Local Section Seminar

Basics of UV Disinfection

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Presentation Outline

Basics of Ultraviolet (UV) Disinfection

Components of UV Disinfection Equipment

Design Considerations

UV Dose

True Cost of Ownership

Basics of UV Disinfection

What is Disinfection?

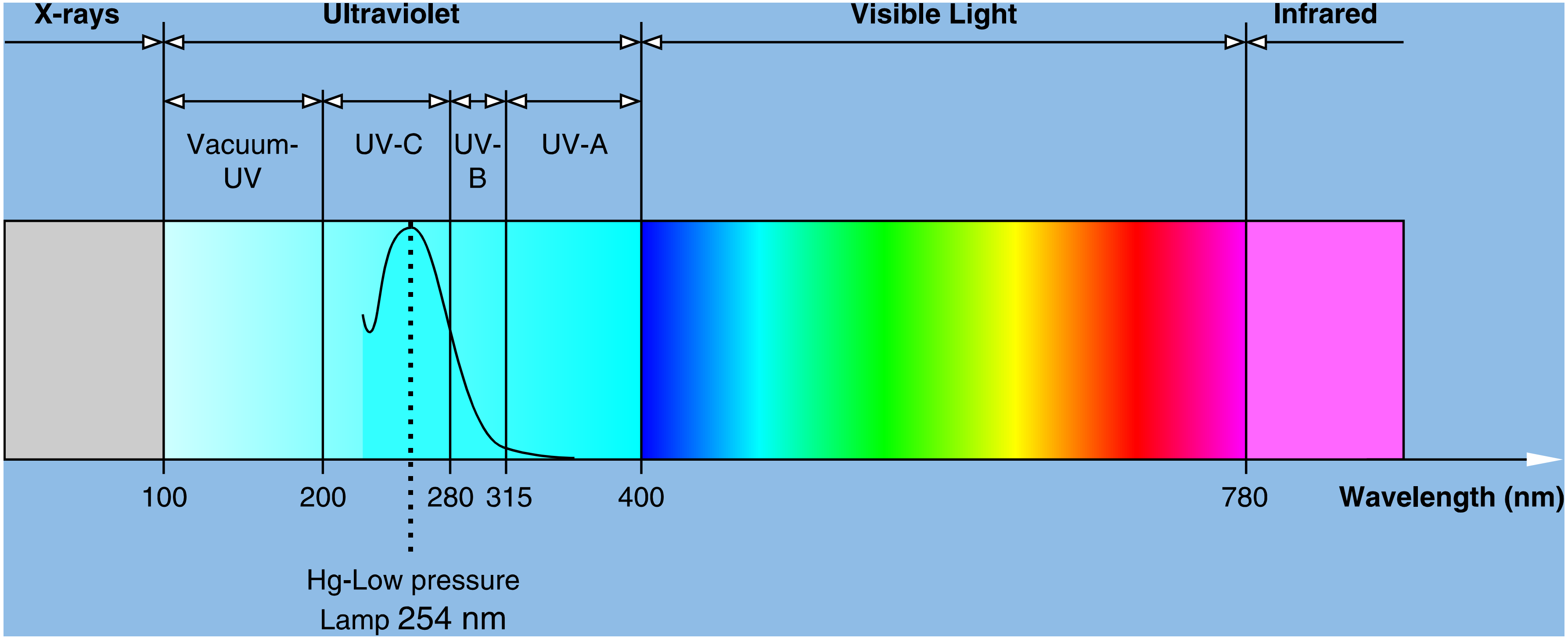
Disinfection is the reduction of harmful (=pathogenic) microorganisms to a concentration which is not harmful anymore

Examples of the most dangerous pathogens in drinking & waste water:

Group	Kind	Disease
• **BACTERIA**	▪ Coliforms ▪ Salmonella ▪ Vibrio ▪ Legionella ▪ E.coli	▪ Fever, intestinal disease ▪ Typhoid fever ▪ Cholera ▪ Pneumonia ▪ Fever, gastro enteral disease
• **VIRUSES**	▪ Hep A ▪ Polio	▪ Hepatitis ▪ Polio
• **PARASITES**	▪ Cryptosporidia ▪ Amoeba	▪ Intestinal disease ▪ Amebiasis

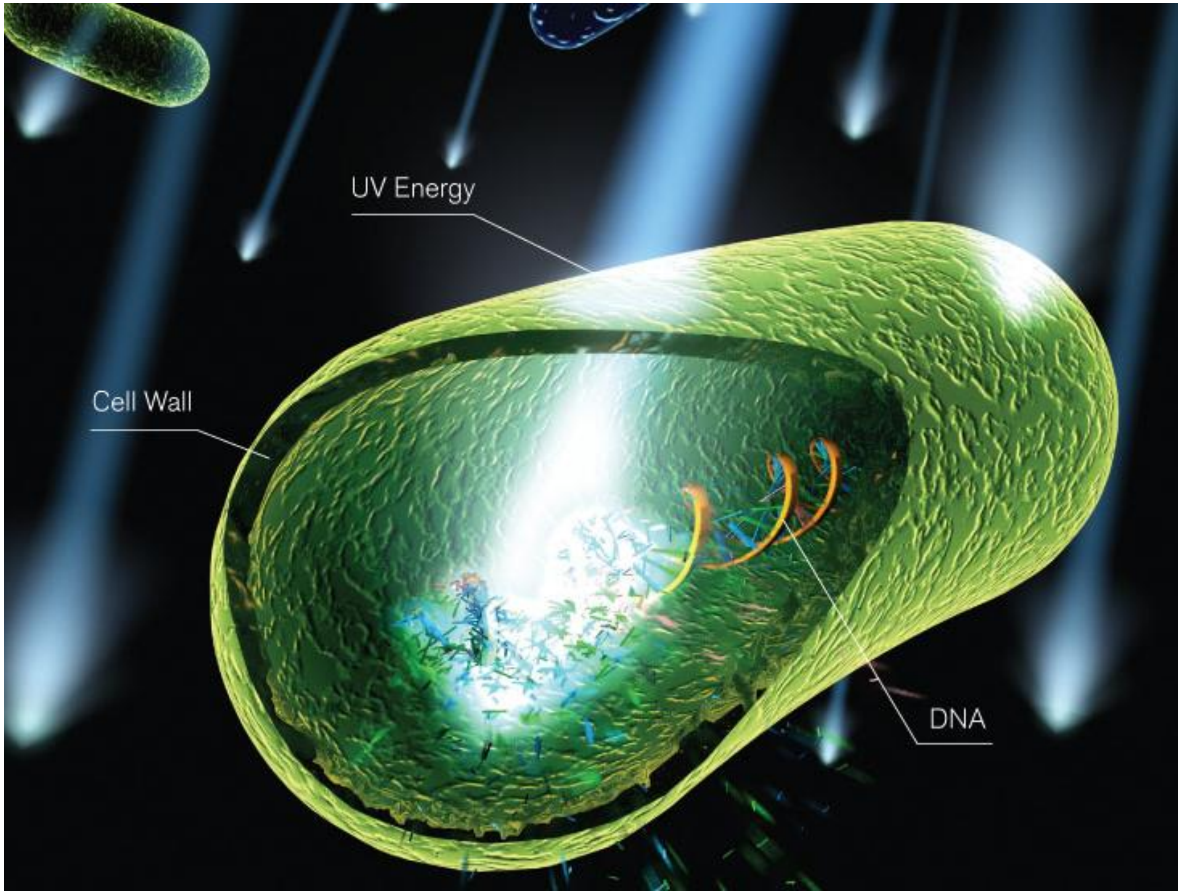
The Principle of UV Technology

Inactivation of pathogenic microorganisms
due to photooxidation of DNA



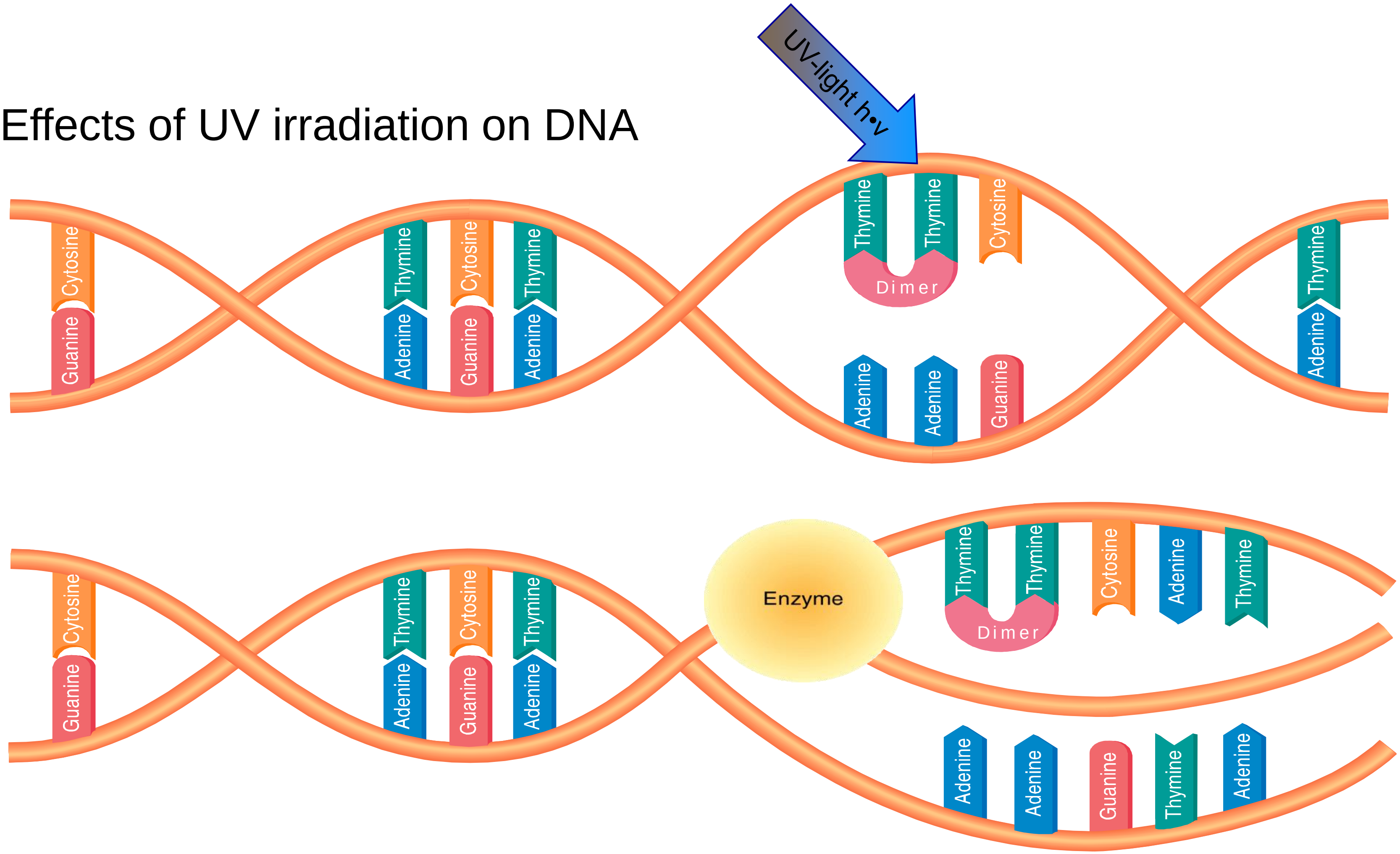
HOW UV WORKS

- UV light penetrates the cell walls of bacteria, virus and protozoa
- The UV energy permanently alters the DNA of the microorganism
- Microorganisms are “inactivated” and unable to reproduce or infect



The Mechanism

Effects of UV irradiation on DNA



The Result

Pure and safe water with UV

Distinct from chlorine and membrane filtration:

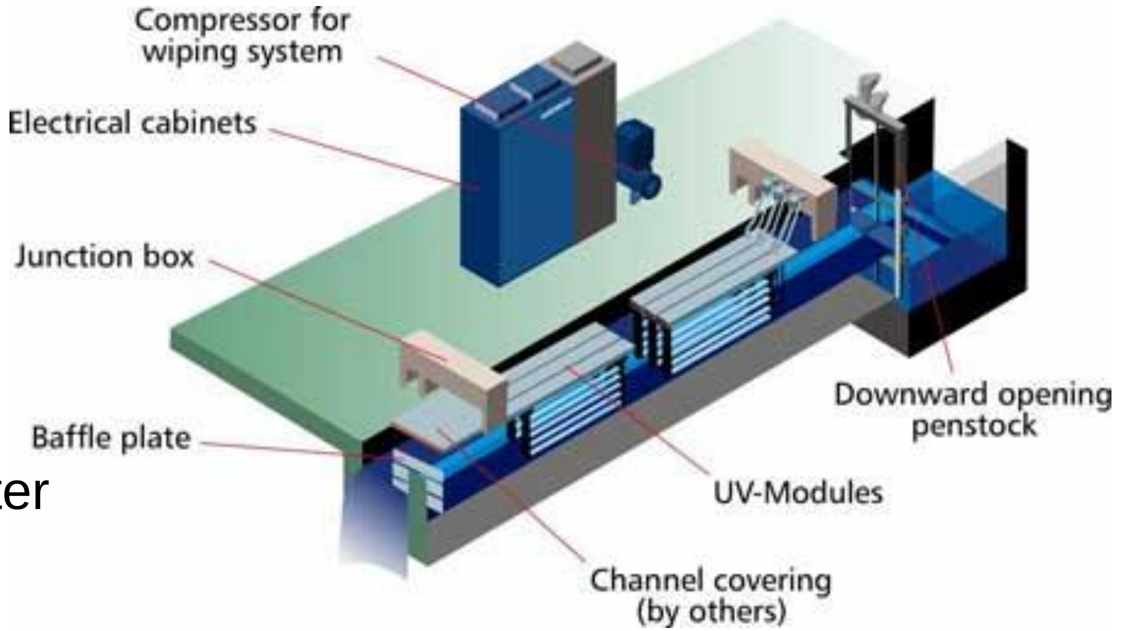
- Easy and reliable to apply
- No change of water chemistry
- No disinfection by-products (DBPs) or residuals
- No effect on odor and taste
- No regrowth of viruses, bacteria and parasites
- No corrosion
- No hazardous chemicals
- No resistance as with chlorine and antibiotics
- No concentration, no sludge

Comparison to Other Disinfection Technologies

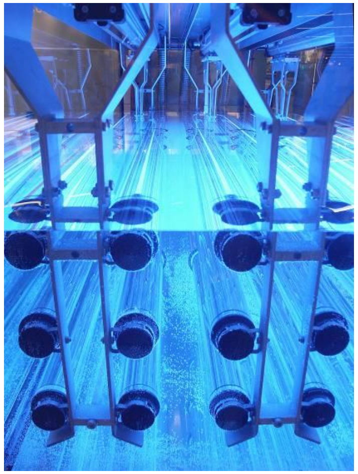
	Toxic by-products (DBP)	Requires chemical inventory	Biofilm removal	Residual disinfectant	Disinfection		
					Bacteria	Virus	Crypto
Ozone	No	No	No	No	+	+	+
UV	No	No	No	No	+	+	++
Chlorine	Yes	Yes	No	Yes	+	+	-
Chlorine dioxide	Yes	Yes	No	Yes	+	+	-
Membrane filtration	No	No	No	No	+	+	+
Other chemicals	Yes	Yes	No	Yes	+	+	-

Components of UV Disinfection Equipment

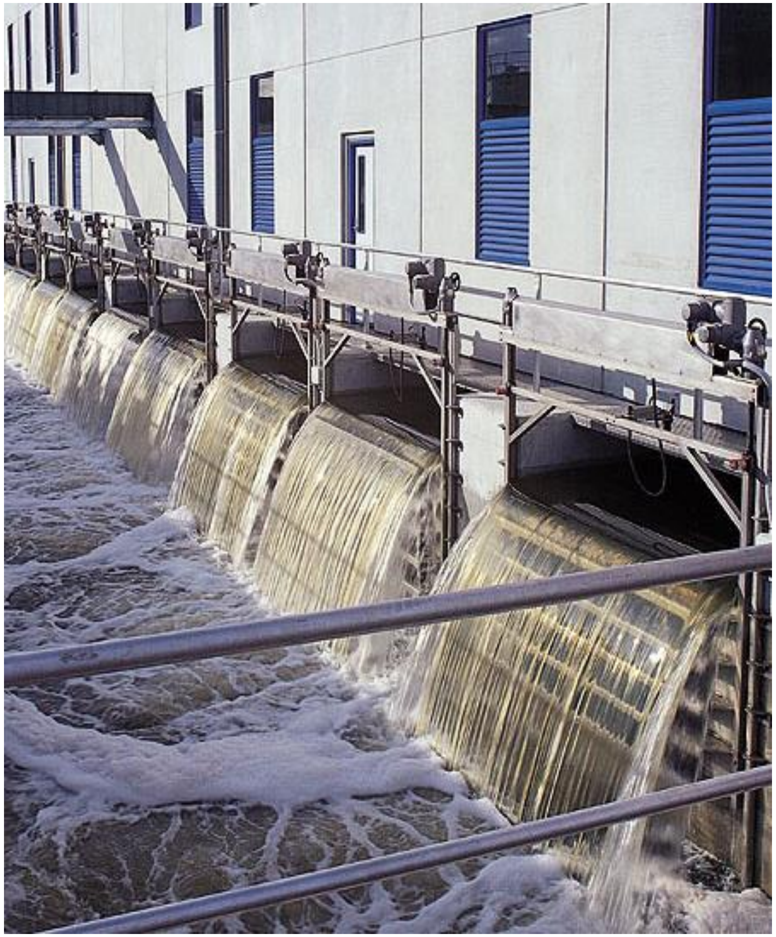
Open Channel UV Unit



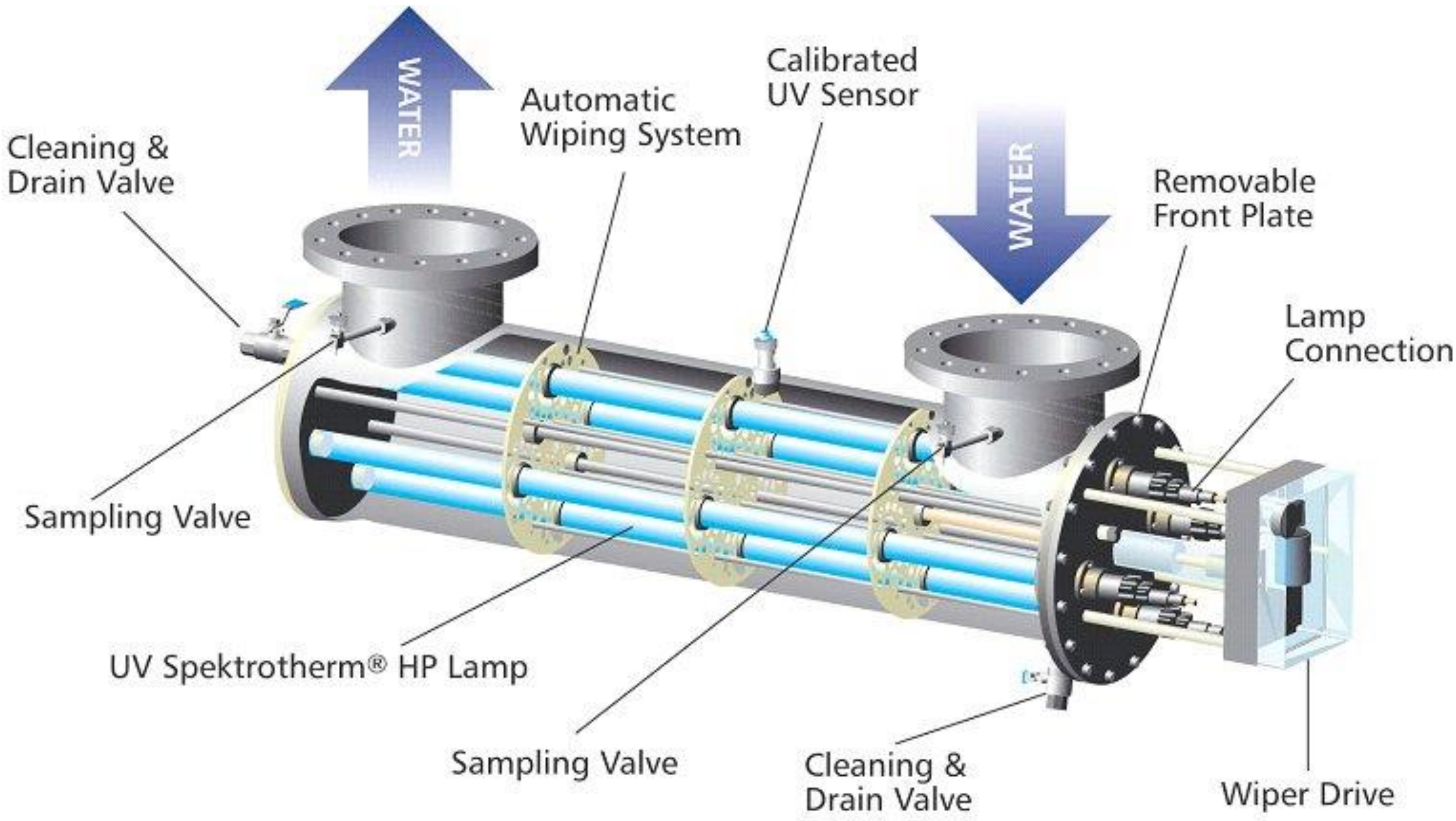
- Banks with modules
- UV lamps in quartz sleeves
- Automatic mechanical wiping system or chemical dip tanks
- UV intensity sensor / flow meter (dose pacing)
- Level control
- Ballast cards / controls
- Air compressor for wiping system
- One or multiple channels
- Lifting equipment




SWL 2000 KG

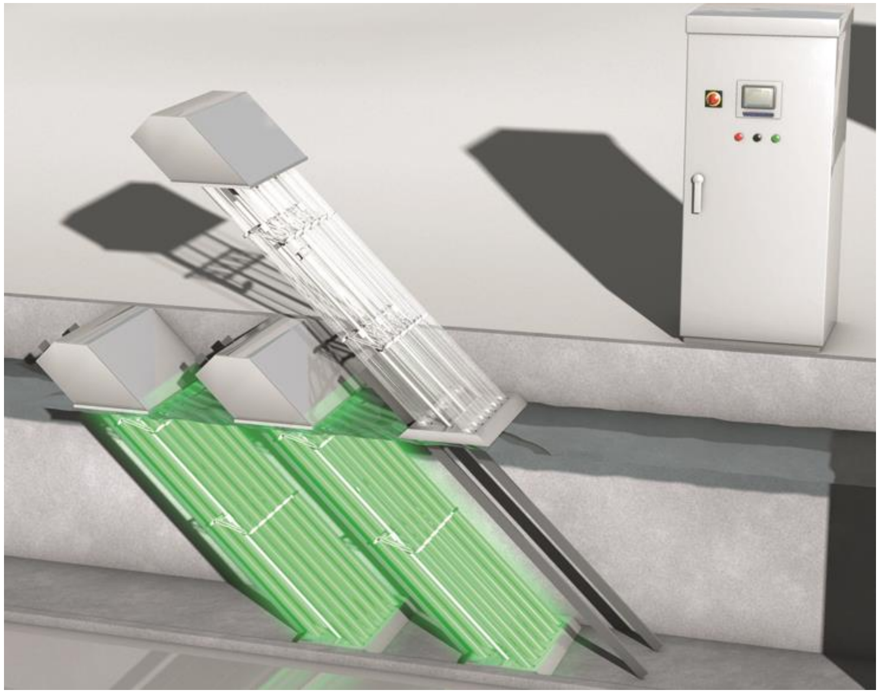


Closed Vessel UV Unit



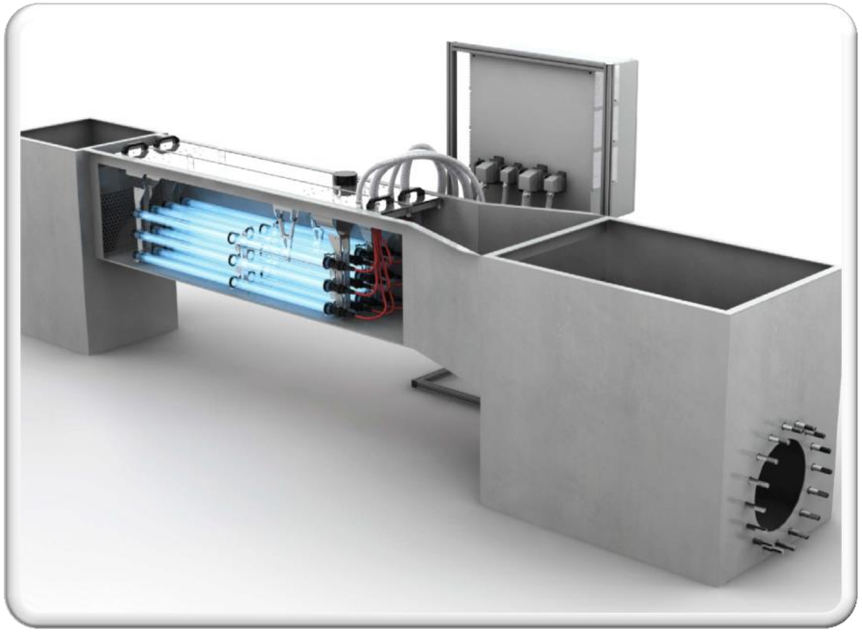
Open Channel UV Equipment - 45º

- 45º vertical incline staggered lamp system to reduce footprint
- Automatic built-in lifting device
- Automatic mechanical wiping system



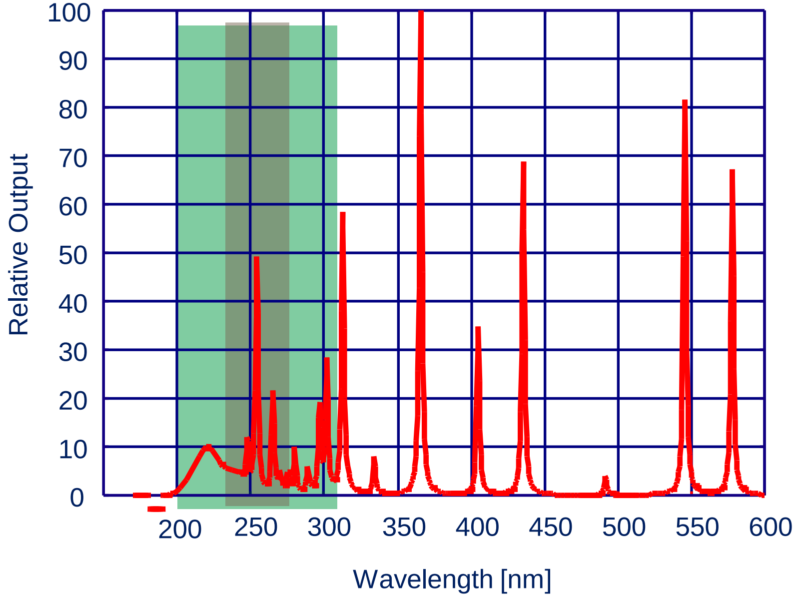
Open Channel UV Inserts

- Small to medium flow wastewater applications (up to 5 MGD)
- 1 or 2 banks, up to 48 lamps
- Reduced installation cost
- Options available:
  - Indoor vs. outdoor cabinet
  - Concrete, SS, or PE channel
  - Sensor-based control
  - Automatic mechanical wiping system
  - SCADA Communication

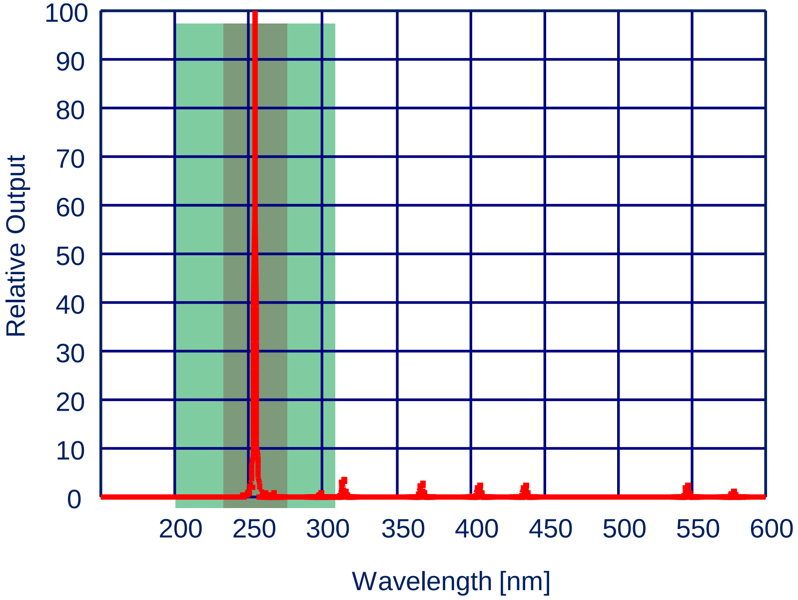


Comparison Between Low Pressure High Output (Lo-Hi) and Medium Pressure (MP) Lamps

Medium Pressure Lamp
(Polychromatic Output)



Low Pressure High Output (Lo-Hi)
Lamp (Monochromatic Output)



Lo-Hi lamps are concentrated in the 254 nm wavelength making them very efficient = less power for the same disinfection.

Ultraviolet Lamp Technology Comparison

Lamp Type	Low Pressure Lo-Lo	Low Pressure Lo-Hi	Medium Pressure
Power Consumption	40 to 80 W	250 to 315 W	3000 to 9000 W
UV-C output	15 to 35 W	100 to 150 W	300 to 900 W
UV-C Output Efficiency	38%	41 to 48 %	10-15%
Output Adjustment	100%	50-100%	30-100%
Operating Temp.	90^{o}C	100^{o}C	600-1000^{o}C
Lamp Life (hours)	9,000	12,000 to 14,000	3,000 to 8,000

Design Considerations

UV Design Considerations

- Flow Rate – average and peak
- Channel Hydraulics (width, depth and headloss)
- Water quality:
  - Inlet and effluent fecal coliform (log reduction)
  - Total suspended solids
  - Iron, manganese, hardness
  - Ultraviolet transmistivity (UVT) @ 254 nm wavelength
- One or multiple channels (or flow streams)
- Redundancy Requirements (which flow?)

Key Design Points of UV Equipment

- UV Dose (10 States, Point Source Summation and Bioassay)
- UV lamp aging factor (end of useful life)

  Typically max of 0.85 to 0.88
- Quartz sleeve fouling factor

  Typically 0.90
- Results in number of UV lamps

UV Dose for Wastewater

UV Dose = Quantity of Cell Inactivation

UV Dose = UV Intensity x Retention Time

$[\mathrm{mJ/cm^2}] = [\mu\mathrm{W/cm^2}] \times [\mathrm{s}]$

Intensity is a function of:

- lamp output
- lamp age
- quartz sleeve transmissivity (coating)
- water quality (UV transmittance)

UV Dose Calculation Approaches for Wastewater

Regulatory (10 States Standards)

minimum UV dose of 30,000 μW s/ cm^2 (or 30 mJ/cm^2)

Calculated sizing models:

PSS (Point Source Summation) - theoretical

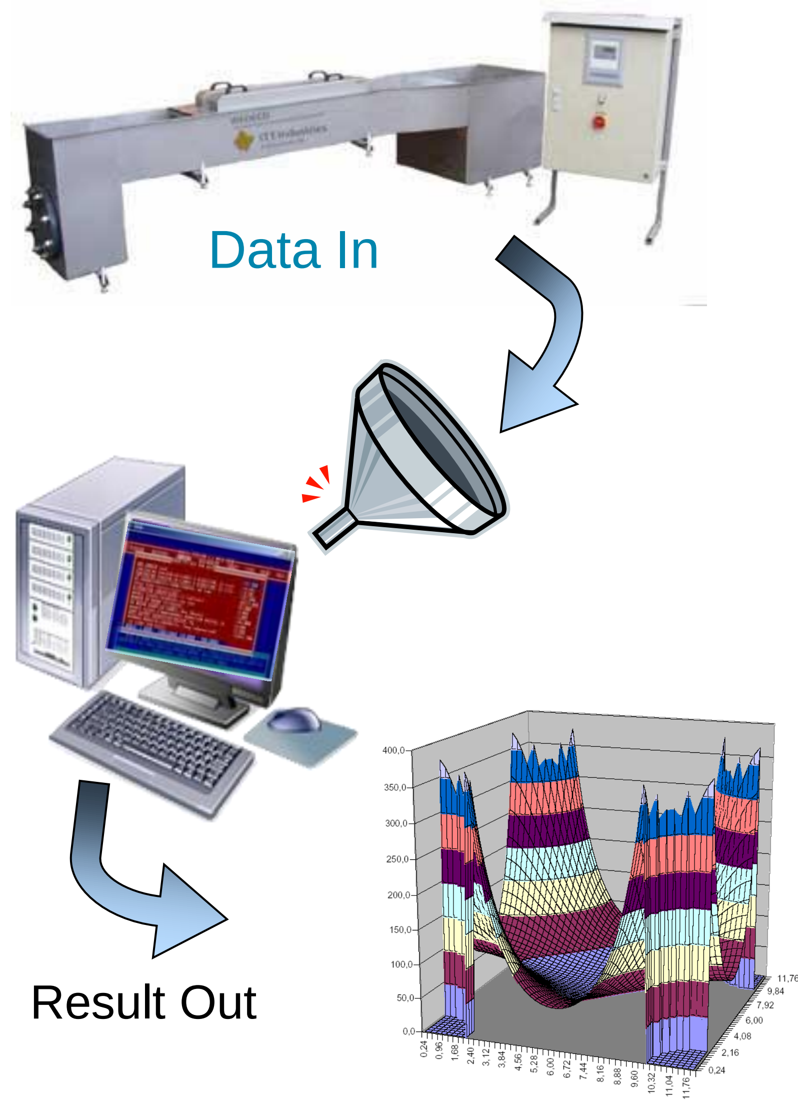
Biologically verified methods (bioassays):

Based on real data / Target a specific microorganism (MS2 or T1)

Should be validated by 3rd party

PSS (Point Source Summation)

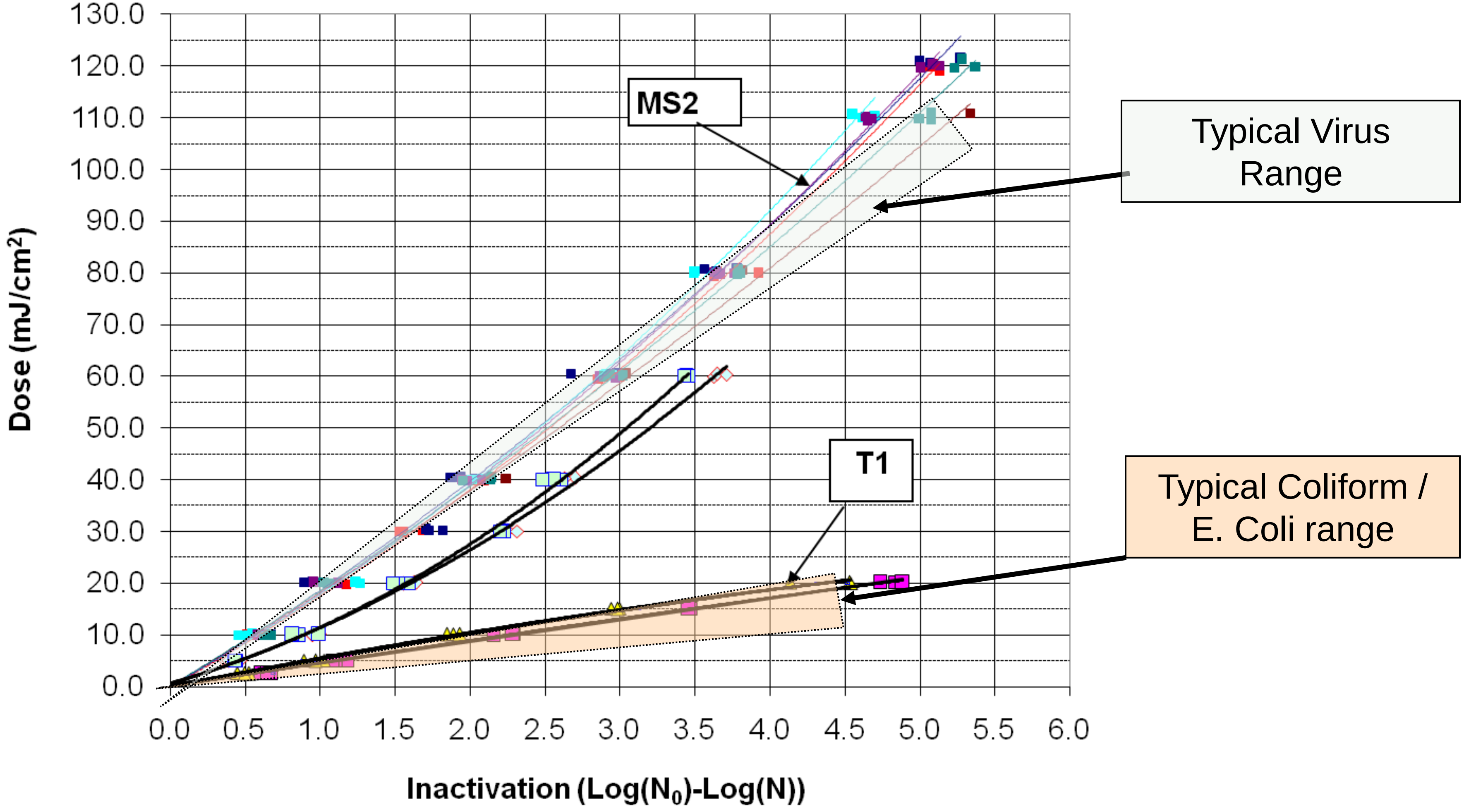
- Purely mathematical approach
- Not based upon a site-specific water quality and target organism
- Not based upon microbiological data
- Adjustment for lamp ageing and fouling
- Introduced in 1986 EPA design manual



Bioassays for Wastewater

- Based on real data
- Take hydraulic performance into account
- Take real intensity distribution into account
- Target a specific microorganism (T1 or MS2)
- Site-specific (water quality/organism)
- Adjustment for lamp ageing and fouling

Using a Surrogate of Similar Sensitivity as the Target Microorganism Provides an Accurate UV-Dose Response Design



Bioassay Doses Can Be Equated to PSS Calculated UV Dose Methodology to Satisfy Necessary Guidelines

10 State Standards

This process should be limited to a high quality effluent having at least 65% ultraviolet radiation transmittance at 254 nanometers wave length, and BOD and suspended solids concentrations no greater than 30 mg/L at any time. The UV radiation dosage shall be based on the design peak hourly flow. As a general guide in system sizing for an activated sludge effluent with the preceding characteristics, a UV radiation dosage not less than 30,000 µW·s/cm^2 may be used after adjustments for maximum tube fouling, lamp output reduction after 8760 hours of operation, and other energy absorption losses.

	T1 Bioassay Dose	PSS Dose
Example project	12.6 mJ/cm^2	40 mJ/cm^2

UV Bioassay Validation

- Procedure to determine the performance of a UV system
- Required because no methodology for direct measurement of microorganisms is available
- Combination of laboratory bench scale testing (Collimated Beam Device) and UV reactor field test
- Because the target organism is too dangerous (e.g. Cryptosporidium) or shows too much variability (e.g. Fecal coliforms), microbial surrogates (e.g. MS2, T1) are being used
- Ideally, the microbial surrogate should have the same sensitivity to UV light as the target pathogen

Collimated Beam

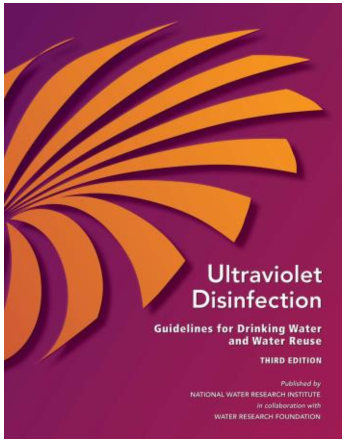
+

Field Test

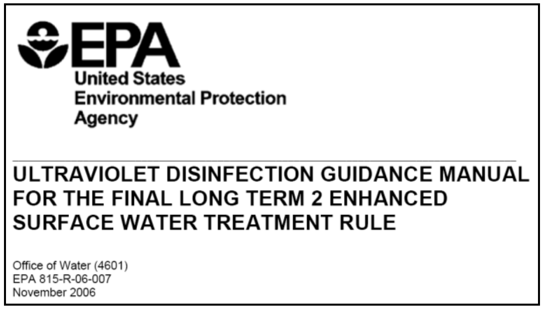
Fecal Coliform UV Dose Response Curve

UV Protocols

- National Water Research Institute (NWRI) Guidelines
  - 2003 (updated in 2012)



- EPA UV Disinfection Guidance Manual (UVDGM)
  - 2006

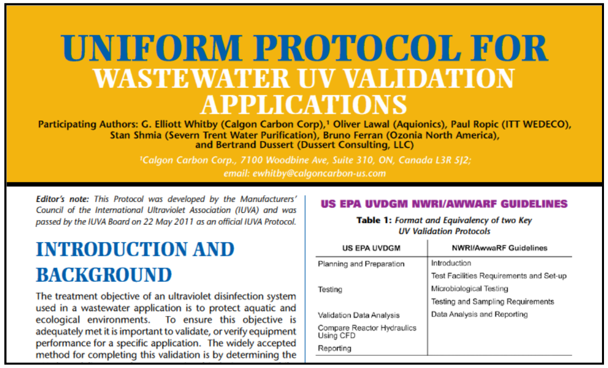


EPA
United States Environmental Protection Agency

ULTRAVIOLET DISINFECTION GUIDANCE MANUAL FOR THE FINAL LONG TERM 2 ENHANCED SURFACE WATER TREATMENT RULE

Office of Water (4601)
EPA 815-R-06-007
November 2006

- International UV Association Protocol (IUVA)
  - 2011



UNIFORM PROTOCOL FOR WASTEWATER UV VALIDATION APPLICATIONS

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Editor's note: This Protocol was developed by the Manufacturers' Council of the International Ultraviolet Association (IUVA) and was passed by the IUVA Board on 22 May 2011 as an official IUVA Protocol.

INTRODUCTION AND BACKGROUND

The treatment objective of an ultraviolet disinfection system used in a wastewater application is to protect aquatic and ecological environments. To ensure this objective is adequately met it is important to validate, or verify equipment performance for a specific application. The widely accepted method for completing this validation is by determining the

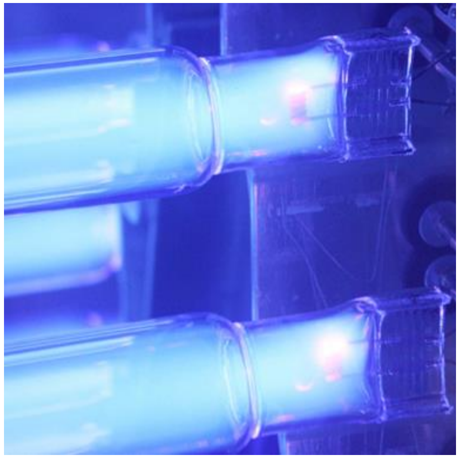
US EPA UVDGM NWRI/AWWARF GUIDELINES

Table 1: *Format and Equivalency of two Key UV Validation Protocols*

US EPA UVDGM	NWRI/AwwaRF Guidelines
Planning and Preparation	Introduction
	Test Facilities Requirements and Set-up
Testing	Microbiological Testing
	Testing and Sampling Requirements
Validation Data Analysis	Data Analysis and Reporting
Compare Reactor Hydraulics Using CFD	
Reporting	

Cost of Ownership

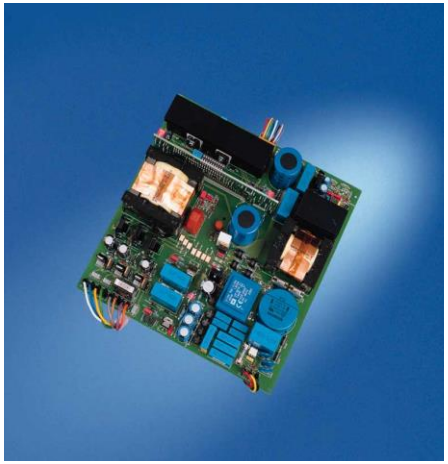
UV Cost of Ownership



Equipment Capital Cost

Installation

Electrical Costs



Equipment Consumables

- UV Lamps – 10,000 to 15,000 hours (1 ½ to 2 years)
- Ballast Cards – estimate 5 to 8 years

Equipment Replacement (at end of Equipment Life)

Thank You!

QUESTIONS