Disinfection Efficiency and Dose Measurement of Polychromatic UV Light [Project #2668]

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OBJECTIVES:
The objectives of this project were to (1) develop and evaluate physical, chemical, and biological methods for calculating effective germicidal UV dose from medium-pressure (MP) and Pulsed-UV (P-UV) lamps; (2) establish a UV dose/log inactivation relationship for specific bacterial and viral indicators for MP and P-UV lamps; (3) determine the extent of photoreactivation and dark repair of heterotrophic bacteria after treatment by MP and P-UV lamps; and (4) compare the ability of MP and P-UV lamps to inactivate Cryptosporidium.

BACKGROUND:
There is currently intense interest in the use of ultraviolet technology for helping to meet future regulations relating to improved microbial inactivation and decreased disinfection byproducts (DBPs). Much of this interest has been fueled by recent research indicating the effectiveness of UV technologies for the inactivation of Cryptosporidium. This scientific discovery, combined with proposed regulations concerning DBPs in the United States, has resulted in a need to evaluate the feasibility and effectiveness of UV irradiation for use as a disinfectant for drinking water.

HIGHLIGHTS:
UV dose measurement on the bench scale was achievable with all the methodologies tested. It was determined that the inactivation of C. parvum was rapid under all the UV lamp types tested. The inactivation of heterotrophic bacteria was also rapid and similar for all lamp types. Any recovery in growth of heterotrophic bacteria was suppressed with chloramine addition. It appeared that the inactivation of MS2 coliphage was appreciably improved when exposed to light from polychromatic, UV lamps as compared to the LP monochromatic UV lamp.

APPROACH:
The research was designed to evaluate the germicidal UV dose emitted from three different UV sources using dose measurement methods that included radiometry, chemical actinometry, and biodosimetry. All work was performed on the bench scale utilizing systems designed to simplify the delivery of UV irradiation to a batch reactor such that accurate measurement of UV irradiance and dose could be made. The most appropriate means for measuring UV dose from polychromatic, UV lamps was determined. The ability of LP-UV, MP-UV, and P-UV lamps to inactivate three different microbes was then compared. The microorganisms tested included heterotrophic bacteria, MS2 coliphage, and Cryptosporidium parvum oocysts. The ability of heterotrophic bacteria to repair UV damage when exposed to light (simulated, uncovered reservoir storage) and dark (simulated, distribution system storage) environments was also evaluated.

RESULTS/FINDINGS:
Measuring UV dose on the bench scale was achievable with all the methodologies tested. A successful approach taken in this work was to define the DNA absorbance spectrum as the weighting factor to compare the germicidal dose from each light source. Based on this germicidal dose weighting, it was determined that the inactivation of C. parvum was rapid and reached 3-log inactivation at a dose of 10 mJ/cm² under all the UV lamp types tested. The inactivation of heterotrophic bacteria was also rapid and similar for all lamp types and reached >2.5 log at a dose of 10 mJ/cm². After UV-treated bacteria were then incubated in environments that may simulate uncovered reservoir or distribution-system storage, significant increases (attributed to both repair and regrowth) in number of bacteria were observed. This recovery was suppressed with addition of 2.5 mg/L of combined chlorine added after UV exposure, indicating that chloramine addition may be an effective control to prevent recovery of UV inactivated bacteria. It appeared that the inactivation of MS2 coliphage was appreciably improved when exposed to light from polychromatic, UV lamps as compared to the LP monochromatic UV lamp. This may have been an artifact of the dose measurement weighting methodology.

IMPACT:
When choosing between different UV light sources, it is apparent that there is no overwhelmingly conclusive difference in the efficacy of one lamp type over another for the microorganisms tested and all light sources are highly effective against Cryptosporidium parvum. The use of a biodosimetry test, such as would be used during a reactor validation, shows good agreement with other dose measurement methods evaluated in this research. This indicates that biodosimetry performed on a UV reactor is a practical means of determining germicidal dose in a reactor. The research on heterotrophic bacteria supports the need for utilities to develop robust treatment strategies that use multiple disinfectants to achieve inactivation of pathogens and nuisance bacteria.

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