# Photocatalytic Degradation of Methylene Blue Dye Using Tin oxide Nanoparticles

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**ABSTRACT**

Textile wastes are the main environmental issues in various dyeing industries. Several treatment methods are proposed to minimize the organic contaminants to reduce Pollutants from the effluents. In photodegradation oxide materials such as ($SnO_2$) have shown promising performance in destroying organic pollutants such as organic dyes with minimal side pollution. This study investigated the green synthesis using pineapple fruit extract and the photooxidation capabilities of tin oxide ($SnO_2$) nanoparticles for their efficiency in degrading organic dyes. By harnessing the unique properties of $SnO_2$ nanopowder, this research aims to advance the field of photocatalysis, particularly in environmental applications such as wastewater treatment. The synthesis, characterization, and photocatalytic performance of the nanocomposites under UV and visible light were systematically examined. Results demonstrate the potential of $SnO_2$ nanocomposites in enhancing the degradation rate of organic dyes, offering a promising solution for mitigating dye pollution.

**Keywords:** Nanocomposite, Photocatalyst, Pineapple fruit, Organic dyes, Textile dyes, Tin oxide

## Introduction:

The presence of organic dyes in effluent from textile , paper and apparel industries results in substantial environmental contamination. Several studies reported that dyes like Rhodamine B, Victoria blue, Indigo Red, Caramine, Eriochrome, Methylene Blue , Eriochrome Black-T , and Thymol blue are utilized annually in textile industries of which a major portion (~20%) is lost during synthesis and processing operations and ends up in wastewater [1]. These dye-polluted effluents comprise non-biodegradable, highly poisonous, and colored pigments that are harmful to living organisms. Conventional wastewater treatment techniques, such as adsorption, coagulation, and biological degradation, often fail to completely remove these pollutants or generate secondary waste [2]. Advanced oxidation processes, particularly photocatalytic degradation, have gained attention as an efficient and eco-friendly approach for degrading organic dyes into non-toxic byproducts [3]. The photocatalysts, $SnO_2$NPs have emerged as a promising material due to their high chemical stability, non-toxicity, and excellent optical properties [4]. $SnO_2$NPs has a wide bandgap (~3.6 eV), making it effective under ultraviolet light for photodegradations [5]. However, the synthesis of $SnO_2$ NPs often involves hazardous chemicals and energy-intensive processes, limiting their large-scale application in environmental remediation.

To address this issue, green synthesis using plant extracts as reducing and stabilizing agents has gained popularity as a sustainable alternative to conventional chemical methods [6]. Plant-mediated synthesis is eco-friendly, and cost-effective, and enables the formation of biocompatible nanoparticles with controlled size and morphology. Pineapple (Ananas comosus) extract is rich in bioactive compounds such as flavonoids, polyphenols, and organic acids, which can act as natural reducing agents for the synthesis of $SnO_2$ nanoparticles [7-10]. Tin oxide nanoparticles are used in various Nanotechnological applications due to their unique properties. They possess a high surface area-to-volume ratio, making them suitable for gas sensing, catalysis, energy storage, and biomedical applications.

In this paper, we studied the green synthesis of the most effective $SnO_2$ nanoparticles using pineapple fruit peels for the removal of organic dyes from textile industrial wastewater. This work focused on the economical synthesis and key parameters that influence the photocatalytic effective degradation process of dyes.

**Materials and Methods:**

**Preparation of Pineapple Fruit peel extract**

Collected fresh pineapple peels from Ulhanagar Market, Maharashtra, India, and rinse thoroughly under running water to remove any dirt or contaminants. Cut the peels into smaller pieces to increase the surface area for extraction. Place the chopped peels in a pot with water (enough to cover them) and boil for 20–30 minutes. After boiling, cool and filter and store it in an airtight container in the refrigerator.

**Synthesis of $SnO_2$ Nanoparticles**

Dissolve a measured amount of tin(II) chloride ($SnCl_2$) in distilled water to prepare a solution. Add slowly the pineapple peel extract to the $SnCl_2$ solution while stirring continuously. Heat the mixture at 70-80°C for 2 hours to initiate the formation of $SnO_2$ nanoparticles. Allow the solution to cool at room temperature and centrifuge the mixture to separate the nanoparticles. Wash the collected nanoparticles with distilled water and ethanol and dry it in an oven at 80°C for several hours. The Schematic representation of Synthesis of Tin (II) oxide nanoparticles is shown in fig.1. Next day the solution is dried at 200°C and calcined at 500°C for 3 h.

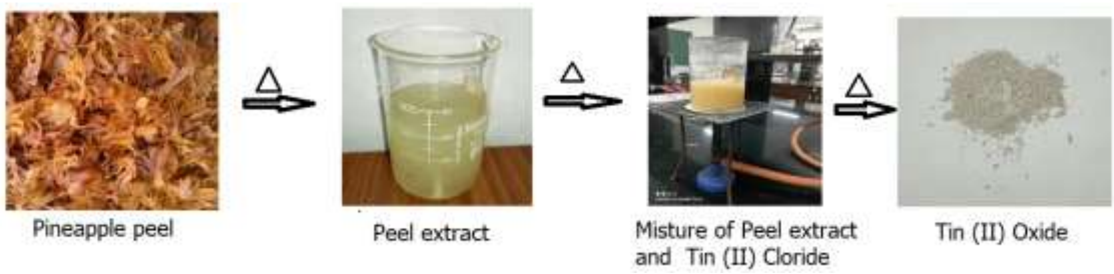



**Fig. 1 Schematic representation of Synthesis of Tin (II) oxide nanoparticles using pineapple peel**

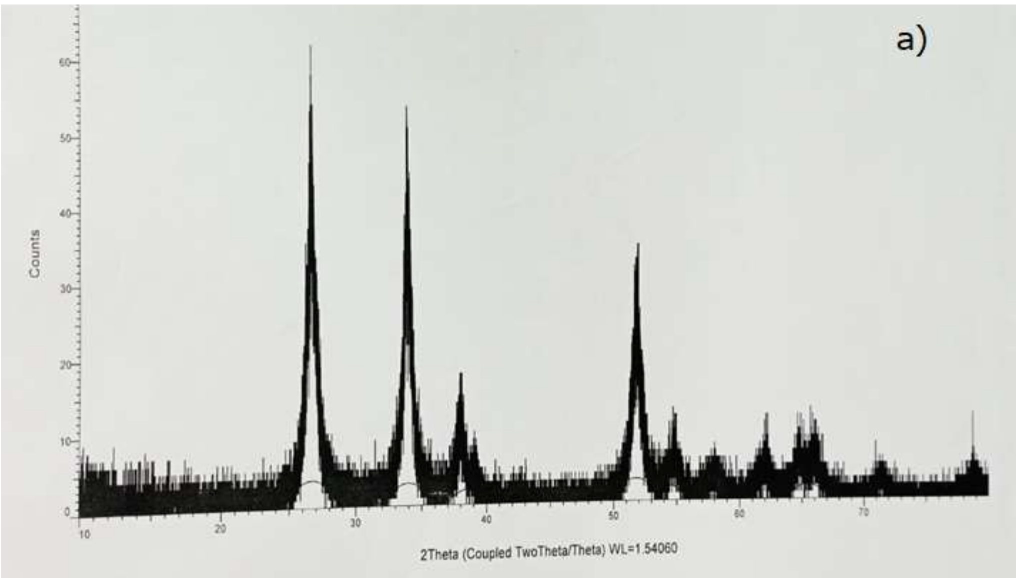
**Results and Discussion**

Pineapple peel extract successfully facilitated the green synthesis of nanoparticles. The conversion of $SnCl_2$ to $SnO_2$ a noticeable color change was observed, indicating the reduction of metal ions and the formation of nanoparticles. The bioactive compounds in the pineapple peel extract, such as polyphenols, flavonoids, and organic acids, acted as natural reducing and stabilizing agents during this process.

The formation of nanoparticles was confirmed using UV-Vis spectroscopy. The characteristic peak was observed at a specific wavelength of 300 nm, indicating the presence of $SnO_2$ nanoparticles. The results show a strong absorption band, confirming the successful synthesis of nanoparticles.

XRD analysis of the synthesized nanoparticles revealed distinct peaks corresponding to the crystalline nature of the nanoparticles. The effect of annealed temperature (200-500ºC) on diffraction pattern of tin (II) oxide is shown in figure 2. The pattern is matched well with the standard reference patterns for the $SnO_2$ nanoparticles, The average crystallite size of the nanoparticles, calculated using the Debye-Scherrer formula, was in the range of 30–40 nm, confirming the nanoscale formation.

The diffraction pattern exhibits sharp and intense peaks, indicating the high crystallinity of the sample. The observed peaks match well with the standard diffraction pattern of $SnO_2$ (Cassiterite phase) as per the JCPDS No. 41-1445. The major peaks appear at characteristic 2θ values around 26.6°, 33.8°, 37.9°, 51.8°, 54.8°, 61.9°, 64.8°, and 78.8°, which correspond to the tetragonal rutile structure of $SnO_2$. Figure 2(b) exhibits higher crystallinity of the particles compared to Figure 2(a) due to the effect of annealing temperature on the XRD pattern.



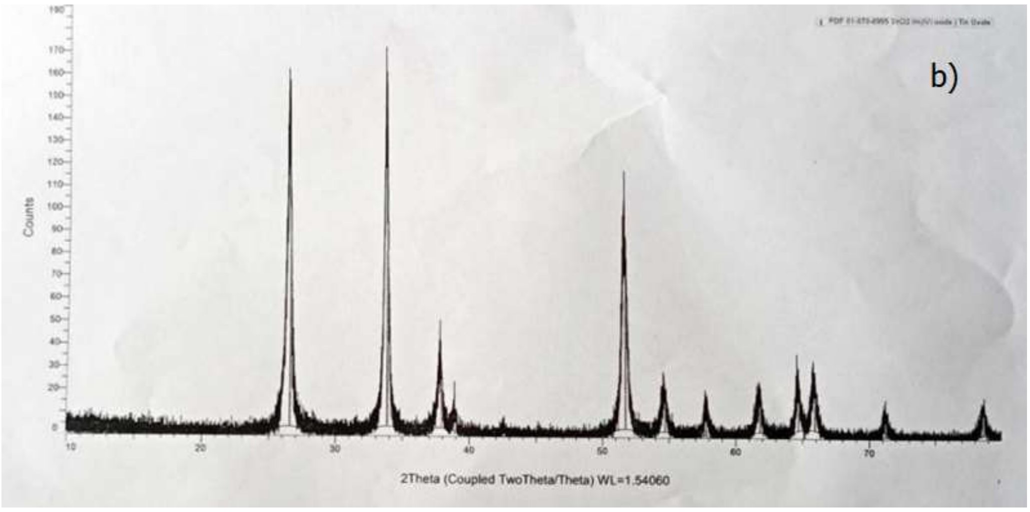



Fig.2 XRD Analysis of Tin (II) Oxide obtained by using Pineapple peel extract and annealed at temperatures a) 200ºC  b) 500ºC

**Scanning Electron Microscopy (SEM):**
SEM analysis showed that the nanoparticles obtained using Pineapple extract were observed spherical with minimum agglomeration. The average particle size, was measured using image analysis software, confirming a diameter in  range of 40–50 nm and a length is in microns. The micrographs displayed relatively uniform distribution, although some particles exhibited slight clustering. The EDX analysis confirms the presence of tin (Sn) and oxygen (O), validating the successful synthesis of $SnO_2$ nanoparticles. The presence of minor impurities (Carbon, Sodium, and Chloride) should be further investigated to improve the purity of the sample. The elemental composition aligns well with the expected composition of tin oxide, demonstrating the effectiveness of the synthesis process.

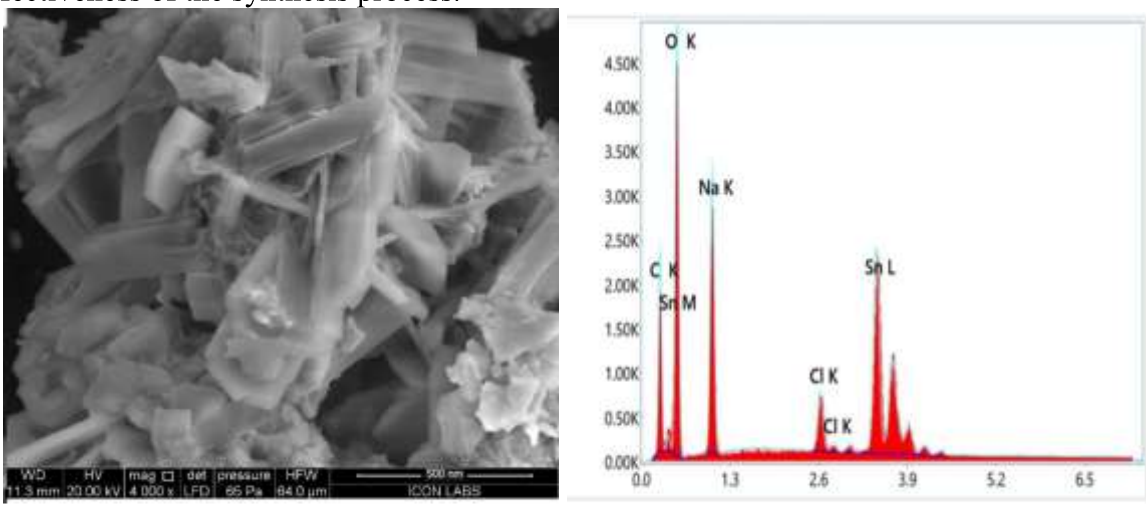
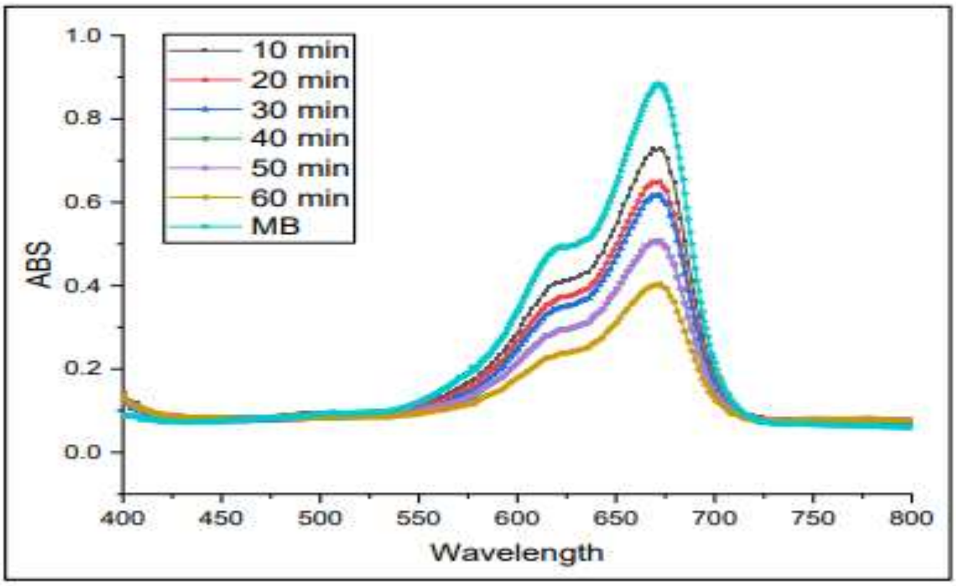



**Figure 3 SEM and Edx image of the SnO2 NPs obtained fro Pineapple peels extracts**

**Measurement of photocatalytic activity**

Dissolve a target pollutant i.e. Methylene blue in distilled water at a known concentration(2mM) and 100ml Volume. Disperse the known quantity of green synthesized Tin dioxide nanoparticles into the pollutant solution. Stir the mixture in the dark for 30 minutes to ensure adsorption equilibrium between the catalyst and pollutant. Expose the solution to a light source (UV or visible light) for a set duration (e.g., 1-3 hours), while continuously stirring. Take small samples from the solution at regular time intervals (e.g., every 30 minutes). Measure the absorbance of each sample using a UV-Vis spectrophotometer to monitor the decrease in pollutant concentration shown in Figure 2. The results show the degradation of $SnO_2$ nanoparticles with respect to time. Upon irradiating the UV light on the dye, the degradation percentage increased (50%) with more exposure time until 60 min. After 60 min, a plateau was reached as there was no improvement in the degradation. This high 90% degradation in a short time showed that the material was highly efficient. When comparing it to other studies, it can be seen that using UV light, there was a higher degradation of the pollutant in a much shorter space of time 60 min, and less of the catalyst (0.5g) was required as compared to the other depicted studies.




The synthesized nanoparticles demonstrated significant photocatalytic activity. In a degradation test using methylene blue dye, the nanoparticles efficiently degraded the dye under UV light exposure. The degradation rate increased with higher concentrations of the nanoparticles, demonstrating their potential as photocatalysts for environmental remediation.

**Conclusion:**

The use of pineapple peel extract as a reducing and stabilizing agent offers an eco-friendly alternative to conventional chemical synthesis methods. The process is non-toxic, cost-effective, and utilizes agricultural waste, thus promoting sustainability. The presence of natural antioxidants and biomolecules in the pineapple peel extract makes it an efficient and green method for nanoparticle synthesis without the need for hazardous chemicals.

The results demonstrate the successful green synthesis of nanoparticles using pineapple peel extract. Characterization techniques confirmed the formation of nanoparticles having size 30-40nm diameter rod-like structure with desirable properties, including small size, crystallinity, and photocatalytic 90 % degradation of methylene blue dye within 60 min. This green approach offers a promising and sustainable method for nanoparticle synthesis, with potential applications in catalysis, environmental remediation, and other fields.

**Acknowledgments**

The authors are grateful for the support of Dr. Naresh Chandra (Director, BKBCK) Dr. Avinash Patil (Principal, BKBCK) Dr. Gawai (Principal. Science College, Nanded) for their support and motivation to carry this research work.

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