Synergistic Inactivation of *Bacillus globigii* Spores Using Combined Aqueous Chlorine and Ultraviolet Light

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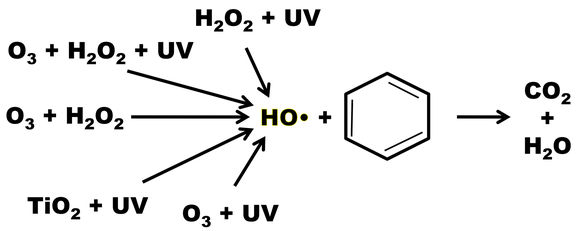
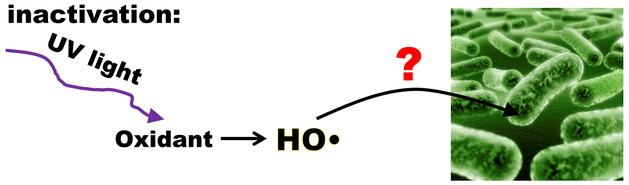
Introduction

Advanced Oxidation Processes (AOPs) employ a combination of a chemical oxidant and ultraviolet (UV) light to produce hydroxyl radicals (HO•), extremely powerful oxidant species capable of destroying organic contaminants in water:



One aspect of AOPs that has not been extensively explored is the impact AOPs have on microbial inactivation:

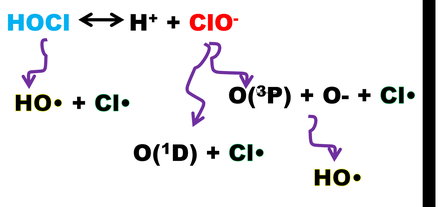


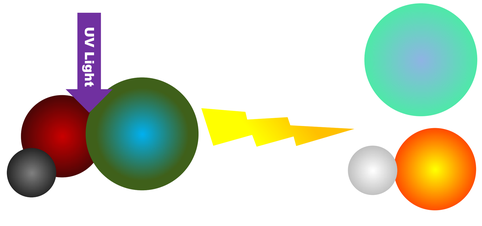
If AOPs demonstrate measurable impact on disinfection, the overall utility of these processes in water treatment will be enhanced.

Aqueous Chlorine Advanced Oxidation Processes

Currently, investigators exploring the use of aqueous chlorine combined with ultraviolet light as an alternative AOP have identified several technical and operational advantages over traditional AOPs, including:

- The quantum yield of hydroxyl radical production is higher for aqueous chlorine than for H_2O_2
- Hydroxyl radical-initial oxidant recombination rate is lower for HOCl than for H_2O_2
- Aqueous chlorine is a less expensive chemical than H_2O_2





- For many applications, it is necessary to quench H_2O_2 after AOP is complete - this is not needed for an aqueous chlorine AOP
- Aqueous chlorine is already used in water treatment for disinfection purposes

Under an NSF SBIR program, MIOX is exploring aqueous chlorine-based AOPs with a strong emphasis on applications research. In this poster, we report the enhanced inactivation of bacterial spores using combinations of aqueous chlorine and UV light.

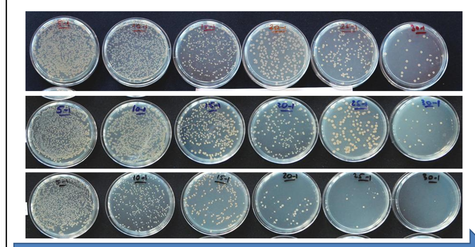
Experimental Methodology

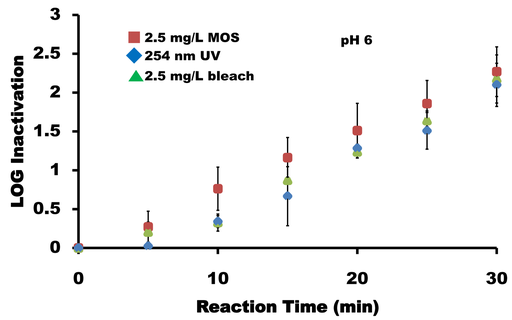
Inactivation of *Bacillus globigii* spores was investigated under various exposure conditions. The oxidants tested were sodium hypochlorite, Mixed Oxidant Solution (MOS), and hydrogen peroxide either alone or in combination with 254 nm UV light. Disinfection due to UV alone was also quantified as a control.

- Oxidant solutions were prepared to a final concentration of 2.5 mg/L, and pH adjusted to 6, 7.5, or 9.0. To these solutions, quantified *B. globigii* spore suspensions were added. These solutions were then irradiated with 254 nm UV light for up to 30 minutes, providing a total UV dose of ~46 mJ/cm². During UV exposure, aliquots of the test sample were removed and the number of surviving spores quantified by counting the number of colony forming units.
- MOS is a proprietary, chlorine-based oxidant solutions produced through the electrolysis of sodium chloride brines. Extensive research has demonstrated that, among other unique properties, MOS is a superior disinfectant when compared to an equivalent Free Available Chlorine concentration of commercial sodium hypochlorite solution.

Inactivation of *B. globigii* Spores - Results

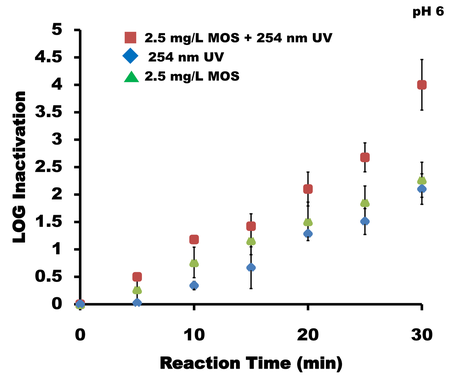
Disinfectant Inactivation Comparison

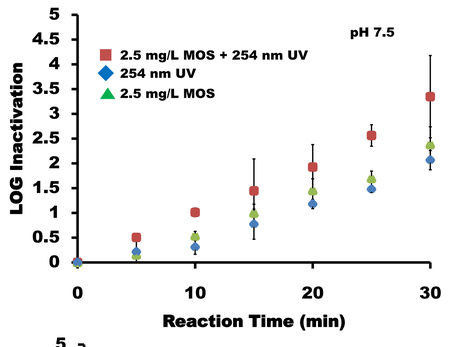


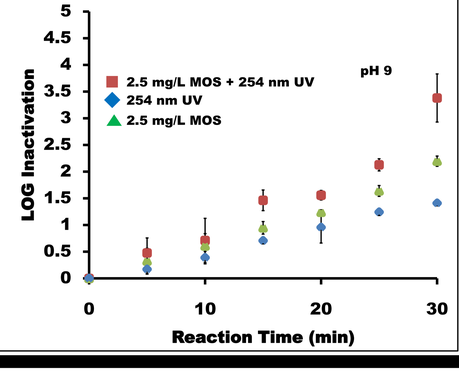


- Reaction times equate to UV doses of up to 46 mJ/cm²
- H_2O_2 alone did not inactivate *B. globigii* spores at 2.5 mg/L concentration
- Independently, all three disinfection methods show similar log inactivation

pH Effect on MOS AOP Inactivation

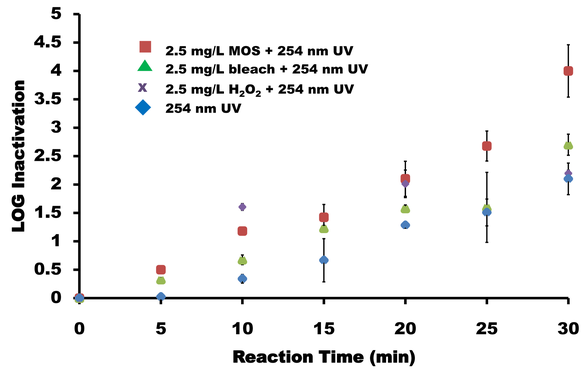






- Combining MOS and 254 nm UV results in a doubling of the inactivation of *B. globigii* spores
- Disinfection was more effective at lower pH, but enhancement of disinfection still occurred at high pH.

Oxidant/UV (AOP) Inactivation Comparisons



- Enhanced spore inactivation is observed for MOS and bleach UV combinations; MOS appears to give the greatest synergistic log inactivation
- Slight enhancement of spore inactivation was seen for H_2O_2/UV combinations at low UV doses
- This enhancement disappeared when the UV dose reached ~50 mJ/cm²
- Overall, MOS/UV was the superior disinfectant combination

Conclusions

- Aqueous chlorine-based AOPs demonstrated an enhancement of *B. globigii* spore inactivation compared to oxidants or UV alone.
- MOS-based AOPs exhibited a doubling of the inactivation of *B. globigii* spores compared to either MOS or UV alone.
- Enhanced inactivation was not observed in studies using H_2O_2 and UV.
- The mechanism responsible for the enhanced disinfection using aqueous chlorine-based AOPs is currently under further investigation.

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