Memorandum

Jacobs

Evaluation of Ultraviolet Light Disinfection System at the Richard A. Heyman Wastewater Treatment Plant

Date: August 29, 2022

Project name: UVDS Technical Evaluation for City of Key West

Attention: Kelly Crowe

Project no: D3601610

Company: City of Key West:

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INTRODUCTION

Jacobs was retained by the City of Key West (City) to perform an independent technical assessment of the operation and performance of the ultraviolet light (UV) disinfection system (UVDS) at the Richard A. Heyman Wastewater Treatment Plant (RHWWTP) located at Key West Trumbo Point Annex-Fleming Key. Under Consent Order OGC Case No. 21-0581 (Consent Order) issued by the Florida Department of Environmental Protection (FDEP), the City is directed to advance several activities focused on reducing sewer infiltration and inflow (I&I) as well as perform an assessment of the UVDS. This memo responds to the requirements provided in Item (A) of the Consent Order assessing the UVDS and development of modifications and/or improvements to prevent future exceedances of ultraviolet light transmittance (UVT), UV dose, and fecal coliform as provided under domestic wastewater facility Permit Number FLA147222.

Jacob's assessment was performed by Professional Engineers registered in the State of Florida as required by corrective action item (A) of the Consent Order. The individuals conducting this assessment include Mr. Joseph Viciere (FL PE No. 59533) and Mr. Erik Jorgensen (FL PE No. 91857). Mr. Viciere conducted a site visit to the RHWWTP on August 16, 2022 to inspect the facilities and to interview plant operators. Mr. Jorgensen reviewed operating and water quality sampling data as well as conducted additional interviews with Operations staff.

BACKGROUND

The RHWWTP is a 10.0 million gallons per Day (MGD) annual average daily flow (AADF) domestic wastewater facility permitted by FDEP under Permit Number FLA147222. RHWWTP is an advanced wastewater treatment plant facility with discharge of treated effluent to an underground injection well system (U-001), consisting of two Class V underground injection wells discharging to Class G-III groundwater.

The current UVDS was installed at the RHWWTP in 2007. Prior to the UVDS installation, filtered effluent was disinfected using chlorine. The physical assets associated with chlorine disinfection system are still present but would necessitate a minor revision of the current permit if it were to be placed in service. However, these assets have not been in service for several years. Before they could be brought into service, the condition of the equipment would need to be assessed and likely refurbished.

The relevant permit exceedances related to the UVDS contained in Exhibit C of Consent Order are provided in Table 1. Discharge of wastewater effluent from the UVDS is monitored by plant staff as required by the facility permit as outlined in Table 2. Table 1 lists a total of nine exceedances of reported plant data related

to the UVDS. Four exceedances were for daily reported fecal coliform. Four exceedances were for daily reported UVT. One exceedance was for UV Dose reported daily. There were no reported exceedances for monthly geometric mean of fecal coliform nor was there an exceedance of reported annual average fecal coliform.

Table 1 – Permit Exceedances Identified in Exhibit C of Consent Order Related to UVDS

Monitoring Group	Date	Description	Reported Value	Permit Limit	Units
U-001	6/7/2021[a]	Coliform, Fecal	2,419.9[b]	800.0 (Max)	#/100 ml
U-001	1/1/2021[a]	Ultraviolet Light Transmittance	63	65 (Min)	percent
U-001	12/30/2020[a]	Ultraviolet Light Transmittance	63[b]	65 (Min)	percent
U-001	10/22/2020[a]	Ultraviolet Light Transmittance	60	65 (Min)	percent
U-001	9/13/2020[a]	Ultraviolet Light Dosage	0	35 (Min)	mW-s/sqcm
U-001	9/13/2020[a]	Ultraviolet Light Transmittance	26	65 (Min)	percent
U-001	9/14/2020[a]	Coliform, Fecal	1,244	800.0 (Max)	#/100 ml
U-001	5/2/2020[a]	Coliform, Fecal	1,336	800.0 (Max)	#/100 ml
U-001	4/27/2020[a]	Coliform, Fecal	1,473	800.0 (Max)	#/100 ml

Notes:

a) The date of occurrence presented is based on recorded plant data and differs from Exhibit C of Consent Order.

b) The value reported is based on recorded plant data and differs from Exhibit C of Consent Order.

Table 2. Monitoring Requirements for the UVDS

Parameters	Units	Max /Min	Limit	Statistical Basis	Frequency of Analysis	Sample Type	Monitoring Site Number	Notes
UV Dosage	mW-s/sq.cm	Min	35	Single Sample	Daily; 24 hr.	Meter	PPI-1	See Permit # IA-6
UV Transmittance	percent	Min	65	Single Sample	Daily; 24 hr.	Meter	PPI-1	
UV intensity	mW/sq.cm		Report	Single Sample	Daily; 24 hr.	Meter	PPI-1	
Fecal Coliform	#/100 mL	Max Max Max	200 200 800	Annual Average Monthly Geometric Mean Single Sample	5 Days/Week	Grab	EFF-1	See Permit # I.A-4

EFF-1 = After the UV reactors

PPI-1 = In the UV reactor

Jacobs reviewed plant effluent water quality data from January 1, 2016 through August 21, 2022. The plant's record of effluent water quality demonstrates a high level of consistent performance exceeding permit requirements. Reported daily fecal coliform data typically is less than 10 count/100 ml and far below the daily requirement of 800 count/100 ml. UV Transmittance (UVT) values are typically above 70-percent, exceeding the minimum requirement of 65-percent. Reported values for UV Dose and UV intensity are consistently within required process specifications. The exceedances reported in Table 1 are not normal or typical for this facility.

Reported monthly geometric mean and annual average fecal coliform values are far below permit requirements even during months when daily reported values resulted in an exceedance(s). For 2020 and 2021, the typical monthly geometric mean was less than 2.0 count/100 ml and the reported annual averages were also less than 2.0 count/100 ml. The highest reported monthly geometric mean for fecal coliform occurred in June of 2021 with a reported value of less than 12 count/100 ml. These values are far below the monthly geometric mean and annual average of 200 count/100 ml.

The effluent water quality record suggests the reported exceedances are not typical and that even with the reported exceedances the monthly geometric mean and annual average for fecal coliform are in compliance with permit requirements. The purpose of the review and assessment of the UVDS focused on circumstances that contributed to the permit exceedances and identification of corrective action measures to minimize their occurrence in the future.

SITE VISIT AND OBSERVATIONS

A site visit to the RHWWTP occurred on August 16, 2022, to inspect the UVDS and assess operation procedures that assure proper maintenance of operation of the facility. The major observation was that the UVDS operates in manual mode. The UV Dose and UV Intensity are recorded by SCADA. The UVDS does not currently have a UVT sensor to continuously monitor and record UVT. UVT is obtained from daily grab samples. Because the system operates without a UVT sensor providing continuous monitoring of UVT, there is little ability to provide a real-time alarm on the facility's System Control and Data Acquisition (SCADA) System based on UVT. Alarming on flow would be possible.

The UVDS consists of two in-channel UV systems installed downstream of the plant filtration system. Each UV channel contains two (2) UV banks (made up of modules placed in parallel positions and spaced 4-inch apart) for a total of four (4) banks for the UVDS. Each UV channel is equipped with two operating banks of UV lamps. It was noted that the UV lamps were an older style with ballasts located adjacent to the UV lamps under water. Newer systems for in-channel UVDS separate the ballasts from the UV lamp so the ballast can be maintained and accessed above the water level. Operators indicated they have serviced the UVDS by replacing individual lamps and ballasts.

There are eight (8) lamps within a module and there are five (5) modules within each bank. The total number of lamps per bank is forty (40), and the total number of lamps in the channel (reactor train) is eighty (80). One hundred and sixty (160) lamps are provided for the entire UVDS. The UVDS includes uninterrupted power supply units to provide a continuous, uninterrupted supply of power during transition from normal to emergency standby power and return to normally used power provided by the local utility.

The UVDS at the RHWWTP should be operated above the designed dose of 35.0 mW-s/sq.cm. The dose is calculated by three variables:

- Flow (Filter effluent flow)
- UVT (measured at the entrance of the reactor channels)
- Power

The first two variables, flowrate and UVT, are dependent upon the wastewater treatment process before the UVDS. Therefore, the only variable the UVDS can change is the power to operate in compliance with permit requirements. Jacobs performed the following calculation to confirm each in-channel system can achieve greater than 35.0 mW-s/sq.cm when flow through the individual channel is 9 MGD. Both channels would be in operation under peak flow of 18 MGD. It should be noted that in 2021, the annual average daily flow was 4.6 MGD.

UV Dose Calculation

Log Delivered dose (D dose) per bank = -4.63 – (0.7 * Log flow) + (2.91 * Log UVT) + (1.09 * Log Power)

Calculation assumptions:

- Peak Flow of18.0 MGD (10 MGD AAF with a max day peaking factor of 1.8)
- Flow per UV channel (reactor channel) is 9.0 MGD per channel or 6250 gallons per minute (GPM) per channel
- Flow per lamp 6250-gpm per channel divided by 40 lamps per bank = 156.25-GPM per lamp per bank
- UVT = 65%
- Power = 100%
- End of Lamp Life Adjustment Factor (EOLL) = 0.98 (1.0 for new lamps)

- Fouling Factor (FF) = 0.95

Log D (Dose per bank) = -4.63 – (0.7 * Log (156.25)) + (2.91 * Log (65)) + (1.09 * Log (100)) =1.29

Dose per bank = 19.5 mW-s/sq.cm

Dose per bank at end of lamp life = D Dose per bank * (FF) * (EOLL)

Dose per bank at end of lamp life = 19.5 * (0.95) * (0.98) = 18.15 mW-s/sq.cm

Dose per channel= 18.15 * 2 banks ON = 36.3 mW-s/sq.cm

The findings of the field visit were the following:

1. The UVDS is operated in manual mode at maximum power output.
2. Because the UVDS does not have a UVT sensor providing continuous monitoring of UVT, there is limited ability of SCADA to provide a real time alarm of adverse conditions at the UVDS.
3. The number of lamps and channel configuration allowed for an annual average flow of 10 MGD with a max day peaking factor of 1.8 allowing for disinfection of up to 18 MGD.
4. The UVDS is an older style lamp and ballast configuration and there is not a UVT sensor to support operation in automatic mode.

The general finding is that the UVDS is suitable for typical plant flow conditions as suggested by long-term reported effluent water quality. However, the UVDS lacks continuous monitoring of UVT, and consequently cannot be operated in automatic mode in this current configuration and has an older style UV lamp and ballast configuration that is harder to maintain than newer systems. The existing system satisfies the requirements of a 10 MGD facility as permitted.

OPERATIONS INPUT RELEVANT TO PERMIT EXCEEDANCES

Table 3 provides the input from Operations regarding conditions and/or circumstances that may have contributed to the exceedances reported in Table 1.

Table 3. Operations Input on Reported Exceedances

Date	Parameter	Reported Value	Permit Limit	Units	Operations Input
6/7/2021[a]	Coliform, Fecal	2,419.9[b]	800.0 (Max)	#/100 ml	Possible malfunction of UVDS, all operating parameters within specification
1/1/2021[a]	Ultraviolet Light Transmittance	63	65 (Min)	percent	Plant staff having challenges with aeration basin in secondary treatment, this was also New Year's Day with associated holiday flow conditions
12/30/2020[a]	Ultraviolet Light Transmittance	63[b]	65 (Min)	percent	Plant staff having challenges with aeration basin in secondary treatment, this time period associated with holiday flow conditions
10/22/2020[a]	Ultraviolet Light Transmittance	60	65 (Min)	percent	Loss of a secondary clarifier due to a failure of the clarifier mechanical system and high influent flow.
9/13/2020[a]	Ultraviolet Light Dosage	0	35 (Min)	mW-s/sqcm	Loss of a secondary clarifier due to a failure of the clarifier mechanical system and high influent flow caused by a named storm (TS Sally)
9/13/2020[a]	Ultraviolet Light Transmittance	26	65 (Min)	percent	Loss of a secondary clarifier due to a failure of the clarifier mechanical system and high influent flow caused by a named storm (TS Sally)
9/14/2020[a]	Coliform, Fecal	1,244	800.0 (Max)	#/100 ml	Loss of a secondary clarifier due to a failure of the clarifier mechanical

					system and high influent flow caused by a named storm (TS Sally)
5/2/2020[(a)]	Coliform, Fecal	1,336	800.0 (Max)	#/100 ml	UVDS bulb failure, lack of UVDS monitoring
4/27/2020[(a)]	Coliform, Fecal	1,473	800.0 (Max)	#/100 ml	UVDS bulb failure, lack of UVDS monitoring

Notes:
a) The date of occurrence presented is based on recorded plant data and differs from Exhibit C of Consent Order.
b) The value reported is based on recorded plant data and differs from Exhibit C of Consent Order.

CONCLUSIONS AND RECOMMENDATIONS

The RHWWTP UVDS meets the requirement of a 10 MGD wastewater treatment facility. The annual average flow to the RHWWTP was 4.6 MGD in 2021. Based on normal operations, there should not be any exceedances related to requirements in the facility's permit related to the UVDS. However, there were exceedances. The explanations for the exceedances provided by Operations fall into four causal categories:

- Non-normal operating conditions caused by holiday season and/or weather;
- Mechanical failure resulting in secondary clarifier shutdown combined with higher-than-normal influent plant flow;
- Monitoring and maintenance of the UVDS; and
- Malfunction of the UVDS

Based on observations in the field regarding the lack of real time monitoring of UVT, and the causal factor identified by Operations as being a malfunction of the UVDS contributing to exceedances as well as monitoring and maintenance of the UVDS, it is recommended the UVDS be upgraded and/or replaced. A new UVDS would provide real time monitoring of UVT and provide greater ease of maintenance of ballasts located out of the water and in a readily accessible location.

The Consent Order directs the City to reduce I&I. The reduction of I&I is outside of the scope of this memorandum's assessment of the UVDS. However, based on the identified causal factors contributing to exceedances, improvements in managing plant inflow by reducing I&I will likely result in reduction of potential future exceedances of fecal coliform, UVT, and UV dose.

The non-normal operating conditions (upsets) and mechanical failures with other plant equipment could still cause problems with the UVDS. One method of improving disinfection resiliency would be to return the chlorine contact chambers to service with the use of sodium hypochlorite as a disinfectant as a standby measure. This would provide Operations with the flexibility to enhance disinfection during plant upset conditions.

Interim Recommendation

1) Implement alarming based on exceeding instantaneous flow equivalent to 8 MGD (5,556 GPM). This condition represents a peak flow of 1.7 times the annual average flow in 2021. This flow condition should be treatable using UV but will provide an alert to Operations of high flow conditions.

2) Operations staff should increase the monitoring of the UVDS. Operators should be informed on what to do when conditions have resulted in UVDS exceedances – a) plant upsets in secondary treatment; b) higher than normal influent conditions; c) proper monitoring and maintenance of the UVDS.

3) For conditions where UVT drops below 65, develop a flow diversion plan to allow correction of treatment ahead of the UVDS. This will be difficult to implement satisfactorily as the finding that the UV exceeding 65% occurs after the fact.

Long-term Recommendations

1) Replace the existing UVDS with the new generation of UVDS incorporating the following enhancements:

a. Provisions including an online UVT sensor

b. Fully automated system with alarm capabilities.

2) Return the chlorine contact chambers to service as a disinfection standby system and modify the facility permit to allow their use.

This memo has been prepared by the following persons registered as Professional Engineers in the State of Florida: