Materials Today Sustainability 26 (2024) 100764

Contents lists available at ScienceDirect

Materials Today Sustainability

journal homepage: www.journals.elsevier.com/materials-today-sustainability

Green synthesis and photocatalytic insights: A review of zinc oxide nanoparticles in wastewater treatment

Rabia Tasaduq Hussain [a], Md Sanower Hossain [b], Jun Haslinda Shariffuddin [a,b,*]

[a] Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhraya Persiaran Tun Khalil Yaakob, 26300, Gambang, KuantanPahang, Malaysia

[b] Centre for Sustainability of Mineral and Resource Recovery Technology (Pusat SMaRRT), Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhraya Persiaran Tun Khalil Yaakob, 26300, Kuantan, Pahang, Malaysia

ARTICLE INFO

Keywords:
Modified ZnONPs
Unmodified ZnONPs
Photocatalysis
Conventional approach
Green approach

ABSTRACT

Embracing sustainable practices like photocatalysis for wastewater management is more crucial than ever. Nanotechnology enhances the effectiveness of photocatalysis, and zinc oxide nanoparticles (ZnONPs) are considered as a promising photocatalyst with large bandgaps and exciton binding energy, which can be synthesized through green approaches. As wastewater treatment with ZnONPs is deemed self-limiting due to various synthesis approaches, a critical evaluation of its purported benefits is necessary. This review summarized current scientific findings based on both unmodified and modified ZnONPs, primarily synthesized using plant sources as reducing and capping agents. The study highlights areas requiring further research, with many plant extracts having been utilized for ZnONP synthesis. Additionally, various dopants, such as carbon derivatives, metal oxides, N-type semiconductors, and metals, have been employed to modify ZnONPs, enhancing their photocatalytic activity. Investigation into biosynthesized ZnONPs, particularly from plant extracts and waste materials, reveals their significant impact on nanoparticle characteristics, including size reduction and bandgap energy control. Secondary metabolites from plant extracts play crucial roles as stabilizing, reducing, and capping agents. The study highlights the superior effectiveness of modified ZnONPs in photocatalysis compared to unmodified counterparts. Integrating renewable, biodegradable resources in bioinspired ZnO-modified photocatalysts opens new opportunities in green technology, offering potential alternatives for water treatment that are cost-effective and environmentally friendly. The utilization of ZnONPs in photocatalysis, particularly when derived from sustainable sources and modified through eco-friendly approaches, presents a promising avenue for addressing global water purification challenges and contributing to a more sustainable future.

1. Introduction

In the technologically advanced twenty-first century, the challenges of human survival are more pressing than ever. The need for pure water and energy is basic for human beings, and to meet this demand, many researchers devoted their lives to working tirelessly to develop improved methods to treat contaminated water. There is no doubt that photocatalysis has been a diverse topic that has spread since 1972 following the discovery of the Fujishma and Honda phenomena involving water splitting via TiO_2 electrodes under exposure to UV light-induced electrocatalysis [1]. Since then, numerous papers have been published on different semiconductors, such as the photocatalyst ZnO [2–4], $BiVO_4$ [5,6], CdS [7,8], and NiO [9]. The most preferable and durable photocatalytic semiconductor is TiO_2 [10]. Many studies have shown the efficient photodegradation of organic pollutants with the help of TiO_2 in various forms, such as nanoplastics [11]. Besides, ZnO is also a suitable choice due to its unique characteristics, such as high conductivity, low cost, and short bandgap, which have properties similar to TiO_2 [6,12–14]. Moreover, ZnO stands out as a photocatalyst among other metal oxides due to its nontoxic nature, thermal and chemical stability, and ease of handling [15,16].

Several recent studies have reported that ZnO can be effectively modified into different dimensional structures, such as zero-dimensional nanospheres [17,18], one-dimensional nanoneedles, nano-springs, and

* Corresponding author. Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuhraya Persiaran Tun Khalil Yaakob, 26300, Gambang, KuantanPahang, Malaysia.

E-mail address: junhaslinda@umpsa.edu.my (J.H. Shariffuddin).

https://doi.org/10.1016/j.mtsust.2024.100764
Received 19 January 2024; Received in revised form 21 February 2024; Accepted 22 March 2024
Available online 22 March 2024
2589-2347/