World Aquatic Health™ Conference

Performance Validation of UV Reactors for Recreational Water

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Mr. Scheible has over 30 years' experience in the development, evaluation, design and validation of UV systems for drinking water, wastewater, and recreational waters. He conceived, developed, and directs the UV Validation and Research Center of New York, Johnstown NY, which validates reactors at full scale.

Abstract

The practice of validating the performance of UV reactors has become standard practice for most drinking water and wastewater reuse applications. This has been driven by regulatory requirements in the United States and Europe, with specific protocols developed for such validations. The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requires that reactors are validated at full scale in order to be assigned credit for *Cryptosporidium, Giardia* and virus inactivation. The rule is supported by the Ultraviolet Disinfection Guidance Manual (UVDGM), which provides guidance on the conduct and interpretation of validation testing for commercial reactors. In the reuse arena, the primary validation protocol has been found in the NWRI/AwwaRF "UV Design Guidelines for Reuse and Drinking Waters." Draft guidance developing in Australia cites the UVDGM protocols for reactor validation in reuse applications.

UV has been widely applied in swimming pool applications, often for removing chlorine and chloramines via photooxidation. However, *Cryptosporidium* outbreaks at recreational facilities such as spray parks have resulted in some jurisdictions requiring the use of UV for protozoan pathogen inactivation. In such cases, regulatory requirements follow the UVDGM guidance that installed UV systems must be validated at full scale for reduction equivalent dose (RED) and log-inactivation performance, a key example is the New York State Department of Health regulation that all spray park water systems have UV installed and operating. Further, these systems have to use reactors that have been validated per UVDGM protocols. A minimum MS2 RED of 40 mJ/cm^2 is required at all times. The performance validation for the NYSDOH generally follows a minimum intensity setpoint approach, expanded to allow development of a sensor-flow relationship that meets the minimum dose requirement. Examples from several performance validations will be presented.

This presentation will discuss the status of UV system applications in aquatic settings. These will include recreational water systems used for pools, spas, spray parks, and water rides. In particular, we will discuss validation protocols that are available, inclusive of biodosimetric and actinometric methods, to the industry, and the issues of high dose requirements for chemical removals in addition to microbiological contaminant reduction.

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Validation of UV Reactors For Recreational Waters

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Overview

- Motivation for Use of UV in Pools
- Current Regulatory/Validation Requirements
- Current Validation Approach
- Recommendations for Future Validation of UV Reactors in Aquatics Applications

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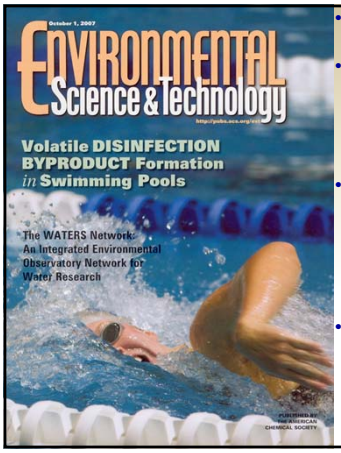

- Extensive Exposure to Pool Patrons
- Multiple Exposure Pathways
  - Ingestion
  - Inhalation
  - Dermal Uptake
- Documented Adverse Health Outcomes
  - Respiratory (*e.g.*, Asthma)
  - Skin/Eye Irritation
  - Digestive Illness
  - Cancer?
- Multiple Agents
  - Microbes
  - Chemicals
  - Combinations

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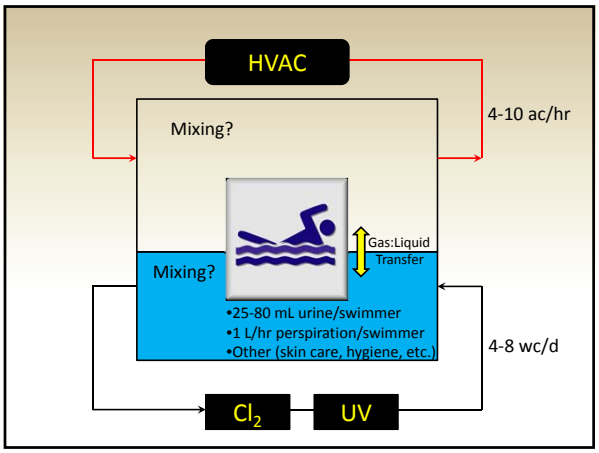

Rules and Validation Protocols - Drinking Water / Reuse

- USEPA – Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requires validation credit for *Cryptosporidium*, *Giardia* and virus inactivation;
- Ultraviolet Disinfection Guidance Manual (UVDGM) provides guidance on the conduct and interpretation of validation testing;
- Draft guidance in UK (for England and Wales) on UV for Disinfection of Public Water Supplies cites/recommends the UVDGM protocols;
- German Association for Gas and Water (DVGW) (2006) UV Disinfection Devices for Drinking Water Supply;
- Austrian Standards Institute (ÖNORM) (2003) ÖNORM M 5873-2 Plants for the disinfection of water using ultraviolet radiation: Requirements and testing;
- In wastewater reuse, NWRI/AwwaRF "UV Design Guidelines for Reuse and Drinking Waters";
- Draft guidance in Australia cites the UVDGM protocols for reuse applications;

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Motivation of Validation on UV Systems in Aquatics Applications

- **Seneca Lake State Park Spraypark Cryptosporidiosis Outbreak - New York**
  - August and September of 2005
  - at least 3900 people in New York State got sick through the ingestion of *Cryptosporidium parvum*
  - 3200 people are behind the joint lawsuit against the New York State Office of Parks, Recreation and Historic Preservation

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Current Regulatory Requirements for UV in Recreational Water Disinfection

- United States
  - New York and Texas (Spray parks)
  - New York State Department of Health (NYSDOH)
    - Follow UVDGM validation protocol
    - Validated MS2 Reduction Equivalent Dose (RED) of 40 mJ/cm^2
- Europe
  - No validation requirement for recreational water disinfection using UV
  - Germany – discussion is ongoing for potential amendment to DIN 19643 (Pool Water Treatment)
- Centers for Disease Control (CDC)
  - Model Aquatic Health Code (MAHC, Draft, Guidance)
  - *Crypto* inactivation (3 log reduction)
    - pool-dependent
    - Emphasis on pools with high proportion of children

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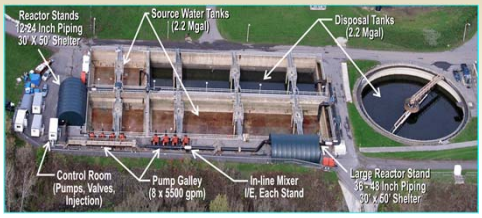
Validation for Aquatics Application in the UV Center

- List of UV Systems
  - *atg UV technologies* (9 different models, MP)
  - Siemens Water Technologies (3 different models, MP)
- Validation method
  - Biodosimetry using MS2
  - Following UVDGM protocols
  - Calculated Dose Approach – test matrix covering a range of flow rate, lamp power level, and UVT

UV Validation & Research Center of New York



- Drinking water or wastewater, UVT up to 99%.

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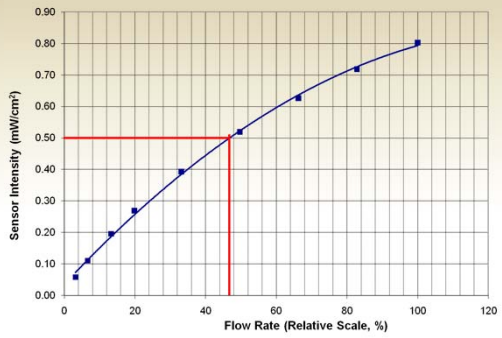
Validation Data Analysis for NYSDOH

- Calculated Dose Approach
- Determine the validation factor

$$\text{Validation Factor} = B_{RED} \times B_{poly} \times (1+U_{val}/100)$$

  - B_{poly} = 1, with germicidal sensor
  - B_{RED} = 1, MS2 RED through MS2 challenge
  - $U_{Val} = f(U_S, U_{DR}, U_{IN})$
- Operation Strategy – Sensor versus Flow Rate curve for MS2 Dose of 40 mJ/cm^2 (after validation factor)

Validation Data Analysis for NYSDOH



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Effects of UV in Recreational Water Disinfection

Microbiology

- Complementary Disinfection
- *Cryptosporidium parvum* control
- Other microorganisms

Chemistry

- Photolysis of DBPs, Precursors
- Susceptible Bonds
  - N-Cl
    - NH_2Cl
    - $NHCl_2$
    - NCl_3
    - CH_3NCl_2
    - Others
  - N-O ($NO_3^- \rightarrow NO_2^-$)
  - N-N
    - NDMA
    - Other Nitrosamines

Accumulated UV dose due to recirculation

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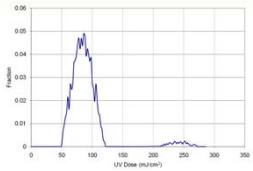
Recommendations to Validation on Recreational Application

- Biodosimetry, but using *Cryptosporidium* log reduction credit per UVDGM instead of a MS2 dose of 40 mJ/cm^2;
- Lagrangian actinometry based on Dyed microspheres
  - Dose distribution measurement
  - Allows calculation of photochemical changes
  - Doses important to disinfection
  - Possible high doses may be critical to photochemistry



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Future Regulation Requirement

- Regulations need to be based on known behavior in terms of UV disinfection (*Crypto*)
- Regulations should not create future problems
- DBP Dynamics are Incompletely Defined
- Centers for Disease Control and Prevention (CDC)
  - Model Aquatic Health Code (MAHC)
  - Living Document
  - IUVA Should Assume Leadership Role for UV
  - Collaboration
    - CDC
    - NSPF
    - Manufacturers
    - Research Community

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Questions?

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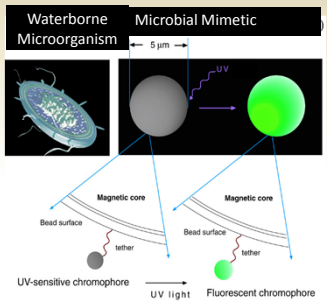
Dyed Microspheres: Lagrangian Actinometry



- Particle mimics microorganism size, specific gravity → trajectory
- Linked UV-sensitive chromophore (*S*)
- Becomes fluorescent under UV irradiation (*P*)
- Bead fluorescence intensity (FI) is correlated to UV dose received.
- Inject dyed microspheres into feed stream; sample effluent
- FI measured by flow cytometry

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Dyed-Microspheres Test and Analysis Protocol