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# UV Disinfection for Municipal Applications

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UV BUSINESS DEVELOPMENT MANAGER

# Agenda

- UV101
- UV Lamps
- UV Design Parameters
- UV Systems
- Wastewater
- Drinking Water
- Installation Snap Shots

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**UV101**
UV Lamps
UV Design Parameters
UV Systems
Wastewater
Drinking Water
Installation Snap Shots

# UV 101

# UV History

| Year | Event |
|---|---|
| 1878 | Scientists discover sunlight “kills” microorganisms |
| 1901 | Fluorescent mercury vapor lamp invented |
| 1910 | 1st drinking water installation (France) |
| 1920s | Medium pressure UV lamp invented |
| 1978 | 1st wastewater installation (New Jersey) |
| 1980s | Expansion industrial (worldwide); drinking water (Europe) |
| 1990s | Expansion wastewater (US) |
| 2000 | Effective against Cryptosporidium and Giardia |
| 2001 | Wastewater reuse guidelines |
| 2006 | USEPA drinking water guidance manual |
| 2012 | Revised reuse guidelines published |

# Where is UV Used?

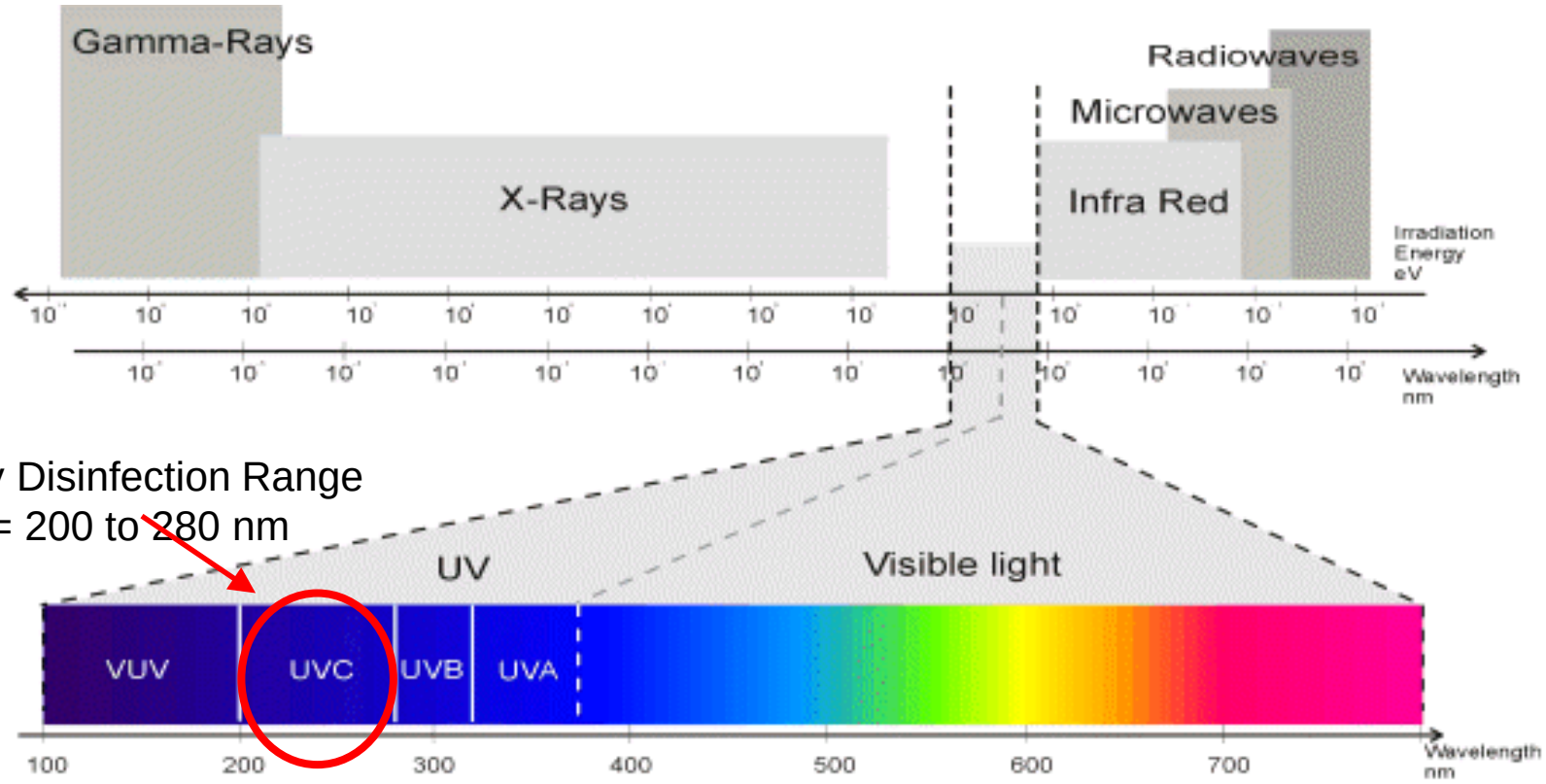
Wastewater & Reuse
Drinking Water
Pools, Waterparks, & Splash Pads
Aquaculture & Fish Farms
Marine & Offshore
Soft Drinks & Breweries
Food Production
Electronics & Pharmaceuticals
Oil & Gas
Power Generation
Data Centers (cooling towers)
Hospitals (Legionella)



# Key Benefits of UV Disinfection

- Environmentally friendly method (no chemicals, energy efficient)
- Easy and reliable to apply, operate and maintain
- No change of water chemistry:
  - No harmful by-products or residuals
  - No effect on taste and odor (chlorine smell) unless using for this application
- No handling of hazardous chemicals (chlorine gas)
- Highly effective against chlorine-resistant pathogens (Cryptosporidium)
- Small footprint due to instantaneous process
- Little impact on infrastructure (no large reaction tanks or equivalent)
- Can easily be used in combination with other methods (=> part of a multi-barrier concept)

# UV and the Electromagnetic Spectrum




| UV Range | Wavelengths [nm] | Applications |
|---|---|---|
| UVA | 315-400 | Sunburn, Blacklight |
| UVB | 280-315 | Sunburn, Germicidal |
| **UVC** | **200-280** | **Germicidal Photochemistry** |
| Vacuum UV | 100-200 | High-energy Applications |

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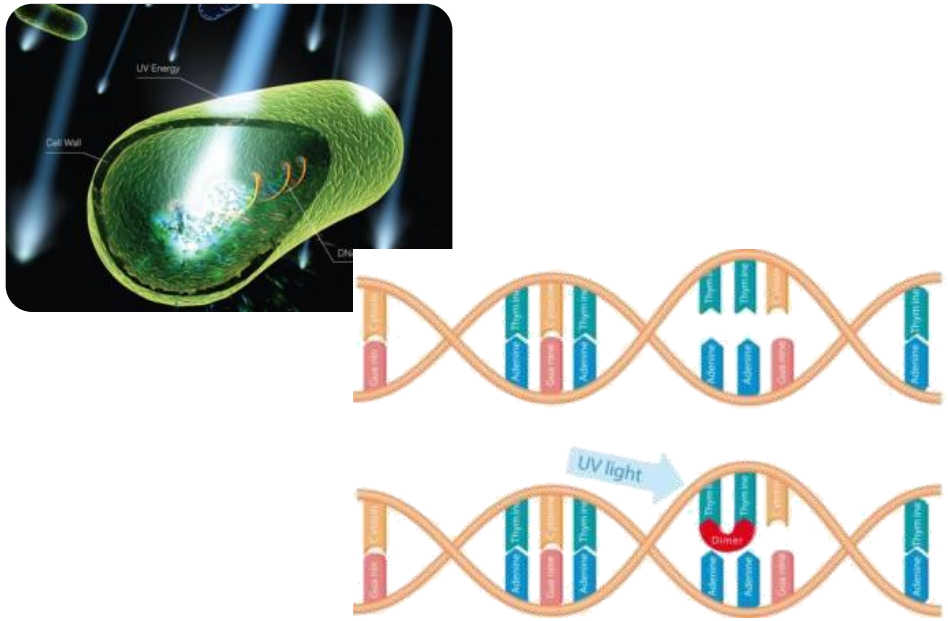
# What Does UV Do?

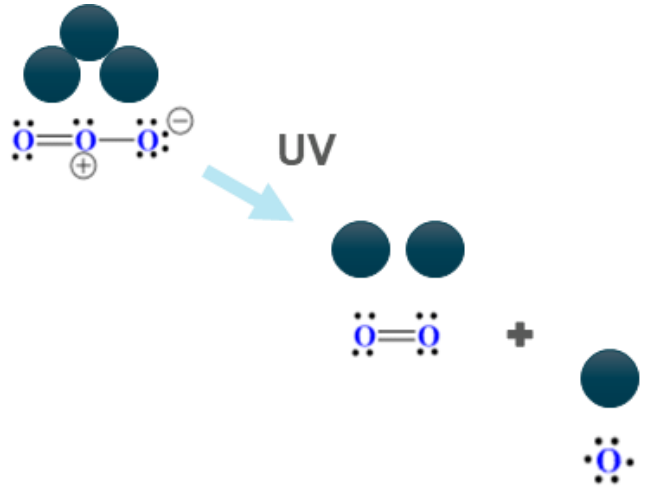
## Disinfection

Photons absorbed by DNA and RNA in microorganisms leads to inactivation (inability to replicate) by altering of thymine base units in the DNA




## Photolysis

Photons of UV light absorbed by molecules such as ozone, chloramines or NDMA lead to chemical change, resulting in their destruction

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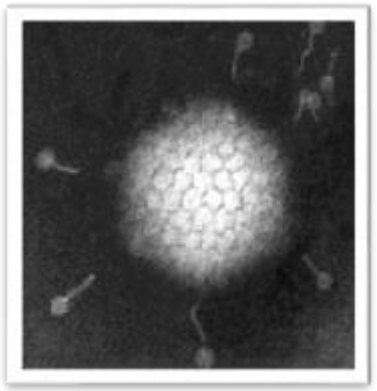
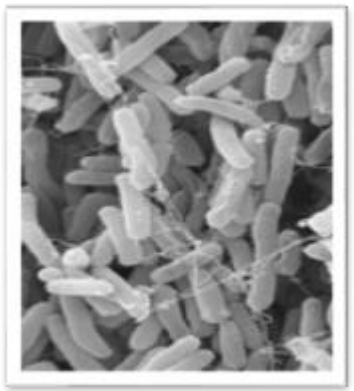
# Disinfection

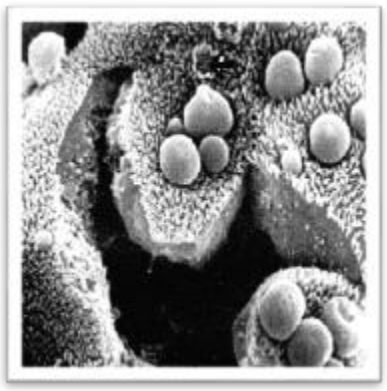
**Protozoa** (*Giardia*)



**Protozoa** (*Cryptosporidium*)



**Bacteria** (*E.coli*)



**Viruses** (*Hepatitis*, *Polio*)

Least resistant

UV Disinfection Effectiveness

Most resistant

| | | | |
|---|---|---|---|
| **Dose** | **X** | **2X** | **23X** |

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UV101
**UV Lamps**
UV Design Parameters
UV Systems
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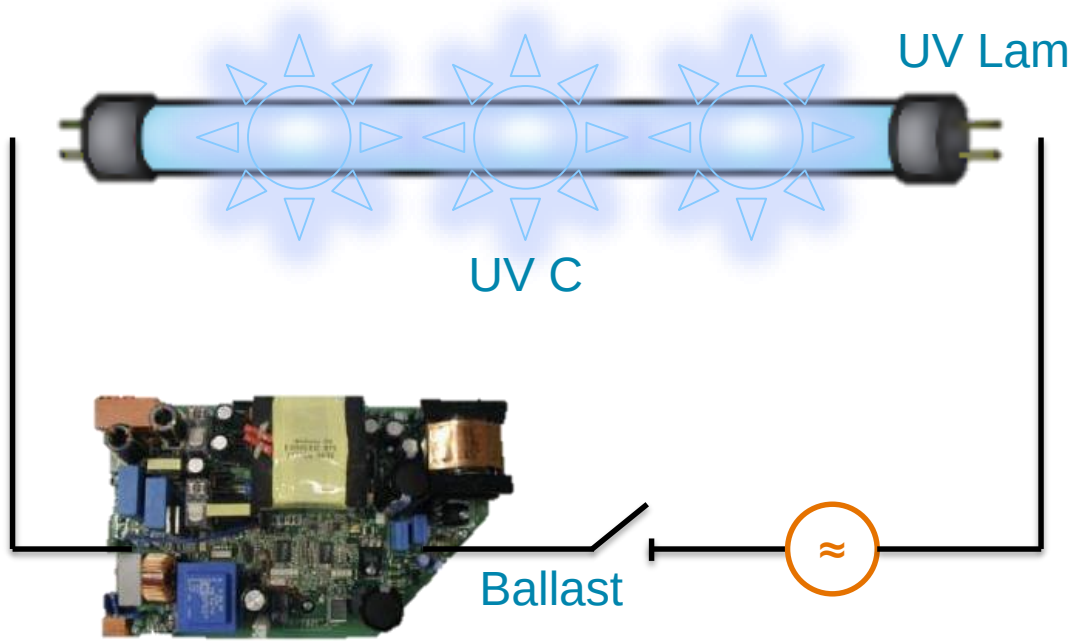
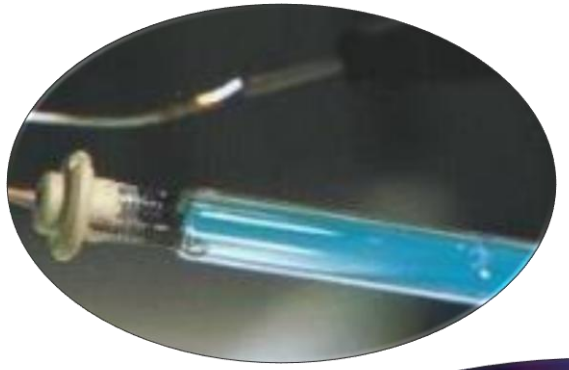
# UV Lamps

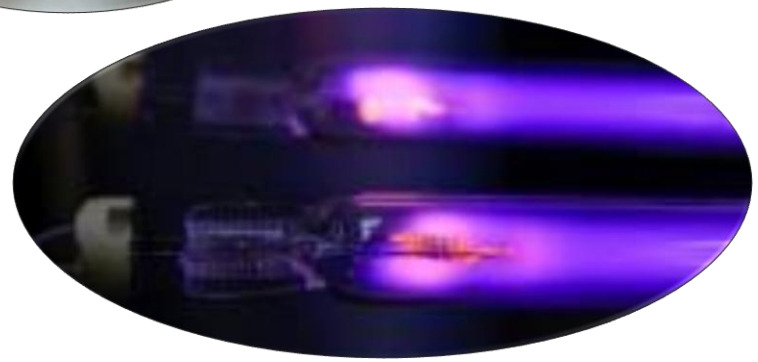
# Generation of UV Light

- Basis: Mercury atoms in gas discharge lamps (like fluorescent bulbs)
  - Electrical field brings mercury into energized but unstable state
  - Release of energy = emission of UVC light



# UV Lamps





- Pressure = internal gas pressure
- It has nothing to do with lamp power
- The difference in gas pressure causes a different spectral output (wavelengths generated)

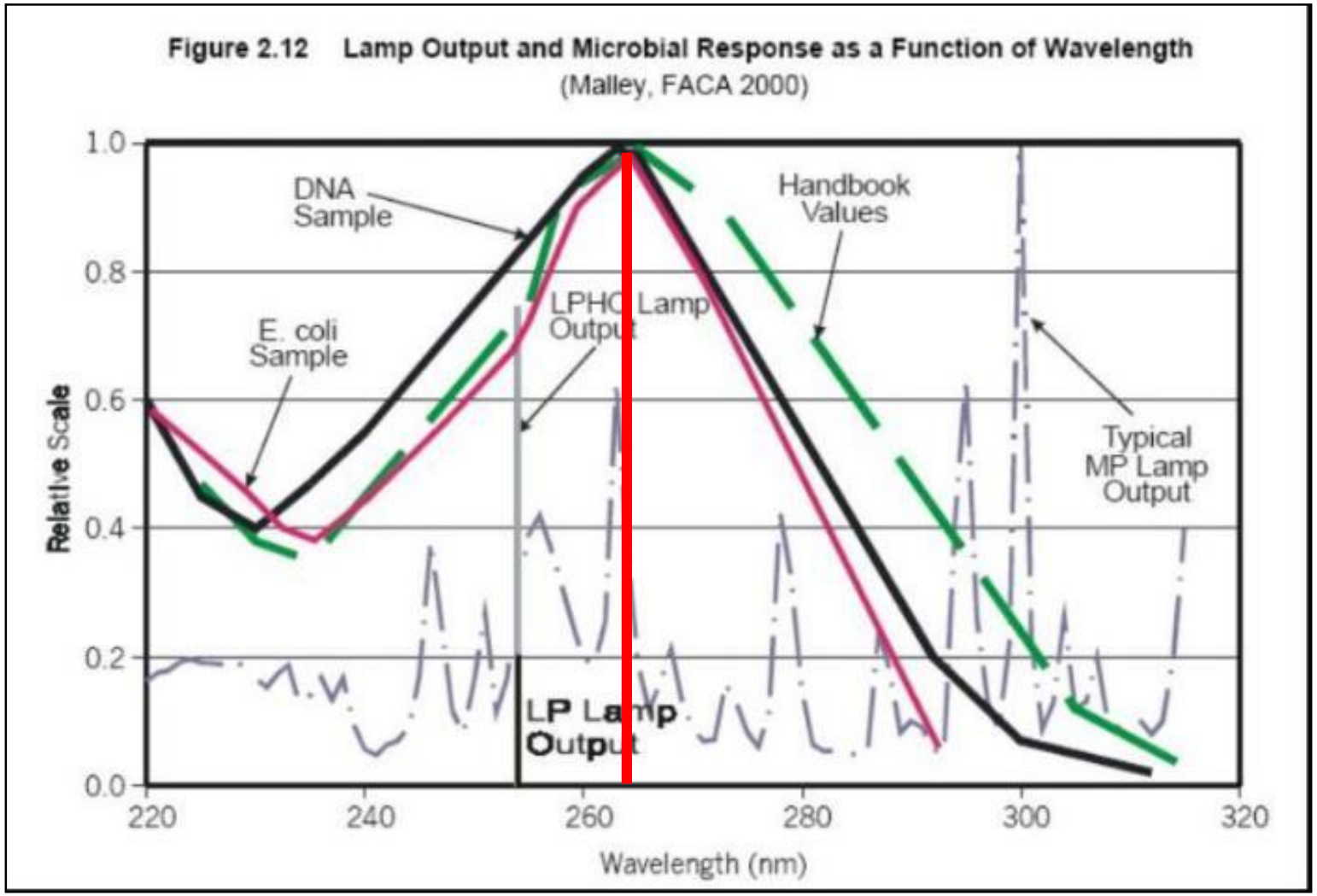
**Low Pressure High Output**

- (35%, 35%, 30%) UVC, VIS, IR
- Medium UVC output
- Monochromatic
- Large footprint

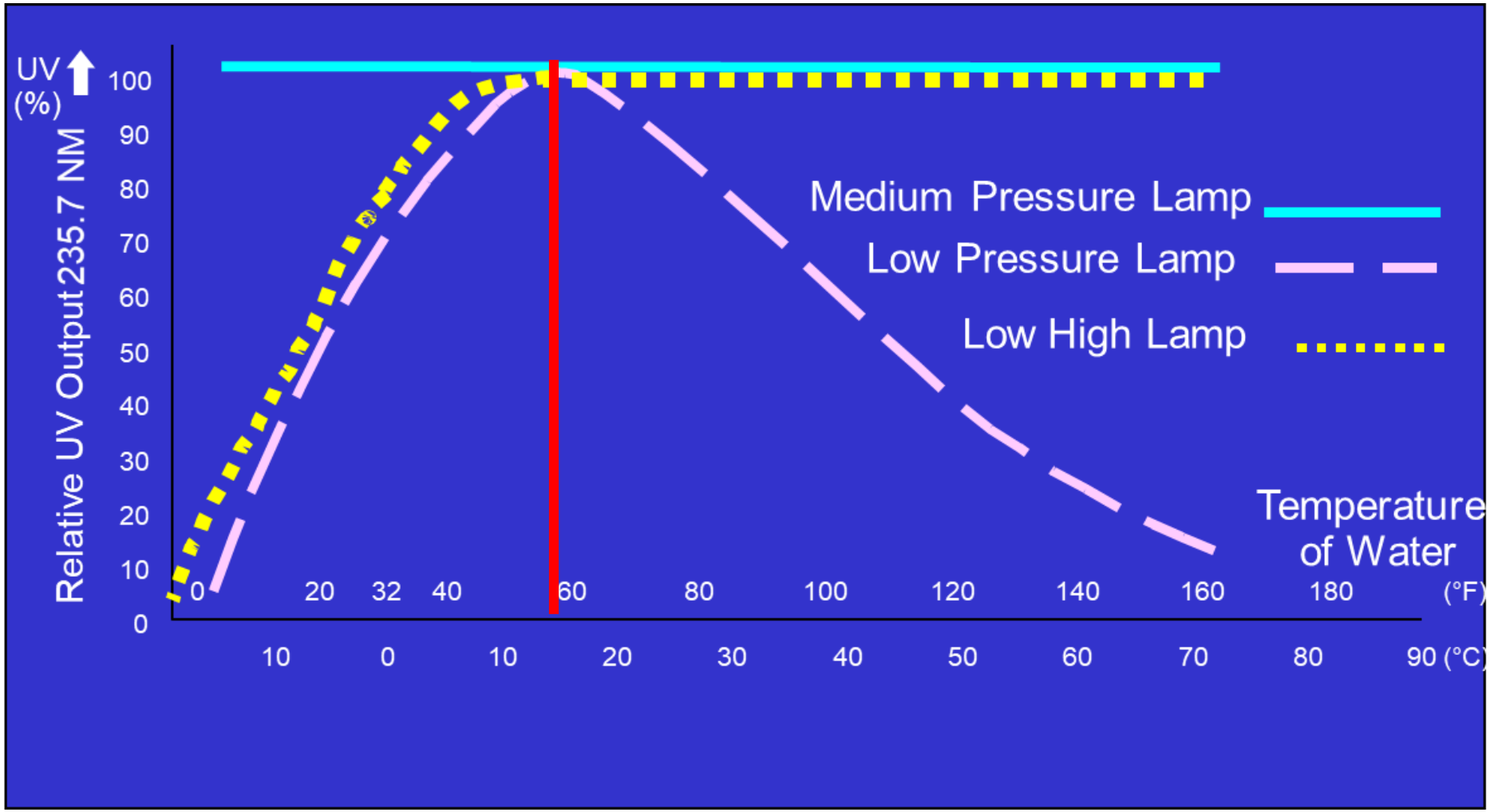
**Medium Pressure**

- (15%, 20%, 65%) UVC, VIS, IR
- Very high UVC output
- Polychromatic
- Small footprint

# Microbial Response to UV



# UV and Water Temperature



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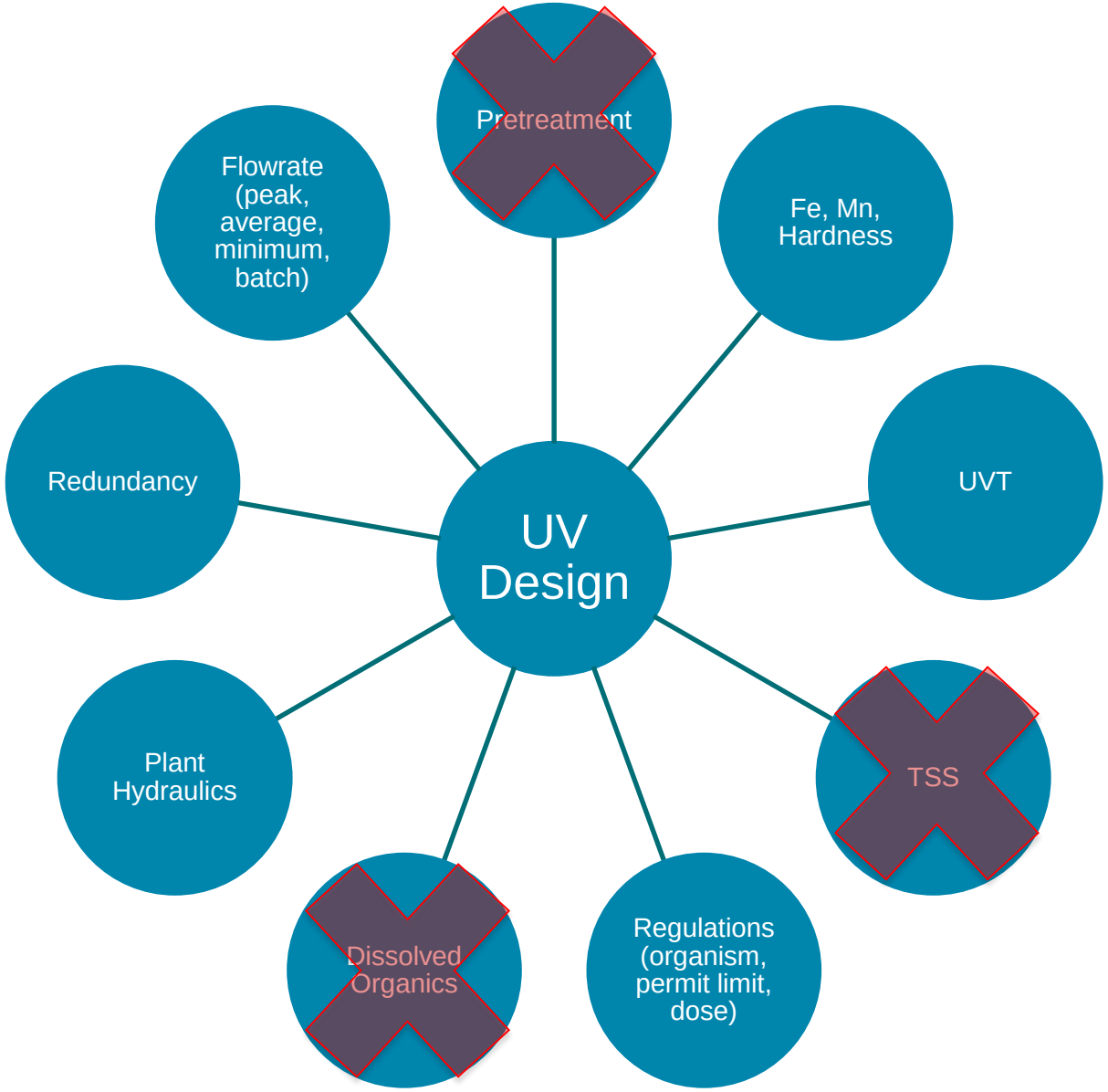
# UV Design Parameters

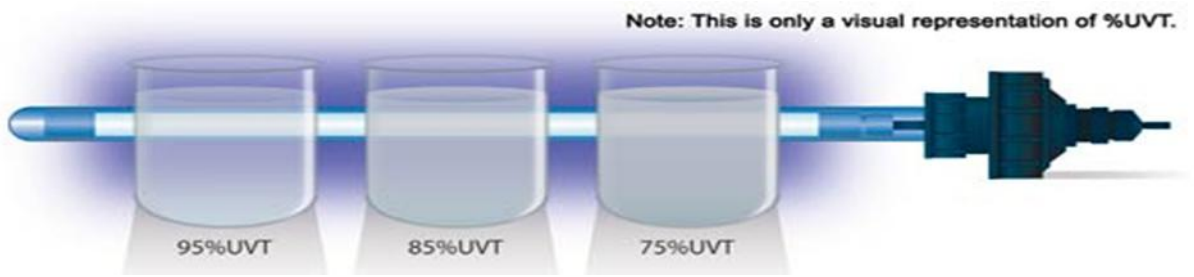
# Required Parameters



# Transmittance

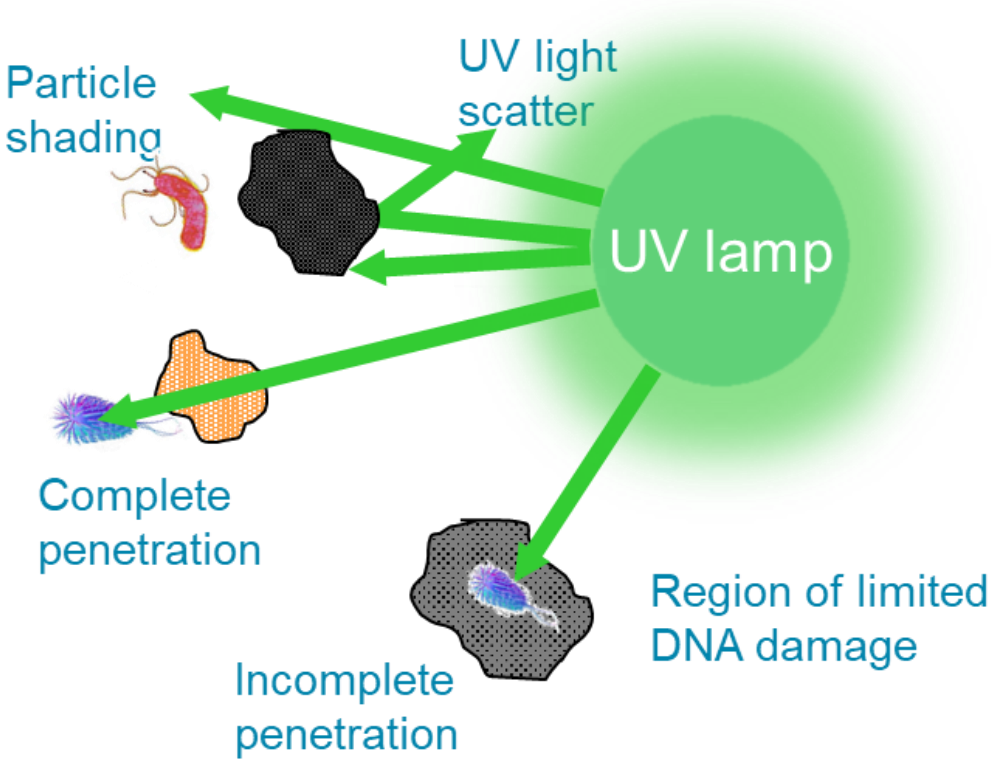
Measurement of the amount of light that penetrates through the water

Tested with spectrophotometer (deuterium lamp) in a quartz cuvette



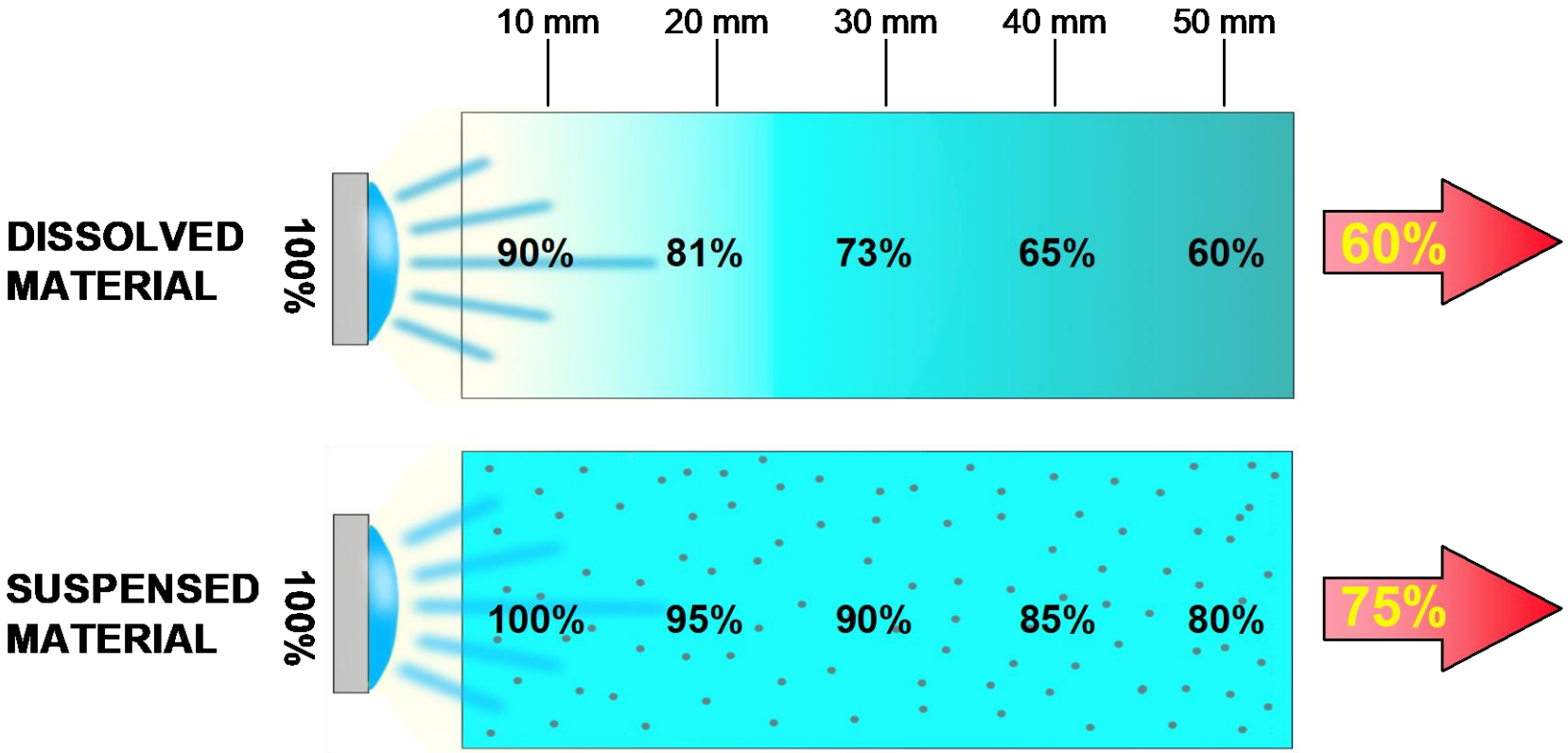

| Water Source | Transmittance (T10%) |
|---|---|
| Ultrapure Water | 100% |
| Distilled Water | 98% |
| Drinking Water | 85-95% |
| Membrane (WW) | 70-80% |
| Secondary Filtered | 65-70% |
| Secondary Unfiltered | 50-65% |
| Meat Brine, Soft Drinks | 0% |

# Total Suspended Solids




The TSS level ultimately determines the possible disinfection level!

# Dissolved Organics




UV “operates” below the visible spectrum, thus effectiveness and performance of UV cannot be assumed based on visual inspection of effluent

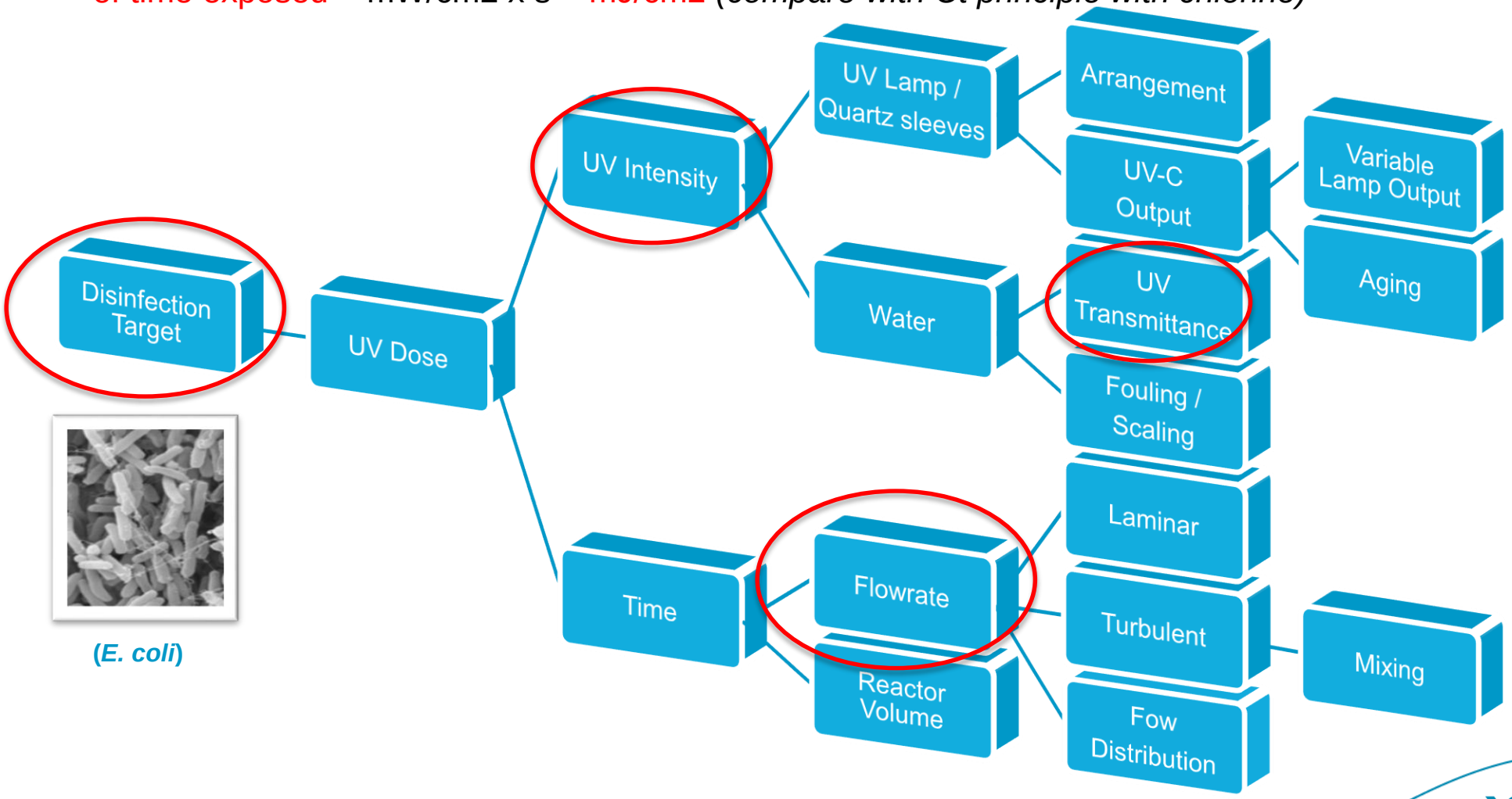
# Iron and Manganese Fouling



Quartz has a negative (-) charge while heavy metals have a positive (+) leading to fouling

# Key Design Parameters that Influences UV Dose

UV dose – UV intensity (I) x Residence time (T) = strength of radiation used x amount of time exposed = mW/cm2 x s = mJ/cm2 *(compare with Ct principle with chlorine)*




(*E. coli*)

# Hydraulics and Redundancy

**HYDRAULICS**

- New Plant
- Retrofit
- Gravity
- Pumped

**REDUNDANCY**

- N + 1
- UV per Filter

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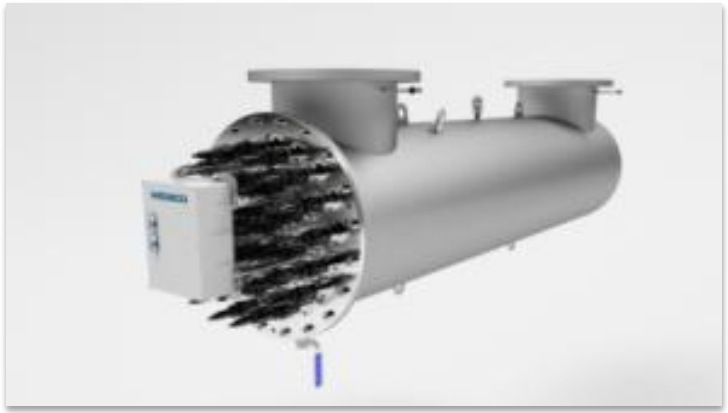
# UV Systems

# Types of UV System

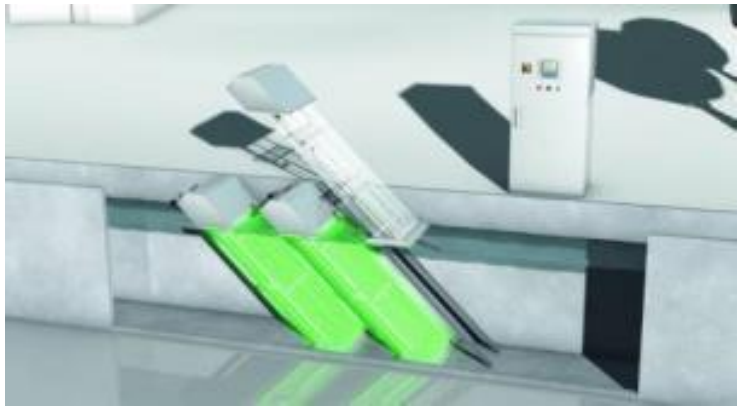
## Closed Vessel Reactors (pressurized or gravity)

- Main applications: drinking water, wastewater, water reuse, aquatics, industrial applications
- Standardized systems
- Installation in pipework
- Isolation valves recommended/ required



## Open Channel (gravity)

- Main applications: wastewater, aquaculture
- Modular design
- Installation typically in concrete channels
- Water level control required



# UV System Components

Reactor


Lamp

Quartz sleeve

Sensor

Ballast

Cabinet & Controller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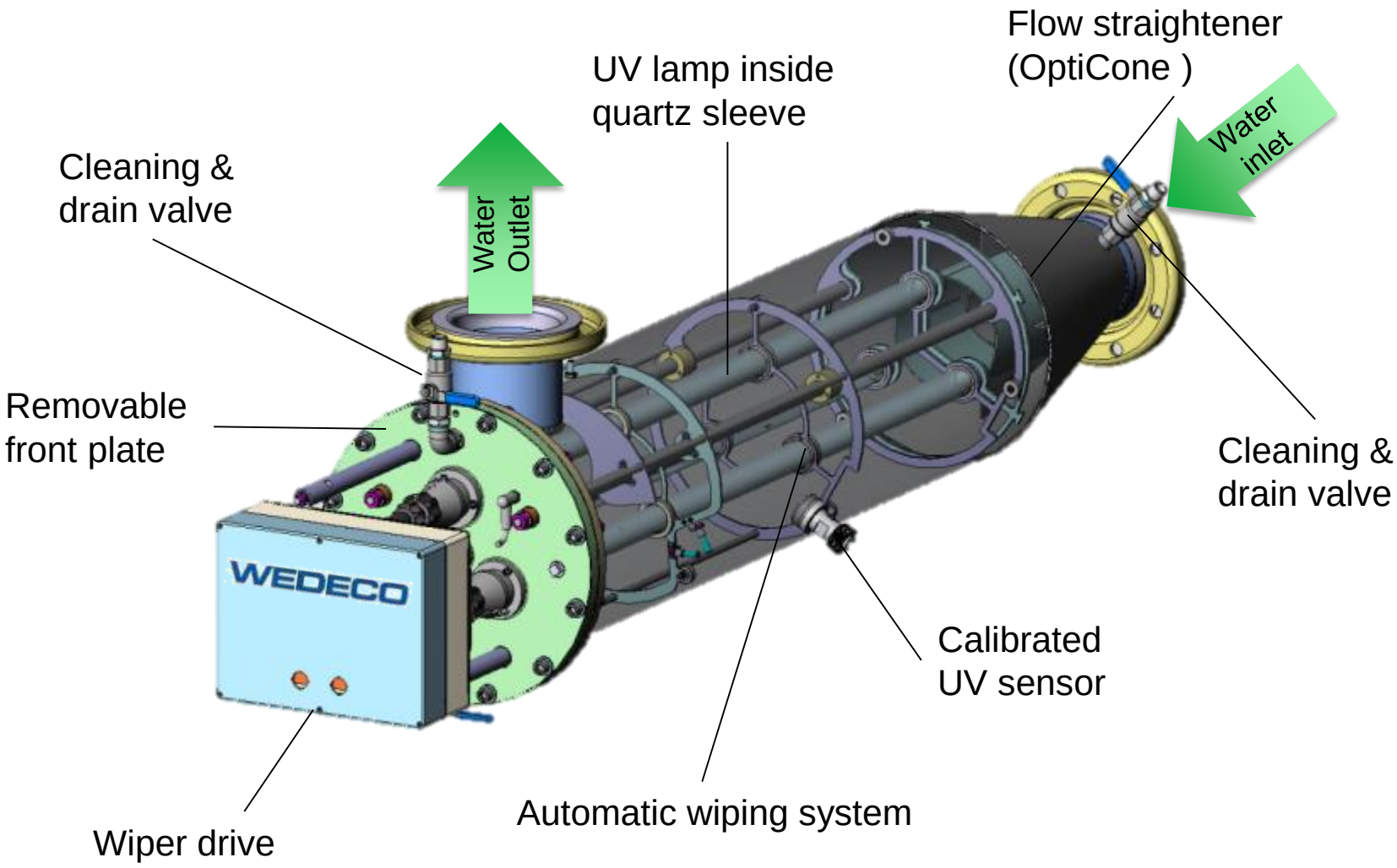
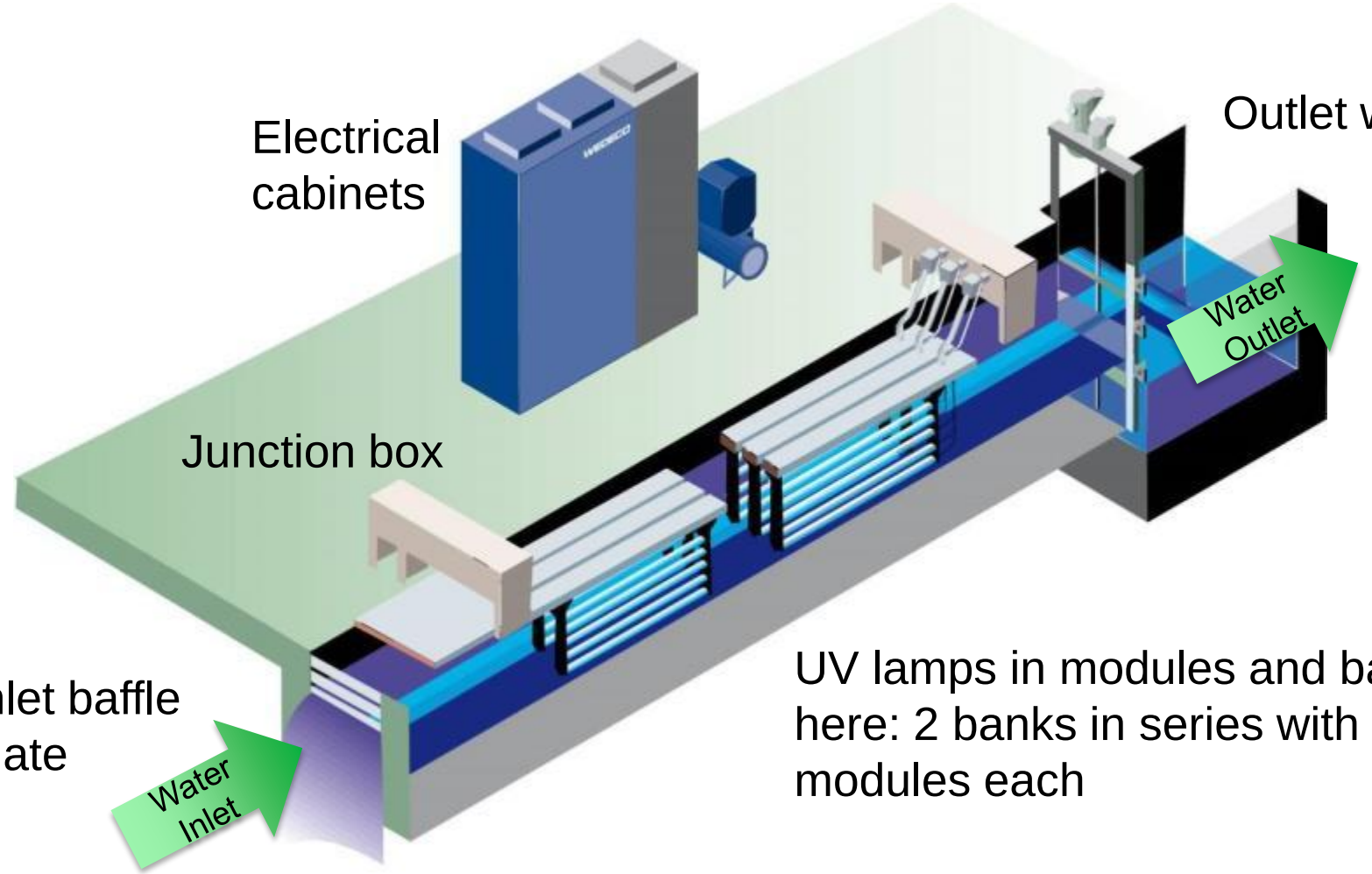
# Components of Closed Vessel UV Systems



# Components of Open Channel UV Systems



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# Wastewater

# Wastewater Applications

- Primary
- Secondary
- Secondary filtered
- Tertiary
- Activated sludge
- Extended aeration
- SBR
- MBR
- Lagoon
- Wetland

- New plants
- Retrofits
- Space constraints
- Head constraints
- Small flows
- Large flows

- Stream discharge
- CSO
- Reuse

# “Traditional” Wastewater

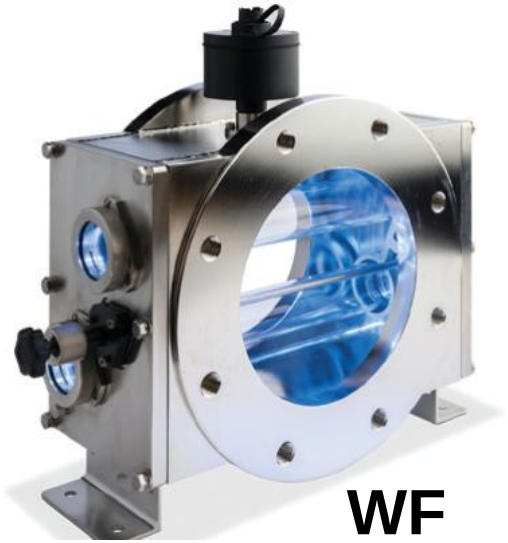
- UV used where receiving water does not permit chlorine discharge
- Can be less expensive than chlorination/dechlorination
- Remote areas where chlorine transport is difficult
- UV dose is typically 20 – 40 $mJ/cm^2$
- Typical effluent permit <200 fc/100 ml or <126 e. coli/100 ml
- Largest municipal market application for UV

# Combined Sewer Overflows

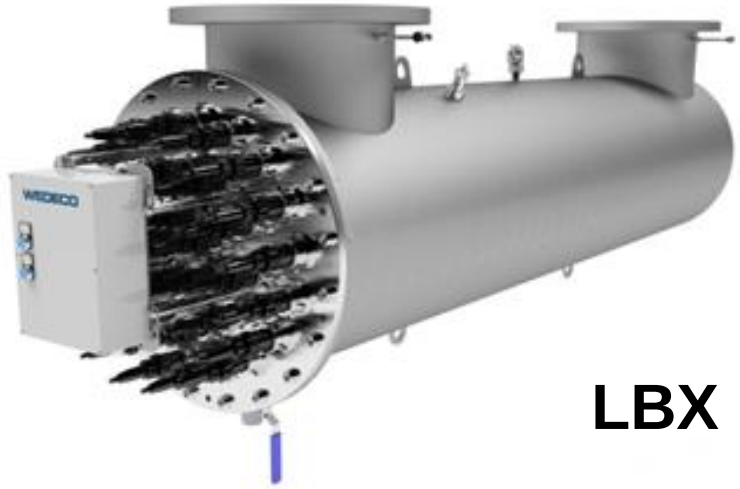
- EPA regulating CSO to prevent watershed contamination
- May only be a few events per year
- Generally rapid filtration followed by UV
- Closed vessel, medium pressure UV: rapid start, small footprint, and reduced lamp count

# Equipment – Closed Vessel

SW

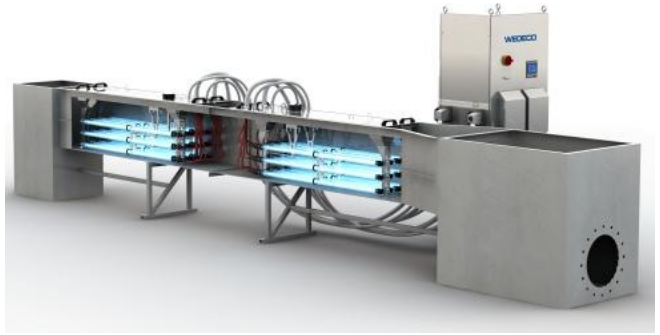


WF



LBX

# Equipment – Open Channel



**TAK Smart**

**TAK55**



**Duron**

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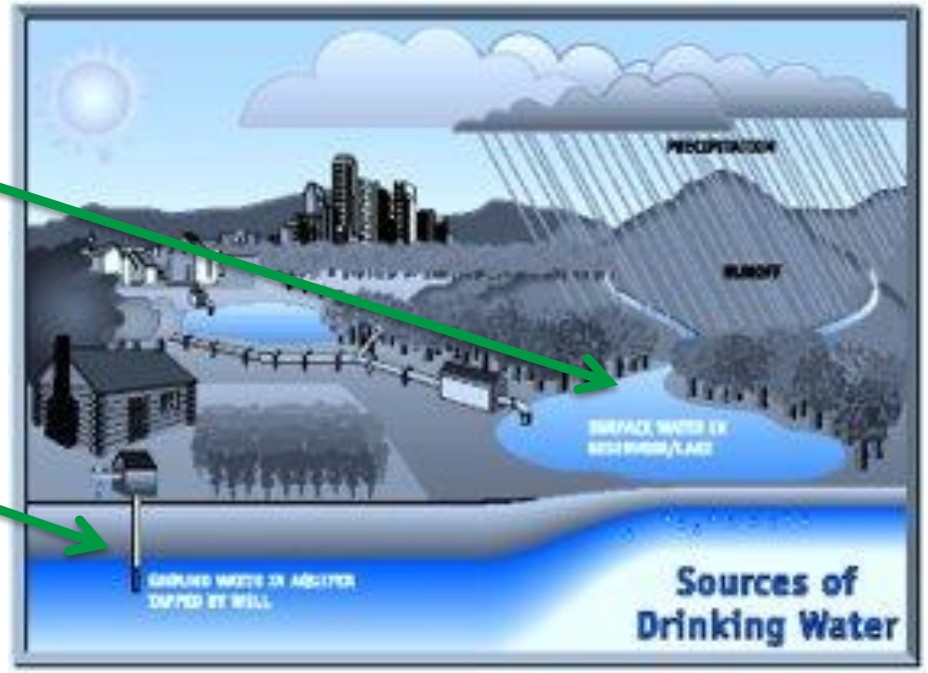
# Drinking Water

# Water Supplies for Drinking Water

## Primary Sources:

- **Surface Water** (lakes, rivers, and reservoirs)
  Major risks are microbial, organic (pesticides, wastewater-derived pollutants)

- **Groundwater** (wells)
  Major risks are inorganic (iron, manganese, arsenic), organic (PCE, MTBE)
  Increasing concerns of pathogen exposure from leaking septic systems or degradation of WW collection infrastructure




## Alternative Sources:

Treated Municipal Wastewater, Seawater, Rainwater

# UV Design Guidance Manual

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

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# Equipment Validation

UV for drinking water must be validated by third party

- Carollo Engineers (Portland, OR)
- DVGW (Germany)
- ONORM (Austria)
- Onsite (not recommended alternative)

Equipment is validated under a range of operating conditions

- Flow
- Transmittance
- Lamp power
- Dose (based on information from above)

Full scale unit (scaling of reactors is not permitted)

# LT2ESWTR – Log Inactivation

**Dose Values (mJ/cm²)**

| Log | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Crypto*** | 1.6 | 2.5 | 3.9 | 5.8 | 8.5 | 12 | 15 | 22 | 30 | 45 | 64 | 85 |
| ***Giardia*** | 1.5 | 2.1 | 3.0 | 5.2 | 7.7 | 11 | 15 | 22 | 28 | 42 | 60 | 84 |
| ***Virus*** | 39 | 58 | 79 | 100 | 121 | 143 | 163 | 186 | 208 | 231 | 253 | 276 |

# LT2ESWTR Bin Classification

## Filtered System

- Results will place in one of four bins based on monitoring results (concentration of crypto)
- Bins 2 – 4 require additional crypto treatment (including UV)

| Crypto Concentration (oocycsts/L) | Bin Level |
|---|---|
| <0.075 | 1 |
| 0.075 to 1.0 | 2 |
| 1.0 to 3.0 | 3 |
| > 3.0 | 4 |

## Unfiltered System

- Crypto inactivation requirement either 2 or 3-log reduction
- Two disinfectants are required, one of must be **UV**, $O_3$, or $ClO_2$

# LT2ESWTR Monitoring

- UV systems must be monitored
- Monitoring must include (plus many others)
  - UV intensity / dose
  - Flowrate
  - Lamp outage
  - Other parameters as required by the regulator
- Calibration and recalibration using a regulator-approved protocol
- Reporting water not treated (off-spec)
- Systems must achieve the required UV dose

# Validation Document

**EVOQUA WATER TECHNOLOGIES**

**THIRD-PARTY VALIDATION OF THE WF-230-10 and WF-430-12 UV REACTORS – REV A**

**May 2021**

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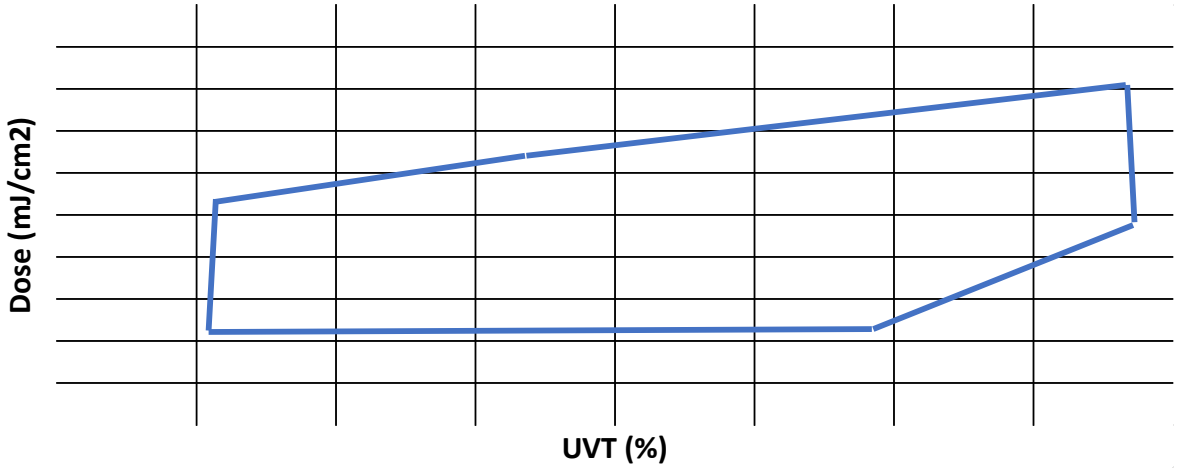


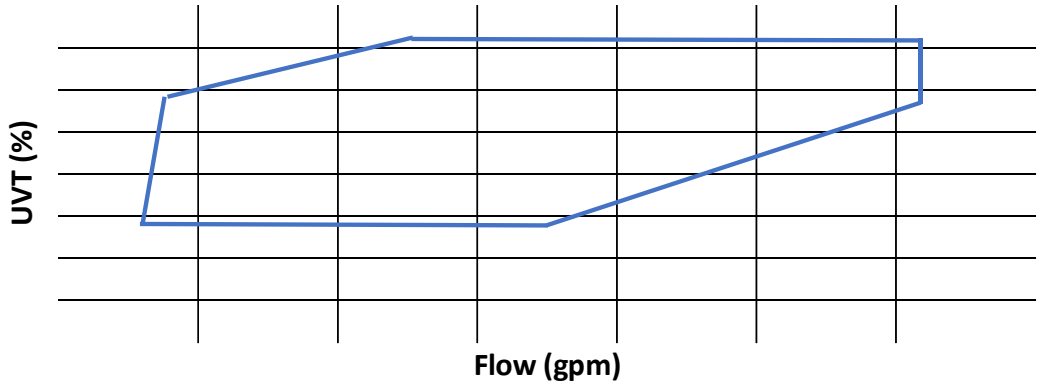


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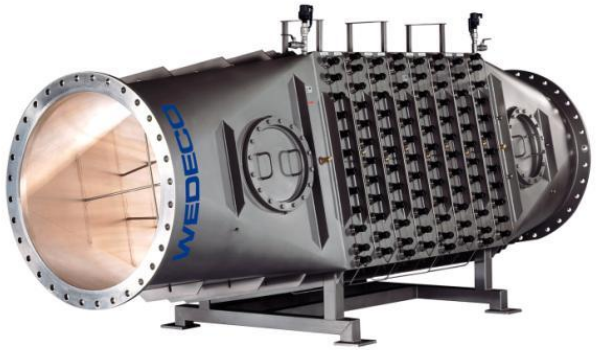
# Installation Options

- Combined Filter

- Individual Filter

# Drinking Water Equipment

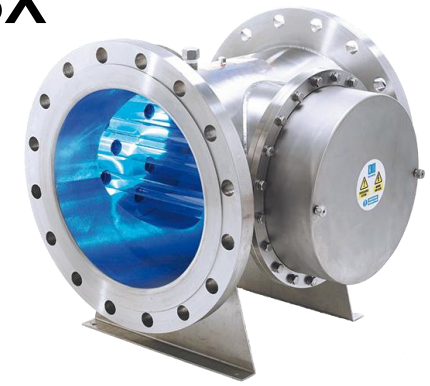
## K Series



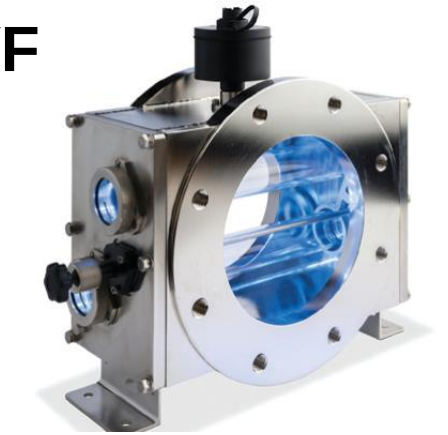

## LBX


## Spektron

## SX



## WF



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# Installation Snap Shots

# Illinois WTP

## Design Parameters

- 24 MGD
- 2.5-log inactivation cryptosporidium
- 2.0-log inactivation of giardia
- 70% transmittance

## Installation

- 8 x SX-635-16
- Retrofit into existing pipe gallery
- UV per filter


# Indiana WWTP

## Design Parameters

- 3.65 MGD
- 2.4-log inactivation of e. coli
- 35 mJ/cm2
- 65% transmittance
- 10 mg/l TSS

## Installation

- 2 x SW-835-14
- Retrofit into sand filter pipework in basement

# Indiana WWTP

## Design Parameters

- 12.0 MGD
- 2.5-log inactivation of e. coli
- 65% transmittance
- 15 mg/l TSS

## Installation

- 2 x SW-1250-20
- Retrofit, replaced chlorine gas
- Dual treatment: stnd WW and CSO during events


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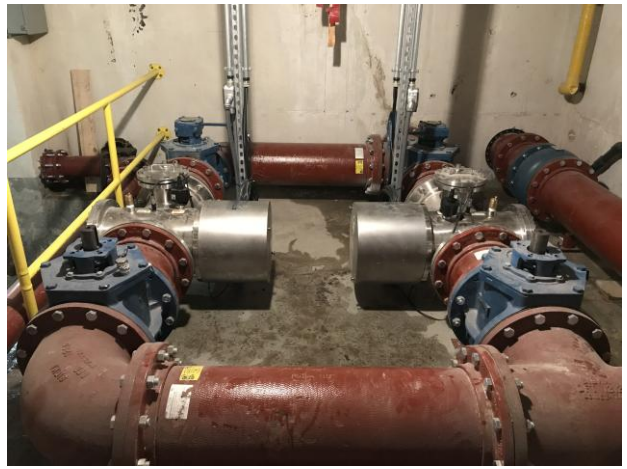
# Wisconsin WWTP

## Design Parameters

- 1.9 MGD
- 2.3-log inactivation of fecal coliform
- 65% transmittance
- 30 mg/l TSS

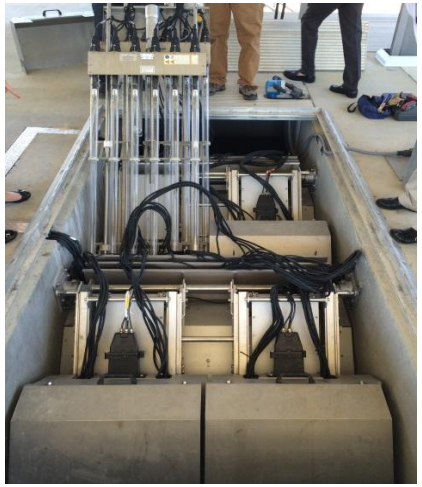
## Installation

- 2 x SW-635-12
- Limited space and head available
- Space to provide bypass line for non disinfection season



# U.S. Installations

Indiana WWTP


South Carolina WWTP

Illinois WWTP

Texas WWTP

Ohio WWTP


New York WWTP

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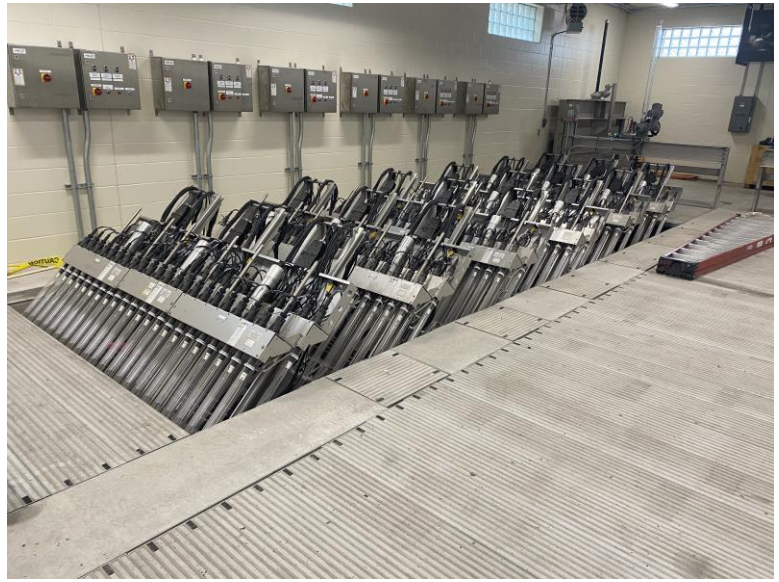
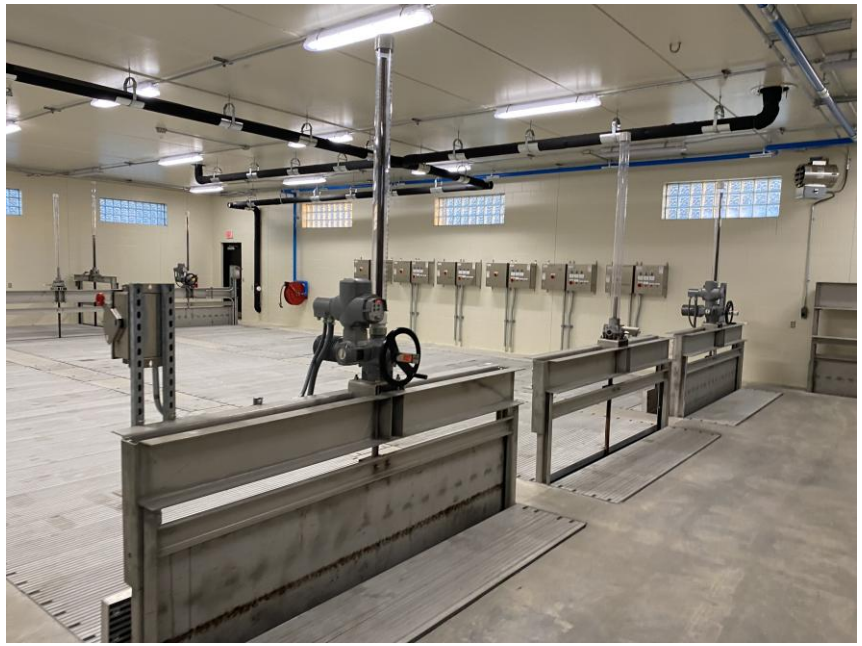
# Iowa WWTP

| | | |
|---|---|---|
| **Model** | : | Duron6 44i3-6x2 |
| **Layout** | : | 2 channels, 6 banks per channel |
| **UVT** | : | 55 - 65% (variable UVT range) |
| **Flow Rate** | : | 55 MGD |
| **Installation** | : | 2022 |
| **Application** | : | Disinfection of combined secondary and tertiary effluent |



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# Summary

- UV has a long history of treating WW and DW
- Two main types of lamps used in today's municipal industry
- Proper design parameters are required to accurately size UV systems
- USEPA UVDGM and LT2ESWTR most often referenced for DW and UV

# Thank You!!!

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IRWA
ILLINOIS RURAL WATER ASSOCIATION

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