Titanium dioxide kills water pathogens with sunlight by membrane peroxidation

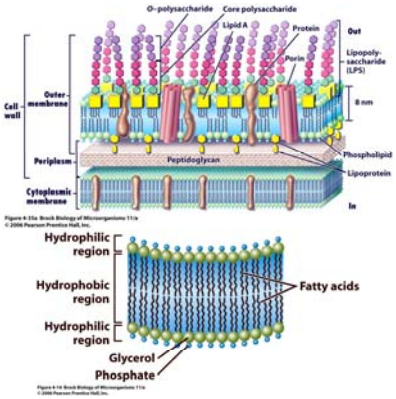
O. Kofi Dalrymple, Maya Trotz, Elias Stefanakos & Yogi Goswami
Clean Energy Research Center, College of Engineering, University of South Florida

Overall Objective

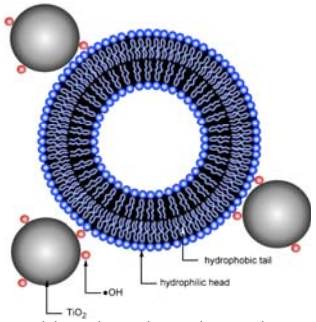
The ***overall objective*** is to build a mechanistic model for photocatalytic disinfection based on the peroxidation of cell membrane lipids

Research Background

- Traditional disinfection, though still very important, has the drawback of producing disinfection byproducts which can be harmful (e.g. chlorinated and bromated organic compounds)
- Photocatalysis uses titanium dioxide (TiO_2), a semiconductor, to absorb light (350-400nm) and produce highly reactive hydroxyl radicals which oxidize organic matter, including cellular macromolecules
- Cell membrane lipids are among the most oxygen sensitive molecules known and, when exposed to hydroxyl radicals during photocatalysis, are easily oxidized. Malondialdehyde (MDA) is a common biomarker for lipid peroxidation in cells.
- Currently, there are no mechanistic models for photocatalytic disinfection. Most of the empirical models used are based on chlorine disinfection which differs from photocatalysis.
- The ***central hypothesis*** of this work is that the rate of overall inactivation is dependent on the rate of lipid peroxidation
- The ***rationale*** is that modeling this process will allow scientists and engineers to achieve the ***long-term goal*** of optimizing photocatalytic disinfection, so that air and water can be disinfected quickly, efficiently, and inexpensively



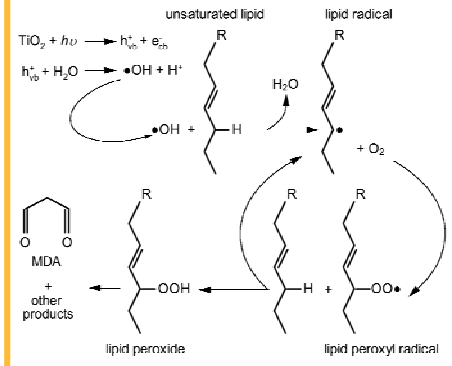
Cell membrane structure of *E. coli*



Model membrane during photocatalysis

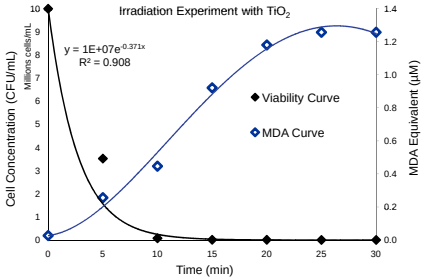
Approach

- Liposomes (lipid vesicles) are used as model cell membranes to build the model
- Phosphatidylethanolamine (PE) vesicles are used since PE is the main membrane phospholipid (~60-80%) of *E. coli*.
- A compartmentalized model based on the following reaction scheme is proposed



Results

- Initial results confirm the production of MDA in the photocatalytic experiments
- MDA production corresponds to loss of cell viability



- The next step is to measure oxygen uptake during peroxidation of liposomes
- Cell membrane will be modified by growing cells in media supplemented with different unsaturated fatty acids

Discussion & Conclusions

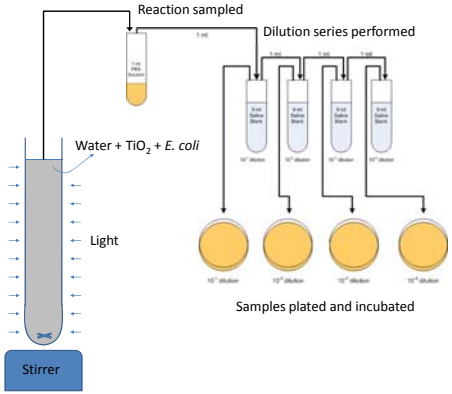
We were able to demonstrate that peroxidation of lipid membranes is linked to disinfection. Our next step is to measure the consumption of oxygen during this process to correlate the rate of peroxidation with the rate of disinfection. This study is *innovative* because, to best of our knowledge, it is the first study to develop a mechanistic model for photocatalytic inactivation of bacteria based on these fundamental processes. We will be able to predict the rate of disinfection for various organisms based on their biological composition.

This work was funded by the State of Florida - Florida Energy Systems Consortium

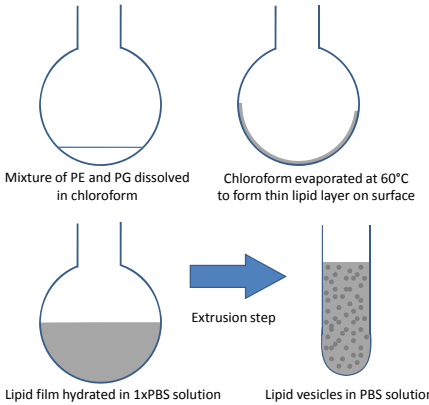
Materials & Methods

- *E. coli* ATCC 25922 was used as the model organism in the study
- Degussa P25 TiO_2 was used as the catalyst (0.1 g/L)
- Compact UV fluorescent lamps (Philips PL-S 9W/08 157529) were used as the light source with peak emission at 365 nm
- A borosilicate glass test tube served as the reaction vessel
- Liposomes were prepared from a mixture of PE and phosphatidylglycerol (PG) in a molar ratio of 3:2
- Liposomes were extruded with a mini-extruder from Avanti Polar Lipids (Alabaster, AL)
- Cellular fatty acids were modified by growing organisms in base broth media supplemented with unsaturated fatty acids

Disinfection Experiment



Liposome Preparation



Liposomes Characterization

		Diam. (nm)	% Intensity	Width (nm)
Z-Average (d.nm): 161	Peak 1:	204	90.7	61.5
PdI: 0.270	Peak 2:	53.7	9.3	9.58
Intercept: 0.983	Peak 3:	0.00	0.0	0.00