Microwave-Assisted Solvothermal Synthesis of Tungsten Oxide (WO_3) Nanoparticles for Microbial Inhibition

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ABSTRACT

Introduction: Tungsten oxide is an n-type semiconductor which possesses the bandgap of 2.6 – 2.8 eV at room temperature. Additionally, tungsten oxide has the absorption capacity of 480 nm in the visible region resulted from its photocatalytic property.

Objective: To synthesize and evaluate tungsten oxide nanoparticles for microbial inhibition.

Methods: Microwave-assisted synthesis of tungsten oxide nanoparticles was carried out by solvothermal route for the development of antibacterial agent. 1 M Sodium Tungstate Dihydrate was dissolved in 100 mL distilled water which was then mixed with 20 mL of 0.1 M NaOH and the Conc. HCL was added into the reaction mixture. The precipitation of yellow colour was collected and rinsed with purified water three times. During 8 hours at 60°C and 4 hours, the precipitate having undergone drying and calcination to get tungsten oxide powder.

Results: The yellow colour precipitate was obtained after the reaction, which was characterized by UV- Vis Spectroscopy and Scanning Electron Microscopy (SEM). The λ_{max} was found to be at 364 nm and bandgap calculated as 3.41 eV.

Conclusion: Antibacterial efficacy was determined by anti-well diffusion assay against *E. coli* and *Pseudomonas Aeruginosa*. The bacterial cultures were found to be sensitive for WO_3 NPs at a concentration of 1000 $\mu\text{g/mL}$. The *E. coli* was more sensitive for WO_3 NPs compared to *Pseudomonas Aeruginosa*.

Key Words: Microwave-assisted method, Solvothermal synthesis, Tungsten oxide, *E. coli*, *Pseudomonas Aeruginosa*, Microbial inhibition

INTRODUCTION

Metal oxide nanoparticles which have unique physical and chemical properties due to change in morphology under the range of 1-100nm. Metal oxide nanoparticles are important in many areas in physics, chemistry, and material science.¹ There are various semiconductor oxides among these tungsten oxides is an important transition metal oxide semiconductor.² Tungsten oxide is an n-type semiconductor which possesses the bandgap of 2.6 – 2.8 eV at room temperature.^{3,4} In addition to that tungsten oxide is having the absorption capacity of 480 nm in the visible region resulted from its photocatalytic property.⁵ Based on high photocatalytic property tungsten oxide has strong antibacterial activities.² The properties of tungsten oxide (WO_3) are electrochromic, photochromic, gas chromic, Photocatalytic, Ferroelectric properties, optical properties and chromic.^{6,7} Tungsten oxide (WO_3) has obtained multiple industrial applications especially in the field of metallurgy, material science, electronic displays and optical modulators^{8,9} smart windows², dye-sensitized solar cell.⁷

There are several methods to synthesize tungsten oxide nanoparticles. Among these methods, microwave irradiation method is most preferable due to less time and uniformity.¹⁰ The synthesized nanoparticle was studied on bacterial cultures such as *Escherichia. coli* and *Pseudomonas aeruginosa*. Thus experimental work was studied on the UV-Visible Spectroscopy, Scanning Electron Microscopy

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MATERIALS AND METHODS

Materials

Sodium tungstate (WO₃) with the purity of 98% was purchased from LobaChemie Pvt. Ltd, Mumbai. Sodium hydroxide pellets (NaOH) with the purity of 98% was purchased from Sisco Research Laboratories Pvt Ltd, Mumbai. Hydrochloric acid (HCl) with the purity of 35% was purchased from Loba Chemie Pvt Ltd Mumbai.

Synthesis of WO₃ NPs

0.1 M sodium tungstate was dissolved in 0.1 M sodium hydroxide. The concentrated Hydrochloric acid added drop-wise into the reaction mixture with continuous stirring until it reaches pH 1 (Fig. 1). The yellow colour precipitate was obtained and washed for three times using distilled water. The precipitate underwent drying and calcination for 8 hours at 60°C and 4 hours at 300 °C respectively, to get tungsten oxide powder.^{7,8}

Figure 1: Schematic diagram of the tungsten oxide synthesis process.

Characterization of Tungsten Oxide Nanoparticles

Tungsten oxide was characterized by UV-Visible spectroscopy and Scanning Electron Microscopy (SEM) to analyze absorption spectra of nanomaterial, the structural and morphological properties.^{4,5}

Determination of Antibacterial Activity of tungsten oxide nanoparticles

Tungsten oxide was tested for its antibacterial efficacy against bacterial culture. *coli* and *Pseudomonas aeruginosa* by Anti Well Diffusion Assay (AWDA). The bacterial inoculum was prepared to a final concentration of approximately 1 X10⁵

CFU/mL for the selected bacterial cultures. The synthesized WO₃NPs of concentration 10, 100 and 1000 µg/mL were dispersed in 0.5 % DMSO by ultra-sonication to make the colloidal solution of nanomaterials. On the surface of agar plates, wells of 5 mm in diameter and of 18 µL in capacity were formed by using sterile gel borer. The 15 µL of WO₃ NPs suspension was placed in each well and was incubated at 37 °C ± 2 °C for 24 hours and zone of inhibition were recorded to understand antibacterial efficacy of WO₃ NPs.^{9,10}

RESULT AND DISCUSSION

Synthesis of tungsten oxide nanoparticles

The yellow-coloured precipitate of Tungsten oxide nanoparticles was obtained. The resultant powder was dried and used for further characterization.

UV-Visible spectroscopy

The synthesized tungsten oxide nanoparticles were characterized in UV-Visible Spectroscopy which was shown in fig.2. In the current work, the λ_{max} was found at 364 nm. The same experiment was done by Wei Hao Lai et al.,^{6,7} by chemical deposition method the change in nanoparticles UV-Visible absorbance λ_{max} at 300 to 900 nm. The optical band gap was calculated by the equation (1), and the calculated bandgap is 3.41 eV.

$$E = h \cdot c / \lambda \quad (1)$$

Figure 2: UV-Visible Spectroscopy.

Scanning Electron Microscope

Tungsten oxide nanoparticles obtained was characterized by SEM to understand its size and morphology. Fig. 3(a) showed a bunch of nanostructures at low magnification and at high magnification, the flakes of WO₃ NPs was observed and overall size was found in the range of 200-1000nm.^{4,5}

Figure 3: SEM of WO₃ NPs at (a) lower magnification (b) higher magnification.

Antibacterial efficacy of tungsten oxide

Tungsten oxide nanoparticles were tested against the bacteria *E. coli* and *Pseudomonas Aeruginosa*. Both bacterial cultures were found sensitive for tungsten oxide nanoparticles and got inhibited effectively at 1000 µg/mL concentration of WO₃ NPs. At different concentration, tungsten oxide nanoparticles tested against bacteria are shown in Table 1 and Figure 4.

Table 1: Antibacterial Efficacy of Tungsten oxide nanoparticles against bacterial cultures

Microorganism / Concentrations	<i>E. coli</i>	<i>P. aeruginosa</i>
10 µg/mL	8 mm ²	10 mm ²
100 µg/mL	12 mm ²	14 mm ²
1000 µg/mL	15 mm ²	18 mm ²

Figure 4: Antibacterial efficacy of tungsten oxide nanoparticles against (a) *E. coli* and (b) *Pseudomonas Aeruginosa*.

CONCLUSION

Tungsten oxide nanoparticles were synthesized successfully which have the maximum absorbance $\lambda_{\max}$ at 364 nm. Nanoparticles of tungsten oxide have been synthesised and characterised by U.V. Vis. spectroscopy and distinguished by SEM. It was observed that the expansion of biofilm formation of *Pseudomonas sp.* and *E. coli* was greatly reduced by tungsten oxide nanoparticles. The solvothermal tungsten

oxide nanoparticles have demonstrated substantial antibacterial action against *Pseudomonas sp.* and *E. Coli*. Thus, it shows positive activity on *E. coli* and *Pseudomonas Aeruginosa* bacteria. Moreover, from the evaluative analysis, it was deduced that the WO₃ NP_s has significant antibacterial potential that can be used in medicine and food industries. The MIC needed to minimize the biofilm formation as observed in microbial studies was 8 wt% of tungsten oxide NPs. Future experiments will explore how tungsten oxide nanoparticle sizes impact on antibacterial activities.

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Conflict of Interest: Nil.

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