UV Process and Fouling Testing at Trickling Filter Plant: Key Factors in UV Design for Trickling Filter Effluent

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ABSTRACT

The City of Olathe, KS has been using ultraviolet (UV) light for over 20 years to disinfect waste-water effluent. The Olathe system was one of the first low pressure/low intensity UV systems installed in the state of Kansas. Two pilot-scale UV systems were tested at the treatment plant to compare the extent of fouling of their quartz sleeves. The pilot testing included a multi-phase process to establish the operation and maintenance requirements for each system. The first phase of the testing was conducted to validate the performance of the pilot system. The second phase of the testing was to conduct a fouling study. Results of the study indicated that after one week the sleeve transmittance was close to zero percent. The results of the fouling study were used to determine projected cleaning requirements for the new UV system. A baseline condition was established to allow a comparison to be made after new equipment is installed.

KEYWORDS

UV, Trickling Filters, quartz sleeve fouling.

BACKGROUND

For over 20 years, Olathe, KS, has used ultraviolet (UV) light for disinfection of treated wastewater effluent as shown on Figure 1. This system one of the first low pressure/low intensity UV systems installed in the State of Kansas, consists of modules that must be raised from below grade, cleaned, and then lowered back into the channels, all by hand- a procedure that requires significant operator effort. The low pressure UV system was designed to provide a dose of 30 mJ/cm^2 at a peak flow rate of 6.4 mgd. At the average daily flow of 1.8 mgd the applied dose is in excess of 70 mJ/cm^2. According to plant operating data, the UV transmittance and TSS values appear to be higher than those from other trickling filter plants, as shown on Figure 2. The higher transmittance may be due to factors such as lower organic loading, a 2 to 1 recycle ratio for the trickling filters, and the use of a nitrifying biotower.

Figure 1. *Olathe UV System*

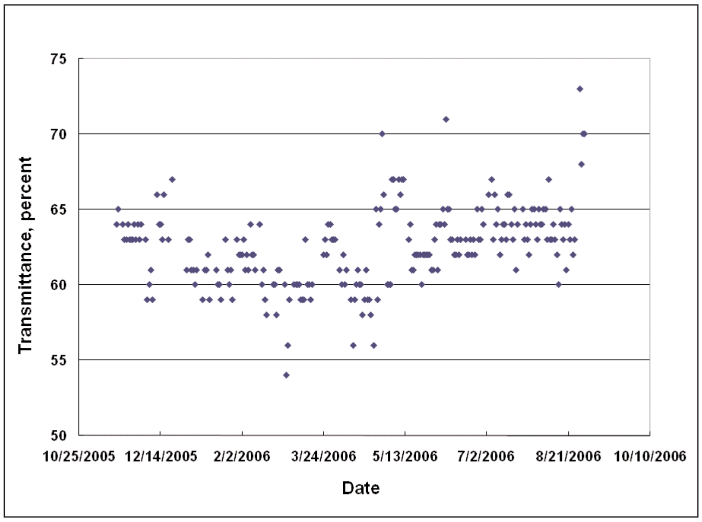

Figure 2. *Historical Transmittance Values – City of Olathe Data*

Ultraviolet (UV) radiation is electromagnetic energy lying within the spectrum of energy reaching Earth from the Sun, but outside the wavelength range of visible light. UV light between the wavelengths of 235 and 270 nanometers (nm) has been found to be biocidal to bacteria and viruses in natural water, wastewater, and process waters. This biocidal property is the basis for using UV radiation as a physical disinfectant in the municipal wastewater industry.

Ultraviolet radiation is readily absorbed by deoxyribonucleic acids (DNA) in certain pathogens found in municipal wastewater. When this energy is absorbed, a pathogen's molecular structure can be altered, making it unable to replicate. While this effect can be reversed (referred to as reactivation) under certain conditions, UV radiation has proven effective in disinfecting municipal wastewater.

Since 1990, more sophisticated and reliable UV systems have been developed that operate much more cost-effectively and have been installed in many treatment plants, as an alternative to disinfection with chlorine as increasingly tighter effluent chlorine, residual limits are being imposed.

PILOT PROJECT

In order to establish design parameters and to compare the two systems, a multi-phase demonstration study was conducted. This paper will focus on the results from performance and fouling tests conducted as part of this study.

Equipment

The two pilot units evaluated as part of this study were supplied by Trojan Technologies and by ITT Wedeco. Trojan System UV3000 Plus was a 12 lamp system with a chemical/mechanical wiping system shown on Figure 3. The 12 lamps were arranged in a single bank consisting of three vertical modules of 4 lamps each, with each lamp rated for a maximum power output of 250 W. Influent flow was monitored using an in-line flow-meter calibrated by City staff. On-line transmittance was measured using a HACH UV transmittance unit. The pilot unit was controlled using a standard Trojan PLC that controlled the UV dose supplied.

Figure 3. *UV Pilot Systems*

ITT/Wedeco supplied a 12 lamp TAK 55 pilot unit with a mechanical wiping system. The lamps were arranged in a single bank of two 6 lamp modules in a 2 by 3 array with each lamp rated for a maximum power output of 360 watts. Influent flow was monitored using an in-line flow meter calibrated by City staff.

Study Elements

The study was divided into several tests to demonstrate and compare the performance of the two UV systems

- Performance
    - Study 1 – Trojan only
    - Study 2 – Trojan and Wedeco units
- Fouling Study
    - Study 1 - Trojan only
    - Study 2 – Trojan and Wedeco units
- Process Transmittance Study – Trojan and Wedeco units
- Flow Impacts – Trojan and Wedeco units
- Power Study – Trojan and Wedeco units
- Reliability Study – Trojan and Wedeco units

Performance Study

The initial performance study was conducted to confirm that the performance of the Trojan System UV3000Plus was similar to that of the plant's existing low pressure UV system. During this study, samples were collected and shipped to Trojan Technologies for collimated beam analysis. A second performance study was completed after installation of Wedeco unit to compare the performance of the two pilot units.

Fouling Study

A major objective of this study was to evaluate fouling of the quartz sleeves. The first system to be tested was the Trojan System UV3000Plus. The purpose of the fouling study was to determine how fast the quartz sleeves would become fouled after the cleaning system was turned off and then to determine the length of time needed for the cleaning system to return the sleeves to their UV sleeves to recover to pre-fouled condition.

The UV transmittance of the quartz sleeves was determined by measuring double-layer UV transmittance through the sleeve and converting the result to single-layer UV transmittance. This method does not give an absolute measurement due to the curvature of the sleeve, but a relative measure that can be used to compare sleeves, or the changes in fouling on a sleeve under controlled test conditions. The measurements were taken using a Varian Cary 50 UV/Visible Spectrophotometer with holders that keep the sleeve stationary and leveled so that the beam passes through the center of both sides of the sleeve and into the detector.

Power Study

The performance of the UV systems was evaluated to determine if the input power to the lamps was the same for both systems. This was done to see if the performance of the Wedeco system was influenced by input power.

Process Transmittance Study

The transmittance study was conducted to determine if changes in the treatment process would result in a decrease in transmittance. A review of the literature indicated that typical transmittance of a trickling filter plant effluent is 50%. The transmittance of the Harold Street plant effluent ranges from 62 to 65%. During this study, temporary changes were made to the treatment process to see if the changes would result in transmittance values that were more typical of an average trickling filter effluent.

Reliability Study

The reliability study was conducted to assess the performance and reliability of the two UV systems with lamps out of service. Because of adverse weather conditions that restricted access to the system this study could not be completed.

RESULTS

Performance Study

During the performance study a number of parameters were validated. One of the key parameters was transmittance. Transmittance data provided by plant staff were based on one grab sample collected daily. Since the plant is operated only 8 h per day, the daily transmittance pattern had to be determined using an on-line transmittance device. A representive 48 h plot of transmittance is shown on Figure 4. In addition, the transmittance measurements did not appear to remain constant throughout the day.

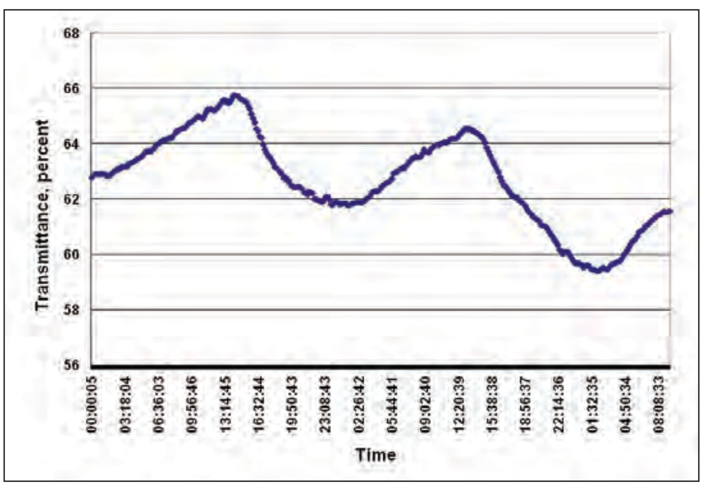

Figure 4. *On-line Transmittance Data*

Based on the previous results, it can be noted that historically the transmittance ranges from a high of 75% to a low 54%. During the pilot testing the transmittance ranged from 63 to 54%, with an average value of approximately 59%.

In addition to transmittance data, influent fecal coliform and *E. coli* data were collected three times each day to determine any variability in the treatment plant as shown on Figure 5. The raw influent data to the UV system collected during the study show a decrease in fecal coliforms during the afternoon's higher temperatures and an increase effluent fecal coliforms as the water temperature dropped. The results of sampling during various times of the day indicate the highest values for effluent fecal coliforms, effluent TSS, and turbidity during the afternoon of each day.

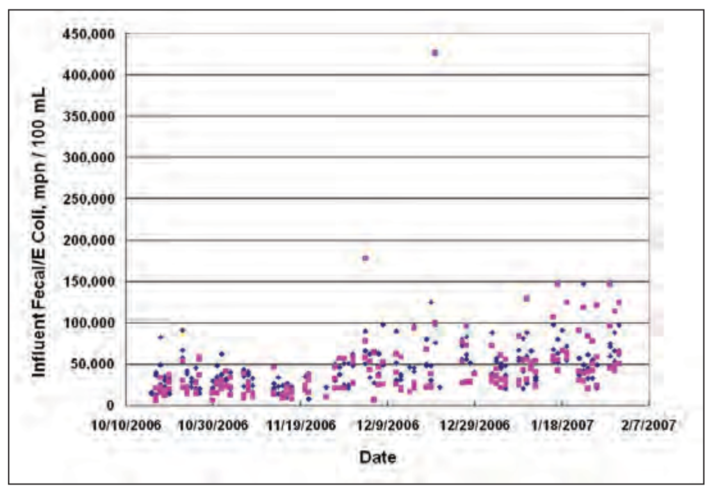

Figure 5. *Influent Fecal Coliforms and* E. coli

To determine the effectiveness of UV in disinfecting the plant effluent, a UV dose response test, typically called collimated beam test, was conducted. In this test, plant effluent is exposed to various doses of UV to determine the effluent fecal coliform count. Both Trojan Technologies and ITT/Wedeco completed collimated beam testing. Trojan Technologies completed the testing during the first 6 weeks of the study (before the performance of the plant was impacted by cold weather). Figure 6 shows the results of the collimated beam study conducted by Trojan Technologies. ITT/Wedeco conducted the tests during the last part of the study.

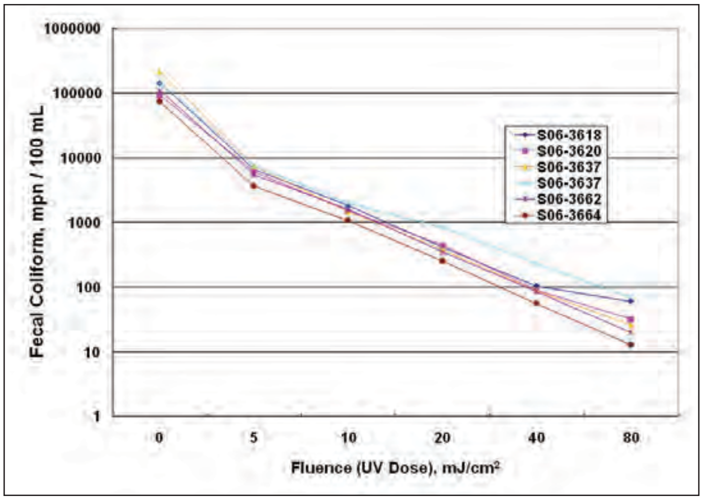

Figure 6. *Trojan Collimated Beam Test Data*

Results of both collimated beam tests indicate that UV can be used effectively to meet the disinfection requirements at the plant.

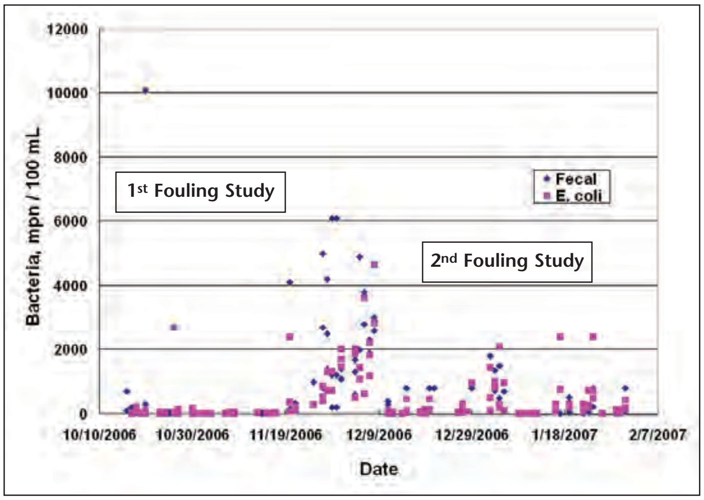

Figure 7. *Trojan's Fouling Study*

Validation of UV Dose

A comparison was made between the collimated beam testing and the actual disinfection performance of the pilot units to validate the UV dose required for disinfection. After comparing the results of the two tests, the following conclusions were drawn:

1. A UV dose of 40 mJ/cm^2 or more will produce an effluent fecal coliform concentration of 200 fc/100 mL or less (Permit requirements).
2. The Trojan pilot unit's disinfection performance results matched the collimated beam data.
3. The Wedeco pilot unit's disinfection performance results did not appear to match the collimated beam data. Since the coliform counts in the pilot unit's effluent were usually low (at or below detection), it is possible that the dose recorded by the Wedeco PLC was not a reflection of the actual dose applied in the pilot unit. Additional study will be needed to determine if the PLC did not function correctly.

Fouling Study

Quartz sleeves were allowed to become fouled by turning off the cleaning system, to determine how many cleaning cycles would be needed to restore the sleeves to their pre-fouling condition. The fouling study for the Trojan unit was done in two phases – 1st fouling study and 2nd fouling study. The fouling study for Wedeco was done in the second phase. Results of the fouling study are shown on Figures 7 and 8. The overall fouling performance was indicated by the effluent fecal coliform count.

As the fouling increased, the sleeve transmittance kept decreasing until it dropped to zero. When the transmittance reached zero, the cleaning cycle was turned on, to slowly increase the transmittance through the quartz sleeves to their pre-fouling condition.

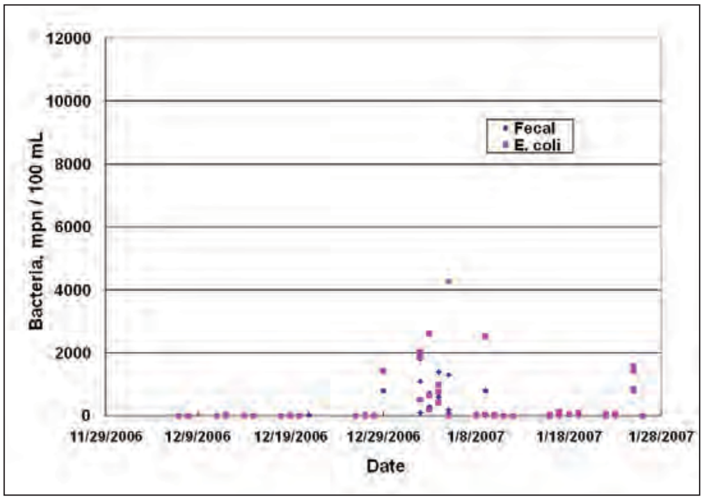

Figure 8. *ITT/WEDECO's Fouling Study*

According to the information from the pilot study, the Trojan system needed an average of 48 cleaning cycles (2 days at a rate of 1 cycle/h) to restore the sleeves to their pre-fouling condition, whereas the Wedeco system needed an average of 96 cleaning cycles (4 days at a rate of 1 cycle/h). This difference in recovery performance may be attributed to the fact that Trojan's system uses a chemical agent to supplement the physical cleaning by the cleaning cartridges, while the Wedeco system relies only on the physical cleaning by the wipers. Both systems returned to the prefouled state after cleaning.

Laboratory tests listed in Table 1 were conducted to determine the composition of the fouling material in the Harold St. WWTP.

Table 1. *Foulant Lab Analysis Results*

Constituent	Concentration (mg/L)	Constituent	Concentration (mg/L)
Ca	35	Mn	0.6
Mg	2.4	Ni	0.019
As	0.01	Pb	0.069
Ba	2.7	Se	0.010
Be	0.0003	Ti	0.0008
Cd	0.003	Zn	0.753
Cr	0.070	P	*
Cu	0.152	Al	9.4
Fe	1.4	Ag	0.009

* Value not validated by Lab; therefore, not used

Based on the results of laboratory testing, it was determined that the foulants accumulated on the sleeves were inorganic; moreover, no measurable amounts of organic foulants were found. This implies that the wastewater characteristics are a major factor in the UV system performance, and those systems that rely on a combination of physical (mechanical) and chemical cleaning are more likely to remove inorganic components from the sleeves than those systems that rely only on physical cleaning alone.

SUMMARY

Testing conducted as part as study indicated that both UV systems tested would achieve the same performance as the existing UV system. This was in part due to the fact that the UV transmittance of the Harlod Street plant effluent averages 65% which is significantly higher than would be expected at a trickling filter plant. The existing UV facility at the Harold Street plant requires additional labor by plant staff because of fouling of the quartz sleeves. Results of fouling testing indicated that both systems would be capable of removing any material that may foul quartz sleeves.