Literature

Book Review — *Pretreatment of Industrial Wastes*

John Paniccia

Eysenbach, Elin et al. *Pretreatment of Industrial Wastes*. Water Environment Federation; Alexandria, Va 22314-1994. Copyright 1994. (243 pages).

The problem of water pollution has been with mankind for throughout recorded history. With the increase in human population over time, the problem has grown exponentially. More specifically, an even greater threat to water resources has been attributed by many environmentalists to the increasing amount of industrial wastes from our highly industrialized society. The demand for goods produced by industry has resulted in a greater demand for resources to provide those goods and, in turn, has increased waste by-products as a result of production. The need for new and more efficient methods of industrial waste treatment systems to meet regulatory standards is evident, and more information is needed to address those needs.

In the book, *Pretreatment of Industrial Wastes*, we find a wealth of information to help us deal effectively with the problem of industrial wastes and to reduce pollution of our water resources.

Wastewater pretreatment standards were developed as a result of the Federal Water Pollution Control Act of 1972; specifically, 40 CFR Part 403.2, which calls for protection of publicly owned treatment works (POTW), prevention of pollutant "pass through" into receiving waters, and reclamation of sludge. The authors provide a combination of ideas and methods, both new and old, that meet these standards and address the myriad of problems associated with industrial waste-water treatment of pollution.

Although some of the methods and technologies described in the book are more than 20 years old, recent emphasis on pollution prevention in the pretreatment industry is emphasized throughout the book.

The authors also offer an excellent perspective on the relation between facility design/technology and regulatory standards throughout the entire text. Pretreatment program planning will become increasingly more important as past environmental regulations established by the Clean Water Act begin to take hold and increase their mandate for the future; this book will be an important tool for pollution program managers in meeting that mandate.

Another major issue that is addressed throughout the book is that of economic feasibility, i.e., cost considerations, that are of the utmost importance in the design of pretreatment facilities. The book yields valuable, detailed information about design costs for nearly all unit processes associated with pretreatment facility construction. It also provides information needed by pollution control managers about costs associated with facility operations and maintenance. These costs are even more significant because they are ongoing, and the authors supply specific information to minimize costs with respect to such issues as chemical usage, operator training, preventive maintenance, and by-product reuse.

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One interesting caveat about the book: the information is presented in such detail that one may forget the fact that it's being offered as a practical application guide for *operation and design* of wastewater pretreatment facilities. The information is to be applied, but the experience of learning about so many complex issues overwhelms the practical aspects and seems to draw your thoughts to the technological theory of the writing; thus by merging both the technical and practical aspects of pretreatment facility operation and design, the authors facilitate a more complete understanding of pretreatment concepts and associated issues.

The presentation of the material is comprehensive and concise. In my view, this ability to provide such a large amount of information in such a concise manner is due, in large part, to the authors' resourceful use of tables, charts, graphs, and references. Section by section, the use of tables defining alternative treatment methods and chemical listings, references — which provide pollution sources and policy standards— and a host of other information give the reader an opportunity to go beyond the text and gain extensive knowledge from the data. Comprehensive references are given at the end of each chapter, with some listings taking more than three pages.

I found two minor problems with the book. First, in Chapter 9 the authors describe treatment of organic pollutants in pretreatment systems and use case studies as part of the description. The chapter contains a section which outlines four case histories related to the use of biological pretreatment methods. The entire four histories cover barely a page, and they are presented in such brevity that it becomes difficult to understand their relevance to the section, or why the authors even chose to include them in the chapter.

The second problem was the complete omission of natural processes, i.e., the application of plant (flora) nutrient removal as a possible alternative in pretreatment systems. Although not specifically a technical process, natural processes are being used in various wastewater treatment applications around the country and in other parts of the world; the writers do the book a disservice by not making some reference either for or against their use in the pretreatment industry.

Nevertheless, I believe the book can be an asset to environmental students, and it is certainly an asset to pollution control managers. Because of the clear and concise manner in which information is presented, instructors of pollution management will find it to be a useful tool. It will provide the student with an insight and depth of understanding not usually described in standard texts for environmental studies. It offers a fundamental understanding of industrial pollution issues for those students with a concentration in pollution management, and it could be extremely important in helping them achieve career goals through acquired knowledge in the field.

The book is directed toward pollution managers who are actively working in the industry. It covers virtually every issue which may confront a pollution control administrator on any given day. Every topic of technical concern from microbiological process control to environmental policy management and most everything in between is discussed, thus providing a broad spectrum of information for managers to utilize in the decision making process.

This book is a significant contribution to the field of wastewater pretreatment pollution control because of its broad base of information and its usefulness as a tool for students, instructors, and mangers of pollution control issues. As we look toward the future, the issues we face in terms of water pollution control will bring us to a point where we must address old problems with new ideas.

The solutions found in *Pretreatment of Industrial Wastes* are environmentally friendly and economically desirable. Emphasis is placed on waste minimization, reuse/recycling, toxicity reduction to receiving waters, and compliance controls. Thus, the authors provide a foundation for addressing wastewater pollution control in a manner consistent with the paradigm of sustainable development; this will help conserve global resources now and into the future. ■

Two Step Disinfection by Ultraviolet Radiation/Chlorination

Brian M. Stahl and David L. Collins

A combination of ultraviolet disinfection and chlorination was used to attain high-level disinfection of an advanced waste treatment effluent used to irrigate a golf course in Bay County, Florida. The majority of the effluent (7 MGD) will be discharged to St. Andrew Bay and 0.4 MGD will be discharged to a public access reuse system. DEP currently has no regulatory requirements that specifically define the permitting steps and monitoring requirements associated with ultraviolet radiation as it relates to municipal wastewater disinfection.

Based on the results of a Level II Water Quality Based Effluent Limit (WQBEL) study, DEP requires the discharge to St. Andrew Bay to have effluent limits of 10 mg/L CBOD, 10 mg/L TSS, 8 mg/L TN, and 2 mg/L of TP, and intermediate-level disinfection is required. FAC Chapter 62-600 states that the arithmetic mean of the monthly analyzed samples must achieve a fecal coliform count of less than 14 per 100 milliliter sample to meet intermediate-level disinfection.

DEP requires the discharge to the golf course to meet high-level disinfection. The FAC requires significantly higher treatment for the high-level disinfection with 75% of the samples achieving a below detectable limit on fecal coliform per 100-milliliter sample and a 1.0 mg/L chlorine residual at a minimum contact time of 15 minutes during peak hour flow along with secondary treatment and filtration to less than 5.0 mg/L of total suspended solids.

Approach

To achieve the desired disinfection levels, we developed a two-step disinfection system design concept using ultraviolet (UV) disinfection to achieve the intermediate-level disinfection followed by a much reduced chlorine dose using liquid sodium hypochlorite to achieve high-level disinfection of the portion of the wastewater to be used on the golf course.

The treatment process includes fine screening, grit removal, biological nutrient removal, secondary clarification, and filtration, which provides for TSS below 5 mg/L and a pathogen criteria of 200,000 fecal counts per 100 milliliters in the influent to the UV system.

The UV disinfection process design incorporates a dual channel system with a total number of 1,120 low-pressure lamps and a minimal UV dosage of 40,240 mWs/cm2 to reduce the fecal coliform concentrations to below 14 counts per 100 milliliters. The process has an automatic control system that monitors the transmittance of the waste stream along with the UV dosage.

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The UV dosage is derived from the number of operating lamps and their continious UV lamp intensity times the contact duration. Wastewater samples from several other local treatment facilities with similar process trains were used to establish typical UV system wastewater transmittance levels. The transmittance level, as partially attributable to the potable water supply, in all samples exceeded 65%.

The UV disinfection system will have two channels, each channel with 14 banks of 40 vertical lamps, for a total of 1,120 available lamps. The Class 1 Reliability UV dosage of 40,240 microwatt-seconds per square centimeter ($\mu W\text{-}s/cm^2$) represents one of the two available channels (560 lamps) dosage for 75% of the peak hourly flow (11.55 MGD) with the other channel out of service. The actual peak hourly flow (15.5 MGD) UV dosage will be 53,653 $\mu W\text{-}s/cm^2$ with both of the two available channels (1,120 lamps) operating. The UV retention time at the peak hour flow will be at least 14.5 seconds. These design criteria require that the low pressure UV disinfection system maintain a minimum UV dosage of 40,000 $\mu W\text{-}s/cm^2$ at peak hour flow. Figure 2 provides an indication of the typical UV dosage to fecal concentration reduction at varying total suspended solids concentrations.

The second step of the disinfection system utilizes the FAC allowance for alternative combinations of chlorine residual and contact time as provided for in 62-600.440(5)(d), which states that alternative combinations of chlorine residual and contact times may be used to meet the criteria for high-level disinfection if justified by the engineer. A sodium hypochlorite chemical feed rate system was used that will be flow-paced off of the effluent

Figure 1. Two Step UV Radiation/ Chlorination Disinfection System

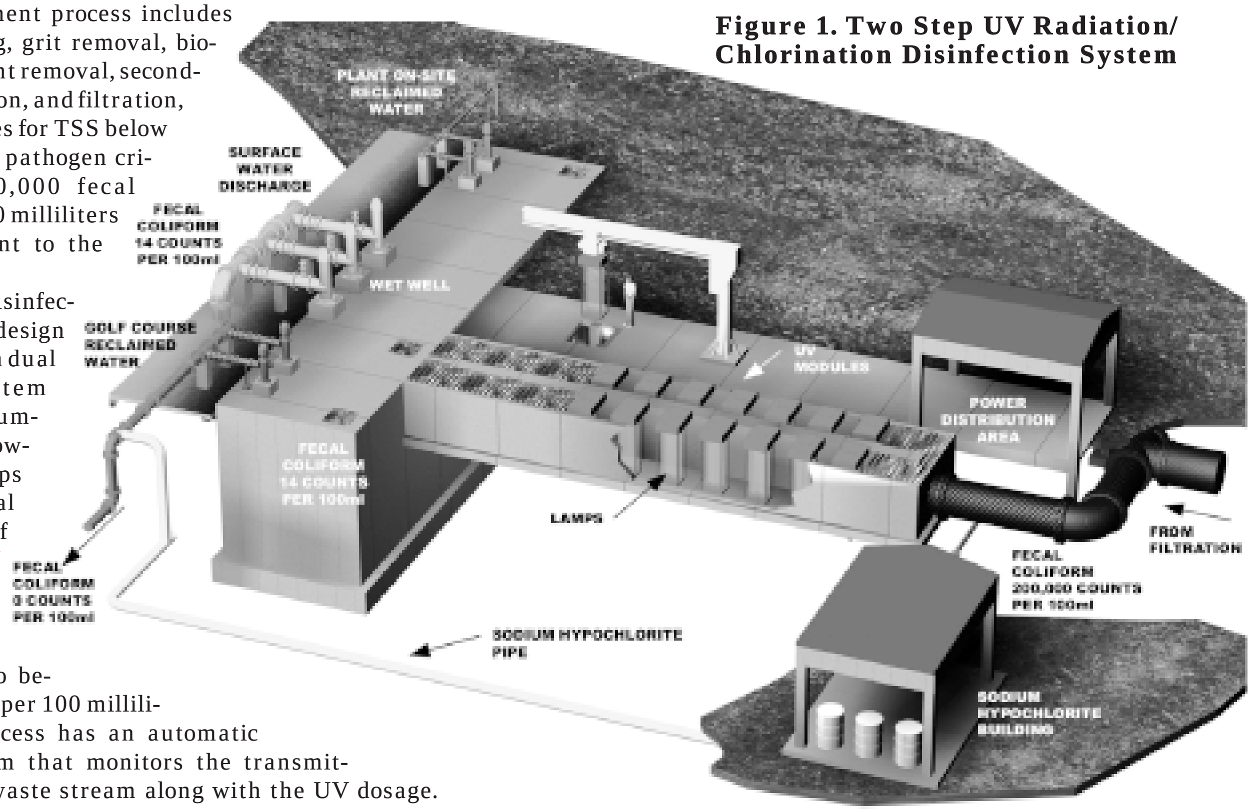
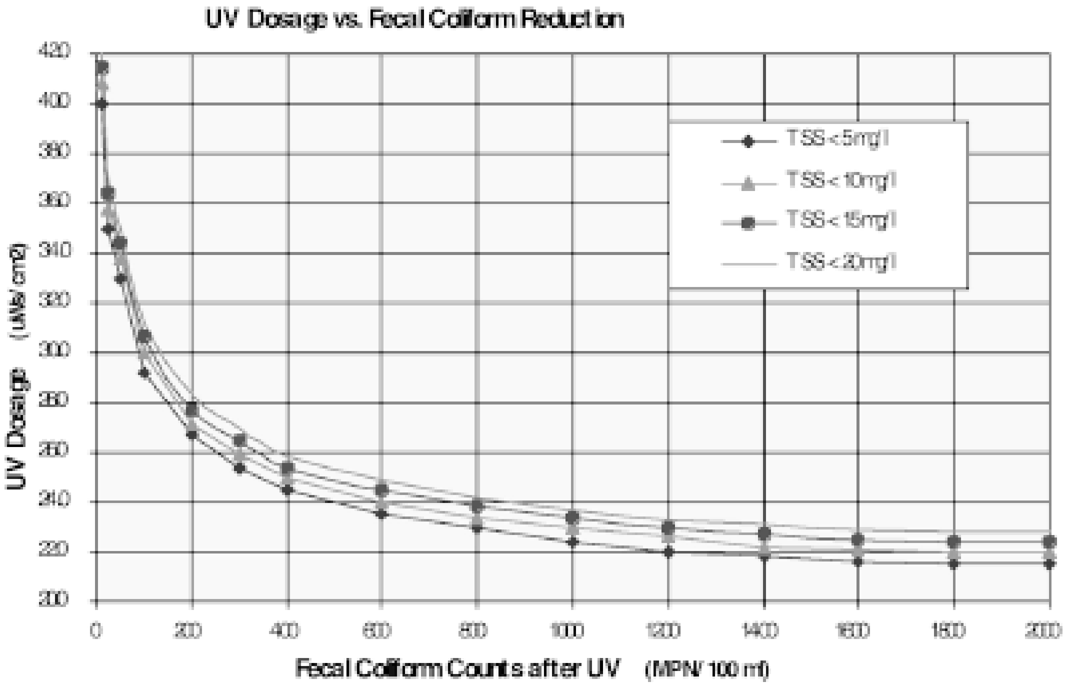


Figure 2. UV Disinfection System Dosage to Fecal Coliform Concentration - Reduction at varying total suspended solids concentrations. (Source: Infilco-Degremont, Inc.)



flowmeters to achieve the high-level disinfection requirements.

For the average daily golf course reuse of 0.4 MGD containing a fecal coliform concentration of 14 counts per 100 milliliters prior to chlorination, a sodium hypochlorite solution will be injected directly downstream of the reclaimed water pump station at a rate sufficient to produce a chlorine residual of 2 mg/L after an 8-minute contact time. This will result in a 2-log reduction in fecal coliform and produce an essentially pathogen-free product (Figure 3). A chlorine residual analyzer, located approximately 1,500 linear feet downstream of the sodium hypochlorite injection point, will enable measurement of the chlorine residual after the 8-minute contact time. The project team will work with DEP upon start-up to minimize chlorine dosage while still meeting high-level disinfection.

The reclaimed water pump station will be operated based on the pressure on the discharge line. The sodium hypochlorite metering pumps engage when the discharge pressure reaches the specified minimum level. After the metering pumps are started, the reclaimed water pumps are engaged. When the discharge pressure increases to the maximum level, the reclaimed water pumps are stopped; after a 5-second delay, the chemical metering pumps are shut off.

The system will incorporate daily sampling for fecal coliform in the reclaimed water after UV treatment and prior to chlorination to confirm that the UV process achieves the design disinfection limit of 14 fecal coliform per 100 milliliters, which in turn assures that a 2-log reduction in fecal coliform will produce an essentially pathogen-free product. Daily sampling for fecal coliform in the chlorinated reclaimed water after 8 minutes of contact time will be performed at the location of the chlorine residual analyzer. The system will include online turbidity monitoring at the effluent channel of the filtration equipment.

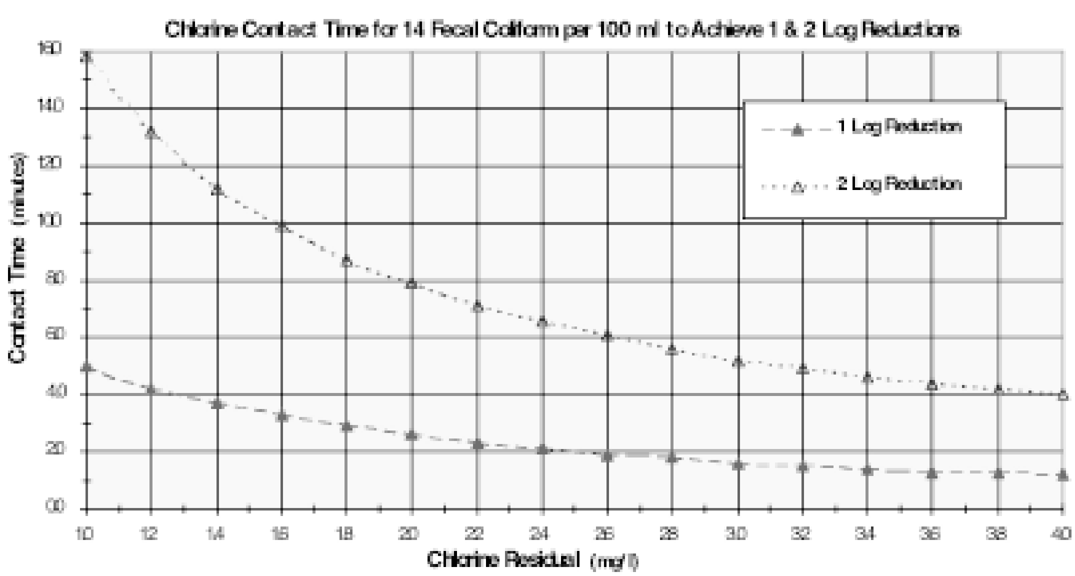
Instrumentation will monitor the supply of sodium hypochlorite and confirm that the feed pump is operational. The reclaimed water pump station will be disabled if the sodium hypochlorite supply runs low, or if the sodium hypochlorite injection pump fails to activate. Such conditions will initiate an alarm, reject the effluent to a reject pond, and require that the reclaimed water pump station be manually enabled after the cause of the problem is identified and corrected.

Since the chlorine feed system may be eliminated in the future, the use of liquid hypochlorite solution was incorporated into its design to provide for minimal capital costs. The entire disinfection system was designed with the flexibility to be modified in such a way to provide high-level UV disinfection once the regulating authorities establish criteria for high-level disinfection for UV systems.

Conclusions

The two-step disinfection design, providea an economical and effective method for achieving both the intermediate and high level disinfection requirements for the Bay County system. It has three distinct advantages over other disinfection systems: (1) the intermediate-level UV disinfection of the majority

Figure 3: Chlorine Contact Time for 14 Fecal Coliform per 100 milliliters to achieve 1 & 2 Log Reductions.



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Designing a UV System to Provide High-Level Disinfection

Kiera S. Fitzgerald and Karla Schmidt

The cost benefits of gaseous chlorination have been decreasing because of safety and environmental concerns. Ultraviolet disinfection has emerged as a safer and more cost-effective method of both basic and high-level disinfection.

UV disinfection is not based on the use of a highly toxic gas like chlorine, so hazardous materials storage practices such as containment and scrubbing systems are unnecessary. Unlike gaseous chlorine and sulfur dioxide, it does not employ a regulated substance requiring a Risk Management Plan (RMP) per Section 112(r)(7) of the Clean Air Act. It does not create toxic chlorinated organic disinfection by-products, which are an environmental concern, particularly when reclaimed water enters freshwater bodies. And it has a relatively low present worth cost because it does not require the hazardous materials handling systems, large contact tanks, or costly chemical consumption that chlorination and dechlorination require.

CH2M HILL participated in a design project for a United Water Florida (UWF) wastewater treatment facility in Jacksonville that required effluent treatment for both public access reuse and surface water discharge. Anxious to eliminate chlorine gas, UWF had recently installed several UV systems for basic disinfection. As a result, the plant was an ideal candidate for high-level disinfection with UV, but no guidelines for permitting high-level UV distinfection systems existed in Florida at the time. So, during project design, UWF and CH2M HILL worked with DEP to implement a system that would meet the regulatory goals for high-level disinfection.

A permit was issued in March 1999 and the project is currently under construction.

Project Background

The need to provide reclaimed water for public access reuse has prompted many utilities to upgrade wastewater treatment plants and, at the same time, reevaluate effluent disinfection practices. They typically consider the following factors in their evaluation, when gaseous chlorination is their current practice:

- Costs to upgrade facilities to comply with building and fire codes for chlorine gas, including requirements for containment and hazardous materials scrubbing
- Health and safety concerns associated with the use of chlorine gas and the implications of preparing and implementing an RMP and the related liability issues
- Costs associated with increasing the required chlorine contact volume and/or the chlorine dosage[1] to achieve high-level disinfection
- Requirements for dechlorinating effluent that discharges to surface waters

UWF weighed these factors when its Ponte Vedra Wastewater Treatment Facility (PVWWTF) needed to be upgraded to provide public access reuse. Having successfully implemented UV disinfection at four other Jacksonville facilities, UWF was confident that UV technology could be successfully implemented at PVWWTF. However, use of UV for high-level disinfection had never been permitted in Florida, and no state permitting guidelines were available.

Defining High-Level Disinfection

High-level disinfection (HLD), as defined by FAC Chapter 62-600.440(5), is achieved when fecal coliform levels in 75 percent of the samples taken from the treated effluent over 30

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days are below detection and no sample exceeds 25 fecal coliforms per 100 milliliters (mL). In addition, a minimum chlorine residual of 1 mg/L total chlorine based on a CT (concentration times contact time) value of 40 must be used for effluent with between 1,000 and 10,000 fecal coliforms/100 milliliters before disinfection.

The chlorine residual criterion required by this definition is not applicable to UV disinfection because it does not involve chlorine. Thus, in planning the PVWWTF upgrade, UWF and CH2M HILL were faced with the question of how DEP would permit a non-chlorine disinfection system.

Although FAC provides no dosage or concentration criteria for UV, the following statement from FAC 62-600.440(2) requires DEP to consider alternative means of disinfection under certain circumstances: "Residual levels, or similar criteria for establishing disinfection of alternative disinfectants, shall be accepted by the Department (DEP) if the information provided by the permittee in the preliminary design report demonstrates that appropriate microbiological criteria will be met and provides reasonable assurance that public health is protected."

Establishing Design Criteria

To provide its staff with some guidance for permitting nonchlorine-based disinfection systems like the one for PVWWTF, DEP commissioned the University of Central Florida to do a desktop review of alternative disinfection technologies. UCF's draft report (Dietz and Keely, 1996) includes the results of a survey of state regulations for high-level disinfection and a summary of the findings of Project 91-WWD-1, Comparison of UV Irradiation to Chlorination: Guidance for Achieving Optimal UV Performance (WERF, 1995).

According to the UCF report, several states use the California Title 22 requirements as the basis for UV permitting standards. Use of Title 22 criteria is further supported by the California Department of Health, which has reported that systems conforming to the Title 22 design guidelines easily achieve a 7-day mean total coliform count of less than 2.2 total coliforms/100 milliliters. Furthermore, the WERF report found that water quality in filtered wastewater (<5 mg/L suspended solids) is uniform enough that mathematical models to estimate required UV dosage can be directly applied.

On the basis of these findings, if a permittee provides a filter and UV system that conforms to California Title 22 requirements, DEP should consider under FAC 62-600.440(2) that the permittee has proven that "appropriate microbiological criteria will be met" and has provided "reasonable assurance that public health is protected."

As the UCF report states, "The WERF study results may be interpreted to support the recommendations adopted in California for guidance in the development of UV systems for water reclamation." On the basis of these findings and conclusions, DEP concurred with UWF and CH2M HILL and stated that it could permit a system that complied with Title 22 standards without additional studies or data.

Evaluating Design Criteria for Permitting

At the outset of the PVWWTF design project, using Title 22 criteria instead of applying available test data to the FAC high-level disinfection requirements seemed a reasonable approach

Table 1. Comparison of Design Criteria for PVWWTF

Criteria	*Design Parameters Based on Florida's FAC 62-600.440(5)*	*Design Parameters Based on California Title 22 Criteria*
Peak Flow, mgd	1.5	1.5
Average Flow, mgd	0.75	0.75
TSS, mg/L	<5.0	<5.0
Turbidity, NTU	not applicable	<2.0
CBOD, mg/L	<5.0	<5.0
Indicator Organism	Fecal Coliforms	Total Coliforms
Mean Standard	30-day average < detection limit	7-day mean <2.2/100 mL (and 4 log inactivation of virus based on poliovirus)
Maximum Standard	No sample >25/100 mL	No sample >23/100 mL
UV Transmission	Not specified; 65% selected based on local pilot data	55% (when no plant-specific data are available)
Minimum Dosage, mW-s/cm2	74.7	130
Number of Modules	4 in series; 160 lamps	9 in series; 360 lamps
Number of Channels	1	1
Estimated Equipment Cost (Uninstalled)	$96,000	$189,000

for developing UV disinfection system design criteria. However, it soon became clear that the two key Title 22 design criteria - coliform requirements and UV transmission requirements[2] - would more than double the system equipment requirements (from four to nine modules).

Table 1 summarizes the differences between design parameters for the PVWWTF based on application of the two different regulatory requirements.

The California requirements are based on total coliforms, whereas Florida's regulations are based on fecal coliforms. The wastewater industry typically equates one fecal coliform to approximately 5 total coliforms (Water Environment Federation, 1996). Thus, by applying Title 22 Criteria, DEP required UV systems to meet more stringent requirements, with a significant increase in the number of lamps required for high-level disinfection over the number required under Florida's regulations.

To achieve the Florida high-level disinfection requirement (30-day average of 75 percent of fecal coliform samples below the detection limit and no sample exceeding 25 fecal coliforms/100 milliliters), the UV system would need four modules with 160 lamps (see Table 1). This system design is based on the manufacturer's recommendations for meeting the fecal coliform standards, which in turn are based on pilot and full-scale testing of similarly sized systems with filtered wastewater, including testing done in the Jacksonville area at two UWF facilities.

Applying the Title 22 total coliform standard, however, increases the system size to seven modules with 280 lamps. The seven-module system is based on a minimum UV transmission of 65 percent, which is derived from the results of UV pilot studies conducted by the UV manufacturer on similar wastewater effluents (Infilco Degremont Inc., 1996). However, California's Title 22 requires the use of a UV transmission of 55 percent in the absence of data or testing. A UV transmission of 65 percent is allowed only when actual water quality data have been collected in a pilot study.

Because the PVWWTF filtration system has not been installed, no plant effluent was available for UV transmission testing. Consequently, DEP determined that in the absence of data for the PVWWTF, the Title 22 standard of 55 percent transmission must be used in the sizing calculations for UV disinfection at the PVWWTF. This requirement further increased the number of required modules to 9 with 360 lamps.

Comparing UV Disinfection Costs with Chlorination Costs

For a four-module system, the cost for UV is significantly lower than the costs of using chlorine. However, increasing the number of modules required further evaluation of the cost-effectiveness of UV disinfection for the PVWWTF. Table 2 summarizes estimated costs to upgrade the PVWWTF for high-level disinfection with UV, gaseous chlorine, and both onsite and delivered liquid sodium hypochlorite.

The cost comparison is based on the following assumptions:

- Capital costs for the chlorine systems include facilities and chemical costs for dechlorination with sulfur dioxide.
- The gaseous chlorine system includes an enclosed building with a chemical scrubber.
- The liquid hypochlorite system and the onsite liquid hypochlorite generation system both include an enclosed building.
- The chlorine contact chamber for all three systems was sized based on providing 40 minutes of contact time at average day flow.

The cost implications for using UV verses chlorine vary for each plant and for each utility involved. The impact of capital versus O&M costs also varies, depending on the time value of money for the particular utility involved. However, in evaluating the costs for PVWWTF, two key issues favored UV-the cost of chlorine containment and the need for dechlorination. The existing PVWWTF uses chlorine, but no chlorination building is available that could easily provide chlorine containment and scrubbing in compliance with the regulations. In addition, UWF recognizes the inherent risk of handling gaseous chlorine, and is averse to keeping it onsite unless absolutely necessary. As for dechlorination, the proposed reuse plan specifies the use of existing golf course ponds for holding and storage of the treated effluent. Discharge of treated effluent to these surface water ponds would require dechlorination. Considering these two issues, the cost for UV, even with the increased module requirements, is competitive with permittable methods of chlorination.

Recommending UV Disinfection

DEP's selection of California Title 22 guidelines for permitting UV systems for high-level disinfection requires UV systems to comply with more stringent standards than chlorination systems. However, the resulting increases in capital cost

Table 2. Cost Comparison for High-Level Disinfection Options at PVWWTF

	Costs ($)			
Item	**Gaseous Chlorine**	**Liquid Sodium Hypochlorite**	**Onsite Sodium Hypochlorite**	**UV Disinfection**
Chemical Feed Building	80,000	32,000	40,000	not applicable
Equipment[1]	70,000	46,000	210,000	302,000
Scrubber	169,000			not applicable
Chlorine Contact Chamber	45,000	45,000	45,000	not applicable
UV Chamber	not applicable	not applicable	not applicable	17,000
Total Capital Cost[2]	364,000	123,000	295,000	319,000
Allowances[3]	146,000	49,000	118,000	127,600
Operations and Maintenance (O&M), $/year	15,600[5,6]	30,600[6,7]	20,300[6,8]	7,300[9]
Net Present Worth[4]	689,000	523,000	646,000	530,000

Assumptions:

1. For chlorination systems, equipment also includes sulfur dioxide dechlorination.
2. Capital costs are based on 20% installation, 10% overhead, 5% profit, 5% mobilization/bond/insurance, and 13% contingency.
3. Allowances of 40% include site work, electrical, instrumentation and control, mechanical, and finishes.
4. Net present worth is based on a 6% discount rate over 20 years.
5. Gaseous chlorine = $0.45/pound (lb).
6. Sulfur dioxide = $0.40/lb; quantity is based on 1.5 lb sulfur dioxide (SO_2)/lb chlorine (Cl_2) for overfeed.
7. Liquid chlorine = $0.80/gallon.
8. Electrical = 2.3 kilowatt-hour (kWh)/lb generated at a cost = $0.06/kWh. Salt = 3.2 lb salt/lb generated at a cost = $0.03/lb salt. Anode replacement is based on $25,000 every 5 years.
9. Electrical = 75 watts/lamp at average flow and average replacement.

associated with those requirements are not sufficient to eliminate the use of UV systems for high level disinfection. Even if the costs were higher, they would be offset by the safety and environmental benefits of using UV for high-level disinfection over either gaseous or liquid chlorine systems. When safety and effluent toxicity factors are considered, UV disinfection is both a financially and environmentally favorable alternative.

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Notes:

[1] Ultraviolet dosage is a function of the UV intensity multiplied by the time in seconds that the water is in contact with that UV intensity. Typical values range from 15 to 200 megawatts per second per square centimeter (mW-s/cm2) (Water Environment Research Foundation, 1995).

[2] UV transmission is a measure of the waste stream's ability to transmit UV energy, which is typically assumed to be 65 percent for most wastewater applications (EPA, 1986).

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of the fecal coliform allows a significant reduction in the chlorine dosage required; (2) deletion of chlorine gas eliminates the need for the system to be in compliance with the requirements of the Accidental Release Prevention Program under Title 3 of the Clean Air Act and process safety management requirements of OSHA; and (3) the flexible ultraviolet disinfection design may be modified to achieve high-level disinfection on the reclaimed water as DEP develops regulatory requirements.

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