Use of metals in the green synthesis of nanophotocatalyst: State of the art

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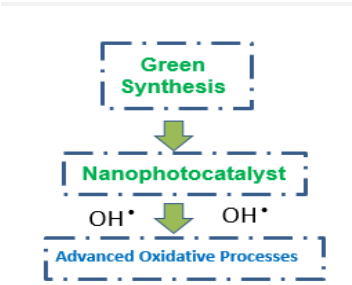

The green synthesis of nanoparticles is an innovative approach, standing out through the use of sustainable and environmentally conscious methods in the fabrication of these materials. In this method, nanoparticles are synthesized using natural sources, plant extracts, or other biodegradable agents as precursors. This methodology reduces the environmental impact associated with traditional processes and results in nanostructures with specific properties for use in photocatalysis. In this context, this work aims to conduct a bibliometric analysis on the use of metals in green nanoparticles for advanced oxidative processes.

Introduction

Green synthesis is related to clean technology, meaning that no chemical reagents harmful to or degrading the environment are used in the process. This synthesis generates less waste, and often the required reagents are low-cost. Initiators of the green route include extracts from different parts of plants, microorganisms, polymeric materials, and even agro-industrial waste. The compounds present in these materials are capable of providing the bioreduction of metals to oxides, a process that until now was carried out with high energy consumption and the generation of toxic waste [1].

In the last decade, interest in research on the production of nanoparticles through green synthesis has increased significantly [2]. Although titanium nanoparticle is widely studied due to its exceptional photocatalytic activity, the high cost associated with it encourages the search for alternatives. This highlights the importance of exploring photocatalytic nanostructures developed through green synthesis, using other metals such as iron, copper, manganese, and magnesium, as more economical options.

Previous research [3] highlights the catalytic, supermagnetic, and reducing properties of iron nanoparticles, beneficial for wastewater treatment. Moreover, manganese nanoparticles are utilized in environmental applications such as dye removal and adsorptive processes [4]. Copper nanoparticles also exhibit unique catalytic properties, attracting scientific interest [5].

In this context, this study aims to conduct a bibliometric analysis on the green synthesis of nanostructured photocatalysts, investigating the number of articles published in the last 10 years with precursor materials such as titanium, iron, copper, manganese, and magnesium.

Material and Methods

The state-of-the-art analysis of the current situation regarding the synthesis of metallic nanoparticles was conducted based on articles found through bibliometric analysis.The tool used to conduct the analysis was the Web of Science database. An initial search was conducted using the words "nanostructured photocatalyst," including "TiO_2," "Fe_2O_3," "CuO," "MnO_2," and "MgO" over the past 10 years. Subsequently, a second search was performed using the words "green synthesis of nanophotocatalyst" on the ScienceDirect, SciELO, and Wiley platforms, covering the last 10 years. It is worth noting that no filter was selected, only filters related to the year of publication. However, the research field was selected as 'Title,' meaning the search returned articles containing those words in the title.

Results and Discussion

Figure 1 indicates that no articles were found in the searched database on the use of nanostructured magnesium oxide as a photocatalyst. Magnesium nanoparticles exhibit relevant properties such as a good refractive index, corrosion resistance, high thermal conductivity, and physical strength [6]. However, investment in the study of magnesium nanoparticles as photocatalysts is low. Regarding manganese, only one review article was identified, discussing the use of manganese ferrite oxide - a type of iron oxide nanocatalyst with manganese. On the other hand, there was a consistent presence of studies on titanium oxide as a photocatalyst in all the years analyzed, with the exception of 2015 and 2022. As for iron, publications were limited to the years 2017 and 2021. For copper, there was one publication in 2020 and another in 2022. This analysis highlights a clear focus on the investigation of nanostructured photocatalysts based on titanium. However, it emphasizes the importance of expanding research to include other metals. Although the advantageous properties of titanium oxide for the synthesis of photocatalysts are acknowledged, its cost is relatively high,

emphasizing the need for research involving other elements as photonanocatalysts.

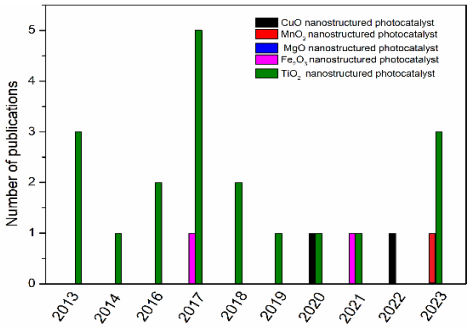

Figure 1. Number of publications of titanium, iron, copper, manganese, and magnesium oxides as nanostructured photocatalysts.

Figure 2 shows the number of articles associated with the term "green synthesis of nanophotocatalyst" in the manuscript titles. Initially, a search conducted on the Web of Science platform yielded only 9 indexed articles. Subsequently, searches were performed on the other three mentioned platforms (Science Direct, Scielo, and Wiley). The search returned a total of 49 articles. It is important to emphasize that the initial search on the three platforms mentioned earlier returned a large number of publications, but many articles were not related to the theme of this research. For this reason, a selection was made to ensure that only the articles related to the theme: green synthesis of nanophotocatalyst were counted.

Additionally, the oldest article, from the year 2013, discusses the green production of nanoparticles for use in photocatalysis but not for the degradation of organic pollutants, rather as a hydrogen generator. According to Figure 2, there was a decrease in the number of publications on this topic during the year 2020, likely due to the COVID-19 pandemic. However, after that year, the number of publications began to rise again. The combination of nanotechnology with green synthesis has shown excellent results in the field of photodegradation. Previous study [7] synthesized an iron photonanocatalyst using pumpkin peel extract to degrade amoxicillin. The authors achieved a 60% degradation of the pharmaceutical in 1 hour of photoreaction. Additionally, the photodegradation of amoxicillin generated only 5 by-products and exhibited significant molecular changes in the studied pharmaceutical molecule. In another study [8], bimetallic nanoparticles of silver with iron were synthesized using Palmyra sprout extract. The nanoparticles were characterized and tested for their photocatalytic activity in the degradation of malachite green dye. The synthesized photonanocatalysts with Palmyra achieved 91.23% decolorization in 180 minutes of photoreaction. These studies highlight the importance of researching green nanoparticles used as photocatalysts due to their high catalytic activity and application in environmental remediation processes.

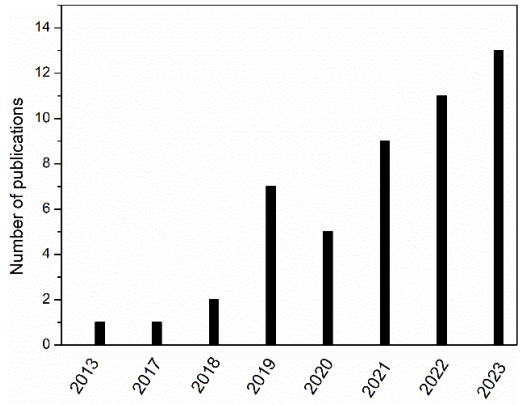

Figure 2. Number of publications of nanostructured photocatalysts through green synthesis.

Conclusions

This study identified a research gap in the exploration of other metals as photonanocatalysts. Furthermore, the bibliometric analysis highlighted the recent emergence of ecologically synthesized nanostructures as photocatalysts. This underscores the necessity for additional studies focusing on characterizing these nanoparticles and investigating their photoactivity and mechanisms to act in advanced oxidative processes.

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