ITT

Design & operation of open channel UV disinfection systems

March 2010

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Water & Wastewater

Outline of the Presentation

- UV Design Approaches for Wastewater
- NWRI at a glance
- Design factors
- Reliable operation

UV Design Approaches for Wastewater

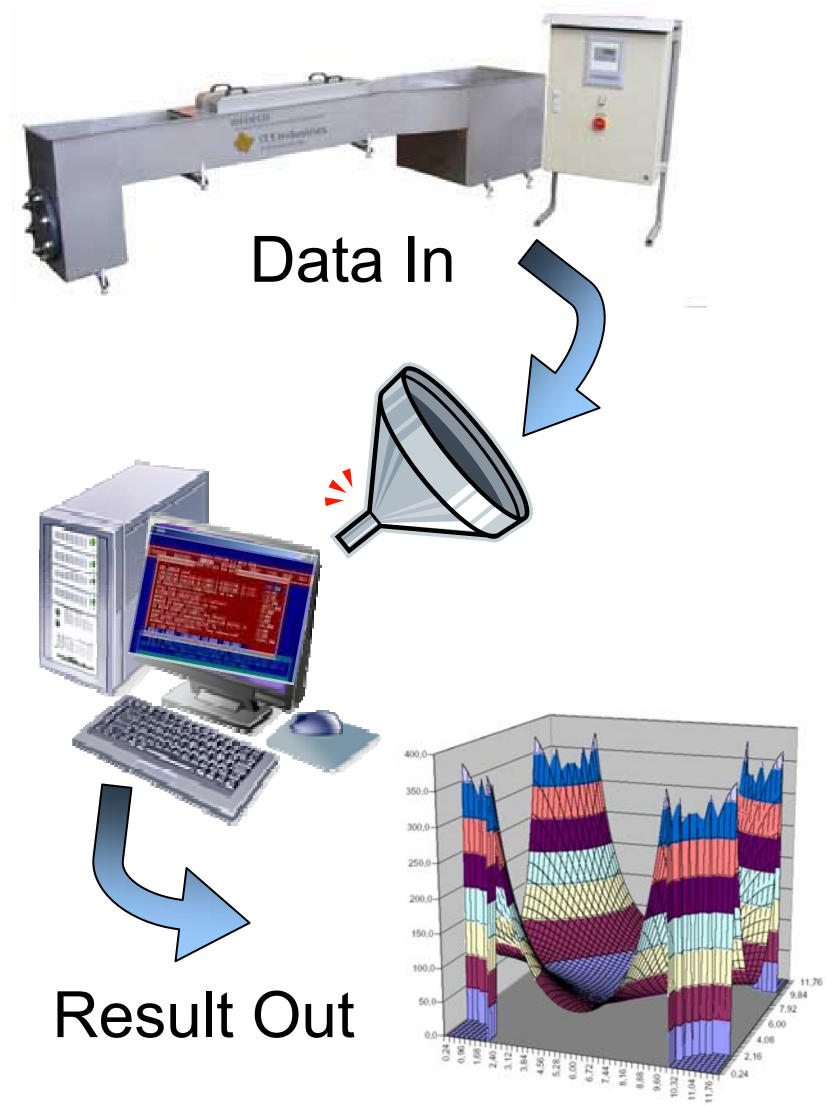
UV Design Approaches for Wastewater

- Calculated sizing models:
  - PSS (Point Source Summation)

- Biologically verified methods (bioassays):
  - NWRI (High Dose Bioassay)
  - Bioassays for Secondary treated effluent (Low Dose)

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
- Allows for apples-apples comparison between manufacturers
- Proven by performance of installed equipment



UV Dose Recommendations (PSS)

Required disinfection level (geom. mean) per 100 ml	Inlet per 100 ml	SS mg/l	Filtration	UV-Transm. cm	Dose mJ/cm²	No of banks per channel	Comments
1000 FC	10^6	20 30	- -	55 55	26 30		
200 FC	10^5	10 20 30	- - -	55 55 55	25 30 37		
100 FC	10^5	5 10 20	Sandfiltr. - -	65 55 55	35 35 40	Min. 2 banks	
100 TC	10^5	aver. 5 max. 10	Sandfiltr.	65	40 - 50	Min. 2 banks	
23 FC	10^5	aver. 5 max. 10	Sandfiltr.	65	40 - 50	Min. 2 banks	
10 FC	10^5	aver. 5 max. 10	Sandfiltr.	65	60	Min. 2 banks	
10 TC	10^5	aver. 5 max. 10	Sandfiltr.	65	85	Min. 3 banks	
2,2 TC	10^5	aver. 2 max. 4-5	Sandfiltr.	65	100 (daily peak) / 140 (weekly peak)	Min. 3 banks	Turbidity < 2 NTU
2,0 TC	10^5	aver. 2 max. 4-5	Sandfiltr.	65	160	Min. 3 banks	Turbidity < 2 NTU

Bioassays for Wastewater

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

NWRI at a glance

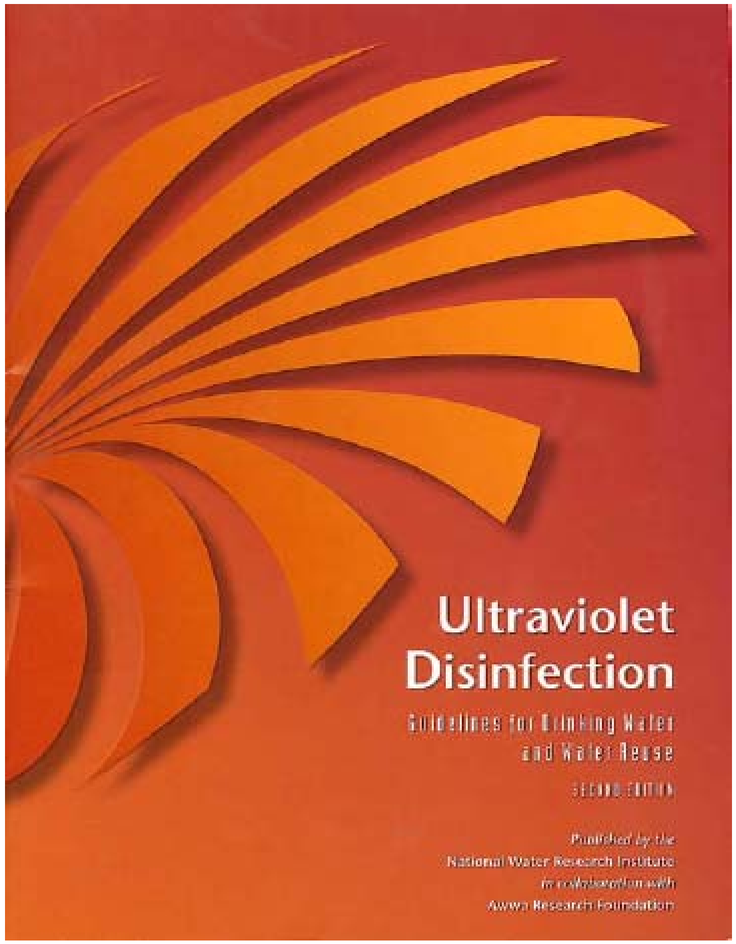
USA Reuse Requirements

State	Microbiological Reuse Requirement	
Arizona "Class A+"	Fecal Coliforms Enteric Virus	not detectable in 4 out of 7 daily samples max. 23 CFU / 100 ml in any not detectable in 4 out of 7 monthly samples
California "Title 22"	Total Coliforms Poliovirus	2.2 MPN / 100 ml @ 7-day median 5 log inactivation
Florida "High Level Disinfection"	Fecal Coliforms	75% of samples below detection limit over 30 days max. 25 CFU / 100 ml in any sample
Hawaii "R1"	Fecal Coliforms Poliovirus	2.2 MPN / 100 ml @ 7 day median 23 MPN / 100 ml in max. one sample in 30 days 5 log inactivation

NWRI (High Dose Bioassay)

- Arizona “Class A+“
- California “Title 22”
- Hawaii “R1”
- Florida “High Level”

→ NWRI/AWWARF
Guidelines for Water Reuse



NWRI Guidelines – Background

- Total coliform and Poliovirus requirement
- Conservative dose establishment
  (safety for variability in effluent quality)

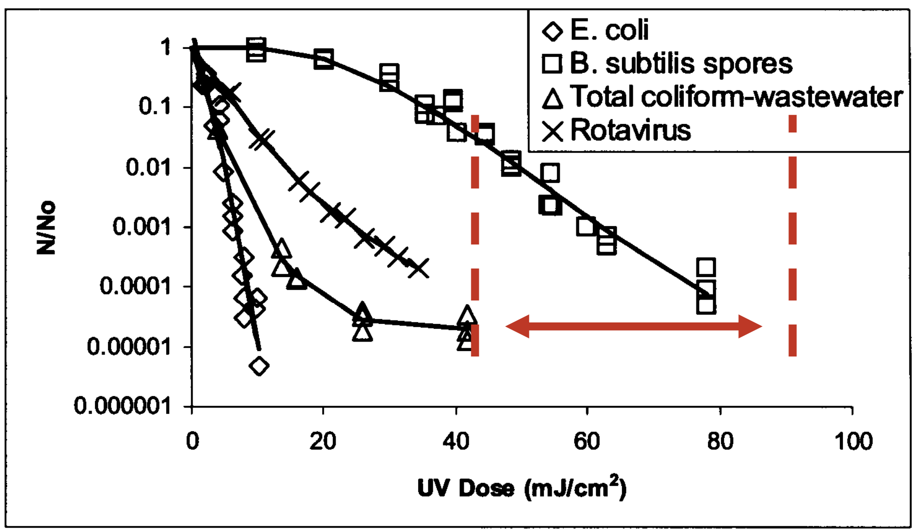
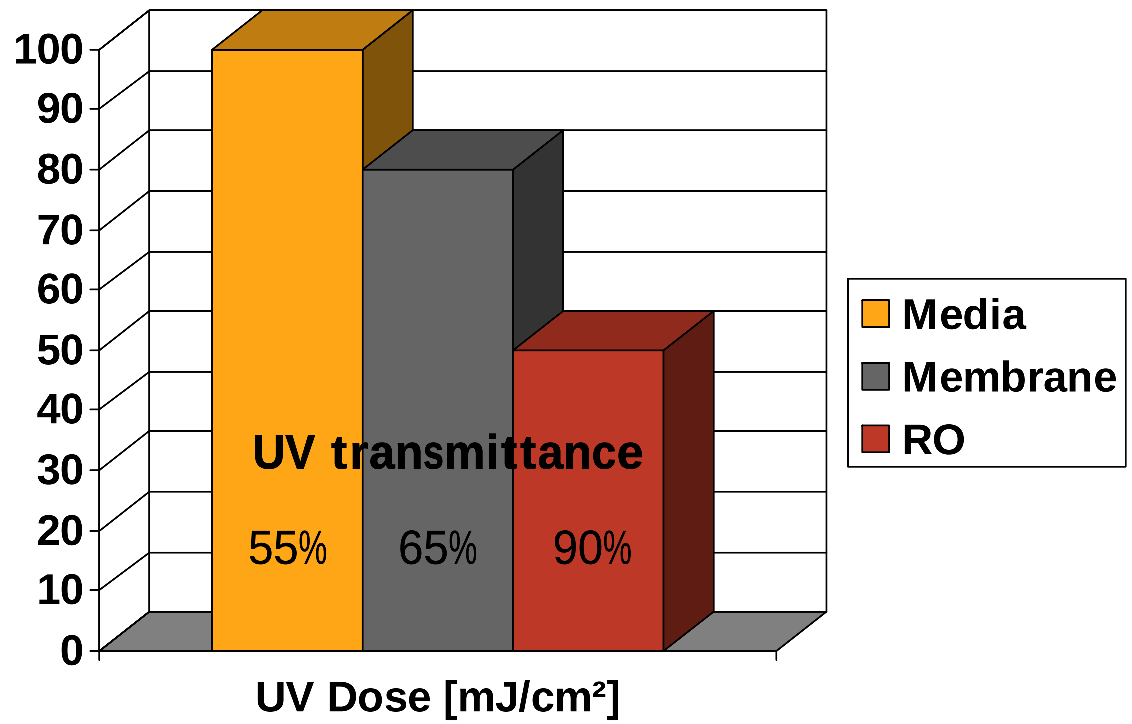


Figure 2-13. UV Dose Response (Adapted from Chang et al, 1985)

NWRI Guidelines – UV Dose Requirements

- Dose requirement depending on pre-treatment
- Safety factors for lamp ageing and quartz fouling



NWRI Guidelines – Design Recommendations

- QA/QC bioassay with MS2 phage
- Velocity profile measurements at test flow rates
- Sensor constructed as reference sensor
- Max. upgrade factor of 10
  (if certain hydraulic characteristics are met)
- Monitoring of power and UV transmittance
- Redundancy in reactor design
- Redundancy in power supply (UPS and multiple PDS)

NWRI Guidelines – Safety factors

- Default factors have to be used, unless the manufacturer establishes better factors (by third party tests)

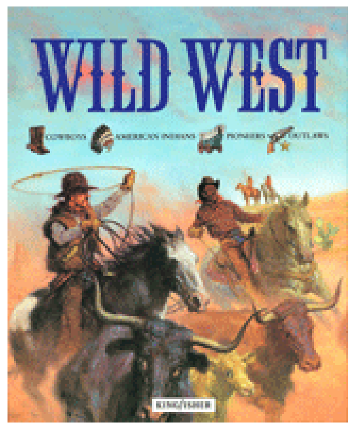
Fouling factor (FF)

Default → 80%   WEDECO → 90%

Lamp ageing factor (AF)

Default → 50%   WEDECO → 88%

Bioassays for Secondary Treated Effluent



Basics Requirements for Bioassays

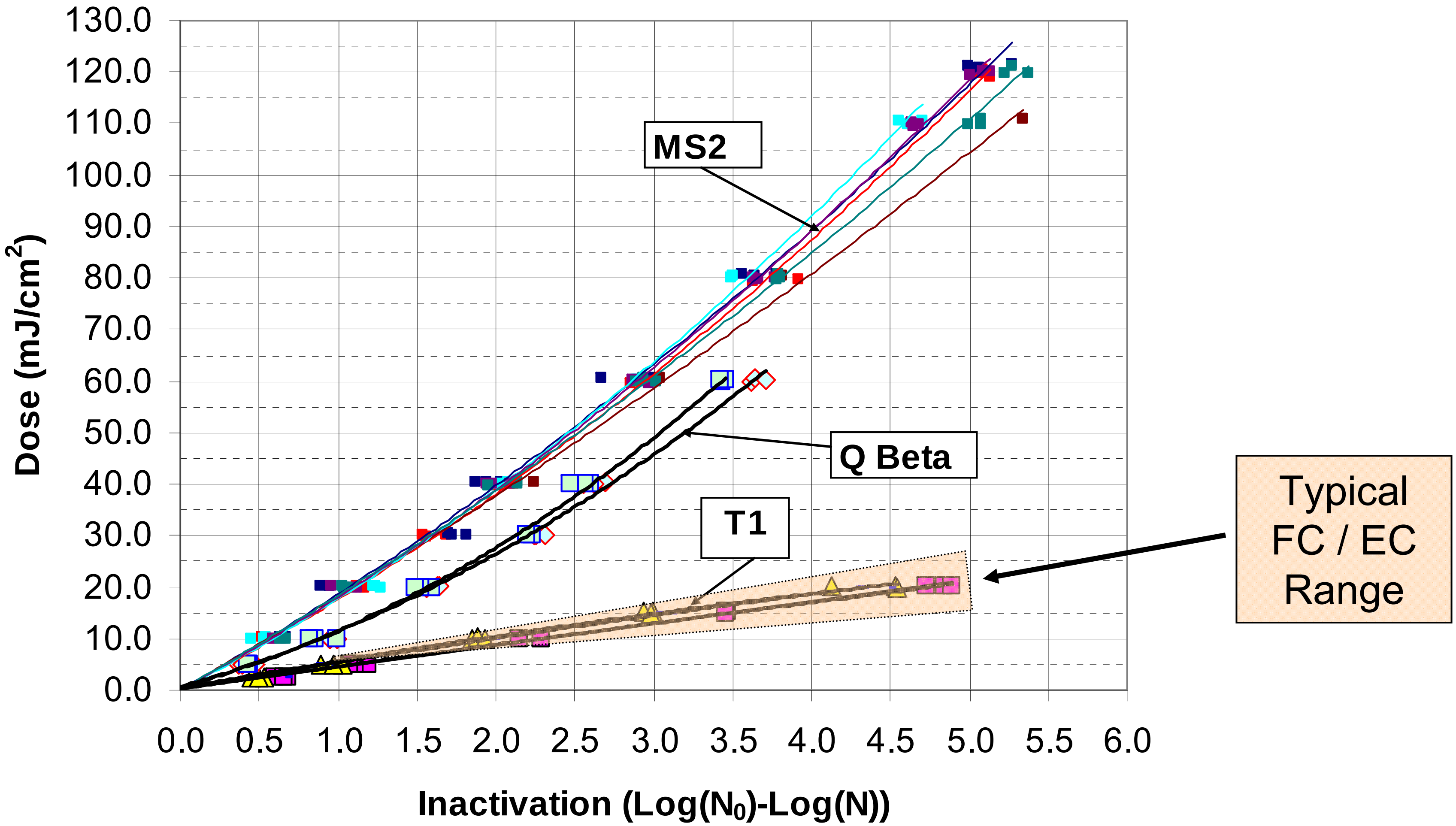
- Ideally, the challenge microorganism should have the same sensitivity to UV light (i.e., the same microbial dose-response) as the target pathogen

Target pathogen	Typical UV design dose	Challenge microorganism	UV dose per log removal
Poliovirus (NWRI)	80 mJ/cm^2 100 mJ/cm^2	MS2	~ 20 mJ/cm^2
Crypto, Giardia (Drinking water)	5.8 – 22 mJ/cm^2 5.2 – 22 mJ/cm^2	T1	~ 5 mJ/cm^2
FC, E. Coli (Secondary WW)	12 – 15 mJ/cm^2 ≥ 40 mJ/cm^2	T1 MS2	~ 5 mJ/cm^2 ~ 20 mJ/cm^2

Microbial Dose-Response

- Typical target pathogen for wastewater disinfection is Fecal coliforms (FC) or E. coli (EC)
- UV dose requirements are
  - Site-specific (!)
  - Depending on UVT, TSS, particle size distribution
  - Typically 3 – 5 mJ/cm^2 per log reduction

UV Sensitivity of Challenge Microorganisms

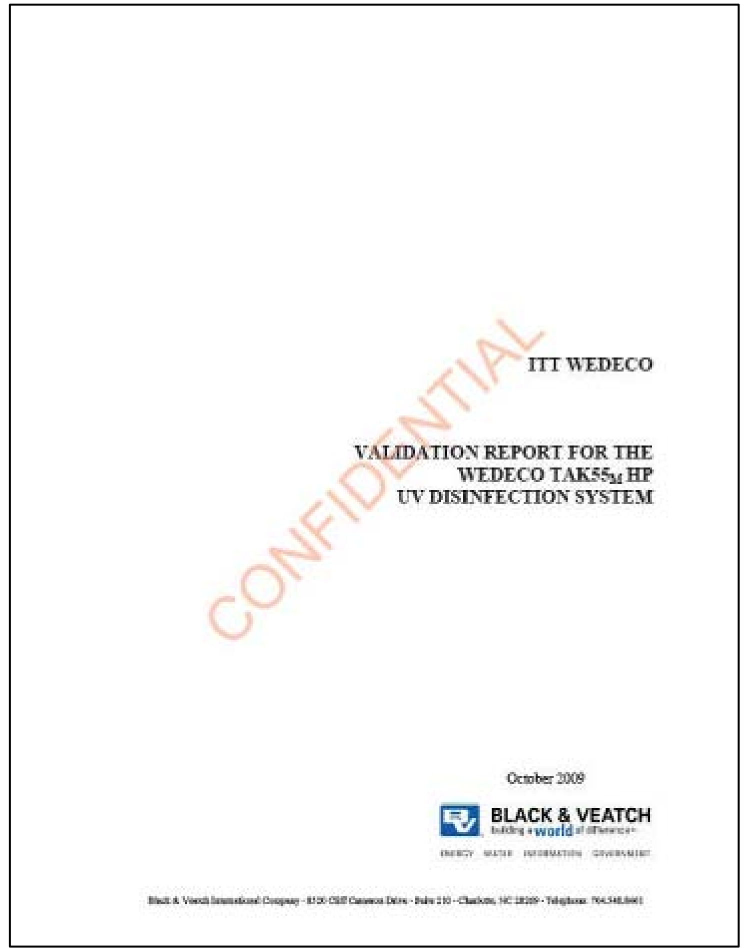


First secondary wastewater bioassay in the industry using a quality approach

- WEDECO TAK 55 Series
- Protocol based on UVDGM 2006
- Use of two challenge organisms (T1 and Qß)
- Accounts for the site-specific UV dose-response of the target organism (e.g. Fecal coliforms, E. coli)
- Independent 3rd party oversight provided by Black & Veatch

Third Party Bioassay Report

- Detailed equipment description; incl. calibration certificates
- QA/QC criteria and controls employed
- Test conditions for reactor validation testing
- Testing results – UV system performance prediction models;
  - UV intensity as a function of UV-T and ballast power
  - RED as a function of flow rate
  - UV-T / ballast power / head-loss per lamp as a function of flow per lamp
  - Others as required
- Appendices
  - Raw data
  - Qualifications; 3rd Party Validated, Laboratory services, Calibration services



Results of the Bioassay

- Functional and Biodosimetry testing were used to develop prediction models for the TAK55 UV system:
  - UV Intensity Model
  - Power Consumption Model
  - Headloss Prediction Model
  - RED Model

Design factors

Design factors rather than safety factors

- UV systems are designed for
  - Max flow rate
  - Min UV transmittance
  - Lamps at the end of life time → **Lamp ageing factor (AF)**
  - Lamps in fouled conditions → **Fouling factor (FF)**

These factors directly impact the sizing of a UV system!

Ageing factor

- Ageing is always implied with amalgam-discharge lamps
- Typical ageing factors range from 0.80 to 0.88 for low pressure, high intensity lamps
- Ageing factor of 0.98 (as claimed)
  - 2% output fluctuation is within the variability of lamp manufacturing
  - Claim is not supported by the lamp manufacturer and should therefore be rejected

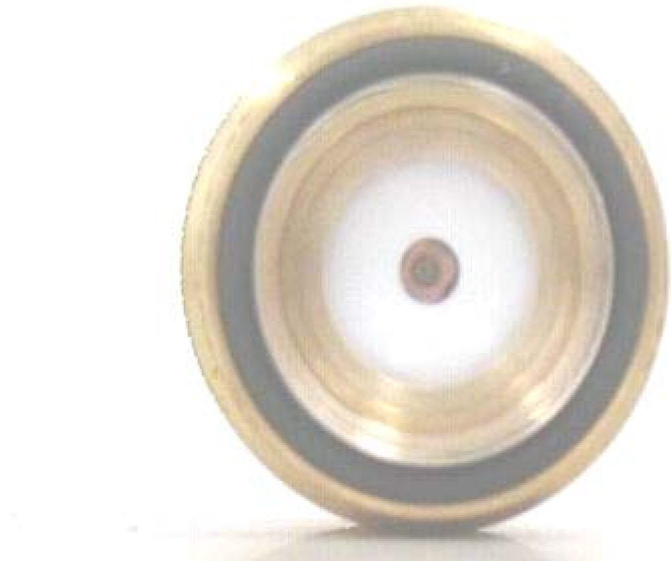
Fouling factor

- Fouling is
  - Site-specific (!)
  - Depending on constituents such as Iron, Manganese, Hardness
- Fouling factors have typically been established according to NWRI, i.e. with tertiary treated effluent
- It seems recommendable to limit the fouling factor to a max of 0.90 with secondary treated effluent
- This holds especially true if lamp aging and quartz sleeve fouling are not directly measured, but estimated based on previous tests under different conditions

Reliable operation

Reliable operation of UV disinfection equipment

- UV system control should be based on intensity
- Measured in real-time by a highly selective, calibrated UV intensity sensor
- Intensity accounts for:
  - Lamp output / power setting
  - Lamp ageing
  - Lamp fouling
  - Quartz sleeve transmissivity
  - UV transmittance



Intensity based UV system control

- Sizing of UV systems is based on design factors such as lamp aging and quartz sleeve fouling
- Only intensity based UV system control allows to
  - Observe worse or better fouling conditions during operation
  - Reduce the number of lamps and / or the UV lamp output with higher UVT or less fouling than expected
  - Saving power & money without compromising safety

Thank You For Your Attention!

Questions?