Next Generation Personal Protective Equipment for Real-time Inactivation of Airborne Biological Threats
Part 3: UVC Powered Symmetrical Flow Disinfection (SFD) Device

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The COVID-19 pandemic has demonstrated that respiration protection is paramount for airborne biological threats introduced by nature, accident, or weaponized means. Thus, more effective, re-usable, and scalable PPE is needed both for military biodefense against specific threats as well as protection for civilian public health.

Informed by data previously shared in this three-part presentation, a novel form of PPE is under development that integrates germicidal UVC (200-280 nm) into a safe, battery powered, wearable device to disinfect air during both inhalation and exhalation leveraging XCMR's Symmetrical Flow Disinfection (SFD) process. Utilizing an enclosed reactor allows a greater selection of UVC sources, eliminating the risk of human exposure, while allowing effective pathogen inactivation under dynamic environmental conditions.

A number of reactor configurations were produced, each with different types of UVC radiation sources (e.g., LED and Low Pressure Mercury Lamps) at various irradiance levels. A microporous diffuse highly reflective material lining was used in the reactors to produce a near perfect Lambertian reflectance. This resulted in internal irradiance that was significantly amplified, yielding effective inactivation of biological agents.

Laboratory testing of the prototype, bench-top reactors included optical characterization and biological analysis using T1 phage which yielded results that aligned favorably with computer simulated models. Utilizing advanced modeling and simulation techniques for performance optimization, a conceptualized device design was realized through rapid digital prototyping.

Further engineering development resulted in the development of a highly efficient battery operated light engine, microprocessor-based controller with mesh-network connectivity, battery charger, and modular sensor feedback bus integrated into the desired form factor. Essential key characteristics based on core principles of human factor design included improved ergonomics and comfort resulting from wearability studies and anthropometric analysis to enable a greater likelihood of user adoption.

Together these data demonstrate feasibility of UVC disinfection systems incorporated into a wearable, reusable, device to inactivate airborne pathogens and achieve equivalent or greater protection to an N95 mask. Relying on enhanced treatment through continuous inactivation of pathogens as opposed to mechanical filtration alone offers (i) superior protection to both users and bystanders alike, (ii) reduced breathing resistance and comfort, (iii) reduced ecological footprint by mitigating biohazard waste of disposable masks, and (iv) adaptability to future biological threats. Prototypes have been successfully created which demonstrate this functionality. Several iterations of these devices are being evaluated against computer modeled simulations and undergoing field testing as part of federally funded research by the US government.