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ZnO nano for remediation of methylene blue dye: A short review

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Abstract
The presence of dyes in wastewater and water resources is one topic that is getting attention on a global scale. In the present decade, dye-based categories have seen vast development due to the rising need for garments by the increase in population. Mostly used dye in textiles is Methylene blue, which gives dye outflow contamination. It is dangerous and very risky for the surroundings. There are countless sources of methylene blue dye and their adequate medical care methods are inscribed in this present review. The multifunctional ZnO nanomaterial is more effective as a semiconducting photocatalyst than other materials because of its low cost, eco-friendliness, structure-dependent characteristics, and complete mineralization of pollutants. Among nanoparticles photocatalysts, ZnO have shown major capability for photoactive methylene blue deterioration. These metal oxides nanoparticles are the best perfect matter for abolishment of water contaminants, like materials are connected to the attributes of purity, malleability, adaptability, productivity and are highly reactive. The structure of methylene blue dye is highlighted and health impact as well as their effect environment are also discussed. Taking account of all these crucial aspects, the recent advances for remedy of cationic dyes methylene blue by applying ZnO nano is spotlighted in this current review.

Keywords: ZnO nanoparticles, dye degradation, methylene blue, environmental remediation

1. Introduction

Water pollution is an earnest ecological delinquent that threatens the delicate balance of the ecosystem. Growing population means that more unnecessary water is being dumped into essential water sources. One of the contaminants in waste water is dye, that is broadly applied in a diversity of industries, like the manufacturing of food, textiles and paper. (Al-Tohamy *et al*., 2022) [1]. Above 10,000 diverse kinds of dyes are available worldwide, and over 7,000,000 tones are generated annually, according to the Colour Index. Over 87.5 tonnes of dyes are released as waste annually in staining and dyeing operations in the fabric industry as a result of the inadequate dying process (Artifon *et al*., 2021) [12]. Industrial wastes that are released into the environment pose major environmental risks because of their color, high COD, and intricate chemical composition. These hues are only slightly affected by detergents, temperature, light, soap, chemicals, water, and other factors like perspiration and bleach. Unwanted water attention does not benefit dyes, and they last a very long time in nature. Due to their artificial manufacture and complex behavior, antimicrobial combinations prevent biodegradation. Mosly dyes are poisonous and can impair microbial diversity, fish species, and produce mutagenesis and other adverse effect (Rolton *et al*., 2022) [5]. They can even kill individuals by harming the reproductive system, central nervous system, and brain. Some colors use benzidine and other aromatic compounds, which are known to be lethal poisons. Dye discharge poses a problem since 1 ppm of dye in potable water may not be suitable for human consumption. Organic molecules known as dyes can interact with a variety of materials or fabrics to provide long-lasting, vibrant color and they may be organic or nonorganic. The existence of aromatics, metals, as well as other substances in dyes makes them potentially harmful to marine life. Since most dyes are synthetic, they are more persistent and challenging to degrade due to their complex aromatic molecular structure. Chromophores and auxochromes are the two categories of chemicals that make up a dye (Vats *et al*., 2022) [7]. In this review, the methylene blue dye's structure is emphasised, and its effects on the environment and human health are also covered.

In addition, this paper highlights recent developments in ZnO nanotechnology for the treatment of cationic dyes like methylene blue.

2. Struture of Methylene Blue

The molecular weight of (heterocyclic basic dye) methylene blue (MB) is 373.9 g/mol and the highest peak wavelength is 665 nm. Its technical name is basic blue, and the chemical formula of M ethylene blue is $C_{16}H_{18}N_3SCl$. The figure shows the chemical makeup of MB dye. More poisonous than anionic dyes are the cat-ionic Methylene Blue dye. A few of the industries that use MB are rubber, leather, textile, cosmetics, plastics, food sectors, and pharmaceuticals (Modi *et al*., 2022) [6]. The structure of Methylene dye shown in Figure 1.

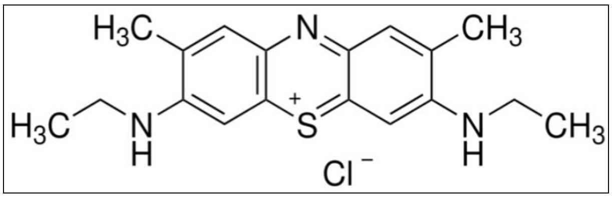

Fig 1: The structure of Methylene dye

3. Environmental and Health Effect of Methylene Blue

A pigment, index, and microbiological chemical, MB is a cationic and basic dye that is frequently used in medical field as medicine. Methylene Blue dye has been linked to cancer, hemolysis anemia, hyperbilirubinemia, mutation, lung toxicity, chromosomal failure, and acute renal failure. A tiny level (microgram) of MB is thought to produce cytotoxicity in human astrocytoma cells and neuroblastoma (U-373 MG and SK-N-MC, respectively). The calculated median lethal dose (LD_{50}) for MB in oral form was to be 1180 mg/kg (Ding *et al*., 2016; Modi *et al*., 2022) [3, 6]. When endotoxemia occurs, moderate and low concentration of MB raise arterial blood pressure, but high doses exacerbate myocardial depression, systemic hypertension and hypotension. High doses of MB have negative effects on gas exchange and increase vascular resistance in the mesenteric and renal blood flow. In addition, it results in a bluish patch of mucosa and skin and self-limiting greenish-blue urine (Oladoye *et al*., 2022) [2].

Because they are resistant to biodegradation and have high thermal and photostability, dyes may be persisted in the environment for extended time periods, which presents a number of health and environmental problems. The main way that dyes affect the environment is by their ability to absorb and reflect sun light into aquatic bodies. An increase in dye concentration in a body of water has an impact on several aspects of algal growth, such as protein, pigment, and other nutrient content (Dabhane *et al*., 2021) [4]. MB from the disposed-of locations has been reported to be able to enter water bodies and have an impact on the other microbial communities living there. The immediate harm that textile MB does to certain freshwater microalgae's development and metabolism. Acute toxicity was seen in *Spirulina Platensis* and *Chlorella vulgaris* exposed to MB. Growth inhibition rate, pigment inhibition, and protein content inhibition were the outcomes of the toxicity (Ramakrishnan *et al*., 2011) [8].

4. Remediation of Methylene Dye by ZnO Nano

Recently, due to overly strict government rules and environmental standards, the remediation of coloring chemical compounds has gained a lot of attention. Long-term sustainability and environmental protection require the exclusion of textile dyes from coloured effluents of manufacturing waste. The chemicals and textile industries release wastewater into water bodies that has a negative effect on the environment in terms of solids, COD, BOD, colour, salinity, pH and suspended (Zandsalimi *et al*., 2018) [11]. This is because the wastewater contains a significant amount of organic matter that is not biodegradable and needs to be treated using new and modified methods. Semiconductive materials like TiO_2 and ZnO have garnered public attention in the last 20 years as a potentially useful alternative to conventional wastewater treatment methods for photocatalysis. This is because of their materials' high photosensitivity, non-toxicity, stability, and wide band gap (Solayman *et al*., 2023) [9]. Although TiO_2 is arguably the most widely used photocatalyst, ZnO is an inexpensive substitute. It can adsorb over a greater portion of the UV spectrum and has a band gap energy of 3.2 eV, which is comparable to TiO_2. It has been found that ZnO has a higher photocatalytic effectiveness than TiO_2, particularly when it comes to the breakdown of organics in aqueous solutions (Abul *et al*., 2015) [10]. Recent studies shows that MB was remediate from the aqueous solutions using the created ZnO nanocomposite, with removal efficiencies ranging from 90 to 97% (Choudhary *et al*., 2023) [13]. By measuring the photo-enhanced catalytic activity of ZnO produced from the broccoli extract against MB under UV light irradiation, 74% degradation efficiency of the subsequent dyes were attained (Osuntokun *et al*., 2019) [14].

5. Conclusion

The primary focus of this review is on the use of modified and pure ZnO for the removal of MB dyes. Dye degradation using photocatalysis is a potential and promising strategy. The most effective method, according to a plethora of research and testing, is dye degradation mediated by ZnO and ZnO modified by dopants or composites. The literature research indicates that ZnO is a cost-effective and easily accessible photocatalyst than other types. ZnO was altered to improve its ability to break down dye compounds and other contaminants. In addition, the light, temperature, pH, dopant concentration, dye concentration and catalyst dose all have a significant impact on how efficiently materials degrade. ZnO is a superior option for research since it breaks down dyes more effectively in the presence of sunlight, which is another key point to remember. Future technological advancements could include the applications of ZnO (As a photocatalyst) to break down contaminants like dyes. It is anticipated that interest in ZnO will grow, leading to the identification of new uses for the substance.

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