Bacterial Disinfection from Selected Water Pathogens Using an Iron-doped TiO_2 Photocatalyst Under Visible Light

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Significance and Relevance

TiO_2 is a widely used photocatalyst for water treatment and pollutants degradation,[1] but is active under UV light due to its bandgap in the 3.0 – 3.4 eV range. Doping with iron (a non-toxic metal) can reduce the bandgap, allowing for a better exploitation of the solar spectrum in the visible range. Current treatment methods like chlorination and UV irradiation may result in the formation of toxic by-products. So far, few studies deal with the disinfection of pathogenic bacteria by Fe-doped TiO_2. This study is related to the use of an Fe-doped TiO_2 obtained by a sol-gel method in the photocatalytic disinfection from *E. coli* and *S. aureus* under visible light produced by a commercial lamp.

Preferred presentation: Oral preferred or Short Oral.

Introduction and Motivations

Bacterial contaminated drinking water may cause serious health problems.[2] For instance, *E. coli* and *S. aureus* found in contaminated water are responsible for several waterborne diseases.[3] Specifically, *E. coli* is considered the indicator bacteria in contaminated drinking water and indicates the contamination source in the drinking water system. Conventional disinfection treatment methods such as chlorination, ozonation, and UV are expensive methods and could produce toxic by-products during disinfection.[4] Therefore, effective alternative methods are needed to disinfect the waterborne pathogenic bacteria from drinking water. In this respect, photocatalytic treatment could be an alternative disinfection method. In this study, Fe doped TiO_2 was synthesized and then tested for disinfection of two Gram-negative and Gram-positive bacteria, respectively *E. coli* and *S. aureus*.

Materials and Methods

The Fe doped TiO_2 photocatalyst was synthesized by a sol-gel method[5], along with an undoped TiO_2, used for comparision. The nanomaterials were characterized through different techniques such as XRD, Diffuse Reflectance (DR) UV–vis spectra, BET, FESEM, and Zeta potential.

The two bacterial strains *E. coli* (ATCC 8739) and *S. aureus* (ATCC 25923)[6] were selected for disinfection experiments with the initial concertation of 10^4 CFU/mL, the photocatalytic disinfection experiments were performed in different conditions in the dark and under the light irradiation, with a catalyst dose of 1 g/L. The disinfection experiments were performed under light and control conditions (in dark: bacteria and photocatalytic nanoparticles and in light: only bacteria). The bacterial disinfection at different times was monitored through the plate count method.

Results and Discussion

The XRD patterns show all the observed peaks were ascribed to the TiO_2 anatase phase in both undoped and Fe-doped TiO_2. The bandgap was evaluated by applying Tauc's plot method for indirect semiconductors (i.e. by plotting $(F(R)*h\upsilon)^{1/2}$ vs Energy, eV) the corresponding Tauc's plot from which the band gap of Fe-TiO_2 undoped TiO_2 resulted to be 2.80 eV and 3.34 eV, respectively.

The Specific Surface Area (SSA), as obtained by applying the BET (Brunauer–Emmett–Teller) method, of Fe-TiO_2 was 123 m^2/g, i.e. slightly higher than undoped TiO_2 (116m^2/g)

The bacterial disinfection for *E. coli* (99.9%), and *S. aureus* (99.8%) was obtained under visible light irradiation with both bacteria in the presence of Fe-TiO_2 whereas the activity of undoped TiO_2 was much lower, due to its different optical properties. No significant Log reduction was observed in control samples. During photocatalytic disinfection in the presence of Fe-TiO_2 reactive oxygen species (i.e. O_2- and OH• radicals) were produced, which are responsible for inactivating the bacteria by damaging the cell wall or membrane, according to previous studies[7].

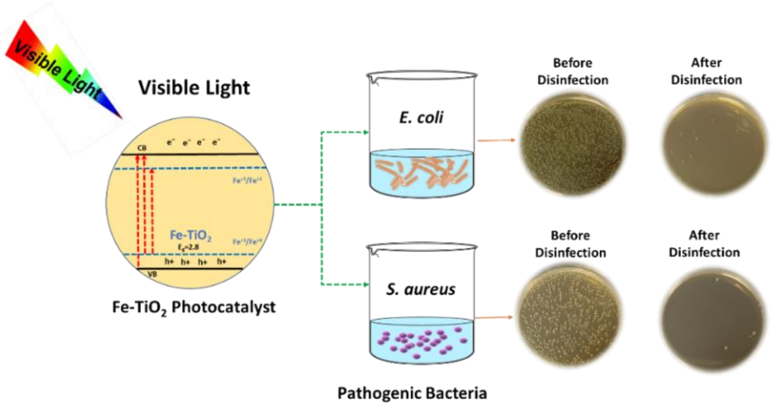

Figure 1. Photocatalytic disinfection mechanism and bacterial reduction on agar plates before and after photocatalytic treatment

Figure 1. The overall mechanism of generating radical ionic species from the photocatalyst surface and their reaction with bacterial cell walls and membranes for their inactivation as depicted from very few bacterial cells on the agar plate after photocatalytic treatment.

In conclusion, Fe-TiO_2 photocatalyst shows the potential to inactivate pathogenic bacteria (99.9%) and could reduce the health risk of waterborne diseases.

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Acknowledgements

The authors acknowledge Prof. Francesca Bosco and Chiara Mollea (Department of Applied Science and Technology, Politecnico di Torino) for fruitful discussion; and USPCASW, MUET, Pakistan for technical support. FSF contribution was carried out within the Agritech National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.