

Ultraviolet (UV) Treatment for Safe Drinking Water

Thomas Larason^{1*}, Keith Lykke¹, Yuqin Zong¹, Ping-Shine Shaw¹, Steve Brown¹, Yoshi Ohno¹, and Mike Lin²

¹. National Institute of Standards and Technology, Gaithersburg, MD, USA

². Jung Research and Development Corp., Washington, DC, USA

* Corresponding author: thomas.larason@nist.gov

Background

Ultraviolet radiation (UV) effectively inactivates common pathogens found in ground and surface waters such as *Cryptosporidium*, *Giardia*, and most bacterial pathogens (e.g., *E. coli*). Water treatment facilities are using ultraviolet radiation for disinfection of drinking water, supplementing standard chemical treatment. NIST has been involved in research concerning the disinfection of drinking water with UV light. Two of the projects are described here.

NIST Measurement of UV Sensors

As part of a project funded by the Water Research Foundation, NIST tested several UV sensors (reference and duty) used to monitor UV reaction chambers in water treatment facilities for several characteristics:

- Absolute irradiance calibration at 254 nm
- Relative spectral responsivity, 200 nm to 400 nm
- Linearity of response
- Temperature dependence

Some problems were identified on the absolute calibration of these UV sensors. The results were published in “Design and Performance Guidelines for UV Sensor Systems” available from the Water Research Foundation.

UV Inactivation of Water Pathogens

The goal of a second project funded by the Water Research Foundation was to develop a guidance document for testing medium pressure (MP) UV light inactivation of adenovirus or suitable surrogates for groundwater systems to comply with the USEPA Ground Water Rule.

Study Microbes:

- Adenovirus – RG 2, also Type 40 and 41
- *Cryptosporidium* oocysts (Iowa strain) – RG 2
- *Giardia* – RG 2
- MS2 phage
- T1UV phage
- T7m phage
- Q beta phage

Collaborators

NIST has collaborated with the several researchers: Harold Wright (Carollo Engineers), Christopher Schulz (Camp Dresser and McKee), Alexander Cabaj (Univ. of Veterinary Medicine, Vienna, Austria), Karl Linden (Univ. of Colorado), Sara Beck (Univ. of Colorado), and Tom Hargy (TetraTech/CECV).

UV Inactivation of All Pathogens

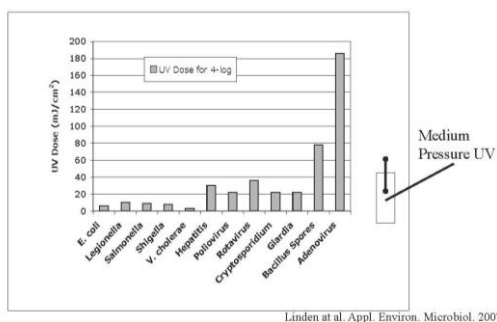
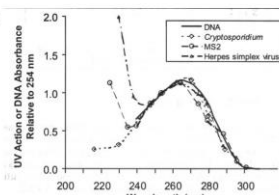


Figure 1. Graph of UV inactivation of water pathogens. Note: “Log inactivation” is the percent of microorganisms inactivated (killed or unable to replicate) through the disinfection process. A 4-log inactivation value means that 99.99% of microorganisms of interest have been inactivated.

Action Spectra Differences

- The germicidal effectiveness of UV varies with wavelength
- Important for MP UV (polychromatic)
- Different microbes have different wavelength sensitivities (action spectra)



US EPA, 2006

Figure 2. Low Pressure (LP) Mercury UV lamps emit light at 254 nm. Medium Pressure (MP) Mercury UV lamps are polychromatic and emit light at several UV and visible wavelengths.

Relative Spectral Responsivities of the UV Sensors

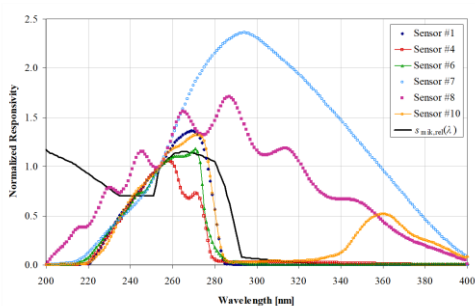
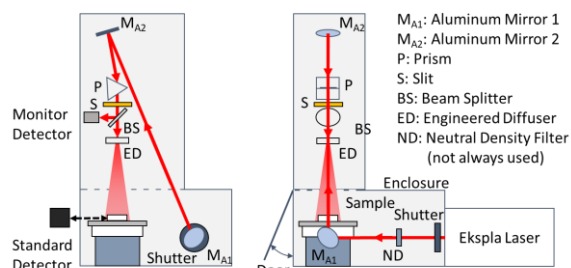


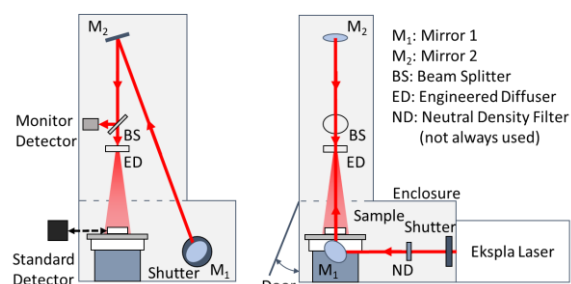
Figure 3. Plot of the relative spectral responsivities of several UV water reaction chamber sensors measured by NIST.

NIST UV Laser System

Optical setup for 210 nm to 230 nm



Optical setup for 240 nm to 290 nm



The Standard Detector is substituted for the Sample to calibrate the Monitor at each wavelength of interest.

Figure 4. Diagram of the NIST transportable tunable UV laser system for providing a known irradiance ($\mu\text{W}/\text{cm}^2$) or dose (mJ/cm^2) suitable for irradiating water samples in Petri dishes over the wavelength range of 210 nm to 300 nm.

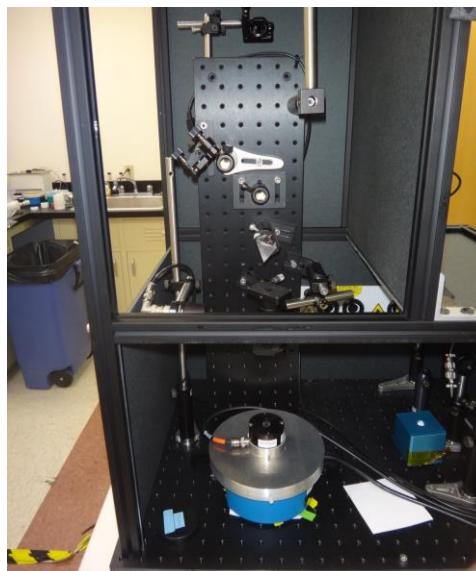


Figure 5. Photograph of the NIST transportable tunable UV laser system.