UV System Performance Audits for Reuse Applications

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Carollo Engineers

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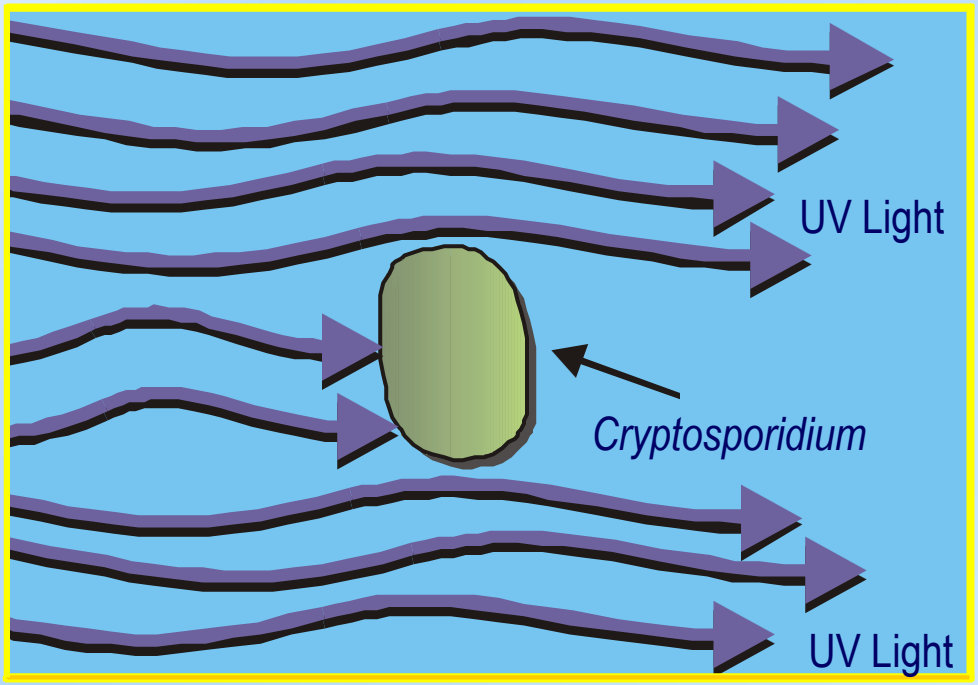
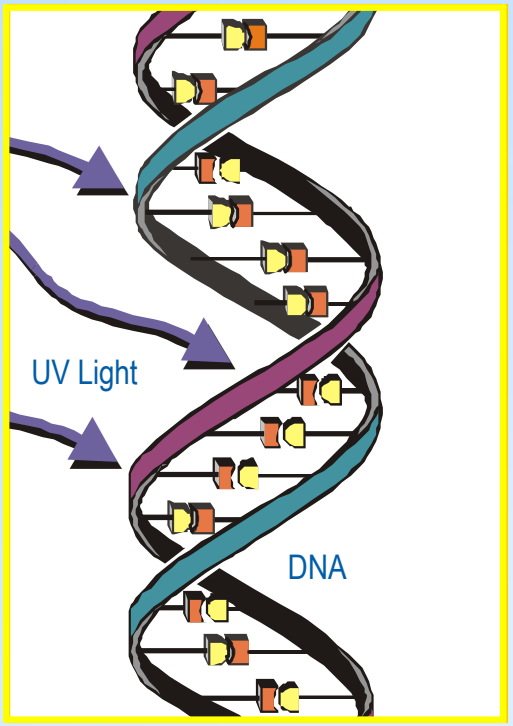
How Does UV Work?

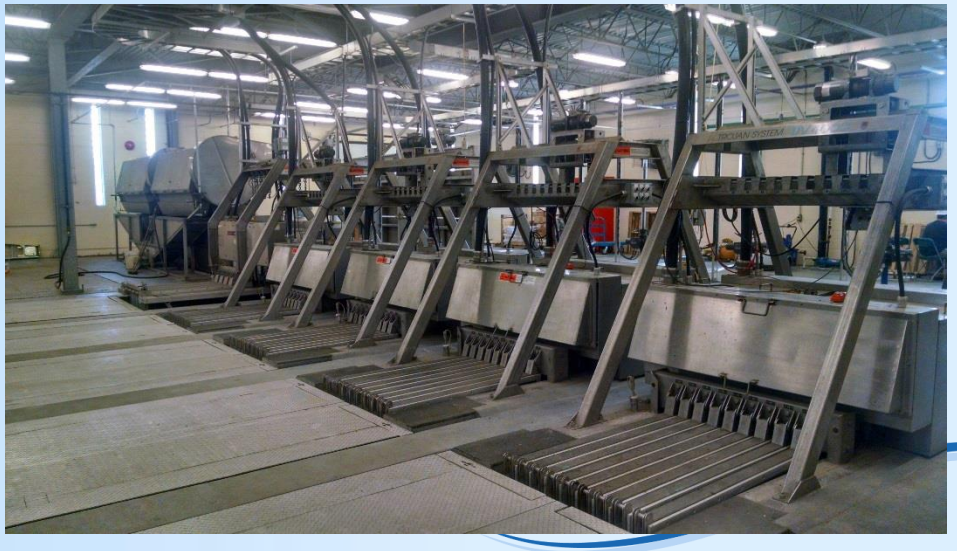


UV light is absorbed by pathogens in the water.



UV light damages the pathogen's DNA making it non-infectious

What Does UV look like?



UV System Components

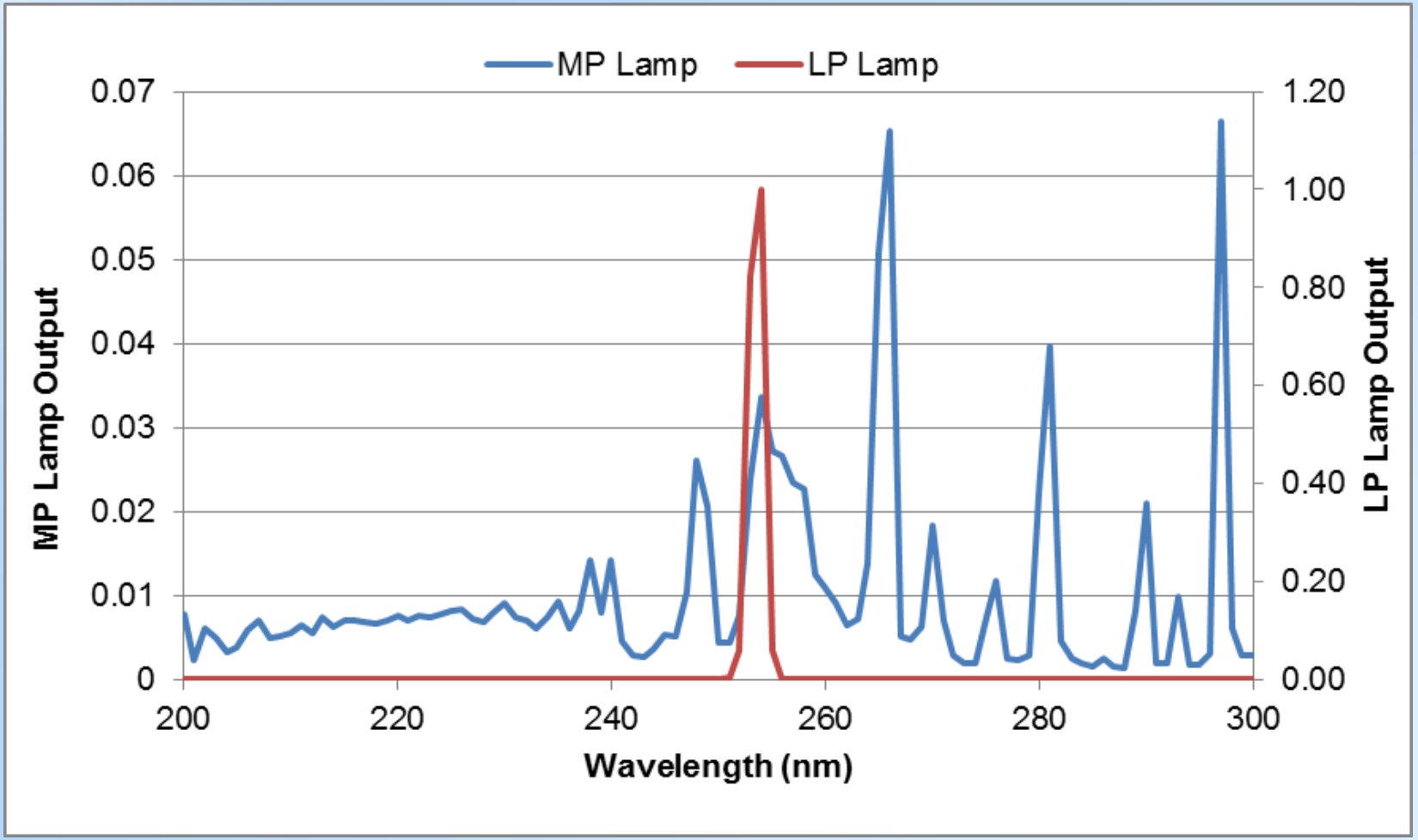
Lamps

Cleaning Systems

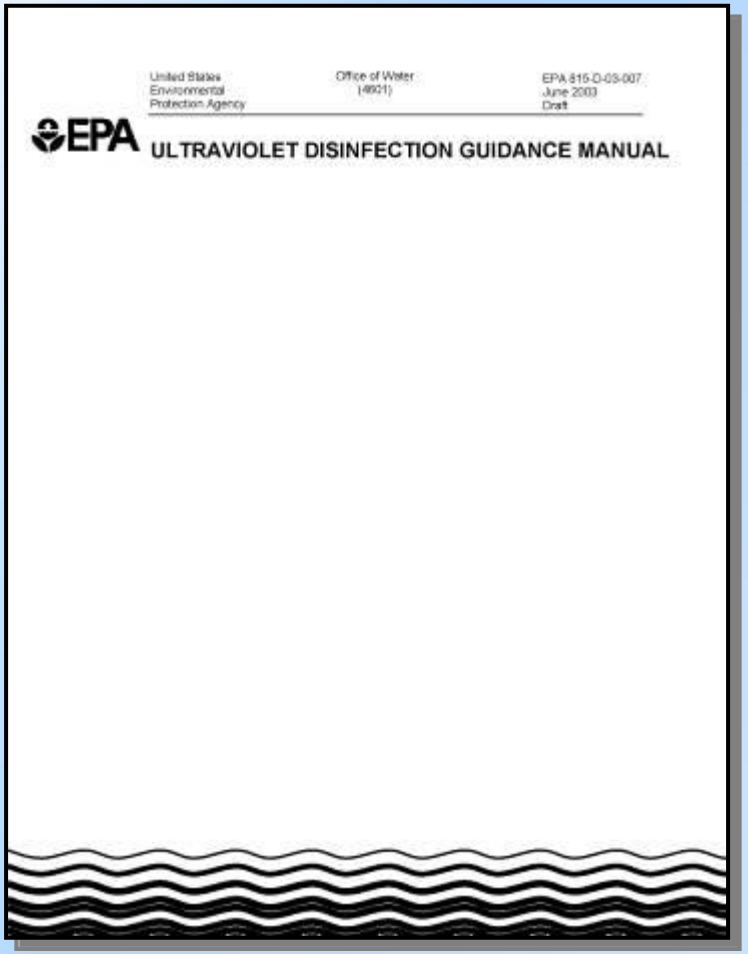
Sleeves

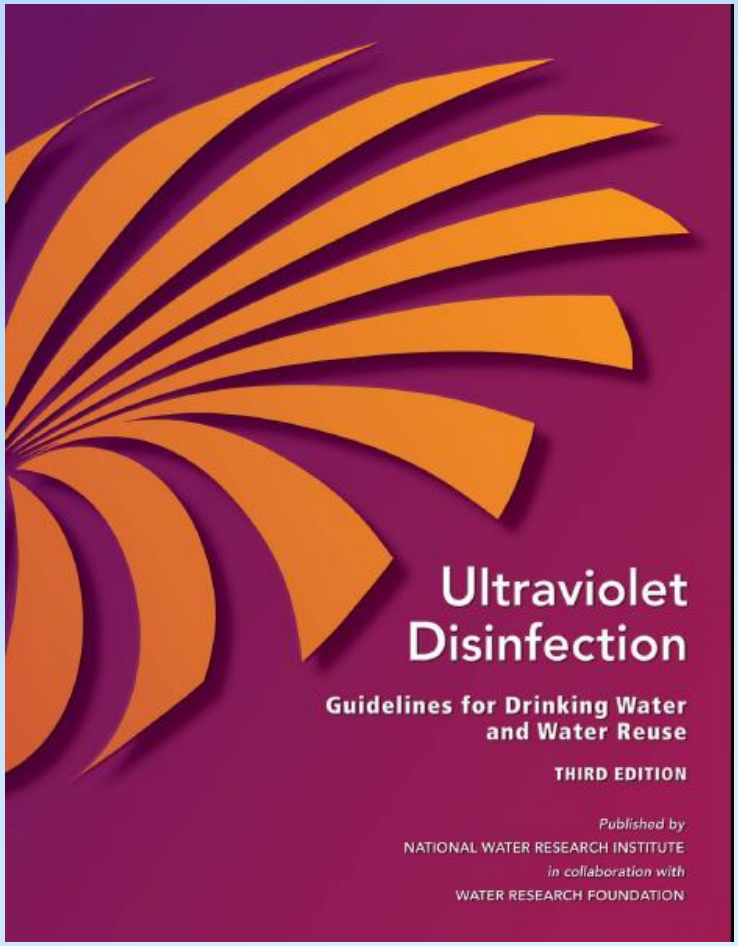
UV Sensors

Medium-Pressure vs. Low-Pressure UV lamps



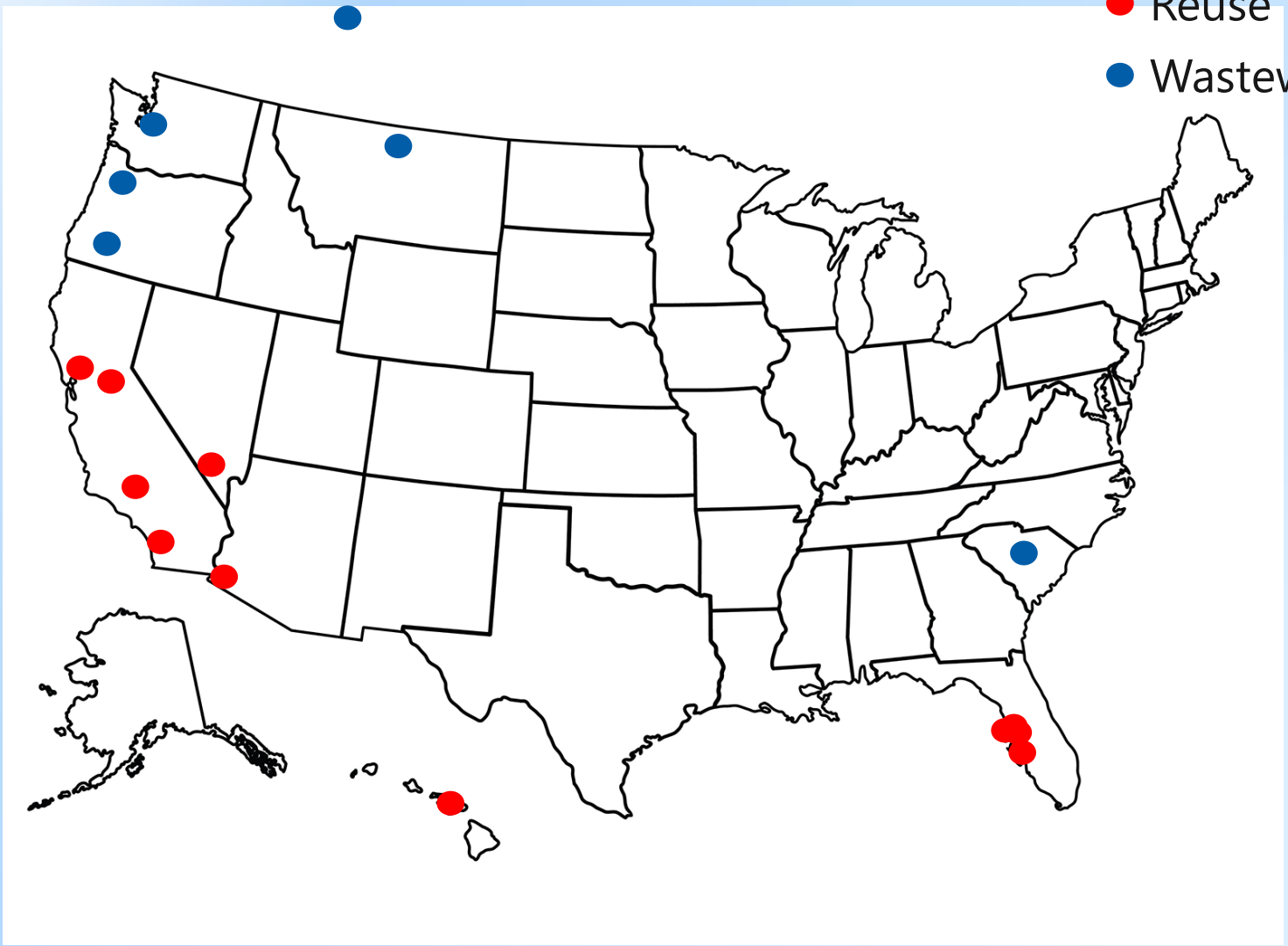
Guidelines





- UV Fundamentals
- Planning
- Design
- Validation
- Startup & Operation

WateReuse Research Foundation Project: WRRF 14-11



WateReuse Research Foundation Project: WRRF-14-11

- UV Audits
  - Visual Inspection
  - Lamp Aging and Sleeve Fouling
  - Microbial Measurement
  - Power Measurements
  - UVT Monitor Accuracy
  - UV dose monitoring and control

Key Messages from the Project

- Lamp aging and sleeve fouling factors need to be realistic for sizing and operation
- Importance of UV sensors for monitoring
- Impact of bypass on UV disinfection
- Realistic expectations for operation and maintenance

Current Criteria for Lamp Aging and Sleeve Fouling

- Reuse systems use indicators (fecal and total coliforms)
- Most systems do not use UV sensors
- Systems are sized for flow, UVT, and lamp aging and sleeve fouling factors

	NWRI Criteria	Vendors Criteria
Lamp Aging Factors	0.50	0.90 - 0.98
Sleeve Fouling Factor	0.80	0.85 - 0.95

What is Lamp Aging and Sleeve Fouling?

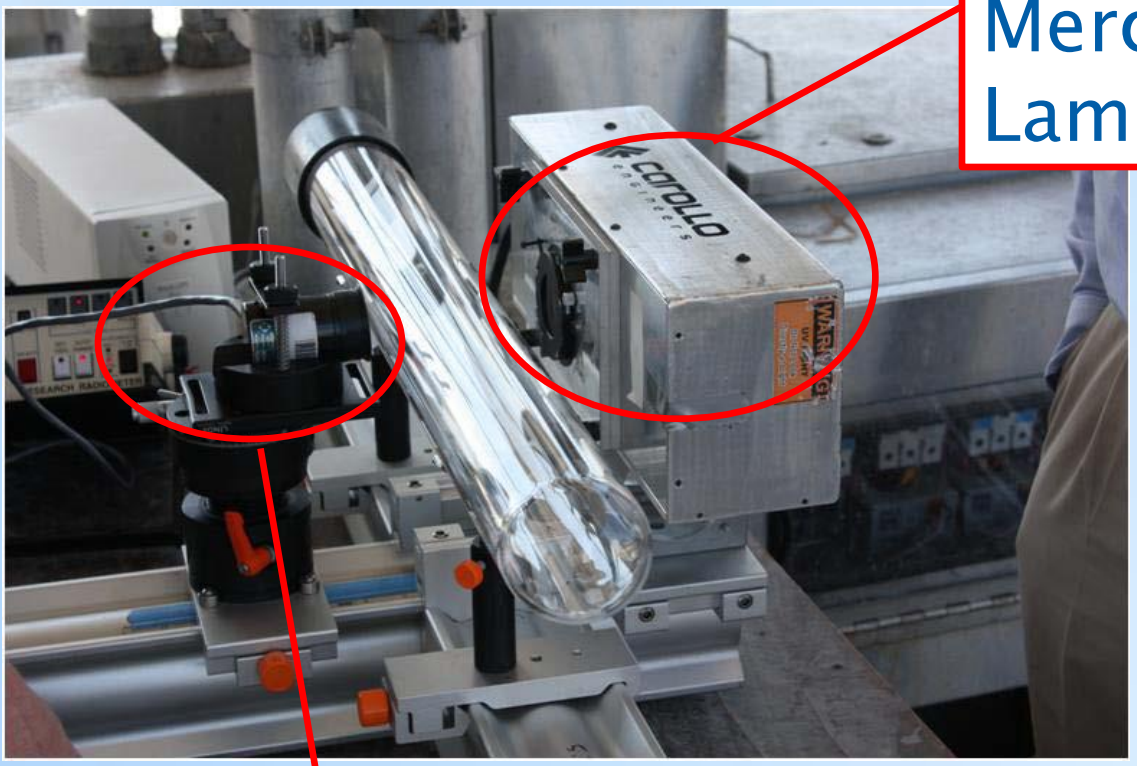
- As lamps age, the output of the lamp decreases

What is Lamp Aging and Sleeve Fouling?

- As lamps age, the output of the lamp decreases

- Sleeve fouling decreases the amount of UV that can transmitted through the sleeve

Sleeve fouling is measured directly as UV transmittance of quartz sleeve



$$SFF = \sqrt{\frac{I_{(dirty)}}{I_{(clean)}}}$$

Sleeve Fouling Varied by Location

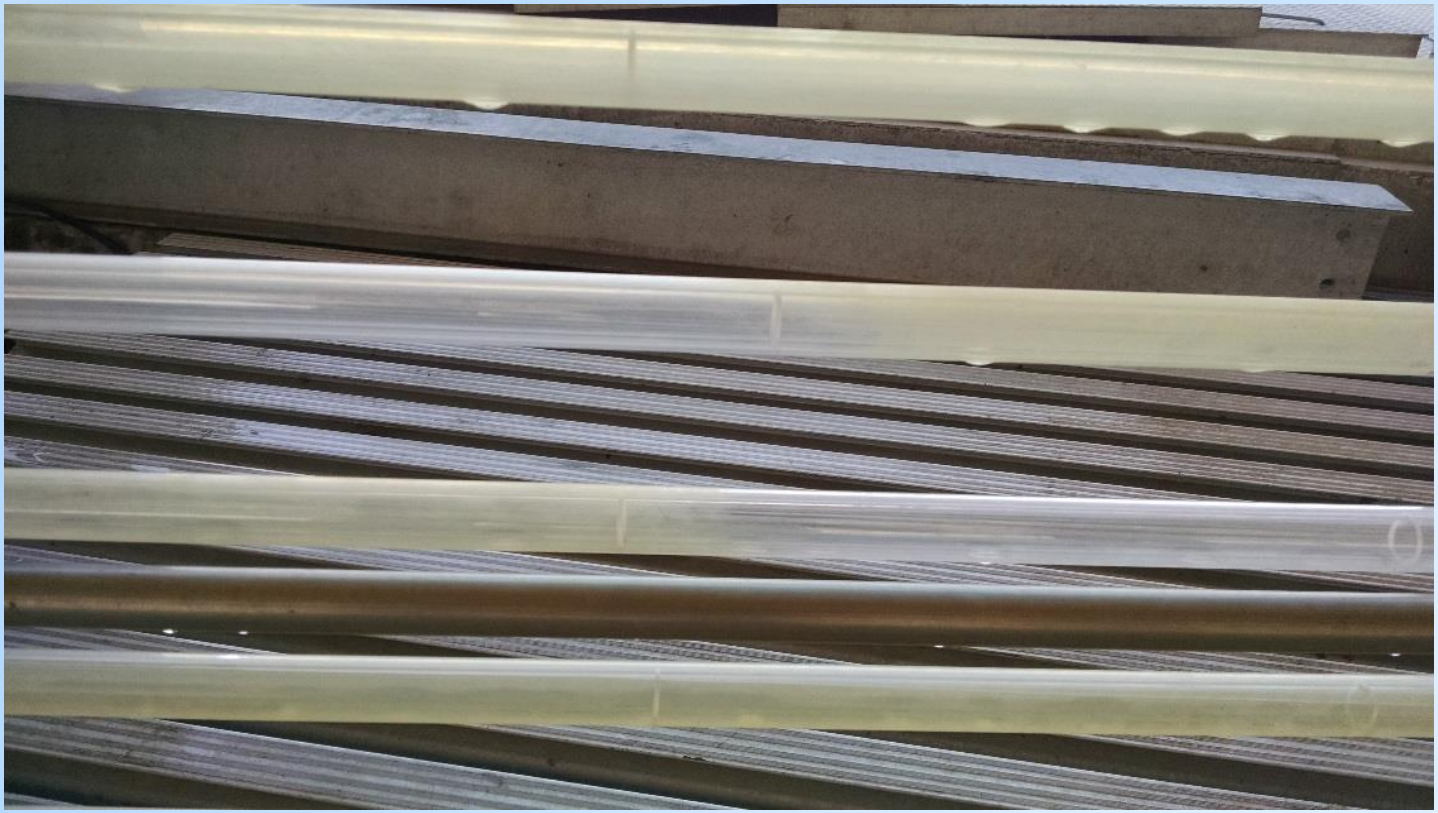
Reactor Type	Sleeve Fouling Factor Range
MP	0.60-0.93
MP	0.75-0.98
MP	0.92-1.00
LP	0.97-1.00
LPHO	0.61-0.70
LPHO	0.89-1.00
LPHO	0.94-1.00
LPHO	0.97-1.00
LPHO	0.92-0.99
LPHO	0.84-0.99
LPHO	0.82-0.98
LPHO	0.95-0.97
LPHO	0.05-0.88

Default NWRI	0.80
Vendor Criteria	0.85-0.95

Used acid wash

Uses acid wash plus automatic wipers

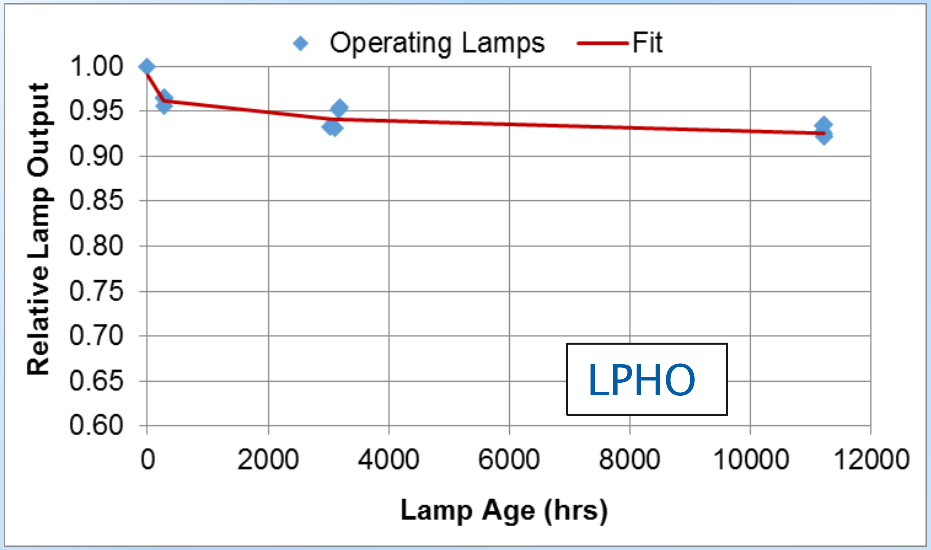
Severe sleeve fouling was measured at one location

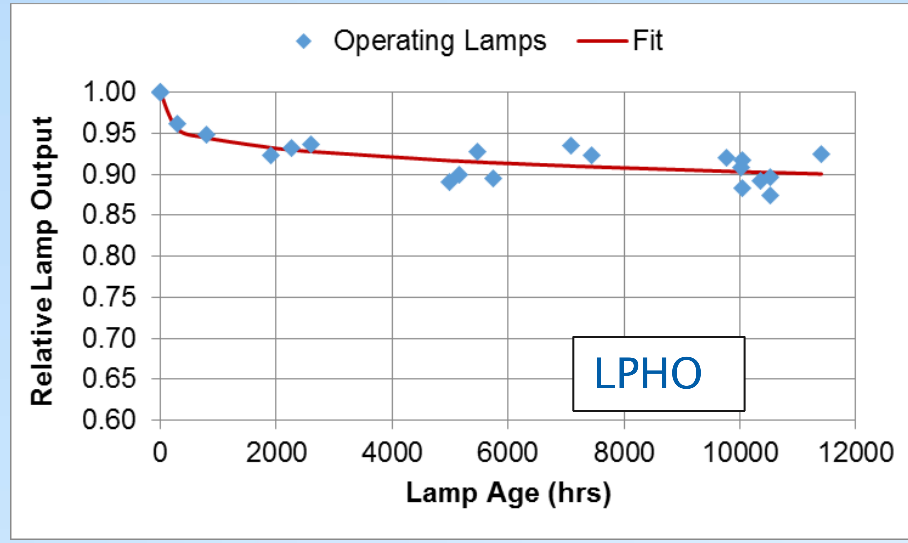


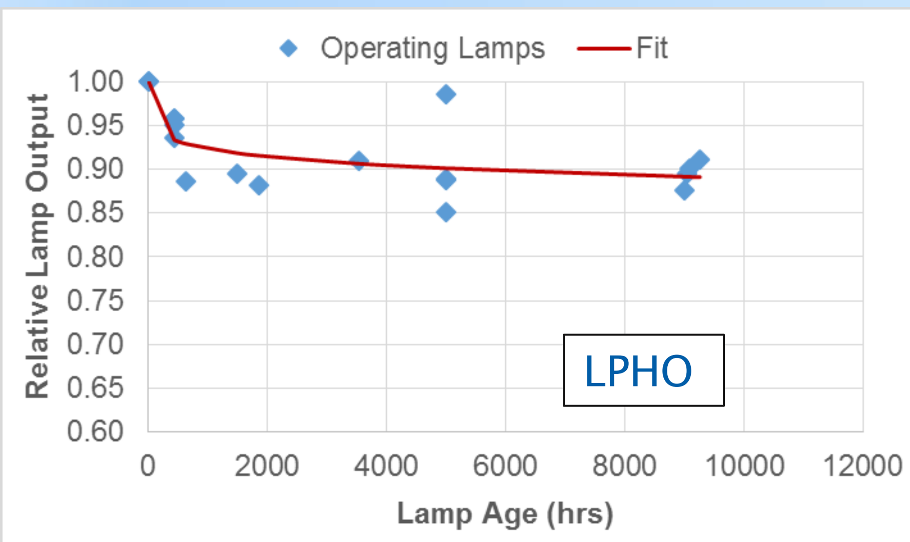
Lamp Aging can also be Measured Directly

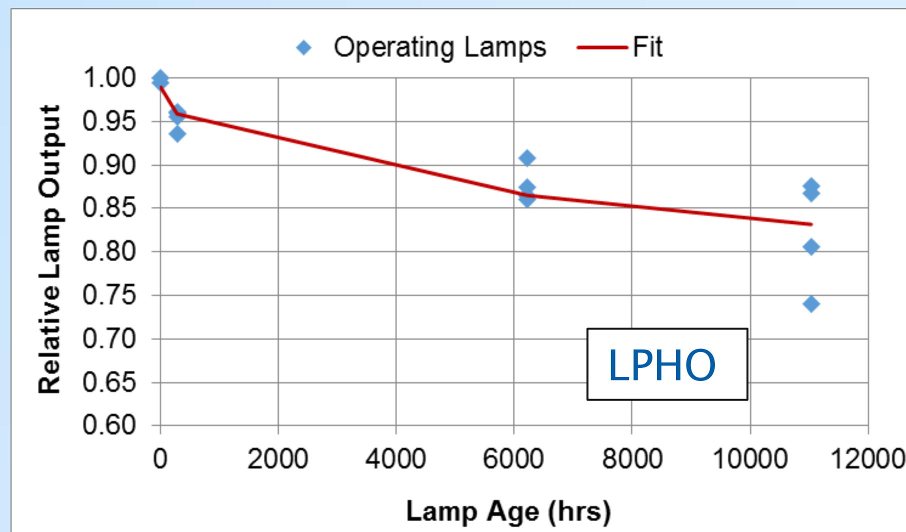
$$LAF = \sqrt{\frac{I_{(aged)}}{I_{(new)}}}$$

Lamp Aging Varied by Reactor Type

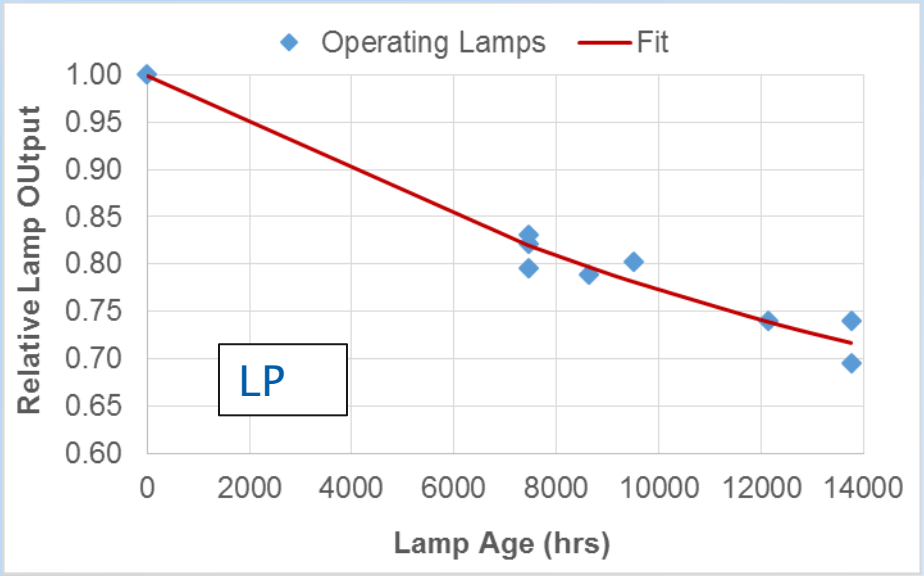


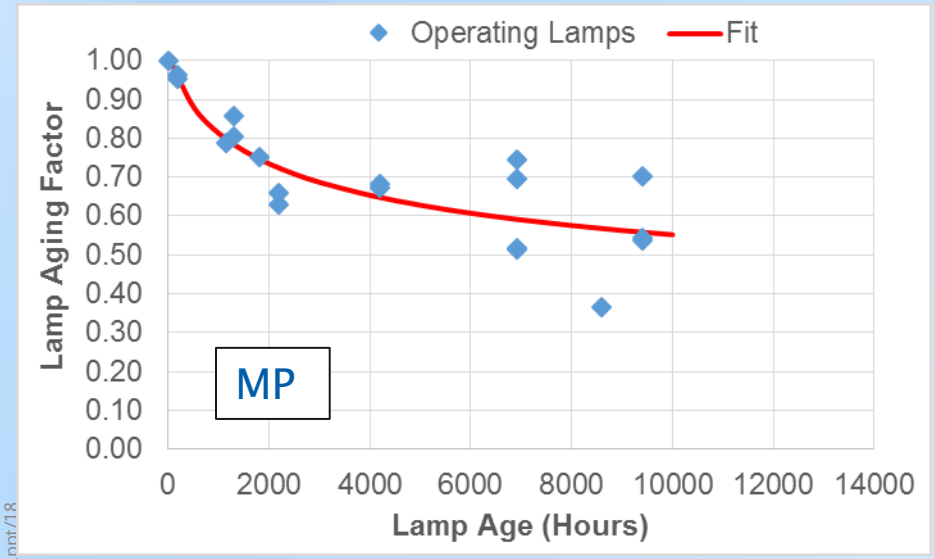


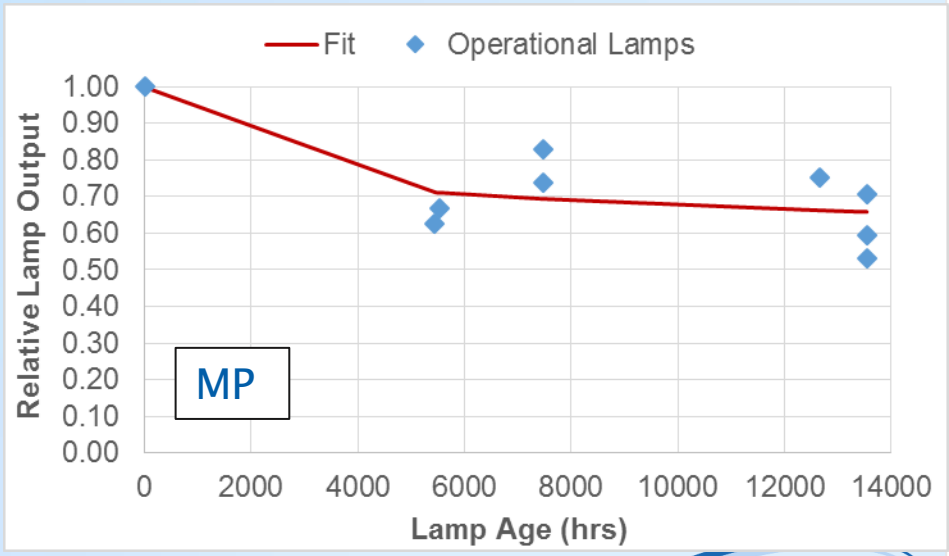




Lamp Aging Varied by Reactor Type







Lamp Aging Varied by Reactor Type

Reactor Type	Lamp Aging Factor
LPHO	0.92
LPHO	0.90
LPHO	0.84
LPHO	0.90
LPHO	0.87
LP	0.73
MP	0.65
MP	0.60
Vendor Aging Factors	0.85-0.98

Recommendations

- Need to use realistic lamp aging and sleeve fouling factors based on data from installed systems
- Need to perform fouling studies or use conservative numbers
- Specify lamp warranties based on lamp output instead of just lamp failures

UV Dose Algorithm and UV Sensors

- UV Dose monitoring typically based on biodosimetry per NWRI Guidelines
- UV sensor signals not always used in algorithm
  - Instead algorithm assumes lamp output based on lamp aging curve and fouling factor
  - Can lead to over estimated UV dose when lamp aging and fouling exceeds assumptions

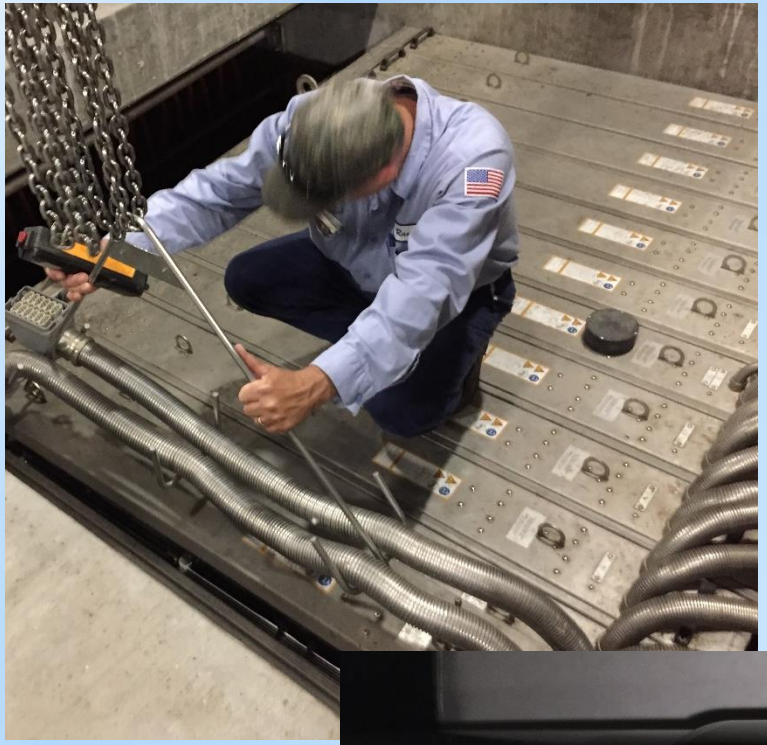
Implications of No UV Sensors

- Target Dose= 100 mJ/cm^2

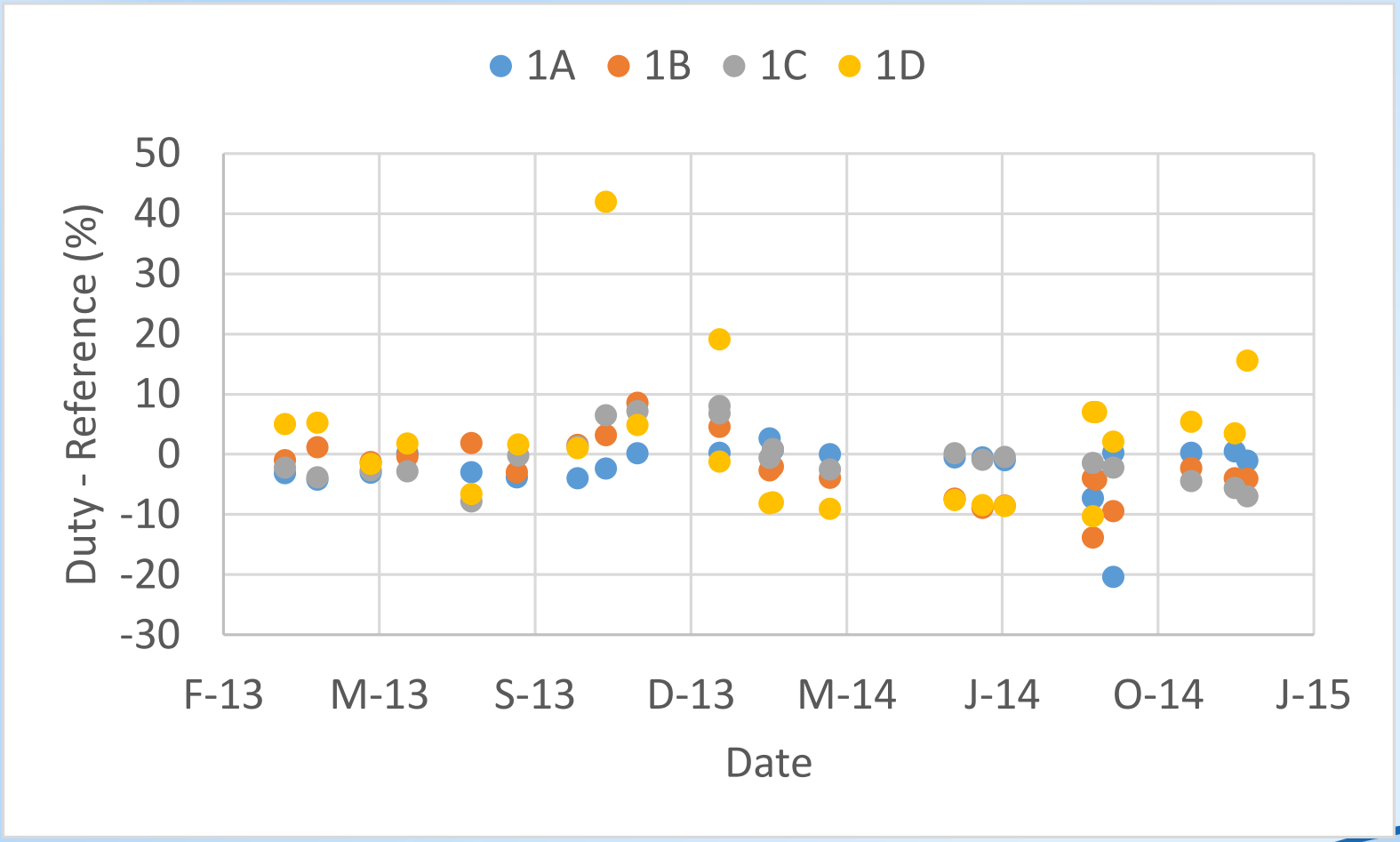
- Assumed Lamp Aging=0.98
- Assumed Sleeve Fouling=0.95
- Predicted Dose=106.4 mJ/cm^2

- Actual Lamp Aging=0.80
- Actual Sleeve Fouling=0.70
- Actual Dose=64.0 mJ/cm^2

Validated UV Dose Algorithm Uses One UV Sensor Per Bank



UV Sensor Accuracy Typically ±10 Percent



Recommendations

- UV sensors can provide accurate monitoring of UV output accounting for lamp aging and sleeve fouling
- Move toward UV sensor based systems

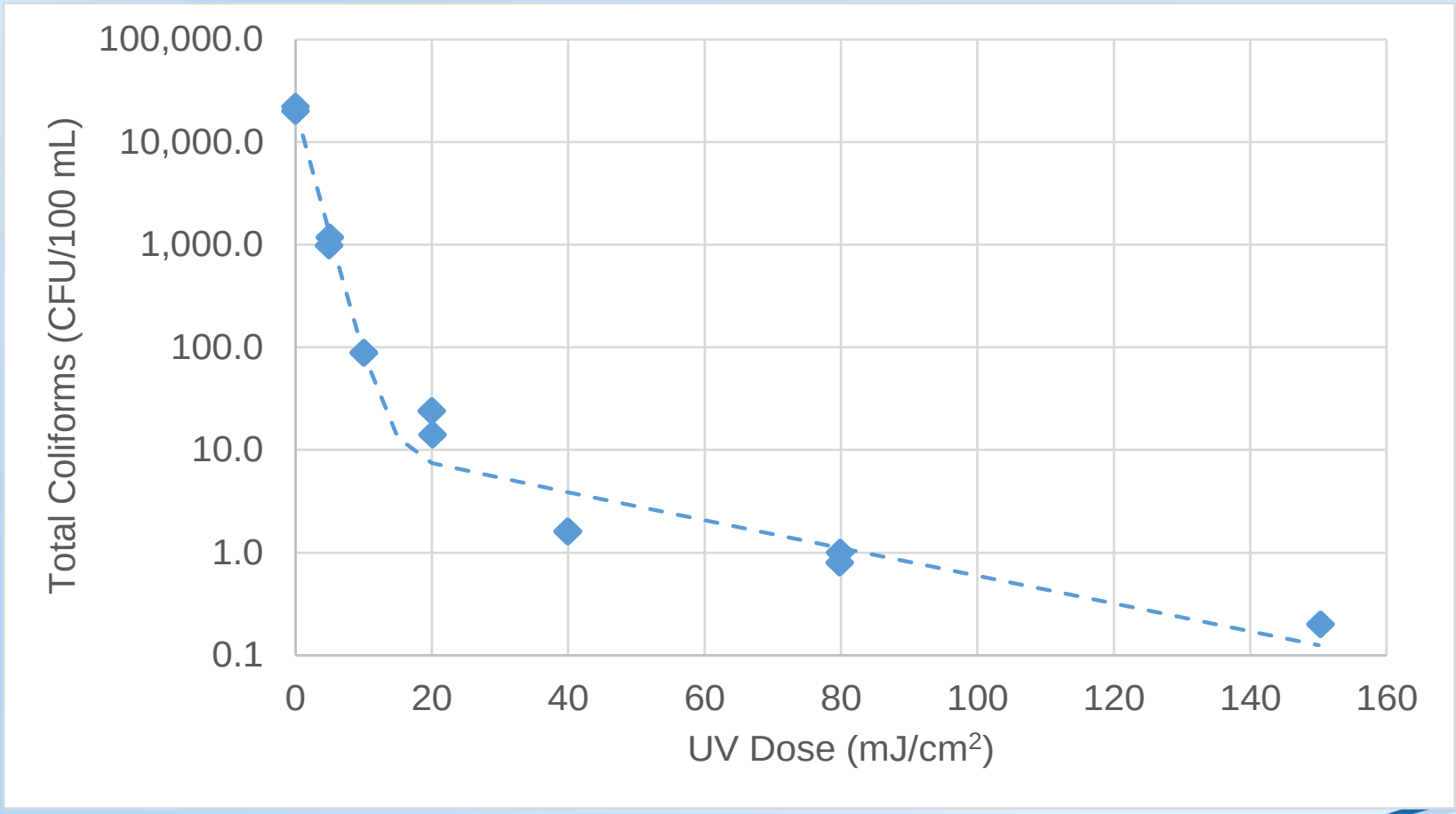
Many Systems Reported Having Coliform Hits

- Most system sample daily
  - Total Coliforms: 2.2 CFU/100 mL as 7-day Median
  - Fecal Coliforms: <1 CFU/100 mL as 75th Percentile
- Many plants attribute coliform hits to:
  - Algae sloughing from channels walls
  - Sediments being stirred up as flow increases
  - Coliform Regrowth
  - Upstream filter performance
- Few consider bypass or short-circuiting through the UV system

Microbial Evaluation of UV Systems

- Measure Coliform UV dose-response using Inlet Sample
- Measure Coliform Concentration Right After Reactors Using Enhanced Assay (~500 mL)
- Measure Coliform Concentration at Downstream Location (e.g., at weir) Using Enhanced Assay

UV Dose-Response Shows Effluents Easily Inactivated Using 100 mJ/cm^2



Enhanced Assays with Many Systems Shows UV Working

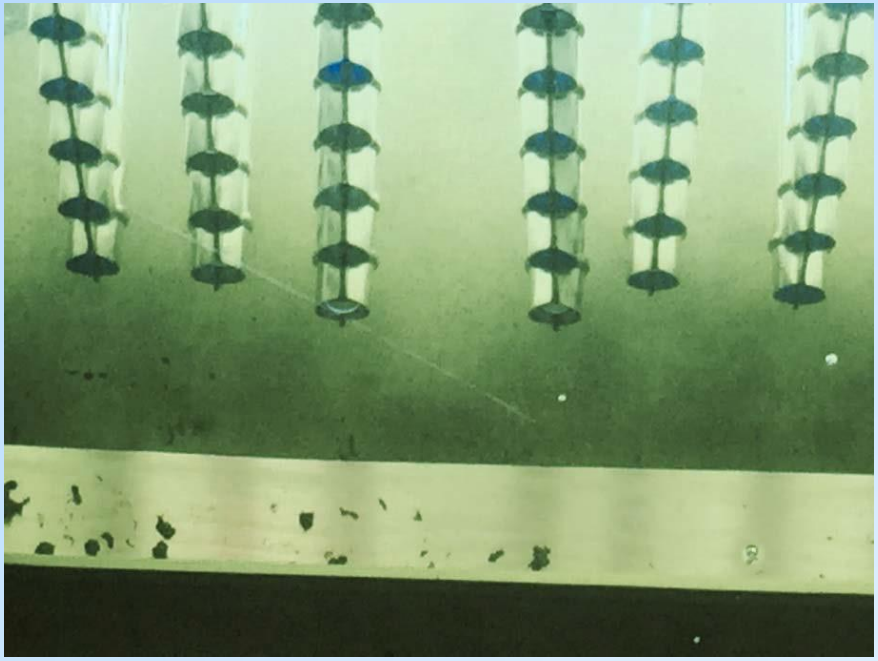
Sample ID	Fecal Coliform (CFU/100mL)	
	After UV Reactors	Downstream Location
1	<0.22	<0.22
2	<0.22	<0.22
3	<0.22	<0.22

But Many Systems Showed Bypass and Short Circuiting

Sample ID	Total Coliform (CFU/100mL)	
	After UV Reactors	Downstream Location
1	<0.2	64
2	<0.2	86
3	0.4	48

What Causes Bypass?

- Low Dose Pathways Past Lamps or Along Channel Walls
- Low Dose Pathways past Aged Lamps
- Bypass through Drains
- Leaking Gates/Valves
- Lamp failures



Recommendations

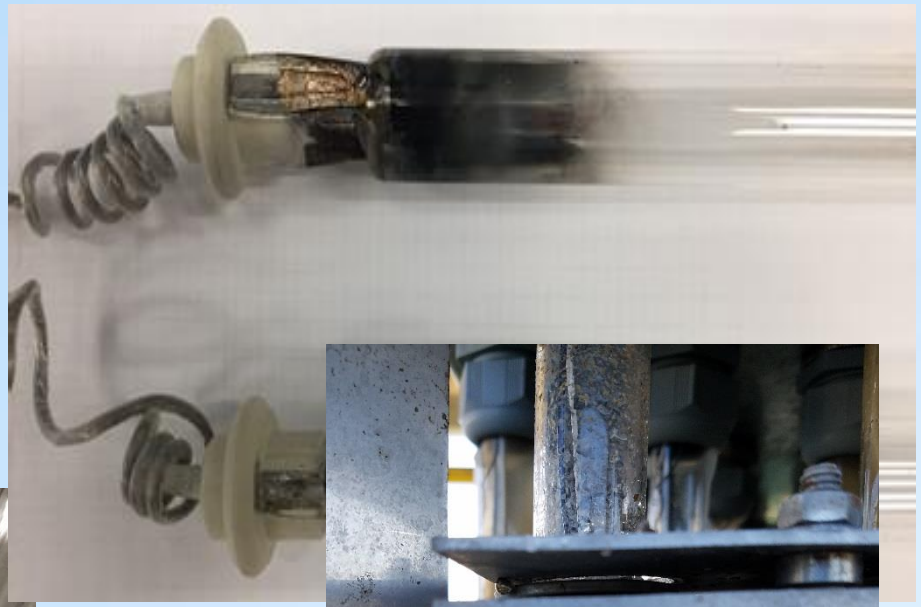
- We need to address bypass with design
  - Make sure drains do not bypass the UV system
  - 2 gates instead of 1
- Do not assume coliform hits are due to regrowth, algae, TSS
- Use enhanced assays to benchmark and troubleshoot your system

Realistic Expectations in Maintenance of UV Systems

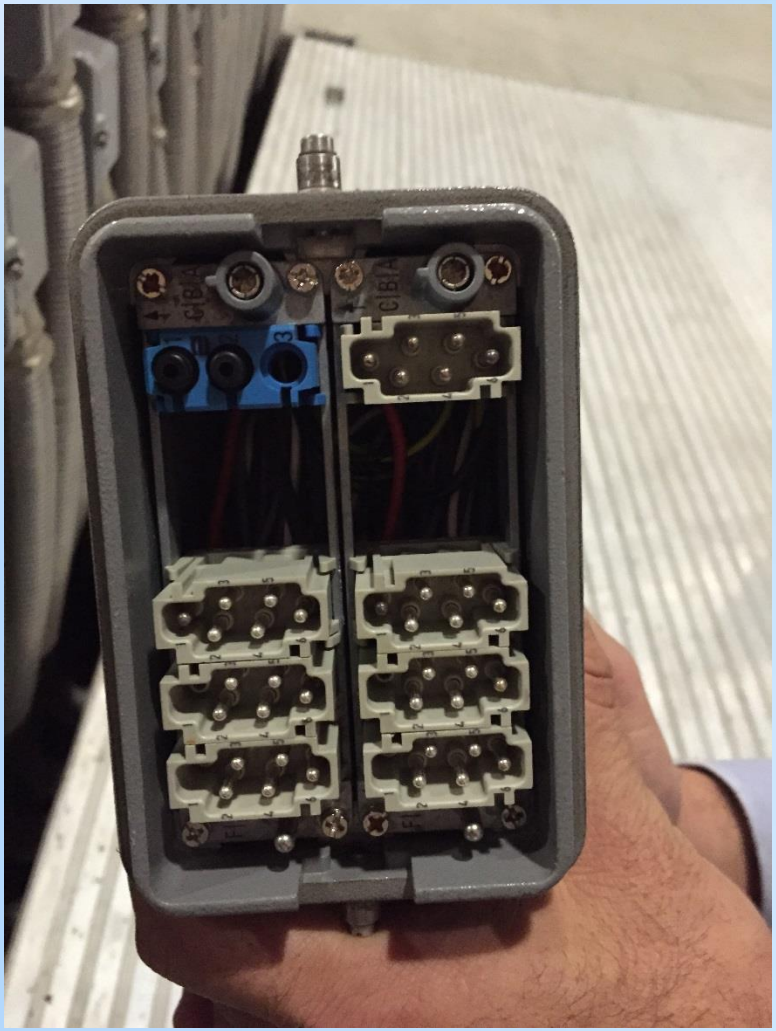
- Many systems are sold as maintenance free or low maintenance
- Discussions with operators on issues included during the UV audit

Issues with wipers and wiper seals

Corrosion of Lamp Ends and Water in Sleeves

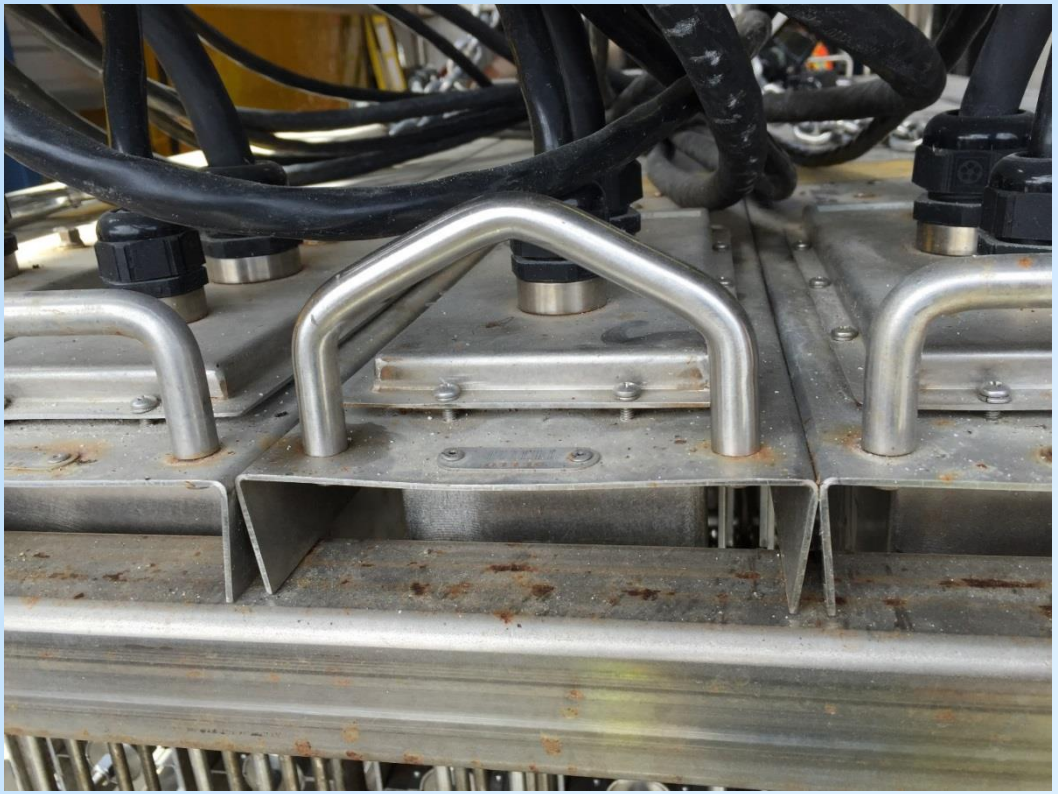


Issues with Lamp and Sensor Cable Connectors



Clearance Issues Removing Modules

Operators Figuring Out Solutions



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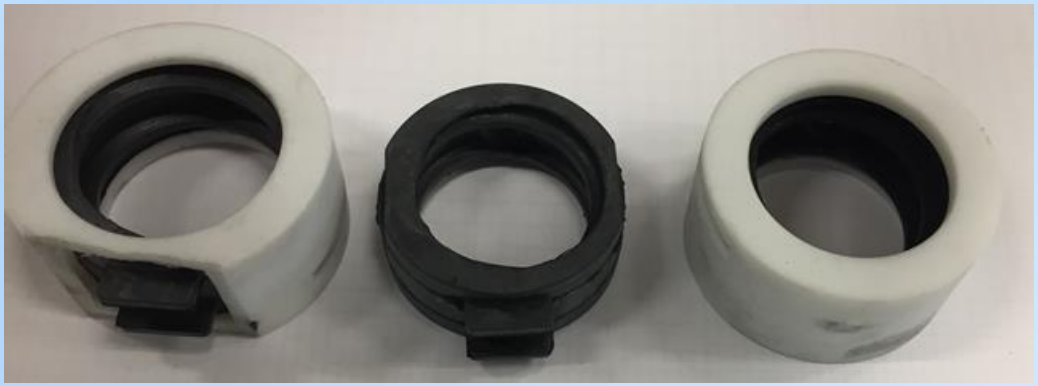
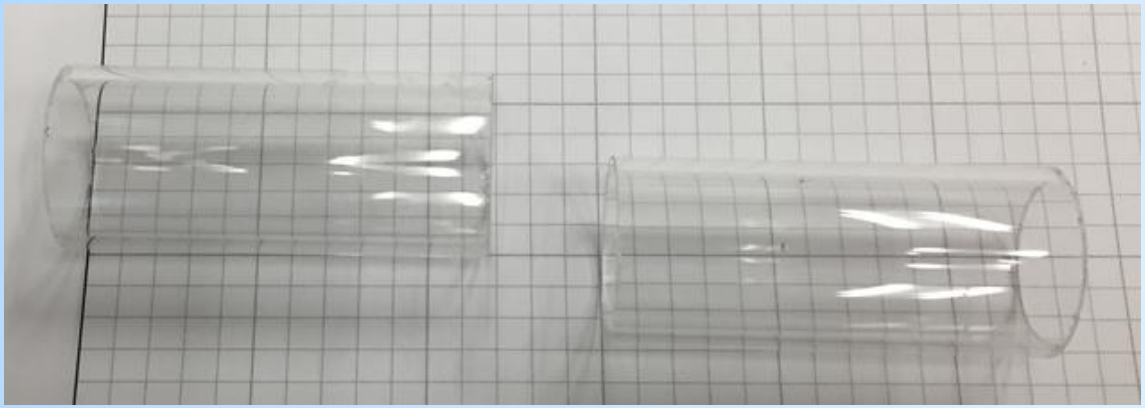


Wiper Mechanism Showing machine collar, wiper, and un-machined collar



Spacers Used to Offset Lamps Axially within the Sleeves

Recommendations

- Visit different systems in your region and talk to operators
- Simplicity is the best
- Complexity is good (if reliable)
- Most systems will go through a break-in phase
- These systems do better when the operators like UV

UV Works But Can Be Better

- Need to use realistic lamp aging and sleeve fouling factors based on field performance
- Make it real using UV sensor based monitoring
- Address bypass issues in design and troubleshooting
- Have realistic expectations for operation and maintenance

Questions?

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