Next Generation Personal Protective Equipment for Real-time Inactivation of Airborne Biological Threats
Part 1: Experimental Measurements

Jason A. Randall,[1] Karl G. Linden,[2,3] Christopher Bowers,[2,4] Joel Ducoste,[2,4] Chris Jones,[2]
Deborah Mosca,[2] Eric Prast,[2] Richard A. Rasansky,[2] and Ernest R. Blatchley III [1,2,5]

[1]Lyles School of Civil Engineering, Purdue University, West Lafayette, IN 47907 USA
[2]XCMR Inc., Narberth, PA 19072 USA
[3]Civil, Environmental, and Architectural Engineering, University of Colorado, Boulder, CO 80309 USA
[4]Civil, Construction, and Environmental Engineering, North Carolina State University, Raleigh, NC 27695
[5]Division of Environmental & Ecological Engineering, Purdue University, West Lafayette, IN 47907 USA

A project was initiated to develop an affordable, mobile, biodefense solution that is on-demand, reusable, and will increase mobility, ease of communication, and mission effectiveness for military personnel; this device will also have civilian applications. Development of this device has involved an integrated team effort based on laboratory experiments, numerical simulations, and prototype design. This three-part presentation will address these components of design and development, as well as the links among these components. Many of the principles of the performance of this system and its design will translate to other UVC-based applications.

The device is built around conventional low-pressure mercury (LP-Hg) lamps and UVC LEDs. The device also involves the use of materials that are highly reflective in the UVC range, with reported diffuse reflectance of greater than 90% at the wavelengths of emission of the LP-Hg lamps and UVC LEDs used in this research (254 nm and nominally 280 nm, respectively). A micropositioning device and a microfluorescent silica detector (MFSD) were used to conduct detailed measurements of the fluence rate field within the irradiated zone of the device. These measurements compared well with numerical simulations based on ray tracing (see Part 2). Measurements and simulations indicated that the inclusion of the reflective surfaces on the interior walls of the irradiated zone resulted in considerable amplification of local and average fluence rate. Moreover, the fluence rate field indicated a strong positive correlation between regions of high fluence rate and high velocity. This correlation promotes uniformity of the dose distribution delivered by the device, which in turn leads to high disinfection efficacy. This behavior is fundamentally different than most UV-based devices, for which the fluence rate field and velocity fields tend to be strongly anti-correlated, resulting in broad dose distributions.

Photon 'recycling' that resulted from efficient reflection also led to effective inactivation of aerosolized viral challenge agents. Specifically, an aerosolized suspension of T1 phage was introduced to the system using a single-port Collison nebulizer; T1 was used as a challenge agent in these experiments because it is slightly more UV-resistant than common viral pathogens (*e.g.*, coronaviruses and influenza viruses). Air samples were collected from the exhaust of the device using a bioaerosol sampler; liquid samples from the samplers were then subjected to a plaque assay to quantify infective phage concentration with and without treatment. The results of these measurements demonstrated effective inactivation of the viruses in early and final prototype devices.