technical brief

Pulsed Ultraviolet Light for Drinking Water Disinfection and Membrane Fouling Control

Energy Delivery & Utilization Division
Municipal Water and Wastewater Treatment Target

The Search for Improved Disinfection

Water utilities are constantly challenged with the problem of balancing effective microbial inactivation (disinfection) with controlling the formation of disinfection byproducts (DBPs). Conventional disinfection with chlorine, while effective in inactivating viruses and most pathogenic bacteria, promotes the formation of DBPs by the reaction of chlorine with organic matter. Further, membrane systems that are used in water desalination and water softening are subject to chemical and biological fouling. Membrane fouling is additionally impacted when biological filtration is used in conjunction with ozone treatment to remove biodegradable dissolved organic matter.

Within the next 5 to 10 years, disinfection regulations will likely require the removal and/or inactivation of *Cryptosporidium parvum* oocysts. *Cryptosporidium*, a pathogenic protozoan commonly found in surface waters, has caused waterborne gastrointestinal disease outbreaks, most notably in Milwaukee, Wisconsin where over 400,000 cases were reported. Common disinfectants, such as chlorine and chloramines, do not inactivate *Cryptosporidium* oocysts. An emerging electrotechnology, pulsed UV irradiation, has been identified as a means of disinfecting pathogenic organisms without increasing DBP risks.

Developments in Pulsed UV Research

Before 1990, most UV treatment installations consisted of monochromatic, low-pressure UV that produced minimal or no DBPs, but could not effectively inactivate recalcitrant protozoan pathogens such as *Cryptosporidium*. Initial investigations on pulsed UV performance, however, indicate excellent inactivation of protozoan oocysts, thus warranting further study of pulsed UV.

Pulsed UV lamps produce extremely high light intensities as compared to conventional UV lamps. In pulsed UV, capacitors build up and deliver electricity in pulses to a xenon flash tube located in the center of a flash chamber, through which water passes (see Figure 1). The equipment is designed to provide microsecond pulses at 1 to 30 Hertz. With each pulse, the flash tube gives off a high-intensity, broad-band radiation (including germicidal UV radiation), which irradiates the flowing water. Disinfection occurs when the UV light alters the DNA of the microorganisms, thereby preventing reproduction, and, consequently, causing cell inactivation.

A Collaborative Project

The California Energy Commission, in association with EPRI and the American Water Works Association Research Foundation (AWWARF), is engaged in research efforts to evaluate the effectiveness of pulsed UV in disinfecting drinking water and controlling membrane fouling. In research under the direction of Southern California Edison and the Metropolitan Water District of Southern California (MWD), post-filtration disinfection of

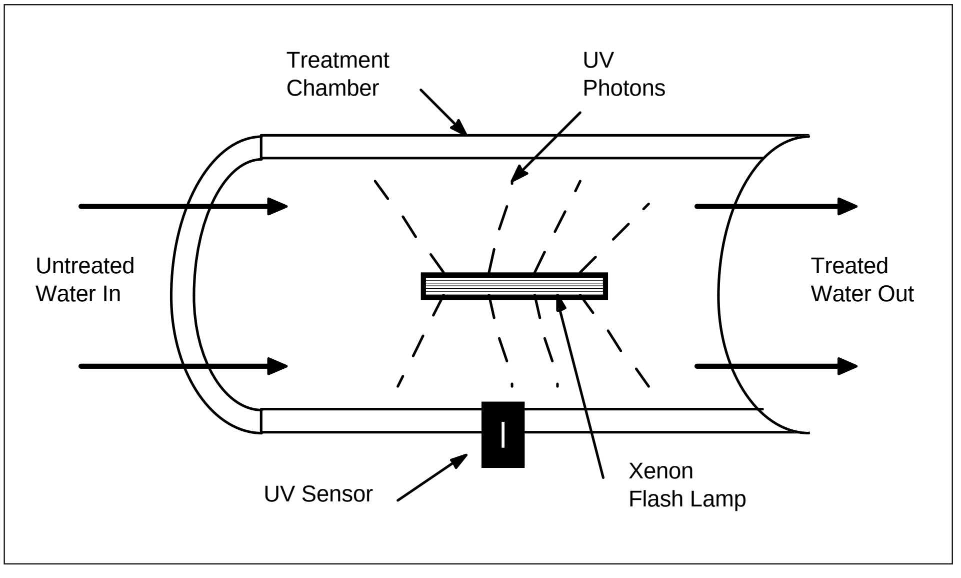

Figure 1. Schematic Diagram of Pulsed UV Treatment Chamber

surface waters using pulsed UV is being evaluated. The purpose of this research is to:

- Determine the disinfection effectiveness of pulsed UV in reducing bacteria, virus, and protozoan cysts in drinking water
- Evaluate disinfection byproducts (DBPs) formed by UV disinfection
- Determine the pulsed UV and chloramine dosages required to prevent bacteria regrowth
- Evaluate the potential for UV to control biological fouling on membrane surfaces

Current Status of Research

Pilot-scale testing was performed by the staff of MWD using California State Project water. Treatment consists of pre-ozonation, coagulation/flocculation, sedimentation, and biologically active filters (BAF). Pilot plant effluent was passed through a pulsed UV chamber manufactured by Innovatech, Inc. of San Diego, California.

Heterotrophic plate count (HPC) bacteria and MS-2 virus were selected as test organisms due to their previous use in UV evaluations and because of their relative ease of quantification. This study also examined the ability of pulsed UV to disinfect *Cryptosporidium* oocysts as measured by cell-culture infectivity assay. Collectively, these measurements were used to establish the disinfection effectiveness of pulsed UV compared to other disinfection systems.

The test results for disinfection and DBP control are:

Challenge	Result
HPC <10 cfu/mL?	Yes at >10 mJ/cm^2
2-log10 Crypto reduction?	Yes, at 11 mJ/cm^2
MS-2 removal?	Yes
DBP reduction?	Yes, <10µg/L

Naturally occurring HPC bacteria were effectively disinfected from levels greater than 10,000 colony forming units per milliliter (cfu/mL) to less that 10 cfu/mL with UV doses less than 15 millijoules per square centimeter (mJ/cm^2). Limited experiments were conducted to determine the potential of repair or regrowth of HPC bacteria after UV irradiation. These experiments were conducted in the presence and absence of both light and chloramines. Test results indicated that the pre-disinfection levels of bacteria were reestablished unless the UV dose was greater than 55 mJ/cm^2 or a secondary disinfectant was present.

An initial estimate of the operating cost for pulsed UV treatment (8 in. diameter pipe, 320 gpm flow rate, and $0.08/kWh electricity cost) (203 mm, 72.7 m^3/h, and $0.08/kWh electricity cost) was $4.12 per acre-foot ($0.0126/1,000 gallons) ($0.00333/m^3) of treated water.

Future Research

The next phase of research will include additional bench scale testing by the Orange County (CA) Water District in evaluating membrane characteristics that relate to potential fouling, and pilot-scale testing by MWD in evaluating the effectiveness of pulsed UV on controlling biofouling of membranes. The research is expected to be completed by September 2000.

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