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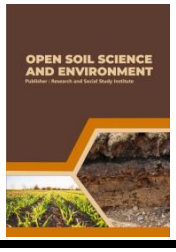

Bibliometric Analysis of Titanium Dioxide Nanoparticle Synthesis Research for Photocatalysis Using Vosviewer

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ABSTRACT

Titanium dioxide (TiO_2) nanoparticles is a metal oxide nanoparticle that gained popularity due to their applications on environmental uses as photocatalyst. This study purpose is to conduct bibliometric analysis of titanium dioxide nanoparticles synthesis by using VOSviewer software mapping analysis function. The data in this study is obtained using the Mendeley. Keywords used to collect and organize the all data are "Titanium dioxide nanoparticle, TiO_2, synthesis, and nanomaterial". Based on the result of analysis, it was found that over the span of 2018-2021 there are 937 papers published under the aforementioned keywords. The graph showed that 2018 is the year where the total paper per year is the highest. This study is expected to serve as a reference for researchers to determine their research theme.

1. Introduction

Titanium dioxide nanoparticle is one of the most well-known and widely used all around the world, some of its uses includes food and drugs colorant, ceramics, cosmetics, and sunscreen component which was reported by Ziental, *et al.*, (2015). Titanium dioxide is also an excellent photocatalyst since it is reported by Rezaei & Mosaddeghi (2006) that TiO_2 nanoparticle can be used as water purifying agent and environmental improving agent.

In the term of agriculture, titanium dioxide nanoparticle was use to support the susatinable agriculture. Cadmium partitioning in roots and leaves was reduced by nano-TiO_2, although significantly higher than control. In comparison to control and sole Cd, nano-TiO_2 intervention increased ascorbate peroxidase and catalase activities in roots and leaves. However, the magnitudes of enzyme activity were larger in $nTiO_2$ treatments than in $bTiO_2$ treatments. The increased enzyme activity resulted in lower malonaldehyde levels in plant tissues. According to the findings, soil application of nano-TiO_2 could be a green alternative for reducing Cd toxicity in cowpea plants (Ogunkule *et al.*, 2019).

Rizwan *et al.*, (2019), TiO_2-nanoparticles increased rice biomass while decreasing Cd levels in tissues, according to the findings. When NPs were applied to rice leaves, the chlorophyll concentrations and gas exchange characteristics enhanced. The NPs reduced electrolyte leakage and malondialdehyde concentration in rice shoots while enhancing the activities of superoxide dismutase, preoxidase, catalase, and asorbate peroxidase. The effectiveness of nanoparticles in lowering Cd toxicity varied according on the type and amount of NPs utilized. The results demonstrated that foliar application of NPs enhanced biomass, photosynthesis, and Cd accumulation in rice, which was attributed to NPs treatment's reduced oxidative burst and improved antioxidant defense system. Zhang *et al.*, (2020), State that in the tillering stage, TiO_2 NPs addition caused a significant increase in plant height, biomass and the total chlorophyll content in the leaves of *Oryza saliva* L.

The use of titanium dioxide nanoparticles (TiO_2 NPs) in conjunction with plant growth promoting rhizobacteria (PGPR) to improve phytoremediation of Cd-contaminated soil was investigated. Trifolium repens seedlings were subjected to various dosages of TiO_2 NPs (0, 100, 250, 500, and 1000mg/kg) and the PGPR, both individually and in combination, to study the effects on plant growth, Cd uptake and accumulation, and chlorophyll content. Co-application of TiO_2 NPs with the PGPR increased T. repens plant growth and chlorophyll content. Cd content in T. repens roots reached 120.3 mg/kg after treatment with PGPR 500mg/kg TiO_2 NPs. The addition of TiO_2 NPs to soil dramatically enhanced T. repens accumulation capability. Cd had the highest accumulation capability of 1235 mg/pot in the PGPR + 500mg/kg TiO_2 NPs treatment. The use of 1000mg/kg TiO_2 NPs had a negative impact on plant growth. The co-application of TiO2 NPs and PGPR may lower the amount of TiO2 NPs required for phytoremediation of heavy metal damaged soils. Co-application of TiO_2 NPs and PGPR aided T. repens growth in Cd-contaminated soil and increased Cd uptake and accumulation by the plant. Intelligent plant-nanomaterial-PGPR interactions have promising applications in soil remediation (Zand, *et al.*, 2020).

Soil salinity is recognized as a major environmental issue, reducing crop productivity worldwide and threatening sustainable agriculture. In this study, we looked at the effects of titanium dioxide nanoparticles ($nTiO_2$) on soil salinity in broad bean, a major leguminous crop. Because $nTiO_2$ is known to have pro-oxidant and antioxidant properties, the effects of three different $nTiO_2$ concentrations (0.01%, 0.02%, and 0.03%) on plant growth and stress responses were compared. Under normal conditions, the application of 0.01% $nTiO_2$ significantly increased shoot length, leaf area, and root dry weight of plants. These growth-promoting effects were accompanied by increased levels of chlorophyll b, soluble sugars, and proline, as well as increased antioxidant enzyme activity. Plant growth was significantly reduced in saline soil conditions, despite increased proline levels and enzymatic antioxidant activities. The addition of 0.01% $nTiO_2$ significantly increased the activities of

enzymatic antioxidants as well as the levels of soluble sugars, amino acids, and proline in salt-affected plants compared to plants exposed to salinity alone. Thus, increased antioxidant enzyme activities contributed to the observed reduction in hydrogen peroxide and malondialdehyde contents, while increased proline and other metabolite levels contributed to osmoprotection, resulting in significant plant growth improvement under salinity. Furthermore, under both control and saline soil conditions, $nTiO_2$-mediated positive effects were concentration dependent, with 0.01% $nTiO_2$ being the most effective, 0.02% showing an intermediate response, and 0.03% being almost ineffective.. Our findings provide a foundation for $nTiO_2$ application in improving growth of plants cultivated on naturally contaminated saline soils (Latef *et al.*, 2018).

In recent years, the increased use of nanoparticles (NPs) has posed a possible hazard to the natural ecosystem. The purpose of this study was to determine the C and N mineralizations of different textured (clay and sandy) soils at increasing doses of TiO_2 NPs and ZnO NPs (25, 50, and 100 mg kg1) biologically synthesized from *Peganum harmala* L. plant extract, and to reveal their potential effects on the soil ecosystem. The carbon (C) and nitrogen (N) mineralizations were determined under controlled laboratory circumstances for 42 days (28 °C, 80% field capacity) using the CO_2 respiration method and the Parnas-Wagner method, respectively. The highest carbon mineralization was found in clay soils mixed with 100 mg/kg TiO_2 NPs. The treatment of clay soils with 50 mg/ kg ZnO NPs increased microorganism activity ($P < 0.001$). Carbon mineralization rates in sandy soils were found to be higher than in clay soils ($P < 0.05$). These rates were found to be higher in TiO_2 NPs treated soils than in ZnO NPs treated soils. The nitrogen mineralization ratios in clay soils were found to be higher than in sandy soils. All of these findings indicate that microorganisms are impacted by the presence of TiO2 NPs and ZnO NPs, as well as texture differences in these two soils (Kizildag *et al.*, 2019).

There are many methods to synthesize titanium dioxide nanoparticle. There are several synthesis methods of titanium dioxide nanoparticle which consists of standard sol-gel and hydrothermal method and green biosynthesis that include the use of bacteria, plants, and oil from plants (Taran, *et al.*, 2018; Hashem & Alkaragoly, 2021, Habibi & Jamshidi, 2020, Abu-Dalo, *et al.*, 2019, Biswas, *et al.*, 2018, Irshad, *et al.*, 2020, Dobrucka, 2017).

Bibliometric analysis data that is visually displayed by a mapping tool will be useful to see the trend of research that is being carried out by researchers all around the world judging by the papers that were released and used in the database Al Husaeni & Nandiyanto (2022). The method that is used to analyze and produce the map of the bibliometric analysis is VOSviewer software that can reflect the trend, impact, and procces of the topic Al Husaeni & Nandiyanto (2022).

This study analyzes the trend of research in regard to titanium dioxide nanoparticle synthesis over the span of 2018-2021. The aim of this study is to conduct a bibliometric analysis of the synthesis of titanium dioxide nanoparticle with bibliographic data on article titles and abstracts. VOSviewer software is used for bibliometric analysis with data that is collected with Mendeley. This study is expected to serve as a reference for researchers to determine their research theme.

2. Methods

This study used research data of journals and articles that is indexed in Mendeley. Mendeley is used due to its ease of access and large amount of journal indexed in the site while being free. If the situation permits, we will use Scopus database in our future study to optimize the result. In this study, Mendeley as a reference manager was used to obtain research data. Every article data that has been obtained must have relevance to the themes needed in this research and then will be backed up into a file that will be used for analysis with VOSviewer.

Every article used in this study is filtered to only articles related to the synthesis of titanium dioxide nanoparticle. Every article is searched on the Mendeley software with keywords "Titanium dioxide nanoparticle, TiO2, synthesis, and nanomaterial" which was adjusted to the criteria of title, and

abstract. The search result from 2018-2021 shows 937 articles that fits the keywords. The articles are kept in *.ris format then the analysis is performed using VOSviewer to visualize and analyze trends using bibliometric maps.

3. Results and dicussion

3.1 Research developments in titanium dioxide nanoparticle synthesis

Development of titanium dioxide synthesis research is analyzed in this study. Figure 1 shows the recent development of the subject of this study based on the number of papers published every year from 2018-2021. As shown in figure 1, the highest paper published was in 2018 that reaches 363 publications, the number of papers published in 2019 took a fall and only reach 174 papers. In 2020 and 2021 the paper published is increased again but only in small steps which was 199 and 201 papers respectively.

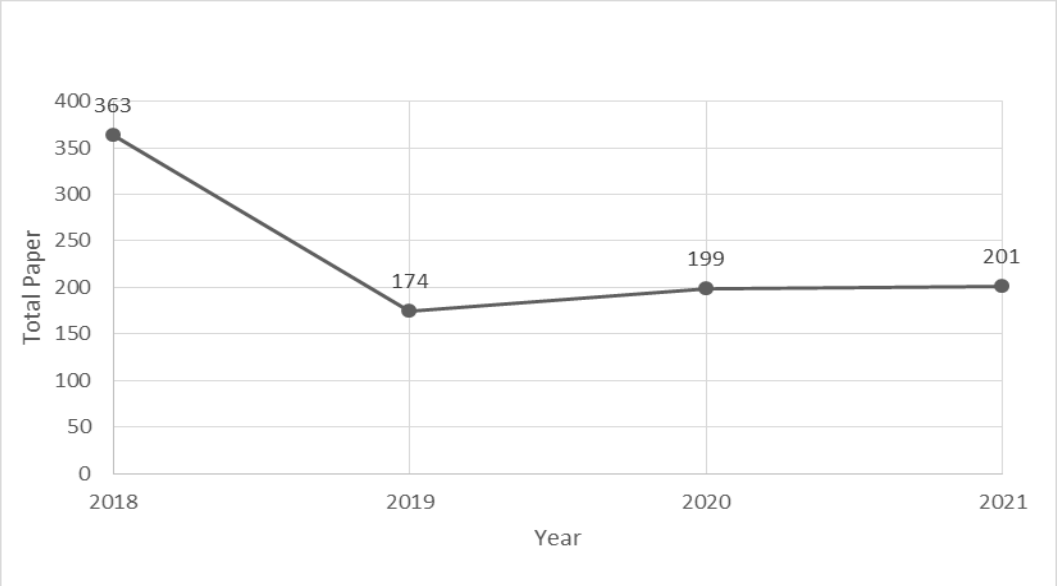

Figure 1. Level of development of research on titanium dioxide nanoparticle synthesis

3.2 Network visualization of Titanium dioxide nanoparticle, TiO2, synthesis, and nanomaterial keyword

Visualization network display in Figure 2 shows the relationship between the terms found and described by the lines connecting each term. From Figure 2 it can be seen that each term found is divided into several clusters. The term titanium dioxide nanoparticle, TiO2 NPs and synthesis method are found in cluster 1 and connected to the rest of the cluster. This shows that titanium dioxide nanoparticle (TiO¬2 NPs) synthesis method is the core keyword in this study. Meanwhile in other cluster such as cluster 2 and cluster 3 the term biosynthesis and green synthesis which is assumed to be derived from synthesis method is found. The terms titanium dioxide nanoparticles, and nanosized titanium dioxide which is synonymous with titanium dioxide nanoparticle term can also be found in cluster 2 and 4 respectively.

In this visualization, the cluster size indicates the number of publications. The bigger the cluster, the more publications. The distance between the clusters also shows the relationship between the clusters. The closer the distance between the clusters, the stronger the relevancy.

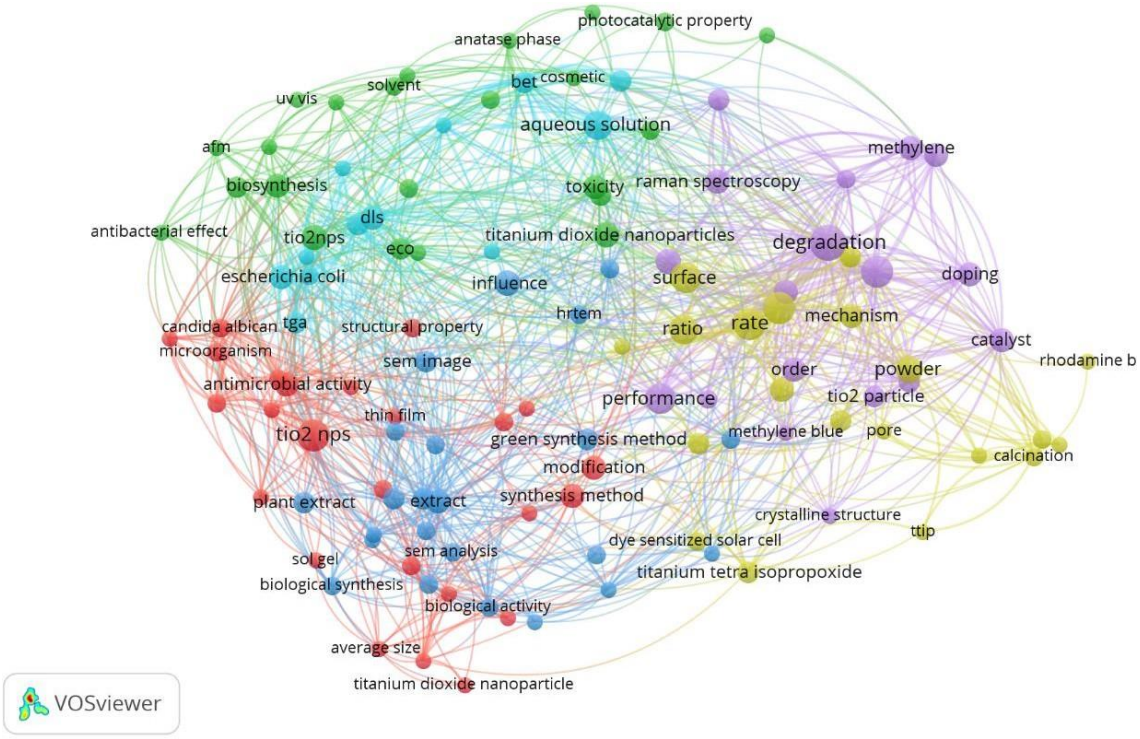

Figure 2. Network visualization of Titanium dioxide nanoparticle, TiO_2, synthesis, and nanomaterial keyword

3.3 Visualization titanium dioxide nanoparticle production topic area using VOSviewer

According to Al Husaeni & Nandiyanto (2022), the minimum number of relationships between terms in the VOSviewer is regulated by 2 terms. Related researches of titanium dioxide nanoparticle synthesis are analyzed into 8 cluster based on the mapping visualization, namely:

i. Cluster 1 has 25 items that consists of antifungal activity, antimicrobial activity, average size, candida albican, cell, crystalline nature, environmental impact, factor, flavonoid, green chemistry, MIC, microorganism, minimum inhibitory concentratoin, modification, nanocomposite, optimal condition, prepared nanoparticle, sol gel, structural property, synthesis method, thin film. TiO_2 NPs, titanium dioxide nanoparticle, wide range, x ray powder diffraction.
ii. Cluster 2 has 23 items which are AFM, anatase phase, antibacterial effect, antimicrobial property, atomic force microscopy, biosynthesis, combination, control, cosmetic, ECO, HRTEM, low temperature, photocatalytic application, photocatalytic property, solvent, TiO_2NPs, titanium, titanium dioxide nanoparticles, titanium isopropoxide, toxicity, UV Vis, UV XRD, zeta potential.
iii. Cluster 3 has 23 items that consists of aloe vera, average crystalline size, average particle size, biological activity, biological synthesis, biomedical application, chemically, crystallinity, extract, green synthesis method, HRTEM, influence, photodegradation, plant extract, purity, room temperature, SEM analysis, SEM image, synthesized nanoparticle, synthesized titanium dioxide nanoparticle, titanium isopropoxide solution, UV Visible spectroscopy, XRD pattern.
iv. Cluster 4 has 20 items namely, calcination, dye sensitized solar cell, FESEM, kinetic, mechanism, nanosized titanium dioxide, photocatalysis, pore, powder, rate, ratio, removal,

rhodamine B, scanning electron microscopy, specific surface area, surface, surface aream titanium tetra isopropoxide, TTIP, x ray diffractometer.

v. Cluster 5 has 18 items, namely band gap, calcination temperature, catalyst, crystalline structure, degradation, doping, high surface area, methylene, methylene blue, min, order, performance, photocatalytic activity, photocatalytic degradation, pollutant, raman spectroscopy, TiO_2 particle, x ray photoelectron spectroscopy.

vi. Cluster 6 has 11 items that consists of aqueous solution, BET, brunauer emmett teller, cell line, cytotoxicity, DLS, EDS, escherichia coli, high resolution transmission electron microscopy, TGA, thermogravimetric analysis.

Cluster 1 is marked in red, cluster 2 is marked in green, cluster 3 is marked in dark blue, cluster 4 is marked in yellow, cluster 5 is marked in purple, cluster 6 is marked in light blue.

4. Conclusions

A bibliometric analysis for titanium dioxide nanoparticle synthesis research analyzed using VOSviewer software in this study. The result of the analysis shows that there are 937 papers published in the period of 2018-2021 with the highest published paper per year is 363 papers in 2018. The articles used as data in this study is obtained in Mendeley index with the keywords "Titanium dioxide nanoparticle, TiO2, synthesis, and nanomaterial". It can be seen in the mapping visualization that all of the cluster is connected into the cluster with ‘titanium dioxide nanoparticle synthesis method’ and the recent trend shows that photocatalytic activities, biosynthesis, and green chemistry/synthesis is popular among researchers that study titanium dioxide nanoparticle.

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6. Authors Note

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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