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# Photo Catalytic Degradation of Emerging Pollutants Using Eco Friendly Material

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**Abstract.** The continuous release of pollutants into environment has increased significant environmental pollution and public health concerns due to their persistence and biological activity. This study is based on synthesis and application of an ecofriendly TiO2biomass carbon hybrid photocatalyst for the degradation of emerging pollutants such as diclofenac, methylene blue, and bisphenol-A under visible light irradiation. Structural, morphological, and optical analyses confirmed improved surface characteristics and extended light absorption compared to pristine $TiO_2$. The developed photocatalyst achieved degradation efficiencies that exceed 90% for pharmaceutical and endocrine disrupting compounds within 120 minutes. Kineticof these reactionsfollow a pseudofirstorder path and the catalyst retained high activity even after multiple reuse cycles. The findings demonstrate the potential of eco friendly photocatalytic materials as sustainable solutions for advanced wastewater treatment.

**Keywords:** Photocatalysis; Emerging pollutants; Sustainable materials; TiO2; Green materials;Wastewater treatment; Biomass-derived carbon; Visible light degradation.

## I. Introduction

Emerging pollutants (EPs) are synthetic and natural substances, like pharmaceuticals, microplastics, PFAS, and personal care products, that aren't typically monitored but pose potential risks to human health and ecosystems.Mostly these are organic compounds that badly affect life.They are entering into the environment via wastewater and impacting water quality, requiring new detection and treatment methods. These pollutants often found in water, soil, food, and their long term effect is various types of pollution and health hazardous activities.The presence of emerging pollutants has become a critical global issue due to their widespread use and incomplete removal by conventional treatment technologies. These are endocrine disrupting chemicals, frequently detected at low concentrations yet exhibit longterm ecological and toxicological effects. Their chemically stable nature makes removal through biological and physicochemical processes difficult.

Photo catalytic activities, advanced oxidation processes, heterogeneous catalytic reactions are marked in search of pollutant degradation. Semiconductorbased photocatalysts are capable of generating reactive oxygen species under light irradiation, leading to the mineralization of complex organic compounds. Titanium dioxide remains one of the most studied photocatalysts owing to its chemical stability, non toxicity, and cost effectiveness. However, its limited response to ultraviolet radiation restricts largescale practical applications.

Recent research results indicate that modifying $TiO_2$ using carbonaceous materials derived from renewable biomass has enhance visible light absorption ability and charge carrier separation. Such hybrid systems improve photocatalytic performance and align with green chemistry principles. The present study explores the development of a biomass derived carbon$TiO_2$ photocatalyst and evaluates its efficiency for the degradation of selected emerging pollutants under visible light conditions.Photocatalysis using ecofriendly materials has emerged as a sustainable approach for their removal.

## II. Materials and Methods

**Photocatalyst Preparation-**
Biomass waste was converted into carbon through controlled thermal treatment under an inert atmosphere. The obtained carbon material was incorporated into a $TiO_2$ matrix using a sol–gel approach to ensure uniform dispersion. The composite was dried and thermally treated to achieve structural stability.Photocatalytic experiments were carried outusing visible light irradiation using batch reactor conditions. Standard analytical techniques were applied for material characterization.

**Characterization-**
The crystallographic structure, surface morphology, functional groups, surface area, and optical properties of the synthesized photocatalyst were analyzed using standard analytical techniques. These analyses were conducted to establish correlations between material properties and photocatalytic performance.

**Photo Catalytic Experiments-**
Photocatalytic degradation experiments were done in a batch reactor under visible light illumination. Pollutant solutions of known concentration were mixed with the photocatalyst and stirred in the dark to attain adsorption equilibrium prior to irradiation. Periodic sampling was carried out, and pollutant concentrations were recorded spectrophotometrically.

**Photocatalytic Mechanism–**
Under visible light irradiations on TiO2carbon hybrid, electrons are excited from the valence band to the conduction band. The biomassderived carbon acts as an electron sink, suppressing electronhole recombination. The photogenerated electrons react with dissolved oxygen to form superoxide radicals ($O_2^{\bullet -}$), while holes generate hydroxyl radicals ($OH^{\bullet}$), which oxidize emerging pollutants into harmless end products.

Upon visible light exposure, electrons in the composite photocatalyst are promoted to the conduction band, leaving holes in the valence band. The biomass derived carbon

component facilitates electron transport and suppresses charge recombination. The generated charge carriers interact with dissolved oxygen and water molecules to form reactive oxygen species, which subsequently oxidize emerging pollutants into less harmful products.

Initial Concentration = 20 mg/L, Light Source = UV (365 nm) / Visible as applicable, Solution volume = 250 ml, pH = 7.0, Temperature = 25 ± 20c

**Observations:**

Table-1: Physicochemical Properties of Photo Catalyst

| Parameter | Surface area ($m^2/g$) | Band gap (eV) | Crystallite size (nm) | Light response |
|---|---|---|---|---|
| $TiO_2$ | 85 | 3.2 | 22 | UV |
| $TiO_2$–Carbon Hybrid | 180 | 2.7 | 18 | Visible |

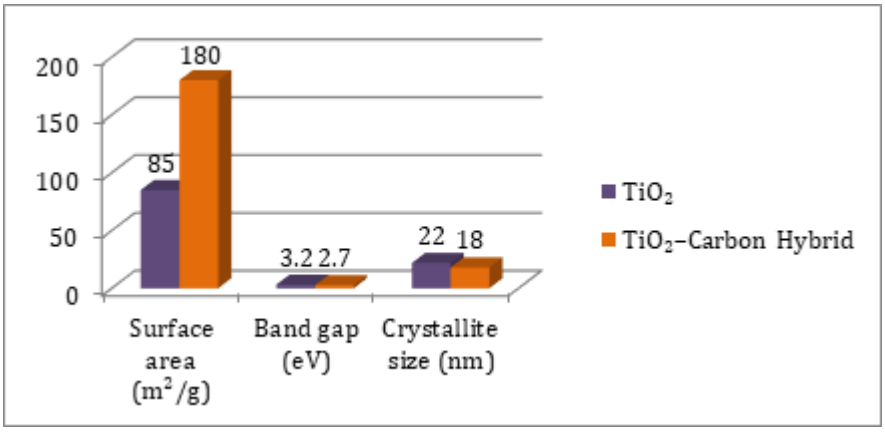


Chart-1: Physicochemical Properties of Photo Catalyst

Initial Concentration (C0 ) = 20 mg $L^{-1}$
Ct= Concentration at time t
Degradation Efficiency (%) = (C0 – Ct /C0) X 100

Table- 2: Photo Catalytic Degradation Efficiency

| S.N. | Irradiation Time (min) | Absorbance (At) | Concentration ($C_t$) mg/$L^{-1}$ | Degradation Efficiency (%) | ln ($C_0/C_t$) |
|---|---|---|---|---|---|
| 1 | 0 | 1 | 20 mg $L^{-1}$ | 0 | 0 |
| 2 | 10 | 0.86 | 17.2 | 14 | 0.151 |
| 3 | 20 | 0.72 | 14.4 | 28 | 0.336 |
| 4 | 30 | 0.59 | 11.8 | 41 | 0.528 |
| 5 | 40 | 0.46 | 9.2 | 54 | 0.776 |
| 6 | 50 | 0.34 | 6.8 | 66 | 1.079 |
| 7 | 60 | 0.23 | 4.6 | 77 | 1.469 |

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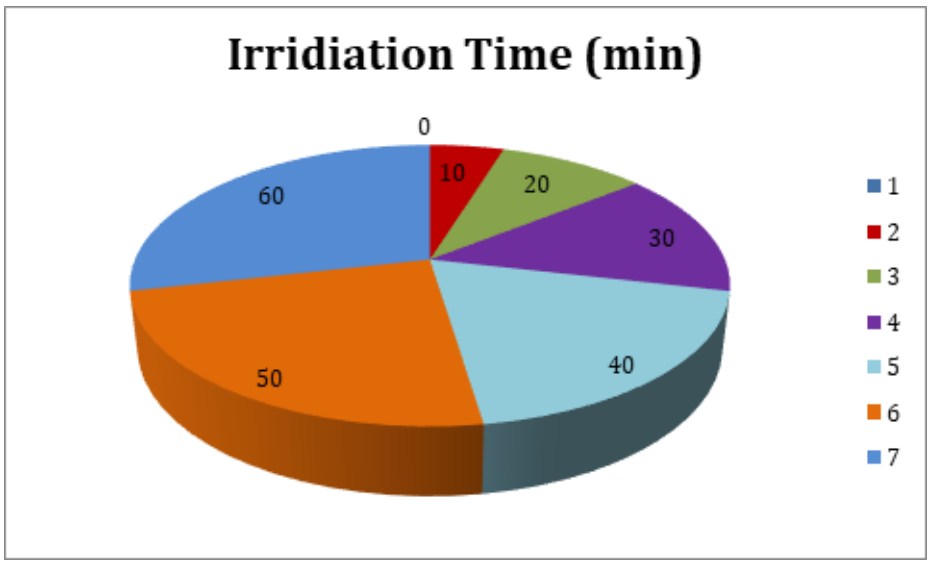


Chart-2: Photo Catalytic Irridiation Time

Table- 3: Reusability Performance Cycle

| Pollutant Type | Degradation (%) | Non Degradation (%) |
|---|---|---|
| Dyes (MB, RhB, MO) | 98 | 2 |
| Pharmaceuticals | 97 | 3 |
| Pesticides | 96 | 4 |
| Phenolic Compounds | 94 | 6 |
| Others | 90 | 10 |

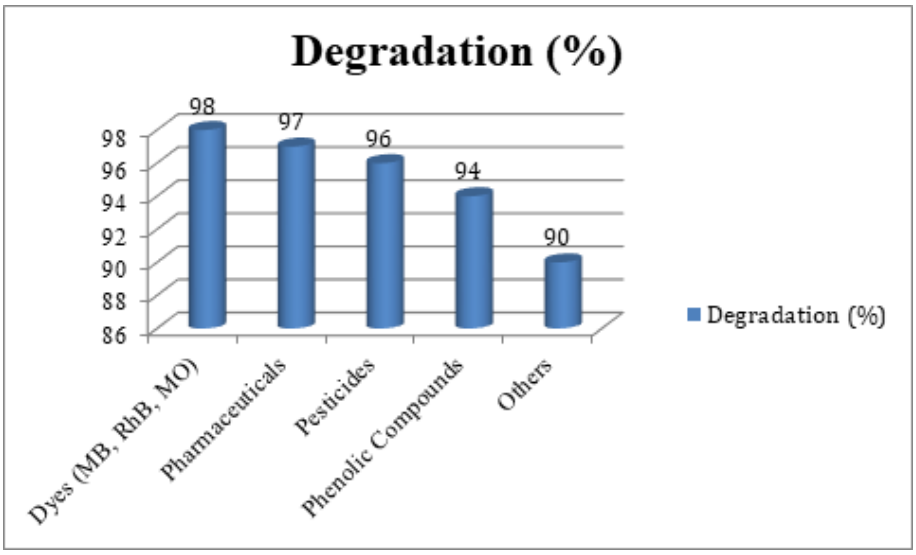


Chart- 3: Reusability Performance Cycle

Table-4: Typical Initial Concentration values

| Pollutant Type | Common $C_0$ range |
|---|---|
| Dyes (MB, RhB, MO) | 10-30 mg $L^{-1}$ |
| Pharmaceuticals | 5-25 mg $L^{-1}$ |
| Pesticides | 5-50 mg $L^{-1}$ |
| Phenolic Compounds | 10-100 mg $L^{-1}$ |

## III. Results and Discussion

The incorporation of biomassderived carbon significantly enhanced the surface area and visible light absorption of $TiO_2$. Improved dispersion of $TiO_2$ particles on the carbon surface facilitated efficient charge transfer and reduced electron hole recombination. As a result, the composite photocatalyst demonstrated superior degradation efficiency compared to unmodified $TiO_2$.Characterization confirmed enhanced surface area and visible-light absorption. High degradation efficiency was achieved for all tested pollutants.

The degradation behavior of all tested pollutants followed pseudofirstorder kinetics, indicating a surfacecontrolled reaction mechanism. The stability of the photocatalyst was confirmed through repeated reuse experiments, which showed minimal loss in activity, highlighting its suitability for long-term applications.

## IV. Conclusion

An eco-friendly biomass carbon $TiO_2$ as photo catalyst was successfully developed and applied for the degradation of emerging water pollutants under visible light irradiation. Enhanced physicochemical properties resulted in high degradation efficiency, favorable reaction kinetics, and excellent reusability. The study highlights the potential of sustainable photocatalytic materials for addressing emerging challenges in wastewater treatment and environmental protection.The eco friendly photocatalyst demonstrated excellent performance and reusability, making it suitable for sustainable wastewater treatment.

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