Sunlight-Driven Photolysis of Free Chlorine to Reactive Oxygen Species for Enhanced Inactivation of Chlorine-Resistant Microorganisms

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Abstract: Aqueous free chlorine remains widely used in water treatment on account of its low cost, ease of use, and generally high efficacy as a disinfectant. However, certain pathogens (e.g., *Cryptosporidium parvum*, *Giardia lamblia*) exhibit considerable resistance to chlorine. We have found that inactivation of chlorine-resistant microorganisms can be significantly enhanced during chlorination processes by utilizing sunlight-driven activation of free chlorine to generate various reactive oxygen species (e.g., $HO^{\bullet}$, $O(^3P)$), as well as O_3, *in situ*. For example, the inactivation of *Bacillus subtilis* spores (common surrogates for chlorine-resistant pathogens) in pH 8 phosphate-buffered solutions dosed with 3-6 mg/L Cl_2 can be accelerated >2-fold by irradiation with simulated sunlight for as little as 12 minutes. Similar results are observed under natural sunlight, as well as in natural water samples obtained from regional drinking water utilities. A lack of spore inactivation under sunlight alone, coupled with nearly complete suppression of enhancement effects during chlorine photolysis in the presence of 50-mM *t*-BuOH (a $HO^{\bullet}$ and $O(^3P)$ scavenger), attest to the role of photochemically-generated ROS in these systems. Implications of these findings will be discussed in the context of possible strategies for practical implementation, with emphasis on both centralized and decentralized treatment.

Bio: Dr. Michael Dodd is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of Washington. He received his B.S. in Civil Engineering (2001) and his M.S. in Environmental Engineering (2003) from the Georgia Institute of Technology. He received his Ph.D. in Environmental Sciences from the Swiss Federal Institute of Technology in Zurich (2008), and undertook a postdoctoral fellowship in the Environmental Engineering Program of Yale University (2008-2009) prior to starting at the UW. His research interests center on characterizing homogeneous and heterogeneous redox reactions in engineered and natural aquatic systems, particularly with regard to their application in optimizing pollutant and pathogen elimination during water and wastewater treatment. Examples of current research areas include: (i) characterization of extracellular and intracellular bacterial DNA degradation kinetics and resulting changes in transforming activity of associated antibiotic resistance genes during disinfection processes applied in water treatment and health care, and (ii) development and optimization of low-energy technologies for decentralized chemical disinfection of water and wastewater (e.g., in situ photochemical activation of free chlorine to reactive oxygen species for enhanced inactivation of chlorine-resistant pathogens during water and wastewater chlorination). Dr. Dodd's awards include a NSF CAREER Award, the CH2M Hill/AEESP Outstanding Doctoral Dissertation Award from the Association of Environmental Engineering and Science Professors; the ETH Medal from the Swiss Federal Institute of Technology-Zurich, and the Excellence in Review Award from Environmental Science & Technology.