Sustainable, composite materials for the photodegradation of waste water contaminants

KEYWORDS : porphyrins, chitosan, photodegradation, nanocomposites, water remediation

1. PROJECT SUMMARY, CONTEXT AND AIMS : Organic dyes are extensively used in various industries, including textiles, plastics, and rubber. However, their presence in wastewater poses a significant environmental threat due to their complex structure, high concentration, and low biodegradability. Existing treatment methods, such as coagulation and biological degradation, have limitations, including high chemical consumption, extended treatment times, and incomplete dye mineralization.

This project aims to develop sustainable photocatalytic systems for efficient and eco-friendly dye removal from wastewater. We will explore supported porphyrins immobilized on chitosan biopolymer as photocatalysts. Porphyrins offer excellent light absorption, while chitosan is biocompatible, biodegradable, and possesses good film-forming properties.

The supervision team is interdisciplinary: composed of Prof. Patrice Castignolles (PC), Dr Lydia Sosa Vargas (LSV) from Sorbonne University and Dr Margarita Rivera Hernandez (MRH) from the National Autonomous University of Mexico. The project will involve the synthesis of novel porphyrin derivatives that can be attached to a chitosan matrix via supramolecular or covalent interactions (Fig.1,I). The chitosan matrix (biopolymer) used will be thoroughly characterized to accurately assess the property-structure relationship (II). A series of new composite films (III) will be prepared and characterized, and their stability and photocatalytic activity in the degradation of aqueous solutions of azo dye (indigo carmine) will be evaluated (IV).

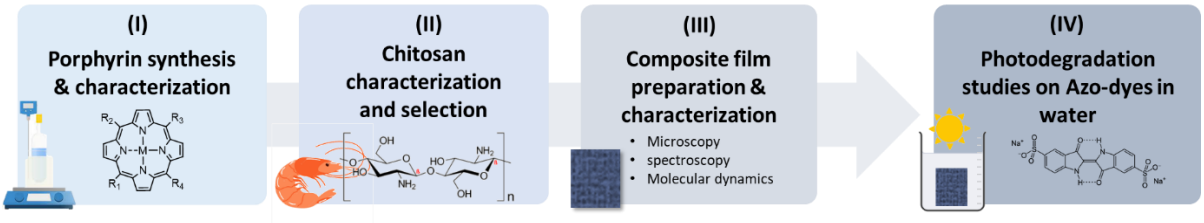

Figure 1. *Overview of proposed project, where phases I and II will be carried out by the French partner (Sorbonne University), and phases III and IV by the Mexican partner (Universidad Nacional Autonoma de Mexico).*

2. SCIENTIFIC OBJECTIVES: The combination of the different expertise of the supervision team allow for an ambitious and innovative project:

- Design, synthesis and characterization of various supported porphyrin-chitosan photocatalysts with different compositions and structures. The chitosan and porphyrin derivatives will be selected based on structure-property relations.
- Evaluation of photocatalytic activity for dye degradation: We will assess the efficiency of the synthesized photocatalysts in degrading different organic dyes under simulated sunlight irradiation.
- Investigation of the mechanism of photocatalytic dye degradation: We will study the mechanism and kinetics of dye degradation by the photocatalysts with different porphyrins using various techniques, including electron spin resonance spectroscopy and scavenger studies. This will help us understand the fundamental processes involved in dye mineralization.
- Assessment of the reusability and stability of the photocatalysts: We will evaluate the reusability and stability of the developed photocatalysts over multiple dye degradation cycles. This is crucial for ensuring the long-term sustainability and economic feasibility of the technology.

3. METHOD AND SCIENTIFIC APPROACH: This research project offers a novel and more-efficient approach to photocatalytic dye degradation compared to existing methods. The key innovation lies in the synergic approach of the supervision team, which given its specific set of skills and expertise can address and overcome the current identified limitations :

a) **Chitosan characterization:** Traditional methods for chitosan deacetylation degree determination are inaccurate and hinder understanding the property-structure relationship crucial for optimizing chitosan films. This project proposes utilizing free-solution capillary electrophoresis and Taylor Dispersion Analysis for accurate characterization. Additionally, heterogeneity measurement will be crucial for comprehensive understanding. (expert: P. Castignolles, SU)

a) **Porphyrin derivatives:** Commercially available porphyrins present limitations due to their incompatibility with chitosan and polar solvents, hindering homogeneous dispersion within the matrix. The project will address this by synthesizing tailor-made porphyrin derivatives specifically designed for compatibility and optimal performance. (expert: L. Sosa Vargas, SU)

b) **Composite film preparation and characterization:** Understanding and optimizing photocatalytic properties requires a thorough nanoscale characterization of the composite films. We will then characterize their physicochemical properties, including surface area, porosity, and light absorption capacity. This project will employ a variety of techniques like SEM, AFM, surface energy measurements, and spectroscopic analyses (Raman, infrared, absorption) to achieve comprehensive characterization.

c) **Photodegradation studies & optimization:** The project will extensively evaluate various parameters (concentrations, film thickness, light exposure times, pH) for different dye contaminants to identify the optimal conditions for efficient photodegradation. (expert: M. Rivera Hernandez, UNAM)

PROFILE AND SKILLS REQUIRED of PhD candidate

- Strong expertise in synthetic organic chemistry
- Rigorous research and analytical skills, demonstrable problem-solving abilities and critical thinking
- Ability to work in an interdisciplinary, multicultural team
- Fluent in English , basic knowledge of French is appreciated

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