Designing for Nondetectable Fecal Coliform: Our Experience with UV Light

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When it was built in the 1940s, the Bethune Point Wastewater Treatment Plant in Daytona Beach was the first contact stabilization facility in the state of Florida. Although the plant was upgraded periodiocally, in recent years the city was faced with several challenges at the facility:

- Problems with chlorine residual and pH led to effluent violations.
- The plant's process used denitrifying filters with an expensive methanol feed stream. The filter restricted plant capacity and often contributed to effluent violations.
- Rather than discharge all the effluent directly into the Halifax River and Intracoastal Waterway, city officials wanted to improve and expand their ability to provide reclaimed effluent for reuse by the public.
- Finally, the city wanted to make certain that its wastewater treatment facilities could accommodate the 500,000 visitors that inundate the area for weeks at a time during special events like Speed Week and Bike Week, as well as the burgeoning permanent local population slated to grow 125 percent faster than the national average for the next five years.

Daytona Beach contracted the firm of McKim & Creed to expand and upgrade the historic riverfront plant, which serves the eastern part of the city. The 18-month project was finished in December 1999, with the resulting improvements:

- Increased capacity from 10 to 13 MGD to help meet the growth and special events needs, without constructing additional treatment tankage.
- Changed the treatment process to allow a re-rating expansion of the existing facilities with only minor construction.
- Converted the plant disinfection process from chlorination, followed by dechlorination for toxicity requirements to a cleaner, nontoxic ultraviolet (UV) light disinfection system, eliminating many of the recurring regulatory violations while ensuring the plant's ability to provide citywide public access reuse. The new UV system is the largest of its type in the state that is designed for reuse operations.
- Incorporated a full-scale inline uninterrupted power supply (UPS) system to ensure that the UV system is never without power.

UV light disinfection has been employed in other areas of the country for many years, but its acceptance in the fragile Florida environment has been slow. Most UV use in other states is primarily for basic-level disinfection to a standard of perhaps 200 fecal colonies per 100 mls of sample. Only Florida and California have adopted very rigorous requirements for public access reuse systems that effectively require nondetectable fecal coliform.

Basic-level disinfection with UV is very simple to achieve and repeat. Nondetectable fecal coliform, or Florida high-level disinfection on the other hand, is quite difficult to accomplish and maintain. Indeed, even today, the state of Florida still does not have its own specific regulations for the application and design of UV disinfection systems; however, the use of this clean, nontoxic form of disinfection does have state blessing under the appropriate conditions and design parameters.

Aerial view of the Bethune Point Wastewater Treatment plant.

Ultraviolet light disinfects wastewater by altering the genetic DNA in cells so that bacteria, viruses, and other microorganisms can no longer reproduce. In UV disinfection, the UV light is produced by lamps that operate in the germicidal energy range. As filtered effluent flows past the UV lamps, the suspended solids and microorganisms are exposed to a lethal dose of UV energy. The UV dosage is measured as the product of the UV light intensity and the exposure time within the UV lamp array. Transmittance is defined as the percentage of UV light actually absorbed by the microorganisms. As the UV light passes through the wastewater flow, any suspended solids or tannic color absorb the energy and decrease the amount of light that actually reaches any organism. A typical effluent transmittance factor ranges from 65 to 75 percent. As the transmittance value of an effluent declines, it takes more and more energy to achieve a kill, thus driving up the cost of the system

Today, UV disinfection for reuse operations in Florida is acceptable following the standards established by the state of California and the National Water Research Institute (NWRI). Such effluent can be permitted for direct discharge to surface waters, indirect restricted access reuse systems, or with great care to nonrestricted public access reuse systems.

For public reuse systems, Florida currently relies on a document called the Title 22 Guidelines, originally established in California and recently revised and re-established by the same bodies. Title 22 is a document and policy that was established by a committee of the California Department of Health Services and the NWRI. The objective of the policy was to establish basic design and operational guidelines for UV to comply with the California Wastewater Reclamation Criteria, Title 22, Chapter 3, of the

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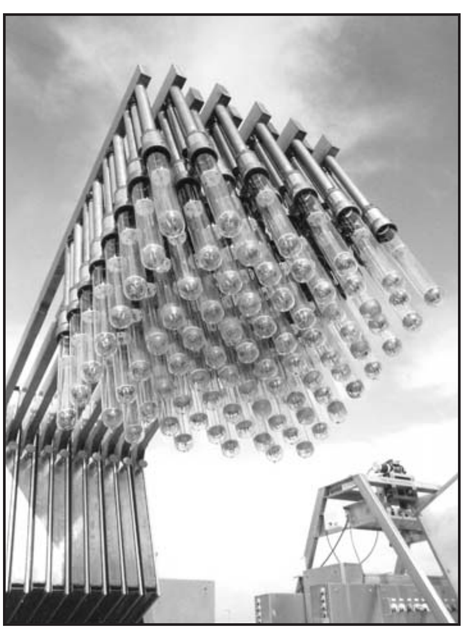
California Code of Regulations. The original guidelines were developed on the basis of demonstrated equivalency of UV disinfection to conventional chlorine disinfection. The original guidelines have been revised and expanded tremendously since first published. They now include UV disinfection for both wastewater and drinking water applications in California.

At this time, however, the state of Florida continues to apply the original guidelines to the disinfection of public access reuse applications. Florida high-level disinfection differs somewhat from the California standards in that the rule is based on fecal rather than total coliform, and requires non-detectable fecals in 75 percent of the samples taken per month. Assuming one sample per day, this means that the facility must average 7 colonies or less per 100 mls sample per month to comply with the high-level rule.

Development of design criteria for the Bethune Point UV project followed the guidelines of Title 22 from the beginning to ensure its acceptance as a reuse source for the city. The work began with a collimated beam test for dose response. During the winter of 1998, city staff installed a low-pressure UV pilot plant and operated the facility for nearly seven months to generate comparative data of UV versus chlorination for Florida high-level disinfection requirements.

Using data from the pilot plant, McKim & Creed designed the first large-volume, unrestricted public access reuse application for UV light disinfection to be permitted in Florida. During the design process, MCE and city staff visited numerous facilities in California to learn from their experiences. Many of the California sites were under construction or had recently gone into service, so no longtime history on the specific equipment was available.



RIGHT: The four banks of UV lights are installed on top of the reactor channel. ABOVE: A view of one of the UV light banks raised out of the water for maintenance.

The full-scale system was designed around a single, continuous, open channel with four banks of lamps, in compliance with the Title 22 guidelines. Due to the existing plant hydraulics, each channel is always full of water. The system was based on the Trojan UV4000 medium-pressure, high-intensity lamp. The base design dose was based on 80 mWsecs per square centimeter to achieve the high-level standard. The standard was based on a 13-mgd average day flow to reuse standards. Transmittance values of the plant effluent have always been very low compared to most communities. This design was based on an average transmittance value of 50 percent. Any time the plant flow exceeds the base reuse volume, the entire flow receives basic-level disinfection and is discharged to the river instead of the reuse system.

One side of the existing chlorine contact tank was retrofitted to take the UV equipment, while the other side was retrofitted to act as a new reuse pump station and wetwell. The modified UV tanks included retractable covers to prevent sunlight from penetrating the water and promoting biological growth in the effluent that does not contain any preventative residuals.

Finally, because the electronic ballasts in modern UV systems are extremely sensitive to power fluctuations and have a failure time in microseconds, standby power and automatic transfer switches alone can not act quickly enough to insure continuous operation. Most power fluctuations in the area are only microseconds in duration, on the order of "Florida flicker" type disturbances with upsets of only three cycles per second. An inline UPS was deemed to be essential to the security of the system.

In the case of this plant, flow can not be diverted or equalized until the lamps restrike and come back into service after a fluctuation (a period of time on the order of seven to 12 minutes), so it was felt that continuous disinfection service in this facility required the presence of a UPS sized to maintain operation through endless flicker episodes or up to 15 minutes of full-scale operation during true power outages. During that time, an automatic transfer switch and self-contained generator package would activate and come online in the space of approximately one minute to pick up the power demand from the commercial grid. This is the largest UV system in the United States to include full-scale UPS to protect the disinfection process continuously.

Plant Performance

Operation of the UV system over the first 18 months of service has provided important insights into the design and operation of such systems for nondetectable level fecal performance. Operation of a basic-level disinfection system, even in a hot climate like Florida, is relatively simple, but continuously meeting the Florida high-level standard of nondetectable fecal coliform can be a real challenge over time, particularly in an effluent with characteristically low transmittance values.

The UV system at Bethune Point began operation in December 1999. For the first few months, the operators ran the system at very high dosages to ensure disinfection while the biological denitrifying filter was still in routine service using methanol. The excess methanol from a denitrification filter interferes with UV transmittance by absorbing available energy before actual disinfection can take place. In addition, the sloughing of heterogenous biological growth from the denitrification filter places an extreme biological load on the UV disinfection. During the period of time that the biological filter was still in service, no attempt was made to document the system's performance; instead, the operators concentrated on working the bugs out of the system and learning to use their new facilities. The electrical and electronic sophistication of this system is particularly complex.

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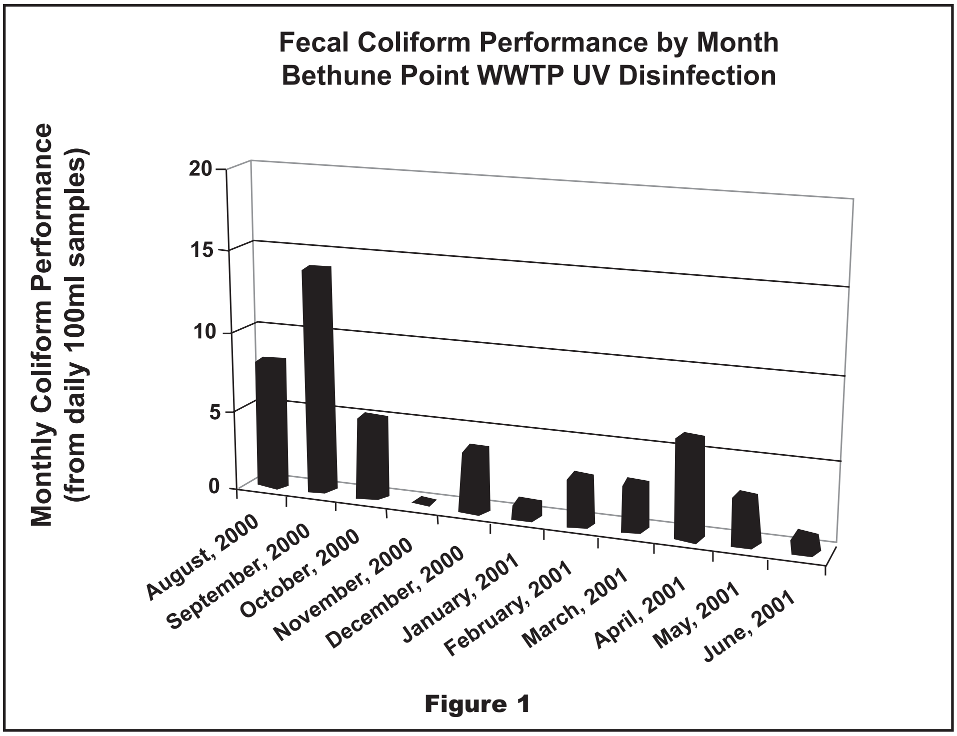

Figure 1

Bethune Point

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By March 2000, the methanol filter had been converted to regular deep-bed filtration and cleaned out. At that time, plant staff had become familiar with their new system and began routine documentation…and some experimentation…with the UV system.

Figure 1 summarizes total fecal coliform in the monthly samples from March 2000 through June 2001. For the first few months of startup, the plant performance simply did not consistently meet the Florida high-level disinfection standards for which it had been designed. After several months of observation, it appeared that there was something more at work than just energy, fecals, and operators learning a new system.

ABOVE: Cleaning systems prevent algae from growing on the UV lamps, but not on the mounting hardware. RIGHT: Algae fluorishes on the stainless-steel environment of the UV reactor.

Since much of the design criteria was based on previous California experience, we made an additional round of visits during the year 2000 to many of the California facilities we had previously visited, plus a number of new sites of various manufacturers. This additional travel was completed in late summer and yielded a surprising fact: Most of the California sites had the same problems as Daytona Beach.

The answer to the performance question turned out to be the growth of algae, stimulated by the UV light. When evaluating UV systems vendors originally, a great deal of effort was focused on the concept of lamp cleaning, especially for systems with mechanical cleaning designs, because in-place cleaning systems are very important to the function of any large-scale UV system.

However, lamp cleaning is not the only answer. Frankly, everyone's lamp-cleaning system seems to work pretty well. We found in Daytona Beach, and throughout numerous sites in California as well, that algae can grow profusely in the presence of UV lamps. It does not grow on the lamps; the lamp-cleaning systems do keep the lamps very clean. However, algae can grow out of control on the underwater surfaces of the equipment and the concrete adjacent to the lamps. In fact, algae can grow profusely anywhere that the UV light can be reflected in the channels: on concrete, wiring, hoses, or even stainless steel. The algae seems to particularly like the stainless-steel environment of the UV reactor, no doubt due to the high efficiency reflection of the UV light. We found that algae could grow profusely on any surface that has reflected UV light.

The algae itself is not the problem; rather it is the regrowth of bacteria on the algae and its byproducts. For basic-level disinfection applications this is not a problem, but for Florida high-level disinfection requiring nondetectable fecal coliform, it is a very serious concern.

Once we realized that algae could grow profusely under high-intensity UV, we started planning for methods to control the growth or clean the channels. California experience indicated that UV channels needed to be drained and pressure cleaned about once per month to compensate for the algae growth. Some of the California sites resorted to continuous chlorination in addition to UV to keep down the growth of the algae.

In the Bethune Point situation, we had designed for a continuous-flow, single-channel installation that didn't lend itself to algae control very easily. After getting rid of chlorine, we did not want to resort to continuous chlorination again. Plant staff began to clean the channels once per month, beginning about the September/October 2000 timeframe. Initially they tried periodic short-term super-chlorination of the channels once per month. This seemed to be relatively successful from the fecal performance standpoint. Fecal counts almost immediately began to decline. UV dosages were reduced somewhat from the high values we tried during the difficult early months.

However, super-chlorination alone merely suppresses the growth to some extent. Physical inspection of the Bethune channels shows the concrete channel itself to be absolutely clean, but algae grows in large colonies immediately adjacent to the UV reactors. As it grows, it spreads into the

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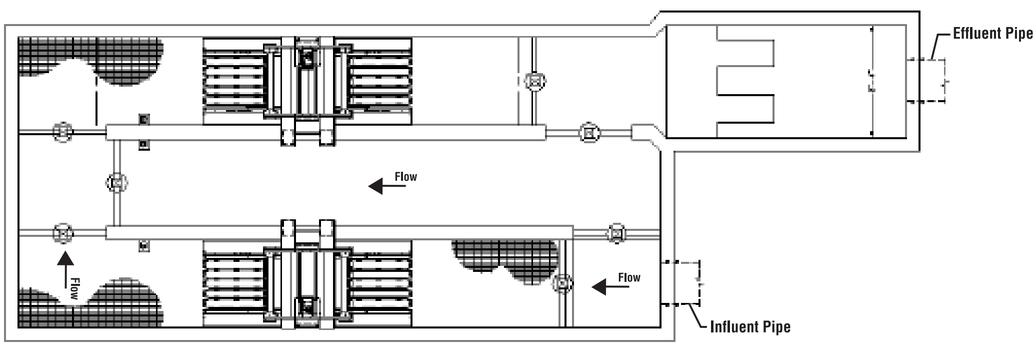

Proposed UV Equipment Layout
Figure 2

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reuse systems and causes problems with system strainers and sprinklers that require additional manpower for maintenance.

Implications for the Future

We find that periodic super-chlorination of the channels inhibits the algae growth to the point that fecal coliform performance can reproducibly meet the Florida high-level disinfection rules. However, the additional maintenance strain on the reuse system has been unacceptable. A self-cleaning fine screen is being installed downstream of the UV system at Bethune Point to ensure that fibrous algae fragments do not escape into the reuse system.

Despite the problems encountered with the Bethune Point project, the facility is clearly capable of meeting the strict Florida disinfection requirements for public access reuse. We have not given up on the future of UV in this application. The city is now moving to convert its other wastewater plant, Westside Regional, to UV disinfection as well. Lessons learned at the Bethune Point site will be incorporated into the new facility at the regional plant.

The regional facility will use multiple channels, each independently dewaterable to make it much easier to pressure clean the reactors on a regular basis. The Bethune Point channels were designed as a single pass that was continuously submerged and therefore hard to access for cleaning. The regional system will be designed from the beginning for access and cleaning. To this end, the new channel layout, shown in Figure 2, will make provision for alternating the flow through the UV reactors while cleaning is underway.

The inline UPS system has proven essential to maintain continuous service during commercial power fluctuations. The UPS system activated over 100 times during the summer of 2001 alone, never long enough to trigger the ATS and standby generator, but long enough to interrupt UV service if the UPS had not been installed. It will be included in the regional system as well, along with dedicated transfer switching and standby power.

The capacity philosophy for the regional facility will follow the precedent set at the Bethune Point plant. The average day flow (ADF) capacity of the plant will be designed for high-level disinfection and reuse. When plant flows peak at greater than the ADF, all the flow will be treated to basic-level disinfection and discharged to the river under the existing permit conditions.

Given these proposed modifications of the original Bethune Point design for the proposed Westside Regional disinfection project, we are confident that performance at the next facility will be even better than the performance experienced at the existing Bethune Point site.

EDITOR'S NOTE: Details on the Bethune Point plant renovation process and start-up were outlined in the July 2001 issue of the *Journal*. To view the article, entitled "Plant Renovation Brings Daytona Beach to Forefront of Water Reclamation," visit our Web site at **http://www.fwrj.com** and click on "Back Issues."