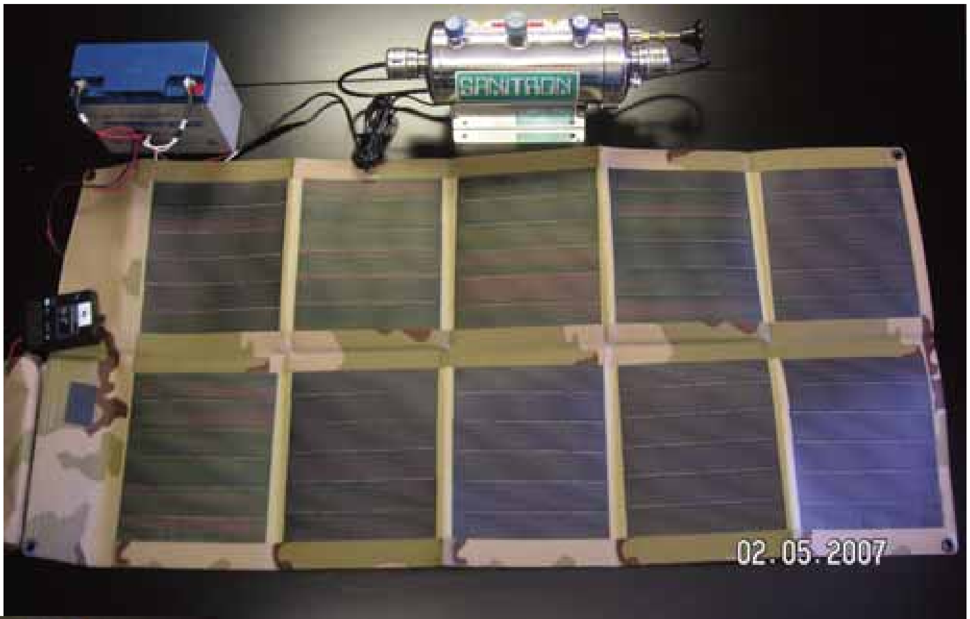

Ultraviolet Radiation Solar Powered Water Treatment

Product Features

- Portable, durable, lightweight
- Weatherproof & rip resistant
- Desert or Woodland Camo
- Continuous power under cloudy or overcast skies
- Can be used to recharge batteries, communication and mobile electronics
- Continuous water purification

SANITRON™ ULTRAVIOLET WATER PURIFIERS

ULTRAVIOLET DOSAGE

Germicidal lamps provide effective protection against microorganisms. A small cross-section is shown below.

ORGANISM	ALTERNATE NAME	TYPE	DISEASE	Dose*
Bacillus subtilis spores	*B. subtilis*	Bacteria	———	22,000
Bacteriophage	Phage	Virus	———	6,600
Coxsackie virus	———	Virus	Intestinal infection	6,300
Shigella spores	———	Bacteria	Bacterial Dysentery	4,200
Escherichia coli	*E. coli*	Bacteria	Food poisoning	6,600
Fecal coliform	———	Bacteria	Intestinal infection	6,600
Hepatitis A virus	Infectious Hepatitis virus	Virus	Hepatitis of the liver	8,000
Influenza virus	Flu virus	Virus	Influenza	6,600
Legionella pneumophila	———	Bacteria	Legionnaires' Disease	12,300
Salmonella typhi	———	Bacteria	Typhoid Fever	7,000
Staphylococcus aureus	Staph	Bacteria	Food poisoning, Toxic Shock Syndrome, etc.	6,600
Streptococcus spores	Strep	Bacteria	Strep throat	3,800

When used as directed to disinfect clear water, SANITRON™ Water Purifiers provide an ultraviolet dosage in excess of 30,000 microwatt seconds per square centimeter ($\mu WSec/cm^2$).

*Nominal Ultraviolet dosage ($\mu WSec/cm^2$) necessary to inactivate better than 99% of specific microorganism. Consult factory for more complete listing.

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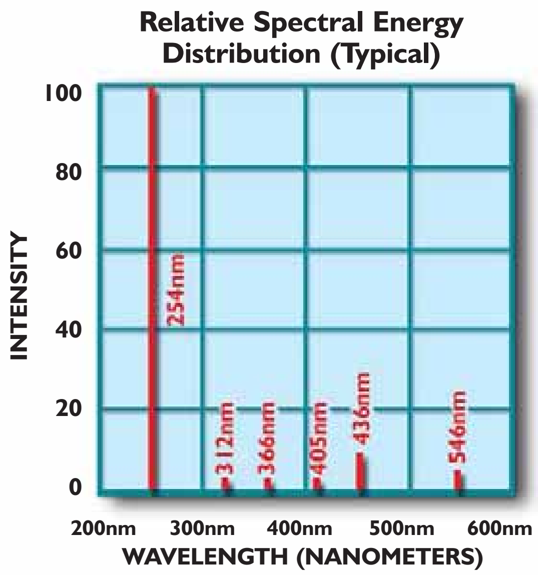
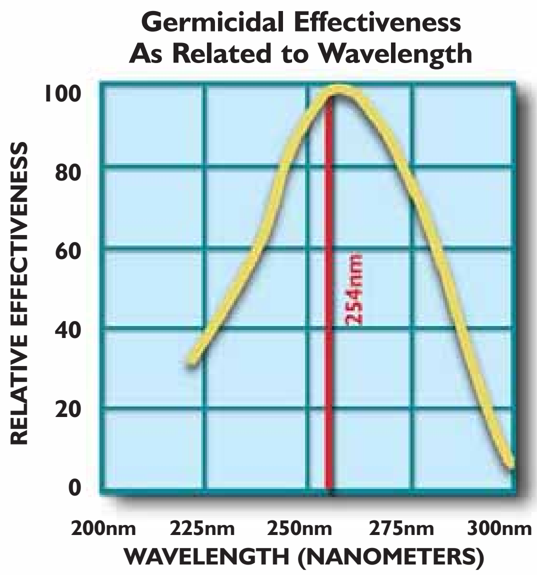
OPERATING CHARACTERISTICS





Approximately 95% of the ultraviolet energy emitted from STER-L-RAY™ germicidal lamps is at the mercury resonance line of 254 nanometers, the region of germicidal effectiveness most destructive to bacteria, mold and virus.

US Army Center for Health Promotion and Preventive Medicine

Water Purification Database

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Disinfectants

Disinfectants kill or inactivate microorganisms preventing them from reproducing, thus rendering them harmless. Disinfectants can be pure or mixed solutions, and can be administered as powder, tablet, liquid, gas, or light. There are five classes of disinfectants that are currently used in individual water purification devices (IWPDs), each with advantages and disadvantages with respect to effectiveness against waterborne pathogens, ease-of-use, and safety. The following papers describe in detail, and tables below summarize, the technologies and mechanisms of pathogen reduction in IWPDs using disinfection.

U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Chlorine Dioxide Disinfection in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

Table 1. Chlorine Dioxide Disinfection Capabilities

Parameter	Chlorine Dioxide Disinfection
General Disinfection Capability	Cysts most resistant. Achieving cyst inactivation will ensure adequate bacteria and virus inactivation. Disinfection capability generally follows: Bacteria > viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective at reasonable CT values for IWPD use
Viruses	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 1).
Giardia Cysts	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 2).
Cryptosporidium Oocysts	Effective at high CT values. Use Table 3 as guide for CT values. If possible, use longer contact times instead of higher dosages to achieve adequate CT values.
Effect of Temperature	Colder water temperatures require higher CT values. Use a two-fold increase in CT for every 10° C decrease. Use longer contact time instead of higher dosages to achieve higher CT values.
Effect of pH	Effective over typical pH levels for raw, untreated natural waters. Disinfection capability generally increases with increasing pH.
Effect of Turbidity	Higher turbidity generally reduces disinfection capability. Use longer contact time instead of higher dosages in more turbid waters to achieve CT values. Higher dosages may be necessary to ensure chlorine dioxide remains after oxidation of organic matter.
Health Effects	Chlorine dioxide and chlorite are potential health concerns. IWPD manufacturer-recommended dosages are not likely to cause adverse health effects for healthy adults. Exposure to much higher chlorite concentrations may occur when using stabilized chlorine dioxide products.

U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Chlorine Disinfection in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

Table 2. Chlorine Disinfection Capabilities

Parameter	Chlorine Disinfection

General Disinfection Capability	Cysts most resistant. Achieving cyst inactivation will ensure adequate bacteria and virus inactivation. Disinfection capability generally follows: Bacteria > viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective at reasonable CT values for IWPD use.
Viruses	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT table for recommended CT values (Table 1).
Giardia Cysts	Effective at reasonable CT values for IWPD use. Use EPA SWTR CT tables for recommended CT values (Appendix B).
Cryptosporidium Oocysts	Ineffective, even at high CT values. Not practical for IWPD use.
Effect of Temperature	Colder water temperatures require higher CT values. Use a two-fold increase in CT for every 10°C decrease. Use longer contact time instead of higher dosages to achieve higher CT values.
Effect of pH	Disinfection efficiency increases with decreasing pH. Recommend pH less than 8.0 to ensure presence of hypochlorous acid (HOCl).
Effect of Turbidity	Higher turbidity generally reduces disinfection capability. Higher dosages may be necessary to ensure the presence of free chlorine after oxidation of organic matter.
Health Effects	Chlorine, THMs and HAAs have potential health concerns at elevated levels. IWPD manufacturer-recommended dosages are not likely to cause adverse health effects for healthy adults.

U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Electrochemically Generated Oxidant Disinfection In The Use Of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

Table 3. Electrochemically Generated Oxidant (EGO) Disinfection Capabilities

Parameter	EGO Solutions
General	As effective or can be more effective than chlorine. Disinfection capability generally follows: Bacteria > viruses > *Giardia* > *Cryptosporidium*
Bacteria	Effective.
Viruses	Effective.
Giardia Cysts	Like chlorine, consider providing additional contact time beyond IWPD manufacturer recommended CTs.
Cryptosporidium Oocysts	Effectiveness is variable and unpredictable. Considered not consistently effective.
Effect of Temperature	Like chlorine, colder temperatures can reduce effectiveness. Higher CTs will ensure for colder temperatures increases effectiveness.
Effect of pH	Like chlorine, higher pH decreases effectiveness. pH less than 8.0 ensures presence of the most effective chlorine species, hypochlorous acid (HOCl).
Effect of Turbidity	Like chlorine, higher turbidity reduces effectiveness. Higher dosages may be necessary to ensure effectiveness.

U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Iodine Disinfection in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

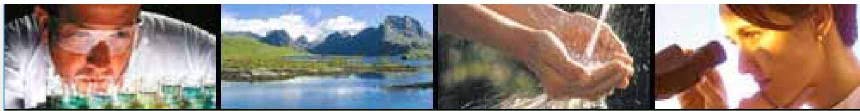
Table 4. Iodine Solution and Resin Disinfection Capabilities

Parameter	Iodine Solutions	Iodine Resins
General	Cysts most resistant. Achieving *Giardia* cyst inactivation will ensure adequate bacteria and virus inactivation	Cysts most resistant. Achieving *Giardia* cyst inactivation will ensure adequate bacteria and virus inactivation.
Bacteria	Effective	Effective
Viruses	Effective	Effective
Giardia Cysts	Provide additional contact time beyond IWPD manufacturer recommended CTs.	Pentaiodide resin effective. Triiodide resin not effective. Provide additional contact time after passing through resin.
Cryptosporidium Oocysts	Not effective.	Not effective.
Effects of Temperature	Major effect. Increase contact time and/or dose at colder temperatures. CTs up to 720 mg-min/L recommended for *Giardia* cyst inactivation in colder waters.	Major effect. Increase contact time after passing through pentaiodide resin at colder temperatures. Allow up to 40 minutes additional contact time for *Giardia* cysts inactivation in colder waters (< 5 deg C)
Effect of pH	Minor effect. Generally effective over typical pH levels for natural waters.	Minor effect. Generally effective over pH range typical for natural waters.
Effect of Turbidity	Affects disinfection capability. Provide additional contact time and/or increase iodine dose in more turbid waters.	Affects disinfection capability. Heavy organic matter loading can significantly reduce disinfection capability.

U.S. Army Center for Health Promotion and Preventive Medicine, 2005. *Technical Information Paper; Ultraviolet Light Disinfection in the Use of Individual Water Purification Devices*, Aberdeen Proving Ground, MD.

Table 5. UV Disinfection Capabilities

Parameter	UV Disinfection
General Disinfection Capability	Viruses most resistant. *Giardia* and *Cryptosporidium* least resistant. UV dose will be based on virus inactivation.
Bacteria	Effective at reasonable UV doses for IWPD use.
Viruses	Effective at reasonable UV doses for IWPD use. Use proposed EPA UV dose table for recommended doses (Table 3). UV doses higher than those recommended may be necessary based on turbidity, particulate matter, and NOM.
Giardia Cysts	Effective at reasonable UV doses for IWPD use.
Cryptosporidium Oocysts	Effective at reasonable UV doses for IWPD use.
Effect of Temperature	Negligible effect.
Effect of pH	Negligible effect.
Effect of Turbidity/Particulate Matter/NOM	Significant effect. Higher concentrations require higher UV doses to achieve same levels of inactivation.
Health Effects	UV lamp breakage during operation may expose user to unsafe levels of mercury.



Integrating UV Disinfection Into Existing Water Treatment Plants [Project #2861]

Ordering Information:
ORDER NUMBER: 91086
DATE AVAILABLE: Fall 2005

	Printed Report	PDF
Subscribers	Order Report	
Non-Subscriber	AWWA Bookstore	N/A

PRINCIPAL INVESTIGATORS:

Christine A. Cotton, Laurel Passantino, Douglas M. Owen, Mark Bishop, Matthew Valade, William Becker, Roopesh Joshi, John Young, Mark LeChevallier, and Rich Hubel

OBJECTIVES:

The project objectives were to (1) evaluate existing and potential pathogen barriers using selected risk analysis approach and determine decision steps (i.e., logic) for a utility to assess these issues; (2) complete an analysis of UV disinfection risks and implementation issues by determining when distribution of inadequately disinfected water may occur (e.g., during a power outage); (3) develop interactive decision tools that will assist utilities in determining whether UV disinfection is necessary and, if so, in evaluating UV implementation issues; and (4) determine if power quality at water treatment plants (WTPs) is a significant UV disinfection implementation issue that should be addressed.

BACKGROUND:

UV disinfection is one of the technologies recognized in the proposed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) for inactivation of *Cryptosporidium* . Many systems exceeding the source water action level of 0.075 oocysts/L will consider incorporating UV disinfection into their existing treatment scheme because it is typically the lowest cost option to inactivate *Cryptosporidium* . However, UV disinfection is a relatively new technology in the water industry, and an in-depth evaluation of potential failure modes (e.g., power quality) and how to address critical process control points is not currently available in the drinking water profession.

HIGHLIGHTS:

- The research team completed a Regrets Analysis that provides a powerful method to evaluate multi-barrier treatment based on total social costs that include capital costs and potential reduction in health effect costs.
- The interactive, electronic tools developed in this project will assist utilities in making critical disinfection decisions and in evaluating UV implementation issues.
- Power quality (PQ) will most likely not cause a water utility to exceed the proposed regulatory requirements; however, PQ problems reduce operational flexibility and may affect UV lamp operations.
- The results of this study indicated that off-specification operation of UV reactors is not likely to pose a significant *Cryptosporidium* health risk in filtered water systems provided that the on-line UV reactors remain functional.

APPROACH:

First, a utility survey was conducted to gather information on issues surrounding multi-barrier treatment strategies and UV disinfection retrofits. A Regrets Analysis was completed to assess multi-barrier treatment issues and was incorporated into the Multi-Barrier Assessment Tool (MBAT). Next, the UV Disinfection Implementation Tool (UVDIT) was developed using the utility survey, existing literature on UV disinfection, a Failure Mode and Effects Analysis risk analysis, treatment costs, water quality data, and regulatory requirements and recommendations. The MBAT and UVDIT were beta-tested by project participants and revised based on their feedback, and case studies for eight utilities were completed based on the tool results. Lastly, the prevalence of power quality events was assessed by monitoring and assessing power quality at eight WTPs.

RESULTS/FINDINGS:

The information provided by the tools gives an initial assessment of multi-barrier treatment strategies and UV facility design issues. The MBAT provides the user with a unique method to evaluate disinfection decisions that is not solely based on capital costs. The UVDIT provides the user with a tool to evaluate UV implementation issues and serves as an educational tool that highlights the most critical issues. The tools are stand-alone, internet-based applications that can be accessed by all users through the public area of AwwaRF's website (see Multimedia below).

The PQ data collected for this report is the first comprehensive compilation of PQ data at WTPs and provides insight into the prevalence of power quality problems. In general, it was determined that PQ alone will most likely not cause a water utility to exceed off-specification requirements.

The results of the *Cryptosporidium* downtime and off-specification risk assessment indicated that off-specification operation of UV reactors is not likely to pose a significant *Cryptosporidium* health risk in filtered water systems provided that the on-line UV reactors remain functional.

IMPACT:

The project will have the following impacts on the water industry:

1. The MBAT and UVDIT are user-friendly web tools that will assist utilities in assessing important disinfection decisions and UV implementation issues.
2. The power quality (PQ) data collection and analysis indicate that PQ will most likely not cause a water utility to exceed the proposed regulatory requirements; however, PQ problems reduce operational flexibility and may affect UV lamp operations.
3. The results of the *Cryptosporidium* downtime and off-specification risk assessment may assist regulators in developing criteria based on *Cryptosporidium* occurrence and risk.

MULTIMEDIA:

The MBAT and UVDIT are available online at the following website address:
http://www.awwarf.org/research/TopicsAndProjects/projectSnapshot.aspx?pn=2861.

PARTICIPANTS:

Eleven water utilities and four UV disinfection equipment manufacturers participated in this research.

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Federal Government

Industry

Christine Cotton, PE

Christine specializes in drinking water treatment, regulations and UV disinfection. She is project manager for USEPA's first comprehensive UV Disinfection Guidance Manual, which can be accessed here, and led an AwwaRF research project investigating UV implementation issues.

Email Christine

Sam Jeyanayagam, PE, PhD, BCEE

With over 26 years of experience, Dr. Jeyanayagam's expertise includes UV disinfection, BNR, and biosolids processing. He serves on the International UV Association Board of Directors, and contributed to USEPA's *UV Disinfection Guidance Manual*. He is also a principal/review author of several WEF publications.

Email Sam

meet the experts

Christine Cotton and Dr. Samuel Jeyanayagam

UV Disinfection for Water and Wastewater Treatment Systems

ISSUE:

The Long-Term 2 Enhanced Surface Water Treatment Rule has been signed — *Is your water system ready for the new requirements?*

IN THIS ARTICLE

Background

The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) was finalized on January 5, 2006, and aims to reduce disease incidence associated with *Cryptosporidium* and other pathogenic microorganisms in drinking water. The LT2ESWTR applies to all systems that use surface water or ground water under the direct influence of surface water, and USEPA estimates almost 3,000 public water systems will have to update their water treatment processes.

Almost 3,000 public water systems will have to update their water treatment processes

Based on the concentration of *Cryptosporidium* present in their source water, this rule requires up to 5.5 log total treatment (99.99968 percent removal and/or inactivation) for *Cryptosporidium*. Additional treatment may need to be in place as early as 2012, depending on the number of customers served by the system.

USEPA has identified several treatment alternatives that are effective in removing or inactivating *Cryptosporidium*. One of the most cost-effective treatment barriers is UV disinfection. Other significantly more expensive, but also effective, treatment technologies include membranes and ozone.

Benefits of UV Disinfection

The primary benefit of UV disinfection isits effectiveness against *Cryptosporidium,* which is resistant to chemicals typically used for disinfection such as chlorine and chloramines.

UV disinfection has other benefits:

- Because UV disinfection is a physical process, it does not involve transport, storage, handling or use of dangerous chemicals.

Related services

> Drinking Water

> Wastewater

Useful tools

> An AwwaRF research project provides interactive tools to help utilities with UV disinfection planning and evaluation:

- Multi-Barrier Assessment Tool (MBAT)

- UV Disinfection Implementation Tool (UVDIT)

View Our UV Experience

Drinking Water

Wastewater

Designing UV disinfection facilities for drinking water treatment can be extremely challenging.

Two recent award-winning UV projects designed by Malcolm Pirnie addressed site-specific constraints.

Malcolm Pirnie has designed several wastewater UV facilities, from 0.15 mgd to 24 mgd.

- Taste and odor of drinking water are not affected by use of UV light.
- UV disinfection has no known carcinogenic or toxic by-products.
- The required residence time, on the order of seconds as opposed to many minutes, allows for smaller reactors and thus lower costs.

UV disinfection can also be used to treat wastewater for reclaimed water applications and is especially effective for meeting stringent re-use standards and minimizing disinfectant residuals for discharge permits.

Evaluation Tools

As part of an AwwaRF research project, Malcolm Pirnie helped develop an interactive electronic tool available on the internet to help utilities during the early stages of UV disinfection planning and evaluation.

This AwwaRF tool addresses such issues as the feasible retrofit locations for UV disinfection, the implementation issues of UV disinfection at each retrofit location and how they can be addressed. It also estimates the cost of various retrofit options by evaluating existing infrastructure, hydraulic limitations, water quality variability, flow variability, power source limitations, and lamp breakage issues.

Another source of help is USEPA's *UV Disinfection Guidance Manual*, which supports the LT2ESWTR, and which Malcolm Pirnie played a leading role in developing. This document, due to be published in the Spring, includes background information on UV disinfection as well as specific information on the design, construction, validation, and operation of UV disinfection systems in drinking water.

Malcolm Pirnie - A Valuable Resource

View Our UV Experience

Drinking Water | Wastewater

To help you decide if UV disinfection is right for your water system, Malcolm Pirnie offers independent planning and design for facilities throughout the U.S.

We can provide assistance throughout the design process, from technology evaluation to construction and startup assistance. Our unique perspective reflects our long-time involvement with regulatory agencies, giving us particular expertise in research projects, regulatory compliance, and design of UV disinfection for drinking water and wastewater. And, because we recognize that resources are limited, Malcolm Pirnie has helped utilities find alternative sources of funding, the right equipment procurement strategy, and innovative approaches for retrofitting or upgrading existing facilities.

We invite you to contact one of our UV disinfection experts: Christine Cotton or Sam Jeyanayagam.

> more "Meet the Expert" articles

Catskill/Delaware UV Disinfection Study

NYCDEP, New York

Problem

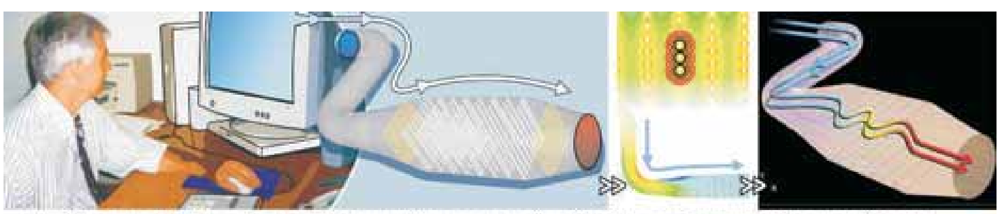
In 1993, the New York City Department of Environmental Protection (DEP) was issued a Filtration Avoidance Determination (FAD) for the Catskill and Delaware supply systems by the USEPA, thereby relieving the City from having to filter these supplies, which provide nearly two billion gallons of water per day. While these upstate supplies generally have excellent water quality, concerns had arisen due to increased growth in the watershed and outbreaks of illnesses in other parts of the US, caused by waterborne microorganisms such as Cryptosporidium and Giardia.

While filtration is not mandated at present, the FAD does require the City to plan for filtration in the event that the water quality in these supplies changes in the future. To comply with this FAD requirement, the DEP selected a team of consultants, including Hazen and Sawyer, to undertake pilot testing, conceptual design, and preliminary design of the 1.8-bgd filtration plant. Such a facility would cost about $2 billion and take six years to construct. While this work progressed according to schedule, we continued to explore alternatives to filtration.

Solution

One alternative, ultraviolet (UV) light disinfection, had long been considered ineffective against Cryptosporidium. However, during the late 1990s, microbiologists conducting laboratory studies on animals began releasing evidence to the contrary. In response, we initiated an in-depth look at UV disinfection as a filtration alternative. The results of this quick thinking, the UV Disinfection Feasibility Study and UV Conceptual Design Report, support the theory that UV disinfection can provide public health protection from microorganisms at approximately 1/5th the cost of filtration.

In order to verify treatment effectiveness, the team used an innovative solution of computational fluid dynamics (CFD) models integrated with light-intensity distribution models. The combined model accurately predicts the fluence (UV dose) to which a particle or microbe will be exposed as it passes through a reactor. The team verified modeling accuracy by comparing model results with those of the manufacturers' bioassay testing.



The Computer Modeling Process: By integrating a computational fluid dynamics model with a light-intensity distribution model, UV dose for a specific reactor can be predicted.

These studies support the breakthrough theory that UV disinfection can inactivate Cryptosporidium. While UV has been commonly used for wastewater disinfection and for drinking-water disinfection on a much smaller scale in Europe, it has never been applied for this purpose near this scale.

In addition to the dramatic cost savings, a UV facility would also impact the environment much less than construction of a filtration plant. It will allow a much-reduced construction period (2 vs. 6 years) and a significantly smaller footprint than a filtration plant, and will not require use of chemicals or require residuals disposal.

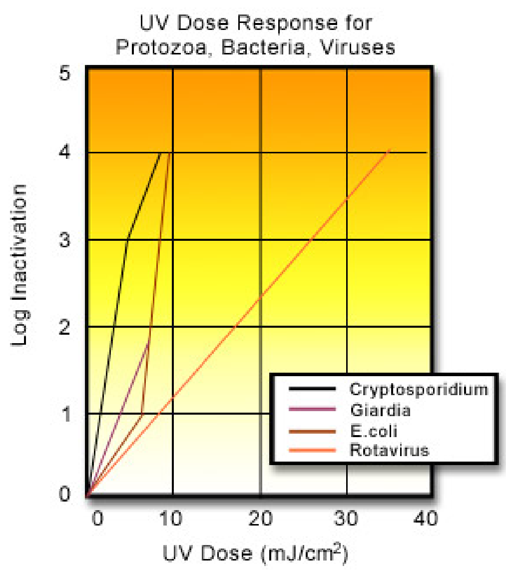
Based on these studies, DEP gained a deferral from designing a filtration plant. (According to the original FAD, final design was to begin in December 2001.)

Hazen and Sawyer, in joint venture, is currently proceeding with the final design of the UV disinfection facility, which is expected to be the largest such facility in the world.

Ultraviolet (UV) Disinfection

Over the past 20 years, ultraviolet (UV) disinfection has developed into a viable technology for drinking water treatment. Using intense beams of ultraviolet light identical to those from the sun, UV disinfection systems inactivate protozoa, bacteria and viruses. Through extensive research and rigorous field trials, UV disinfection has proven to be safe, reliable and inexpensive. These benefits have motivated dozens of utility owners worldwide to re-evaluate their current method of drinking water disinfection and resolve to use a UV system.

One of the main reasons UV technology is gaining widespread attention is its ability to inactivate cryptosporidium, a protozoa resistant to traditional chlorine disinfection methods. The graph below illustrates that even with a very low dose of UV light ($10mJ/cm^2$) can inactivate 99.99% of cryptosporidium and E. Coli. The same UV dose will inactivate approximately 99% of Giardia.



This graph illustrates the effectiveness of UV light on Cryptosporidium, Giardia, E.Coli and Rotavirus. Four log inactivation (or 99.99%) of Crypto and E.Coli is easily achieved through a dose of $10mJ/cm^2$. At the same dosage, UV can easily achieve a 2 log inactivation of Giardia. Rotavirus, the orange line, requires slightly more UV exposure at $35mJ/cm^2$. It is important to note that all Sentinel UV systems are designed to deliver a minimum dose of $40mJ/cm^2$.

EPCOR, in partnership with Calgon Carbon Corporation, provides Sentinel™ UV Disinfection Systems for industrial and municipal use throughout Western Canada. The Sentinel unit has a flexible design that can accommodate water flows ranging from 500,000 litres per day to 150-160 million litres per day.

EPCOR has installed large UV systems in Canmore, AB, and the E.L. Smith Water Treatment Plant and Rossdale Water Treatment Plant in Edmonton, AB.

Additional Information

- For more information, download EPCOR's UV Disinfection Fact Sheet (45KB pdf)

Contact Information

Related Information

- Water Quality Glossary
- Canmore Water Treatment Plant
- E.L. Smith Water Treatment Plant
- Rossdale Water Treatment Plant

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