A Review Removal of Organic Pollutants in a Wastewater using a Solar Titanium Dioxide Photocatalysis Method[1]

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ABSTRACT

Solar titanium dioxide photocatalysis is an effective method for the removal of organic pollutants from wastewater. This method uses a photocatalyst, such as titanium dioxide (TiO_2), which is activated by ultraviolet light to break down organic pollutants into harmless byproducts. The photocatalyst is suspended in the wastewater and exposed to sunlight, which causes the TiO_2 to absorb energy from the UV light and produce reactive oxygen species (ROS). These ROS react with the organic pollutants, breaking them down into harmless byproducts such as carbon dioxide and water. This process can be used to remove a wide range of organic pollutants from wastewater, including dyes, pharmaceuticals, pesticides, and other contaminants. Solar titanium dioxide photocatalysis is an efficient and cost-effective way to reduce organic pollutant levels in wastewater.

Keywords: *AOPs; titanium dioxide; wastewater; photocatalyst*

INTRODUCTION

Water pollution has become a major global concern in recent times, as rapid urbanization and industrialization have led to an increased focus on freshwater conservation and management **(Shandilya *et al.*, 2018).** Despite the implementation of various environmental regulations to control water pollution, pollutants such as dyes, heavy metals, and organic compounds are still being released into freshwater ecosystems, causing disruption to their associated resources **(Gupta *et al.*, 2013).**

The advanced oxidation process (AOP) is a widely used technique for controlling organic pollutants in water or air, due to its potential for the oxidation of non-traditional pollutants such as dyes and phenolic compounds **(Zewde *et al.*, 2019).** Chemical precipitation, electro-deposition filtration, membrane systems, and ion exchange adsorption are some of the traditional methods of treatment of water; however, these methods may not be very effective for the removal of highly toxic compounds from potential sources of drinking water **(Teh and Mohamed, 2011).** Therefore, it is necessary to investigate the use of active catalysts for this purpose. Semiconductor heterogeneous photocatalysis has been found to be a promising approach for this application **(Akerdi and Bahrami, 2019).**

Heterogeneous photocatalytic oxidation, which was developed in the 1970s, has gained considerable attention due to its ability to completely mineralize organic compounds into carbon dioxide, water vapor, and inorganic components when exposed to sunlight **(Chen *et al.*, 2019)** and lead us to a " clean and green sanctification technology " for treating defiled air and water **(Madjene *et al.*, 2013)**.

The process of photocatalysis involves the use of semiconductor material, such as titanium dioxide (TiO_2), which is activated by light to produce reactive oxygen species (ROS) (**Ribao *et al.*, 2019**). These ROS are highly reactive and can oxidize organic pollutants, leading to their decomposition into harmless products (**Sun *et al.*, 2019**). The efficiency of this process is dependent on the type of semiconductor material used, the intensity of light, and the presence of other catalysts or additives **(Chen *et al.*, 2020)**. In addition, the pH and temperature of the solution also play an important role in determining the effectiveness of photocatalysis **(Jiang *et al.*, 2015)**. The use of photocatalysis for water treatment has been studied extensively in recent years and has been found to be effective in removing a wide range of pollutants from water sources.

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TiO_2 Photocatalysis

TiO_2, also known as titania, is widely used in photocatalysis due to its high activity, inertness, stability, affordability, and non-toxicity **(Raza *et al.,* 2020).** It is the most studied semiconductor for chemical conversion and solar energy storage as it absorbs only 5% of the solar light that reaches the Earth's surface. Its properties make it an ideal choice for the degradation of organic pollutants **(Khalilova *et al.,* 2018).**

TiO_2 is a semiconductor with a band gap energy of 3.2 eV. When exposed to photons with an energy greater than 3.2 eV (wavelength $\lambda < 388$ nm), the band gap is bypassed and an electron is promoted from the valence to the conduction band **(Khani *et al.,* 2019).** This process is known as charge carrier generation:

$TiO_2 + 2h\nu \rightarrow 2\ e^- + 2\ h^+$

$H_2O + 2h^+ \rightarrow 1/2O_2 + 2H^+$

Due to the large band gap of TiO_2, researchers have been attempting to modify its structure in order to reduce the energy requirements for electron-hole production and separation, making it compatible with solar light. Currently, doping with metal ions such as rare earth metals, noble metals (Au, Pt Ag, and Pd), transition metals (Mn, Fe, Co, Ni, Cu, Zn) and non-metals has been explored as a potential solution **(Khalilova *et al.,* 2018).**

Table 1. summarizes some of the results of the literature regarding the application of TiO_2 catalyst for the removal of organic pollutants from wastewater.

Treatment System	Classification	Materials	Pollutant	Light Source	Effects %	Ref
Organic CHemicals	**Dyes** (Water-soluble, not readily biodegradable, harmful to the ecosystem)	TiO_2/ZnO/ rGO Ni-TiO_2 Fe-TiO_2 nanotubes Pt-TiO_2 nanoparticles	MB, RhB, MO MB MB RhB	UV/simulated solar illumination (300 W) Xenon Lamp Solar UV/Visible light	99.6 98.9 98.79 63	**(Nguyen *et al.*, 2020)** **(Mohseni-Salehi *et al.*, 2018)** **(Wang *et al.*, 2017)** **(Pol *et al.*, 2015)**
	Phenolic Compounds (Highly soluble in water,toxic, biologically recalcitrant	TiO_2-x CuO-TiO_2 Mn-TiO2 nanopowder	BPA Phenols phenols	Vis light UV light (96 W) UV	95.3 100 90	**(Tang *et al.*, 2020)** **(Çinar *et al.*, 2020)** **(Sudrajat *et al.*, 2020)**
Pharmaceutical	**Anti-biotics** (Water-soluble, not readily biodegradable, harmful to the ecosystem)	TiO_2/CuO/MCM-41 Fe,N–TiO_2	Tetracy-cline Amoxycilin streptomycin, diclofenac	UV light (125 W) Visible light lamp (23 W with wavelength emission above 400 nm	70.4 58.6 49.7 72.3	(**Khanmohammadi *et al.*, 2021)** **(Aba-Guevara *et al.*, 2017)**

	Anti-inflammatories (High polarity, hydrophilicity, the absorption coefficient in the soil is low	TiO_2	Ibuprofen	Simulated solar irradiation (500 W)	87	**(Khalaf *et al.*, 2020)**
	Lipid regulators (Highly soluble in water, acutely toxic, biologically recalcitrant	TiO_2-ZrO_2 TiO_2	Metformin, Amoxicillin, metformin	UV light (125 W) UV lamp (125 W)	50.0 90 98	**(Carbuloni *et al.*, 2020)** **(Chinnaiyan *et al.*, 2019)**
Pesticides	Toxicity, biological resistance	Ag/Ag_2O-TiO_2 TiO_2/Ce Au/TiO_2	Imazapyr Profenofos Triazophos Phenoxyacetic –acid	Vis light (1 mW/cm2) Simulated xenon light Vis light	100 98.7 87	(**Mkhalid *et al.*, 2020)** **(Liu *et al.*, 2019)** **(Lannoy *et al.*, 2017)**
Herbicides	Toxicity, biological resistance	Ti-N(1: 1.6)	Picloram, Clopyralid Triclopyr (5 mg/L of each)	Black light lamps (UVA range);	95 45 90	**(Solís *et al.*, 2016)**
Micro organisms	Causing a variety of gastrointestinal diseases, adenoviruses	g-C3N4@Co-TiO2 nanofibrous	Escherichia coli	Vis light (300 W)	6 log inactivation	**(Song et al., 2020)**

MB: methylene blue; **MO**: methyl orange; **BPA**: bisphenol A; **RhB**: rhodamine

CONCLUSION AND FUTURE OUTLOOKS

The use of modified TiO_2 photocatalysts, incorporating metal ions to increase their photocatalytic efficiency, is becoming increasingly popular for the removal of organic pollutants from water. This is due to its low cost, safety, and high photocatalytic activity when exposed to ultraviolet light or solar radiation. This paper aims to provide insight into this trend and help researchers understand the potential of this advanced oxidation technology for water treatment.

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