The Effects of Bioaugmentation in Collection System on WWTP Operations, a Case Study

M. Kelter*, R. Dickerson** and A. Newbold***

*Legacy Civil Engineers, Inc., Coral Springs, FL, USA, mkelter@bellsouth.net
**In-Pipe Technology, Wheaton, IL, USA, jrodneyd@bellsouth.net
***In-Pipe Technology, Wheaton, IL USA, anewbold@in-pipe.com

ABSTRACT

The wastewater treatment plant in the Town of Orange Park, Florida was challenged to meet a new discharge permit issued by the Basin Management Action Plan (BMAP) for the lower St. John's River that was 70% lower than the plant was capable of delivering. The Town's existing wastewater treatment facilities utilized three parallel Contact Stabilization package-type systems to treat 1 MGD and discharge approximately 76,100 pounds per year of total nitrogen into the St. John's River. The new BMAP permit went into effect for the Town in May 2009 and limited effluent total nitrogen to an annual load of 21,998 pounds.

In accordance with the new limit, the Town planned to upgrade the treatment processes to Biological Nutrient Removal (BNR) systems, reconfiguring the plant into two, five-stage Bardenpho Plants. In order to maintain performance during the construction activities, the Town implemented a bioaugmentation program which delivers specialized bacteria into the collection system, transforming it into a pre-treatment step to reduce influent load, enhance biological treatment and nitrogen removal as well as to provide operational flexibility. With bioaugmentation in place, the average daily influent Carbonaceous Biological Oxygen Demand (CBOD) loading to the plant decreased by over 50% and the effluent total nitrogen load decreased by 60% to about 25,000 lbs/year, nearly meeting the new discharge limit before the BNR upgrades were online.

The WWTP underwent a number of process changes during the construction term, which is ongoing. This paper will focus on the effects of the bioaugmentation program which, combined with process modifications and operating adjustments, enabled the plant to operate at two-thirds of its former capacity while demonstrating excellent nitrogen removal and delivering improved effluent water quality. The case study addresses the challenges of upgrading the plant and the substantial operating expense savings that the Town realized by reducing air delivery to the biological treatment process and the aerobic digester as a result of the effects of bioaugmentation in the collection system.

Keywords: bioaugmentation, biofilm, compliance, nitrogen, nutrient removal

INTRODUCTION

The Ash Street Wastewater Treatment Plant (WWTP) had to comply with more stringent discharge restrictions that exceeded the performance capability of existing infrastructure. This necessitated a plan for process improvements and upgrades to the treatment equipment, constrained by budget and the terms of the consent order for ongoing discharge violations. The Ash Street Wastewater Treatment Plant decided to utilize collection system bioaugmentation program to attenuate the inevitable process disruptions and limited treatment capacity during the improvement process.

The Florida Department of Environmental Protection (FDEP) issued new discharge permits for the contributors to the Lower St. Johns River under the directives set forth in the latest Basin Management Action Plan (BMAP). Without extensive improvements to the current facility, the WWTP could not produce effluent quality required by the new BMAP permit.

This case study focuses on the challenges of upgrading the wastewater treatment processes and the bioaugmentation program that the Town adopted to lower the amount of nitrogen discharged during retrofit construction. The bioaugmentation program proved to have many beneficial effects at the WWTP: reducing influent pollutant load, improving effluent water quality, and mitigating the anticipated construction-related plant disruptions during the ongoing construction and modifications to the plant.

REGULATORS ISSUE MORE STRINGENT DISCHARGE PERMIT

In 2004 the Town of Orange Park was issued a WQBEL permit for the Ash Street Wastewater Treatment Plant which limited effluent discharge of Carbonaceous Biochemical Oxygen Demand ($CBOD_5$), Total Suspended Solids (TSS), Total Nitrogen (TN) and unionized ammonia (NH_3) loading to the surface water discharge at the levels shown in **Table 1**.

Unfortunately, the Ash Street WWTP was not designed to perform to the standards set in the 2004 WQBEL permit. The plant processes were not designed for the denitrification requirements implicit in the 1996 re-authorization of the Clean Water Act, nor mandated in the 1999 Watershed Restoration Act[1].

2004 WQBEL Permit Limits	
$CBOD_5$	20 mg/L
TSS	20 mg/L
TN	150 lbs/day
NH_3	0.02 mg/L

Table 1 – 2004 WQBEL Permit Limits for the Orange Park WWTP.

In 2004 the FDEP cited the Town of Orange Park for violation of its wastewater permits and the Town entered into a Consent Order (OGC Consent Order # 04-0739) which required mitigation for the violations and implementation of a plan to correct the deficiencies by July 2007. The consent order established an interim limit of 300 lbs/day for effluent total nitrogen.

While the WQBEL-based Consent Order required the Town to remedy the problem by 2007, the WQBEL permit itself was set to expire in late 2005 and the imminent replacement regulations based on the BMAP for the Lower St. Johns Watershed were currently under development. Thus, the FDEP could not legally issue a new permit for plant construction or wastewater operations. This left the Town under a mandate to design and construct improvements in accordance with the Consent Order without the benefit of knowing exactly what the new discharge regulations would be, and without the review and approval of plant construction plans by the FDEP.

To help define the new regulations, the Town hired Legacy Civil Engineers in late 2006, to begin negotiation of a BMAP with the FDEP pursuant to the anticipated TMDL for the Lower St. Johns River. Legacy Civil was tasked with designing a treatment process that would satisfy the existing Consent Order (what would become Phase 1) while meeting the anticipated, but not yet defined, wastewater discharge requirements for the Lower St. Johns River BMAP (what would become Phase 2). In order to proceed with the design and construction, the Town estimated a worst case scenario that the FDEP BMAP permit would limit discharge to 12,236 pounds of TN annually to the St. Johns River—a reduction of 46,355 pounds per year based on the previous 2 years of operation.

The Town decided to design a refit to the existing Contact-Stabilization package plants to convert them into facilities compliant with the requirements of the new permit.

In the summer of 2007, plans and specifications for Phase 1 were completed and issued for competitive bid. The Town also applied for an extension to the Consent Order to set the deadline for completion of Phase 1 plant improvements to November 1, 2009.

MILESTONES TO ACHIEVING COMPLIANCE

The Town of Orange Park planned a phased approach to satisfying the new discharge permit. A summary of each phase is presented below as it pertains directly to the Ash Street WWTP. This case study is concerned with the activities during the Phase 1 process improvements which were: construct system which immediately brings the plant into compliance with the conditions of Consent Order # 04-0739. This included the specific tasks of (partial list):

1. Modifying Plants #1 and #2 from the current configuration of Contact-Stabilization to the Extended Aeration Process.
2. Modification of the Plant #3 Contact-Stabilization process to a Biological Nutrient Removal (BNR) process (Five-stage Bardenpho).
3. Construction of a 165,480-gallon surge tank.

The Town started construction on Phase 1 in December 2007.

DEPLOYING COLLECTION SYSTEM BIOAUGMENTATION

Out of concern that the construction activities required for the renovation of the operating wastewater treatment plant would compromise biological treatment or upset the plant process, the Town initiated a collection system bioaugmentation service with In-Pipe Technology® Company, Inc. (IPTC). In-Pipe's patented process involves the addition of a proprietary blend of heterotrophic, facultative bacteria to the wastewater collection system. The documented results of the In-Pipe Technology (IPT) treatment include reducing influent pollutant load and sludge production[2] as well as improving effluent quality, sludge settleability and nitrogen removal. All benefits to the Ash Street plant while it operating under reduced treatment capacity during construction.

The IPT collection system treatment program began in March 2008. At that time construction had just started and the plant was still operating as a Contact-Stabilization process. The condition of the collection system improved as fats, oil and grease (FOG) related sewer line blockages and odor problems ended.

RESULTS FROM COLLECTION SYSTEM BIOAUGMENTATION

A detailed timeline of the retrofit construction is shown in Table 2.

	Package Plant 1	Package Plant 2	Package Plant 3
Pre April 08	Contact-Stabilization	Contact-Stabilization	Contact-Stabilization
April 08 - August 09	**Retrofit to extended aeration**	Contact-Stabilization	Contact-Stabilization
August 09 - January 10	Extended Aeration	**Retrofit to extended aeration**	Contact-Stabilization
January 10 - August 10	Extended Aeration	Extended Aeration	**Retrofit to Five-stage Bardenpho**
Initial Flow (MGD)	0.5	1.0	1.0
Designed Flow (MGD)	N/A	1.25	1.25

Table 2 – Detailed timeline of construction activities. The collection system bioaugmentation program started in March 2008.

Under the bioaugmentation program, and while Plant 1 was offline, the average effluent TN decreased by 30%, from 19.3 mg/L to 13.5 mg/L, with large variance between individual testing events. The mass loading went down a corresponding 27%, from 147 pounds/day to 108 pounds/day. At the same time, average influent $CBOD_5$ concentrations dropped by 52%, from 293 mg/L before bioaugmentation to 139 mg/L.

	Inf. Flow MGD	Inf. CBOD5 mg/L	Inf. CBOD5 lbs/day	Inf. TSS mg/L	Inf. TSS lbs/day
Pre April 08	0.95	290	2258	354	2784
April 08 - August 09	0.97	139	1085	273	2250
August 09 - January 10	0.85	169	1270	230	1774
January 10 - August 10	0.73	170	981	285	1642

Table 3 – Changes in influent water quality using the collection system bioaugmentation program. Bioaugmentation started in March 2008.

Note that this was before any modifications to the treatment process configuration; the process remained Contact-Stabilization and was operating with 20% less biological treatment capacity. A complete tabulation of the change in influent and effluent water quality parameters observed during the construction period can be found in Table 3, Table 4a and 4b.

	Eff CBOD5 mg/L	Eff CBOD5 lbs/day	Eff TSS mg/L	Eff TSS lbs/day
Pre April 08	3.3	25.8	2.4	19.2
April 08 - August 09	2.4	18.7	2.6	21.1
August 09 - January 10	1.4	10.6	1.1	8.7
January 10 - August 10	2.4	13.8	1.9	10.9

Table 4a – Changes in effluent water quality through each phase of the plant retrofit using the In-Pipe collection system bioaugmentation program. Bioaugmentation started in March 2008. *As part of Phase 1 - tertiary filtration was added to the plant process.

	Eff TN mg/L	Eff TN lbs/day
Pre April 08	19.3	147
April 08 - August 09	13.5	108
August 09 - January 10	11.1	94
January 10 - August 10	10.3	61

Table 4b – Changes in effluent nitrogen through each phase of the plant retrofit using the In-Pipe collection system bioaugmentation program. Bioaugmentation started in March 2008.

In October 2008, the FDEP issued the final BMAP discharge permit for the Ash Street WWTP. The permit set the allowable annual nitrogen load to the St. Johns River of 21,998 lbs[3].

In August 2009, Plant 1, now an extended aeration process, restarted service and Plant 2 shut down for conversion to extended aeration. As a result, during the period between August 2009 and January 2010, the plant was operating with just 60% of its former biological treatment capacity. In-Pipe's goal of ensuring efficient biological treatment, improved nitrogen removal and positive settling characteristics. The influent pollutant load remained low as organic material was converted within the sewer (see Table 3) while effluent nitrogen continued to drop. The daily effluent TN averaged 11.1 mg/L or 94 pounds/day, representing an improvement of 36% over previous conditions.

In-Pipe recommended reducing the plant aeration to deliver more consistent nitrogen removal performance. The WWTP staff and Legacy Civil reduced dissolved oxygen levels for aeration to fully utilize the In-Pipe proprietary microbiology. Effluent total nitrogen values decreased with D.O. levels in the range of 1.0 mg/l in the basins. This change in plant operations was a significant modification for the Town.

The ability to both nitrify and denitrify makes In-Pipe bacteria attractive candidates for application in the removal of nitrogen from wastewater[4]. The In-Pipe proprietary blend of heterotrophic, facultative bacteria that are constantly delivered into the collection system transforms a normally passive conveyance system into an active part of the treatment process. This approach initiates a gradual repopulation of the sewer biofilm by bacteria that are more efficient at degradation of organic material than the bacteria that are present in natural, untreated conditions[5]. As the facultative heterotrophic bacteria enter the WWTP, they enhance biological treatment and nitrogen removal. As a result of these two functions, the extended aeration plants were able to operate with dissolved oxygen (DO) levels far below traditional practice.

The retrofit on package Plant #2 was finished and placed back into service as an extended air process in January 2010. The project continued as planned by removing Plant #3 from service and starting construction to convert it into a five-stage Bardenpho process. While both treatment processes were operated as extended aeration plants with very low D.O. levels for aeration, the best nitrogen results were achieved. The average daily effluent TN was just 10.3 mg/L or 61 pounds/day; a 47% improvement over untreated conditions.

Plant-wide energy consumption that dropped dramatically during the retrofit term with In-Pipe treatment. This is a result of both the lower air delivered to the biological treatment units and the conversion of the aerobic digesters to “facultative” digesters, which requires about 2% of the energy that typical aerobic digesters require.

After retrofits were completed on Plant #3, it was recommissioned as a five-stage Bardenpho process. This completed Phase 1 of the Ash Street WWTP plan for meeting the FDEP permit limit of 150 pounds/day TN. Phase 2 will bring the plant into compliance with the BMAP TN limit of 21,998 pounds/year at 1.45 MGD.

The project to achieve compliance with the first milestone of the consent order lasted over three years. The Town decommissioned and recommissioned their various package plants 7 times since project inception; they emptied the mixed liquor of one plant into another; they processed serious rain events with limited capacity; and never experienced any loss in treatment capability. Throughout the construction, In-Pipe Technology constantly maintained the plant with their beneficial bacteria that processed the organic and nutrient load quickly with low D.O. levels needed for wastewater and digester aeration.

CONCLUSION

As the cost of energy continues to rise, the In-Pipe Technology collection system bioaugmentation program represents a sustainable option for municipalities seeking money saving opportunities in a difficult economic environment. The Ash Street WWTP, which processes 1.0 MGD, was able to save nearly $85,000 in energy cost by utilizing IPT’s professional services and specialized, proprietary microbiology. This is a favorable program for facilities like Orange Park that currently operate aerobic digesters or need to maximize aeration efficiency.

The Town of Orange Park plans to continue the In-Pipe Technology bioaugmentation collection system program after completion of the wastewater treatment plant modifications. The benefits of controlling collection system FOG, odor, corrosion and the ongoing energy savings at the WWTP will continue long after construction ends. Legacy Civil Engineers confirms that In-Pipe Technology's service program enhances the biological nutrient removal process in a similar way as the previous processes discussed in this paper. Based on the results in this paper, other facilities can achieve the same results without capital expenditure and will receive significant savings on operating expenditures.

REFERENCES

[1] Metcalf & Eddy (2003) *Wastewater Engineering Treatment and Reuse.* 4th Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi

[2] Liu Y., Giraldo E. (2010) The Side Effects of Feeding Cultured Bacterial in Collection System on WWTP Operations, a Case Study. *Proceedings WEFTEC October 2010, New Orleans, LA.*

[3] Lower St. Johns River TMDL Executive Committee (October 2008) Basin Management Action Plant for the Implementation of Total Maximum Daily Loads for Nutrients Adopted by the Florida Department of Environmental Protection. *Florida Department of Environmental Protection*

[4] Kim et al. (2005) Aerobic nitrification-denitrification by heterotrophic Bacillus strains. *Bioresource Technology* 96, 1897-1906

[5] Gerardi M.H. (2006) *Wastewater Bacteria*. John Wiley and Sons, Inc.; Hoboken, NJ 41-47

[6] Ramos et al. (2000) Fermentative Metabolism of Bacillus subtilis: Physiology and Regulation of Gene Expression. *Journal of Bacteriology* Vol. 182 No. 11, p 3072 - 3080