**Photocatalytic Inactivation of MS2 Bacteriophage and *E. coli.***
**Kinetics Modeling and Quantum Efficiency**

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Introduction
Titanium dioxide based photocatalysis for water purification has been the focus of much research over the past twenty years. However, despite this, only a few studies have explored its biocidal applications.

Two strategies are generally employed in photocatalysis for water purification: a) Thin film reactors where the titania is fixed to a solid substrate; and b) Slurry type reactors. One difficulty in evaluating the literature is that different laboratories have commonly selected only one of these strategies, used different volumes of water and types of microorganisms. Other sources of variation arise from the different types of light sources and reactor dimensions that have been adopted.

Salaices et al. [1] have indicated that progress in photocatalysis will benefit from the definition and use of fundamentally based efficiency parameters. Such parameters permit the direct comparison of results obtained from different experimental systems and conditions. Quantum efficiency is defined as the ratio of the total number of molecules formed over the total number of photons absorbed. To account for the different light sources used and the variation in their spectral characteristics, it is preferable to have an efficiency parameter based on the total energy of absorbed photons. This study evaluates the biocidal application of TiO2 photo-catalysis using a six-liter Photo-CREC-Water-Reactor and introduces a new inactivation quantum efficiency (IQE) for data analysis.

Results and Discussion
Experiments were developed using a 6-liter Photo-CREC-Water slurry reactor with 0.24g of Degussa P25 TiO2/liter and powered with a 15 w near UV lamp[1]. Inactivation of both MS2 bacteriophage (ATCC-15597-B1) and *E.coli* were studied. Regarding progress of MS2 inactivation was assessed using their ability to infect *E. coli*. Phage particles from bacterial lysates were purified, concentrated and titrated to determine the number of PFU (particle forming units) per milliliter. Nonlinear regression was used to determine the inactivation kinetics of MS2 and *E. coli*.

In both cases, $TiO_2$-based photo-catalysis showed better inactivation than the controls: 1) black-light-only and, 2) Catalyst-only. Inactivation kinetics is reported in Figs. 1 and 2, respectively. Each datum point represents an arithmetical average of triplicate-plate counts. Average error for the triplicates was less than 10 percent.

Phage inactivation showed insignificant inactivation for the control conditions while *E. coli* inactivation was significant for each of the controls. These results indicate that *E. coli* may be more sensitive to shear (from the pump) and irradiation than MS2. In addition under irradiation and TiO2, *E. coli* showed a different inactivation pattern with a three-minute lag-phase in the inactivation kinetics (Fig. 2.). This lag was assigned to the ROS-neutralizing enzymes that are inherent to *E. coli*.

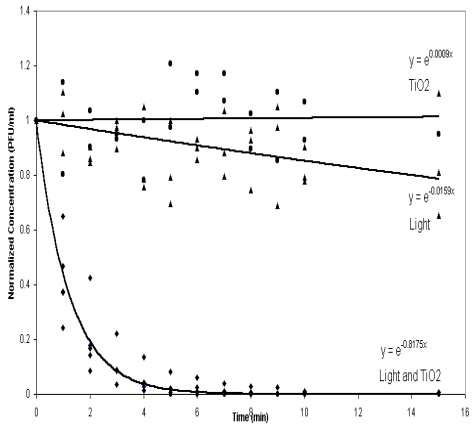


Fig.1. Normalized MS2 Inactivation. $[phage]_{init} = 10^3$-$10^5$ (PFU/ml.)

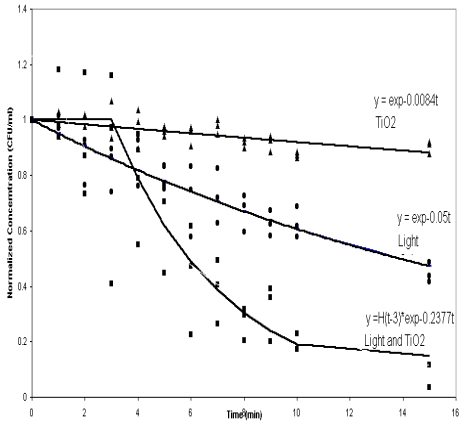


Fig. 2. Normalized *E. coli* Inactivation. $[E.\ coli]_{init} = 10^3$- $10^5$ (CFU/ml.)

In the case of biocidal applications, the quantum efficiency can be modified introducing an "inactivation quantum efficiency" (IQE), the ratio of the total number of organic cells/ particles or components thereof inactivated over the total number of photons absorbed. IQE are calculated with initial rates of inactivation with those for the *E. coli* assessed after the 3-minutes lag phase period.

Table 1 reports IQEs for a concentration of $10^4$ particles/cells per milliliter. IQEs in both cases were much larger than 1. IQEs for both MS2 and *E.coli* are very encouraging and this particularly in the context that quantum efficiencies for the photo-conversion of organic molecules in water always remain below 1. Moreover, the much larger IQEs for *E. coli,* versus the MS2 can be assigned to the more abundant oxidatibe-inactivaion of *E.coli* bacteria with the *E. coli* having an higher dependence of numerous interrelated physiological systems for survival.

Table 1. IQE for E. coli and MS2 bacteriophage $TiO_2$-black light mediated inactivation

| Organism | First Order inactivation constant ($min^{-1}$) | IQE (Carbons inactivated/ photon) |
|---|---|---|
| MS2 Bacteriophage | 0.8175 | 22 |
| E. coli | 0.2377 | $5.19\ 10^5$ |

Note: Average carbon contents of phage and *E. coli* assessed at $1.16\ 10^5$ and $7.27\ 10^9$ respectively. Energy of the photon assessed at 327000J/mol [2].

**References**

1. Salaices, M., Serrano, B., de Lasa, H. I. Ind. Eng. Chem. Res. 40 (2002) 5455
2. Serrano B., PhD Dissertation, Univ.Western Ontario (1998)