# A Recent Trends on Nanomaterials Based Photocatalysts for Antibiotic Degradation

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*Abstract*— **Nano materials are effective for the removal and photo catalytic degradation of organic contaminants because of their textural characteristics, wide surface area, electrical conductivity, and magnetic properties. The literature claims that solar energy can efficiently (i) be transformed into fuel or electricity, (ii) degrade chemical and microbiological contaminants, and (iii) aid in the purification of water when combined with a photo catalyst. Nano-photo catalysts are particularly promising for treating antibiotic-resistant bacteria and removing antibiotics from wastewater. Their small size also makes them effective for treating bacterial infections caused by intracellular pathogens in water, offering an eco-friendly and sustainable approach. Thus, there is a lot of interest in finding novel, stable, and effective photo catalysts with a wide range of possible applications.**

*Index Terms*— **Antibiotics, Emerging Pollutants, Hetero junction, Nano materials, Photo catalysts**

## I. INTRODUCTION

Antibiotics are used to prevent or decrease bacterial development and infection, lower mortality rates, and boost both human and animal immune systems [1, 2]. Among aquaculture and livestock, Antibiotics are frequently used to enhance animal development and productivity and stop bacterial illnesses [3, 4]. According to the World Health Organization (WHO), antibiotics account for almost 80% of use in the animal production sector. Over 100,000 tons of antibiotics are consumed annually worldwide [5, 6]. However, the complex microbial community in the environment has developed antimicrobial resistance as a result of the uncontrolled release of antibiotics into the environment. Hospital, residential, and animal wastewater, as well as industrial sewage from pharmaceutical enterprises, releases antibiotics into the environment [7]. Chloramphenicol, tetracycline, sulphonamide, and nitrofurans are the most widely used antibiotics in the aquaculture sector, particularly in Asia. These antibiotics effectively inhibit positive and negative microorganisms

Among a number of environmental contaminants, including nutrients, dyes, and heavy metals. During the wastewater treatment process, antibiotics are not completely broken down [8–11], but the majority of these antibiotics are released into the environment where they were found. Therefore, it is essential to eradicate the environmental toxicity of both human and animal creatures and stop the rise of microorganisms resistant to antibiotics in water and wastewater.

Nanotechnology is a field of science where nano materials play a vital role in antibiotic applications. Due to their low cost, high efficiency, and environmental friendliness, nanomaterials have gained attention for breaking down antibiotics and other pollutants. A nanometer (nm) is one thousand millionth of a meter ($10^{-9}$). When bulk particles become nano sizes, the surface to volume ratio increases, a greater number of atoms present at the surface and material becomes more reactive. Because of this, nanomaterials provide great benefits on human health and environment [12]

## II. LITERATUREREVIEW

The increasing rate of water and air pollution, they may impact human health, causing depletion of biodiversity, climate changes, respiratory diseases, which may negatively impact the world economy.

Therefore, the need for innovative and sustainable pollution control and clean energy production systems is urgent [13]. Semiconductor assisted photo catalysis is essentially a cost-effective process in this regard; it has drawn a lot of interest among AOP approaches and can happen at both solid/liquid and solid/air interfaces. Photo catalysis is a phenomenon, in which an electron-hole pair is generated on exposure of a semiconducting material to light (includes reactions that take place by utilizing light and a semiconductor). It is necessary to find the best metal doping because too much metal doping will block reaction sites, resulting in a decrease in photo catalytic reaction activity. When compared to photo catalysts made of a single material, heterojunctions typically perform better. The method for constructing the heterojunction enables the photo catalyst to have a proper band gap, widens the light absorption range of the photo catalyst, inhibits their combination of electron-hole pairs, and improves the photo catalytic effect [14].

Nano photo catalysts are tiny semiconductor particles that utilize light energy to break down antibiotic molecules into harmless byproducts, offering a promising approach to treat antibiotic-contaminated water by generating highly reactive oxygen species (ROS) through a process called photo catalysis. Nano photo catalysts can be developed due to the oxidizing ability by generating oxidizing species. They can degrade different compounds under light irradiation as the water treatment method, and water, carbon dioxide, and other inorganic ionic compounds are formed

In recent decades, plenty of technologies have been employed to enhance semiconductor photo catalysts' photo catalytic coating performance. Though very well-known photo catalysts, $TiO_2$, ZnO, and $Cu_2O$, cadmium sulfide (CdS), bismuth oxide ($Bi_2O_3$), cerium oxide ($CeO_2$), iron oxide ($Fe_2O_3$), tungsten trioxide ($WO_3$), silver nano particles, Carbon nanotubes and antimicrobial coatings and copper oxide (CuO), with $TiO_2$ being the most widely studied due to its stability and low toxicity. Both photo catalyst development and coating characteristics need to be taken into account in order to create an antimicrobial coating that is both effective and long-lasting. The three main strategic methods for enhancing photo catalytic performance are doping, synthesis, and heterojunction creation [15]

$TiO_2$

The primary focus of this review has been on the photo catalytic performance of different $TiO_2$ and $TiO_2$-based materials as well as the impact of various process factors (amounts of pollutant and photo catalyst, pH, light, reaction media, presence of inorganic ions, natural organic matter, and oxidants). Sulfamethoxazole, trimethoprim, and ciprofloxacin are highlighted in particular since they are the most frequently found antibiotics in many aquatic systems, from fig. 1 which raise serious issues. It has been emphasized how urgently contaminated water must be cleared of antibiotics. Given that traditional wastewater, several antibiotic removal technologies have been briefly described in case treatment is unable to eliminate such complex pharmaceutical contaminants. The principles of the photocatalytic process over $TiO_2$ have been discussed [16], as well as techniques for modifying TiO2 to get around its drawbacks and improve efficiency.

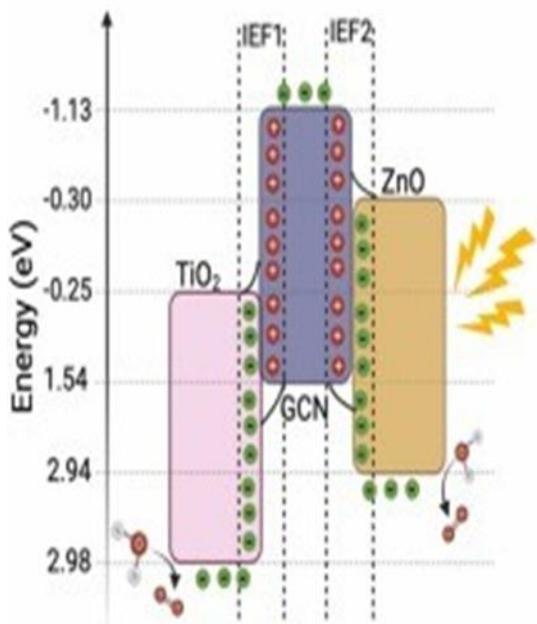


Fig1:Graphitic carbon nitride sheets sandwiched metal oxides: A novel platform for S-Scheme heterojunction generator for efficient photodegradation of volatile organics[17]

A thorough examination at the market for TiO2-based photocatalytic building materials reveals that many Nanomaterials companies (>2000) have created building materials in the form of water purification facilities (waste and sewage water purification), air purification systems (air cleaners, air conditioners, air cleaner hybrids, etc.), and interior decoration products (antibacterial and self-cleaning tiles, smart windows, wallpapers, etc.). [18].

$Bi_2O_3$:

The photocatalytic activity of a bismuth oxide with different dyes and their efficiency are explained here. (fig.2), the review also emphasized the importance of reducing the particle size of $Bi_2O_3$ nanoparticles to increase their surface-to-volume ratio, which enhances their photo catalytic and antibacterial activities, if the $Bi_2O_3$ material is exposed to the light of larger photon energy, the wide band gap of $Bi_2O_3$ enables the development of electron hole pairs. The findings of this study provide valuable information for optimizing the parameters of $Bi_2O_3$ nanomaterials for photocatalytic and antibacterial applications. By selecting the most stable phases of $Bi_2O_3$ and optimizing synthesis parameters, efficient and effective [18]

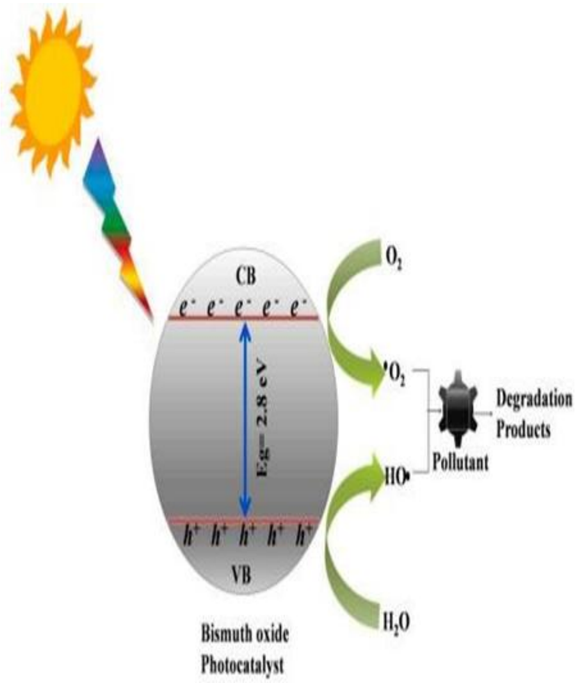


Fig 2: Mechanism of photocatalytic activity of $Bi_2O_3$[19]

$Bi_2O_{3v}$based hetero junction materials can be developed for various applications. These insights into the properties and characteristics of Bi2O$_3$ provide a solid foundation for future research in the field of nano materials and their applications.

ZnS: ZnS based nanostructures, use to their strong photocatalytic properties, these nanostructures are useful for the breakdown of a variety of pollutants, including antibiotics (e.g., norfloxacin, penicillin G, dyes in aquatic and non-aquatic settings, as well as antibiotics (such as ampicillin, cloxacillin, amoxicillin, and penicillin V). In photocatalytic applications, ZnS nanostructures exhibit promising potential, especially when it comes to the degradation of toxic organic dyes in aqueous conditions. ZnS-based QDs have shown exceptional ability in dye degradation, as evidenced by the single-step synthesis of ZnS QDs, which completely degraded under visible light and rapidly decayed under UV light.

$MoS_2$: Molybdenum disulfide-based photo catalysts are efficient, nontoxic and useful in the treatment of antimicrobial contaminants. This is the first discussion of the technologies utilized by $MoS_2$-based nano composites and aerogels for effective antibiotic degradation. This review clarifies the degradation mechanism from photoelectron transfer pathways and ROS features of $MoS_2$-based nanocomposites and aerogels, which may aid researchers in better understanding the state of research on these materials for the removal of antibiotics

## III. AQUA CULTURE WASTEWATER BY BIONANOPARTICLES

The environmental pollution caused by antibiotics has seriously affected human health and eco system. This literature shows that a number of parameters affect photocatalysis efficiency. The elimination mechanism of the antibiotic is suggested by the following observations made by several authors; Nano particles like ZnO and $TiO_2$ facilitate the photocatalysis of antibiotics. At neutral pH, photo catalytic degradation demonstrated great efficiency. The catalyst facilitates the photo catalytic breakdown of antibiotics by hydroxylation and releasing the drugs' functional group. Additional nanoparticles used in the bio synthesis process utilizing microorganisms or plants, as well as nanoparticles employed on an industrial scale in the breakdown of antibiotic residue, are planned for future research. Because photo catalysis is an environmentally benign process, sophisticated methodologies are employed to identify the most favorable element influencing it [20]

## IV. METHODOLOGY

NPs are produced by physical, chemical, and biological methods. Methods for sol-gel, hydrothermal, co-precipitation, thermal breakdown, and precipitation. Electrochemical techniques are also used in chemical processes. New methods for creating novel mechanisms for the breakdown of antibiotics have been made possible by the synthesis of NPs from diverse sources

Depending on their size, shape, characteristics, morphology, and electrical charges, NPs can degrade through a variety of ways. To enhance the degradation process, the antibacterial impact against microbial growth, and the production of biofilms, additional ingredients are used. Various synthetization techniques are available to prepare nano materials.


Fig 3: Nano materials synthesis techniques [21]

## V. RESULTS

In this, yields outstanding insights that may encourage foster researchers and beginners to proceed and expand their investigation of nature's potential, as well as the development of effective for nanoparticle synthesis with desirable characteristics, which can be utilized in a variety of disciplines and sustainable methodologies.

Table: 1 Nano materials with suitable irradiation and environmental uses [22]

| NM type | Synthetic method | Light used for Irradiation | Environmental Applications |
|---|---|---|---|
| $Ag_2S/Bi_2WO_6$ | Hydrothermal Method | visible light | RhB degradation |
| CuS/ZnS | Hydrothermal method | visible light | $H_2$ Production, Acid blue degradation |
| $SnO_2$ | Microwave assisted | visible light | Photo oxidation of RhB |
| NM type | Synthetic method | Light used for Irradiation | Environmental Applications |
| Nano spheres Cds Nano particles | Solvothermal method | visible light | Degradation of methylene blue and RhB |
| Cds | Chemical Precipitation method | visible light | Acid Blue-29 degradation |
| Nano particles $Fe2O_3$/BiOI | Hydrolysis method | visible light | RhB degradation |
| ZnO/ Zn(OH)F | Micro fluidic Chemical Method | UV light | Photo Degradation of MB |
| $TiO_2/WO_3$ | Hydrothermal method | visible light | Degradation of diclofenac |

## VI. DISCUSSION

The development of $TiO_2$-based photocatalysts that are active in the presence of sunlight should receive particular attention. Solar photocatalysis is not only a cost-effective solution, but also a sustainable one, given that the use of visible and ultraviolet light sources is linked to high energy expenditures. Additionally, extremely stable photocatalysts that are easily removed from aqueous solution (immobilized/supported catalysts) and effectively reused over several cycles can be developed to further reduce costs; the promise of the photocatalytic technique over $TiO_2$-based materials for the effective removal of antibiotics as well as ARB and ARGs from wastewater need more investigation [23].

Real wastewater samples should be used for photo catalytic testing in order to meet industrial application requirements. Wastewater has a complex makeup that includes a variety of inorganic materials, organic contaminants, and various medications, when compared to the degradation efficiency of a single antibiotic in filtered water; this lowers the degradation efficiency of antibiotics.

It is also necessary to build and develop pilot plant facilities that run constantly in the presence of sunlight. More research should be done to determine how effective integrated techniques are. Researching heterogeneous photo catalysis alongside more conventional therapy methods, such biological treatment, is crucial to developing a technically an affordable and useful wastewater treatment system [24]. One popular way for increasing photocatalytic activity is doping, which involves adding foreign elements or ions to the host materials by altering the MO semiconductor materials' electronic structure and bandgap. Finding the ideal metal doping is essential because too much metal doping will obstruct reaction sites and reduce the activity of photocatalytic reactions. The performance of heterojunctions is generally superior to that of single material photocatalysts. It has been demonstrated that Z-scheme heterojunctions enhance charge carrier separation and visible light absorption.

Heterojunction devices with enhanced photocatalytic activity have been created as a result of ZnS coupling with other semiconductors because enhanced usage of a larger solar spectrum and better charge separation. Metal doping, heterojunction assembly, and shape engineering are some of the techniques used to increase ZnS ‘photocatalytic activity in the visible light spectrum. Creating and creating stable ZnS-based heterostructures is especially crucial to extending the visible region's photocatalytic response and enhancing the photocatalytic performance of single ZnS photocatalysts, which are vulnerable to photo-corrosion.

## VII. CONCLUSION

Metal oxides are promising photo catalysts for photo catalytic antimicrobial applications. Photo catalytic antimicrobial coatings or self-disinfecting surfaces are effective solutions for preventing the spread of microorganisms to combat the spread of contagious diseases.

$Cu_2O$, $TiO_2$ and ZnO are among the metal oxides with the potential to be used for photo catalytic antimicrobial applications. A highly effective photo Catalyst must have the desired band gap, an ideal morphology, a large Surface area, stability, and reusability.

Doping techniques, or the Incorporation of foreign elements or ions into the host materials, is a Common method for improving photo catalytic activity by modifying the Band gap and electronic structure of MO semiconductor materials. The strategies for boosting the photo catalytic activity of photo catalysts and selecting the right coating method need to be further explored to broaden the photocatalytic antimicrobial applications for various microorganisms.

## VIII. ACKNOWLEDGEMENT

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