Journal of the Indian Chemical Society 99 (2022) 100560

Contents lists available at ScienceDirect

Journal of the Indian Chemical Society

journal homepage: www.journals.elsevier.com/journal-of-the-indian-chemical-society

Trash GGBFS-based geopolymer as a novel sunlight-responsive photocatalyst for dye discolouration

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ARTICLE INFO

Keywords:
Photocatalysis
GGBFS
Geopolymer
Wastewater
Solar energy
Methylene blue

ABSTRACT

In this study, we report a waste material-ground granulated blast furnace slag (GGBFS) as a low cost geopolymer, hybridised with ZnO to form a novel and efficient photocatalyst capable of discolouring textile wastewater. GGBFS is a waste material in an iron industry. Methylene blue was used as the probe dye and natural sunlight was used for activation of the photocatalyst. It was observed that under the experimental conditions, ZnGP-40 exhibited twice the discoloration efficiency than conventionally used ZnO or TiO_2. This enhanced performance is majorly attributed to increased surface area of ZnO when strewn in the GGBFS matrix. The photocatalysts were characterized by SEM, TEM, PSA, TGA, BET and UV–Vis/NIR. The effect of photocatalyst loading, speed of agitation and solar insolation has also been studied. Since this study has been performed in direct sunlight, it exhibits a realizable application of solar energy in the treatment of wastewater.

1. Introduction

Photocatalysis is an advanced oxidation process that uses a semiconductor material with appropriate bandwidth to generate electrons and holes, upon activation by light of suitable wavelength [1–4]. These electrons and holes react with the available oxygen and water to form reactive oxygen species (ROS) like $\cdot O_2^-$ (superoxide radical), $\cdot OH$ (hydroxyl radical), etc. These powerful and unstable radicals attack the organic pollutant molecule and degrade it into harmless carbon dioxide and water.

However, there are a few gaps identified in the implementation of this process. Firstly, the light source used for activation of the photocatalytic material. Most of the research is done using an artificial source of light like a xenon lamp, halogen lamp etc., with/out a cut-off filter. With the objective to lower the dependency on electricity and encourage the usage of naturally and abundantly available solar light, the authors have attempted to carry out and report the efficacy of natural sunlight in the treatment of wastewater.

One of the most popular photocatalyst materials is ZnO [5–8]. It gives excellent photocatalytic results, can be easily separated and reused and is cheaply available. However, it undergoes a key limitation of being able to employ only the UV part (~4%) of the solar spectrum. Hence efforts have been made in this study to modify ZnO by hybridising it with a suitable material to make it workable in the visible region (~47%) as well.

Several studies have been carried out to expand the spectral usage of photocatalysts [9–17] to make them visible-light effective. Here, we report the use of ground granulated blast furnace slag (GGBFS), a waste and a by-product of iron industry, as a potential material that can be hybridised with ZnO. Though researchers have recently and briefly reported GGBFS geopolymer as a potential photocatalyst [18–21], to the best of the author's knowledge, its efficacy in combination with ZnO, in direct sunlight has not yet been reported anywhere. In this article, we report ZnO-GGBFS geopolymer as a low cost, porous and effective photocatalyst capable of fairly utilising the visible range along with UV. So here we attempt to treat a dye solution using a waste material and freely available solar energy. Hence, this is our small step towards environmental benign-ness and sustainable development.

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https://doi.org/10.1016/j.jics.2022.100560
Received 27 March 2022; Received in revised form 28 April 2022; Accepted 3 June 2022
Available online 6 June 2022