = 10 truck loads/yr reduced to Bergen Point WWTP for dewatering

10 loads per year x 70 miles round trip = 700 miles/yr reduced

700 miles/yr / 10 MPG = 70 gallons of Diesel #2/yr reduced

70 gallons/yr x 129,500 BTU/gallon of Diesel #2 = 9.07 MBTUs reduced per year

70 gallons/yr x 22.2# CO_2/gallon Diesel #2 = 1,554 # CO_2 reduced per year.

**Note: This does not include the energy consumed during dewatering the sludge at Bergen Point WWTP and the associated cost and impact of hauling the dewatered sludge from Bergen Point WWTP for ultimate disposal.

A5

Actual O2 required (AOR) (Pre-IPT) = [(BODin-BODout) + 4.6 ・ (TKNin-TKNout)]/24 = 45.8 lbs/hr

Actual O_2 required (AOR) (With-IPT) = $[(BOD_{in}-BOD_{out}) + 4.6 \cdot (TKN_{in}-TKN_{out})]/24$ = 32.3 lbs/hr

Reduction in O_2 requirement (With IPT vs. Pre-IPT) = 29.5%

Standard Actual Oxygen Required (SAOR) = $(AOR \cdot (Cs \cdot \theta^{20-T}))/(\alpha \cdot \beta \cdot (Cs-Co))$

Where,

θ is temperature correction factor = 1.024

T is temperature = 17 ^{o}C

Co = 2 mg/L

Cs = Saturation oxygen concentration = 9.02 mg/L

α = 0.8 and β = 0.95

SAOR (With-IPT) = 58.6 lbs/hr

SAOR (Pre-IPT) = 83.1 lbs/hr

For coarse bubble air diffuser used in EQ tank, O_2 transfer rate = 0.8-2.0 lbs O_2/HP・hr (Using an avg 1.4 lbs O_2/HP·hr in HP calculation)

HP required (With-IPT) = SAOR/O_2 transfer rate = 41.8 HP

HP required (Pre-IPT) = SAOR/O_2 transfer rate = 59.4 HP

Assume 75% blower efficiency (blower efficiency = 0.75; Blower efficiency for diffused aeration systems (typ. range 0.7-0.9)

Actual blower HP required With-IPT = 56 HP

Actual blower HP required Pre-IPT = 79 HP

This result could provide justification to install smaller blower motors for the planned replacement wastewater treatment facility.

A6

A reduction in 18 pounds/day of sludge generation will save approximately 2.1 MBTU/yr in Diesel #2 fuel consumption-

18 dry weight pounds/day sludge x 365 days/yr = 6,570 dry weight pounds sludge

6,570 dry weight pounds/yr @ 2.5% solids in liquid sludge = 262,800 pounds reduced

262,800 pounds / 8.34 #/gallon = 31,560 gallons reduced

31,560 gallons / 5,000 gallons per truck = 6 truck loads/yr reduced to Bergen Point WWTP for dewatering

6 loads per year x 26 miles round trip = 164 miles/yr reduced

164 miles/yr / 10 MPG = 16 gallons of Diesel #2/yr reduced

16 gallons/yr x 129,500 BTU/gallon of Diesel #2 = 2.1 MBTUs reduced per year

16 gallons/yr x 22.2# CO_2/gallon Diesel #2 = 355# CO_2 emissions reduced per year.

**Note: This does not include the energy consumed during dewatering at Bergen Point WWTP and the associated impact of hauling the dewatered sludge from Bergen Point WWTP for ultimate disposal.

A7

A case study at Crown Point, Indiana is noteworthy in the performance of In-Pipe Technology to reduce energy consumption and sludge production for over four (4) years. This Case Study is included with the permission of the NYSERDA Research Director to increase the educational value of this NYSERDA report. The information is not reviewed or affirmed by the Suffolk County Department of Public Works Staff. The project highlights are summarized below.

PROJECT SUMMARY

Due to capacity issues, the City of Crown Point, Indiana was forced to either start planning for expensive capital expansions of the facility or to investigate alternative technologies that would increase capacity without capital expansion. In 2007 the City chose In-Pipe Technology to improve the treatment capacity of the plant without capital improvements. In-Pipe's goal was to improve the efficiency of the plant, reduce sludge production, improve effluent water quality and control odors at the plant.

Since In-Pipe Technology started treatment in 2007, the amount of sludge produced per pound of influent TSS and influent BOD was reduced by 36% and 41% respectively. This improvement in efficiency has resulted in a 27% reduction in the total hauled sludge, a reduction that saves the City nearly $19,000 per year and eliminated the need to expand its facility. In the four (4) years since the In-Pipe project began, the WWTP has produced 3,120 fewer tons of biosolids compared to operation before In-Pipe treatment.

Additionally, the plant has been operating with 50% of the aeration energy previously needed for effective biological treatment while maintaining the high average effluent water quality of 1.4 mg/L BOD, 1.5 mg/L TSS and less than 1 mg/L ammonia.

PRESENT CONDITIONS

The following bullet points summarize performance at the Crown Point WWTP for the months of August 2009 through July 2010. The baseline for comparison is plant operation data during the

12 months prior to August 2007, the year before IPT began treatment.

- $153,000 in annual savings for sludge disposal, aeration energy reduction, FOG control and chemical usage.
- $12,000 in annual energy savings from lowering the return activated sludge (RAS) pumping rate.
- The improvement in effluent TSS now allows the WWTP to utilize secondary effluent for plant non-potable utility water, saving 50,000 gallons per day of City water, or $61,000 per year
- Collection system has been maintained in good condition with no odor complaints logged. Documented Combined Sewer Overflows (CSOs) have been reduced 92% since implementation of IPT due to FOG elimination.
- Capital expansion of the sludge storage building ($0.5 million) and digester tank ($1.1 million) remains on hold.

In October, 2010 the City of Crown Point extended its agreement with In-Pipe Technology by issuing a three (3) year fixed price contract valued at over $0.5 million. Based on current performance, the City will save more than $0.68 million in operating expenses over the course of the contract by using the collection system as an active part of the treatment process and increasing the efficiency of their existing assets.