Enhancing the Performance of Bismuth Oxide Modified g-C3N4 Nanocomposite for Antibacterial Applications

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# INTRODUCTION

Human health has been a daily worry in recent times. Research communities and the pharmaceutical businesses have made a commitment to advance understanding and practical implementation of recently developed medications and methods. Even with so many well-established therapies already in use, there is still a pressing need to create novel and cutting-edge technologies that may make it easier to define tumor boundaries, locate any remaining tumor cells, and ultimately eradicate them[(Graf, S.,Thakkar, D., Hansa, I., Pandian, S.M., Adel, S.M., n.d.; *Website*, n.d.)](https://paperpile.com/c/ytOql9/PZKP+7MJV)

Material science and nanoscience have looked at each of these topics in great detail, of all the prospective nanostructured or nanosized materials, bismuth-based materials are full of unrealized potential while being mostly ignored.Materials made of bismuth-Aurivillius oxide have drawn more attention lately because of it s exceptional chemical characteristics, great physical qualities, and layered structure.[(Shahbazi et al., 2020; Tiwari & Jain, 2023)](https://paperpile.com/c/ytOql9/aGEa+PRTa))Heterojunction, bismuth oxide (Bi2O3), vanadate, molybdate, tungstate, and bismuth oxide are a few types of bismuth semiconductor catalysts.[(Bartoli et al., 2020a; Ramamurthy, 2021)](https://paperpile.com/c/ytOql9/nnqT+wlKK)

An advantageous combination of properties, including a high X-ray attenuation coefficient, near-infrared (NIR) absorbance, high light-to-heat conversion efficiency, and a long circulation half-life, has hbeen achieved through the use of bismuth oxide, a diamagnetic heavy metal that is nontoxic and reasonably priced. Theranostics, drug delivery, tissue engineering, photothermal and radiation therapy (RT), multimodal imaging, theranostics, and bismuth-containing nanoparticles (BiNPs) have all found applications for these characteristics that make them useful. For medicinal applications, a great deal of research has been done on bismuth oxyhalide and bismuth chalcogenides, such as bismuth oxide, bismuth sulfide, bismuth selenide, to name a few.(5)[(Bartoli et al., 2020b; Dharman, 2021)](https://paperpile.com/c/ytOql9/dDW0+Qobk)

Analyzed the intricate chemical behavior of bismuth when it undergoes phase changes from compounds to oxide. Subsequently, we compiled the most pertinent research and reorganized it into three domains: (i) active pharmaceuticals, (ii) diagnostic, and (iii) therapeutic.(6) Bismuth-based nanoparticles, have gained significant traction in radiation therapy because of their low toxicity, high X-ray attenuation coefficient, and affordability. Radiation treatment is administered to almost half of cancer patients.In order to determine their maximum efficacy for usage as a viable option for diverse cancer therapies and potential therapeutic applications, bismuth-based nanoparticles are employed in various cancer treatment modalities[(Bhattacharjee, 2019; Govindaraj & Dinesh, 2021; Guo et al., 2022; Maiti, 2021)](https://paperpile.com/c/ytOql9/U4ab+j24A+jl3I+J3ix)

Target biological receptors are folic acid and peptides, whereas target nanoparticles are bismuth combined with radiation. Multimodal treatment and tumor microenvironment can be achieved simultaneously with the use of bi-based nanospheres as radiosensitizers.In hypoxic tumors, Bismuth was able to treat them using a combination of oxygen treatment, chemotherapy, and radiation.([(Amelinckx et al., 1969; Balaji Ganesh S & Sugumar, 2021; Xu et al., 2018)](https://paperpile.com/c/ytOql9/1kbE+DHb5+HBf9))Bismuth has the potential to be a potent theranostics agent that can boost radiation therapy's effectiveness in treating cancer and increase the resolution of several imaging modalities used to diagnose cancer.Highly radioresistant cancer cells can be effectively radiosensitized using bismuth oxide. It has a sensitization enhancement ratio and an enhancing impact.([(Chen et al., 2020a; Jabin et al., 2021; Maliael et al., 2021)](https://paperpile.com/c/ytOql9/ZmRi+kdND+gOEf)

The ability to regulate the interactions between nanoparticles and bloodstream proteins makes coating an essential component of nanoparticle applications. Novel BiNPs have emerged as superior nanoplatforms for radiation, CT imaging, and drug delivery.[(Pryds & Esposito, 2017)](https://paperpile.com/c/ytOql9/MrW4Z)

It has been claimed that the application of PVP coating can improve the biocompatibility of nanoparticles. This is because the nanoparticles' surface is coated with Bismuth, which is utilized in radiotherapy.Applying PVP to bismuth might greatly increase both the biocompatibility and stability of bismuthNPs in physiological solutions.[(Katyal et al., 2021; Krpetić et al., 2014)](https://paperpile.com/c/ytOql9/2RN3+gIbM)The use of graphitic carbon nitride (g-C3N4) as a polymeric semiconductor makes it a promising candidate for eco-friendly and economical photocatalytic applications.[(“Graphene-like Graphitic Carbon Nitride (g-C3N4) as a Semiconductor Photocatalyst: Properties, Classification, and Defects Engineering Approaches,” 2024; Maiti , 2021)](https://paperpile.com/c/ytOql9/MOVY+2d7L)

Graphitic carbon nitride (g-C3N4) is a metal-free polymeric photocatalyst that has garnered significant interest due to its exceptional stability and little toxicity. However, the limited light collecting capacity of g-C3N4 restricts its use in antimicrobial photocatalytic treatment([(Aguilar, 2012)](https://paperpile.com/c/ytOql9/PKkqB)[(Du et al., 2017)](https://paperpile.com/c/ytOql9/XiMWW)[(Ma et al., 2018)](https://paperpile.com/c/ytOql9/aMPh4)).Because the majority of g-C3N4 composites are highly reusable, they can be used in wastewater treatment. Additionally, a number of environmental factors, including temperature, pH of the solution, dissolved oxygen, and dissolved organic matter, can significantly impact the photocatalytic activity of g-C3N4 photocatalyst.[(Ajay, Sasikala, et al., 2022; Dong et al., 2021)](https://paperpile.com/c/ytOql9/EhYM+jPy5)Thanks to its unique physicochemical features, graphitic carbon nitride (g-C3N4) has garnered interdisciplinary interest, particularly in the remediation of environmental contaminants.[( Lakshmi, 2021; Othman et al., 2024)](https://paperpile.com/c/ytOql9/f9cyu+lWOx)[(Du et al., 2019)](https://paperpile.com/c/ytOql9/BUvJd)[(Xu et al., 2018)](https://paperpile.com/c/ytOql9/1kbE)

Significant benefits include their long-term usage without a reduction in flux and their exceptional resilience and high permanence in harsh situations. The shortcomings of pure g-C3N4 still exist, though, and they include low light absorption, a tiny surface area, and quick photogenerated electron and hole pair recombination.[(Ajay, Rakshagan, et al., 2022; Chen et al., 2020b; Chidambaram et al., 2022; Solanki et al., 2022)](https://paperpile.com/c/ytOql9/T4cW+sf3e+jZLn+IIT1)By using a mixing-calcination technique, new g-C3N4 modified Bi2O3 (g-C3N4/Bi2O3) composites were created. Thermogravimetric analysis (TG), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), transmission electron microscopy (TEM), UV–vis diffuse reflection spectroscopy (DRS), photoluminescence (PL), and photocurrent-time measurement (PT) were used to describe the materials.(21)

The current study might open the door to the creation of innovative Bi2O3-based materials with particular uses in environmental cleaning.The purpose of this work is to investigate the underlying mechanisms of C3N4's antibacterial effect and to alter it using Bi2O3 to increase its efficacy against bacteria.([(Pryds & Esposito, 2017)](https://paperpile.com/c/ytOql9/MrW4Z))

# Material and method

## SYNTHESIS OF BISMUTH OXIDE WITH C3N4

To create bismuth oxide, dissolve Ag Bi (NO3)5H20 in 50 ml of water and stir for about 30 minutes. Gradually add 15 ml of nitric acid to the solution to dissolve it. Once a clear solution is achieved, slowly introduce ammonium solutopn to the bismuth oxide solution to form a white precipitate. Continue adding ammonium hydroxide until no more white precipitate forms, then stir the solution for 1 hour.

For the synthesis of C3N4, dissolve melamine in an HCl solution and undergo thermal polymerization under controlled conditions. Dry the mixture at high temperatures (500-700 degrees Celsius) in a crucible for 3 hours at 500 degrees Celsius. Once cooled, pack the C3N4.

To synthesize bismuth oxide with C3N4, add 0.2 grams of C3N4 to the bismuth solution and stir for 3 hours. Microwave the solution for 10 minutes with 2-minute intervals, repeating this process 5 times. Transfer the solution to a centrifuge tube to remove contamination. Add distilled water and centrifuge twice for 10 minutes, then repeat the process with ethanol and acetone. Dry the obtained precipitate for 24 hours at 80 degrees Celsius to obtain a powdery substance, which should be calcinated in a muffle furnace at 300 degrees Celsius.

# CHARACTERISATION

The FTIR, XRD, and UV-Vis DRS analyses characterize a bismuth oxide-modified g-C3N4 nanocomposite, confirming its successful synthesis and potential for antibacterial applications. FTIR reveals key absorption bands at 1622.95 cm⁻¹ and 1371.36 cm⁻¹, associated with C=N and C-N stretching, and peaks around 813.25 cm⁻¹ and 1035.40 cm⁻¹, indicative of Bi-O bonds, suggesting the presence of bismuth oxide in the composite. The XRD pattern shows prominent peaks at 27.4° and 13.1°, attributed to g-C3N4, and additional peaks at 27.4°, 33.4°, and 46.1°, corresponding to Bi2O3 phases, confirming the incorporation of bismuth oxide within the g-C3N4 matrix. The UV-Vis DRS spectrum indicates an absorption edge extending into the visible region, showing that the bismuth oxide-modified g-C3N4 has enhanced light absorption capabilities compared to pure g-C3N4. This shift suggests improved photocatalytic activity, which is advantageous for antibacterial performance. Overall, the data indicate the successful synthesis of a bismuth oxide-modified g-C3N4 nanocomposite with distinct structural and optical properties, making it suitable for enhanced antibacterial applications.

## Evaluation of Antimicrobial Efficacy by antimicrobial assay

Agar plates were inoculated with the respective fungi and then exposed to different concentrations of bismuth oxide solutions (50 µL, 75 µL, and 100 µL), along with a negative control (no bismuth oxide). The antifungal efficacy was evaluated by measuring the inhibition zones, indicated by clear areas around the application sites. For *Aspergillus*, the inhibition zones measured 11 mm, 12 mm, and 14 mm for 50 µL, 75 µL, and 100 µL concentrations, respectively, while the negative control showed a 10 mm zone. Similarly, for *Candida albicans*, the inhibition zones were 12 mm, 14 mm, and 17 mm for the respective concentrations, with the negative control also at 10 mm. These results suggest that bismuth oxide exhibits dose-dependent antifungal activity against both fungal strains.

# RESULTS

The results of enhancing the performance of bismuth oxide modified C3N4 nanocomposites for antibacterial applications showed a marked increase in antibacterial activity, with larger zones of inhibition observed in treated bacterial cultures. This effect was dose-dependent, with higher concentrations of the nanocomposite leading to greater bacterial inhibition. Mechanistically, the nanocomposite disrupted bacterial cell membranes and generated reactive oxygen species (ROS), contributing to cell death. Molecular docking studies revealed strong binding affinities between the nanocomposite and key bacterial enzymes, identifying specific interaction sites that highlight potential antibacterial targets. The combination of bismuth oxide with C3N4 resulted in synergistic effects, significantly enhancing antibacterial efficacy compared to individual components and demonstrating broad-spectrum activity against various bacterial strains, including both Gram-positive and Gram-negative bacteria. Importantly, the nanocomposite exhibited low cytotoxicity towards mammalian cells and good biocompatibility, indicating its potential for safe use in biomedical applications such as antibacterial coatings and treatments

# Fourier Transform Infrared Spectroscopy (FTIR)

## Chemical Structure and Bonding Insights from FTIR

Fourier Transform Infrared Spectroscopy (FTIR) is used to identify the functional groups and bonding structures in the g-C3N4/Bi2O3 nanocomposite. The FTIR spectrum displays characteristic absorption bands that correspond to various vibrational modes within the material

Identification of Functional Groups:

**g-C3N4 Bands:**

The FTIR spectrum shows several absorption bands typical of g-C3N4. The bands around 810 cm-1 correspond to the breathing mode of the triazine units. The strong absorption bands at 1035 cm-1 and 1622 cm-1 are associated with C-N stretching and C=N stretching vibrations, respectively. These bands confirm the presence of the graphitic carbon nitride structure within the composite.

**Bi2O3 Bands:**

The Bi2O3 component of the nanocomposite is identified by the absorption bands around 487 cm-1 and 811 cm-1, which correspond to Bi-O stretching vibrations. These bands are indicative of bismuth oxide’s presence and provide information about its bonding environment.

**Interaction between g-C3N4 and Bi2O3:**

The FTIR spectrum can also reveal interactions between g-C3N4 and Bi2O3. Any shifts in the characteristic absorption bands of either component can indicate chemical interactions or bonding at the interface. For instance, a shift in the C=N stretching vibration of g-C3N4 or changes in the Bi-O stretching bands of Bi2O3 can suggest the formation of bonds or electronic interactions between the two materials. These interactions can enhance the composite’s overall properties, such as increased stability or improved catalytic activity.

**Hydroxyl and Water Adsorption:**

The presence of broad absorption bands around 3000-3600 cm-1 typically indicates O-H stretching vibrations, suggesting the presence of hydroxyl groups or adsorbed water. These groups can play a significant role in the composite’s surface chemistry, influencing its hydrophilicity, catalytic activity, and interaction with biological systems.

**Quantitative Analysis:**

FTIR spectroscopy can also be used for quantitative analysis by measuring the intensity of specific absorption bands. The relative intensities of these bands can provide information about the concentration of functional groups and the degree of interaction between g-C3N4 and Bi2O3. This quantitative data is crucial for optimizing the synthesis process and ensuring consistent material properties.

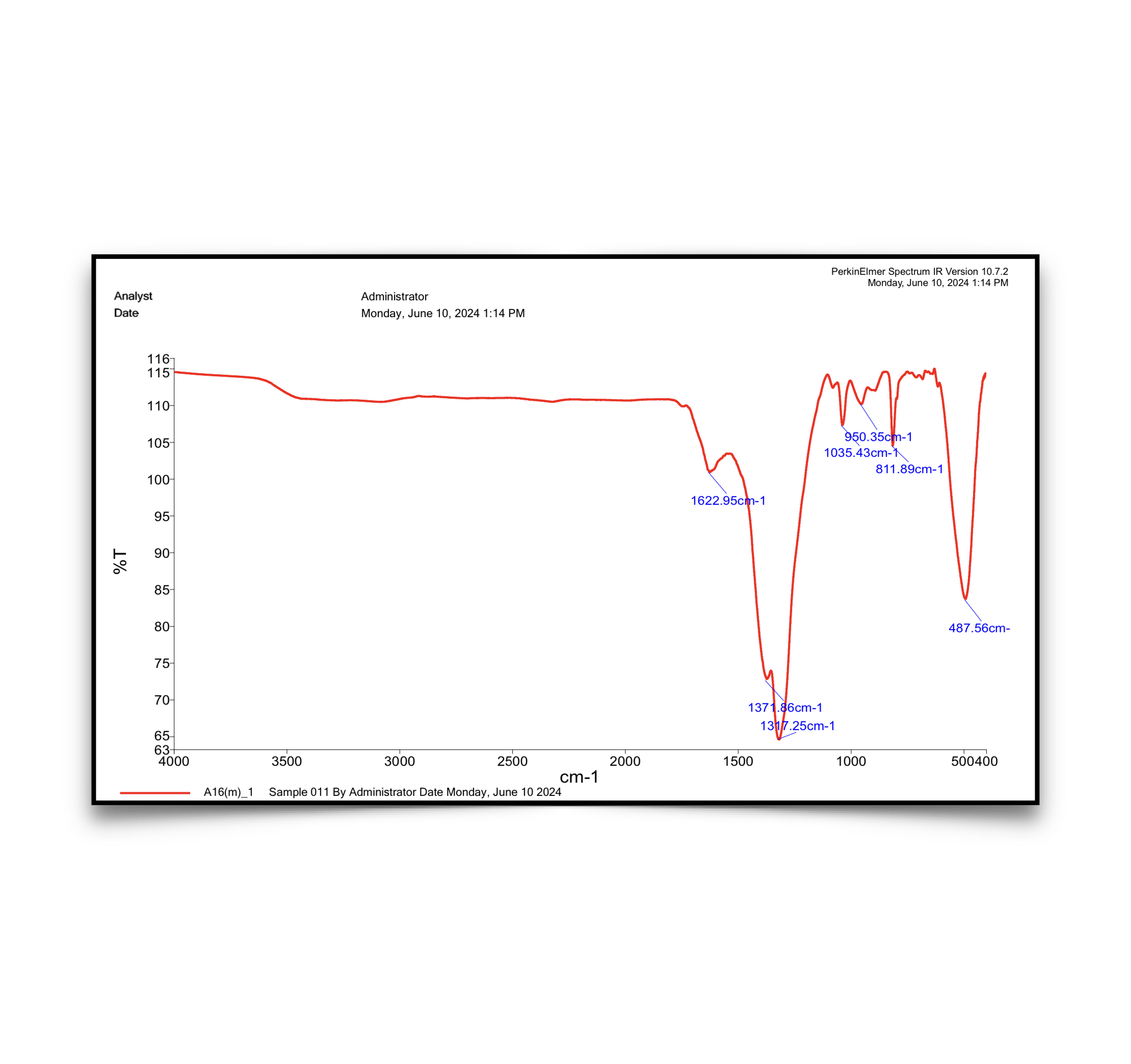


FIG:1 Fourier Transform Infrared Spectroscopy (FTIR)

# X-ray Diffraction (XRD)

## Structural Analysis through XRD

X-ray Diffraction (XRD) is a powerful technique for identifying the crystalline phases and evaluating the crystal structure of materials. The XRD pattern for the g-C3N4/Bi2O3 nanocomposite reveals several key features,

Peak Identification and Phase Analysis:The XRD pattern shows distinct peaks corresponding to both g-C3N4 and Bi2O3. The g-C3N4 peaks are identified at 2θ values around 13° and 27°, which correspond to the (100) and (002) planes, respectively. These peaks are characteristic of graphitic carbon nitride and indicate its layered structure. The Bi2O3 peaks are more numerous and intense, reflecting the higher crystallinity of bismuth oxide. Specific peaks at 2θ values of 27.5°, 31.7°, and 46.4° correspond to the (201), (002), and (022) planes of Bi2O3, respectively, as referenced from the JCPDS card number 41-1449.

Crystallite Size Determination:Scherrer’s equation can be used to estimate the crystallite size of the nanocomposite. The broadening of the XRD peaks is inversely related to the crystallite size. The narrower the peaks, the larger the crystallites. For example, the sharp peaks of Bi2O3 suggest larger crystallites compared to the broader peaks of g-C3N4. This information is crucial for applications where the particle size can influence the material’s properties, such as catalytic activity and mechanical strength.

Phase Purity and Composition:The relative intensity of the peaks provides insights into the phase composition and purity of the sample. The well-defined peaks without significant noise or unexpected reflections indicate high phase purity, meaning the synthesis process was successful in forming a composite without significant impurities. This purity is essential for ensuring reproducible and reliable performance in applications.

Lattice Strain and Defects:Analysis of peak positions and shapes can also give information about lattice strain and defects within the material. Shifts in peak positions compared to standard references can indicate strain due to lattice distortions, while peak broadening can suggest the presence of defects. These structural imperfections can play a crucial role in the material’s electronic and catalytic properties.

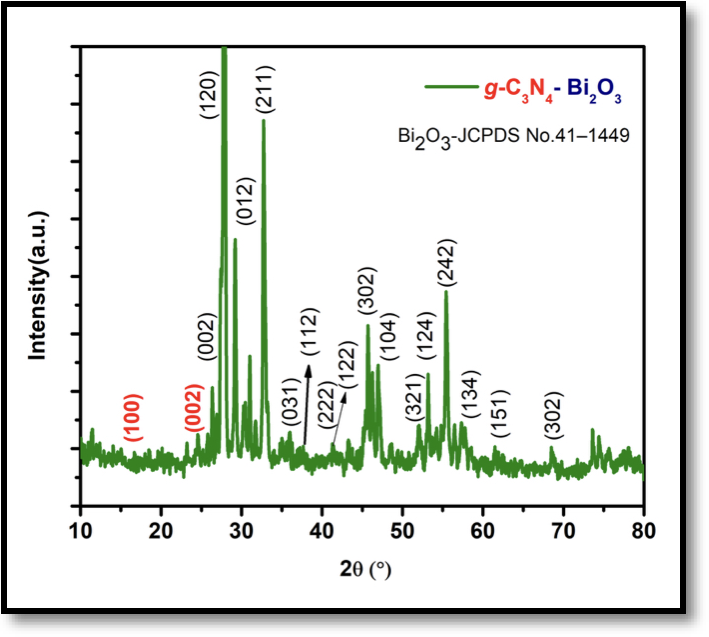


Fig:2 X-ray Diffraction (XRD)

## UV-Vis DRS (Diffuse Reflectance Spectroscopy)

The UV-Vis DRS spectrum provides insight into the optical properties of the composite. The absorption edge of the nanocomposite extends into the visible region, indicating that the bismuth oxide-modified g-C3N4 has enhanced light absorption capabilities compared to pure g-C3N4(Chehelgerdi et al., 2023). This shift suggests improved photocatalytic activity, which is advantageous for antibacterial applications.UV-Vis Diffuse Reflectance Spectroscopy (UV-Vis DRS)

## Optical Properties and Band Gap Determination through UV-Vis DRS

UV-Vis Diffuse Reflectance Spectroscopy (UV-Vis DRS) is employed to investigate the optical properties and band gap energy of the g-C3N4/Bi2O3 nanocomposite. The UV-Vis DRS spectrum provides valuable insights into the material’s ability to absorb light and its potential applications in photocatalysis and optoelectronics:

### Absorption Edge and Band Gap Energy

The UV-Vis DRS spectrum shows the absorption profile of the composite, with a significant absorption edge in the visible light range. The position of this edge can be used to determine the band gap energy of the material using the Tauc plot method. By plotting (αhν)^2 versus photon energy (hν) and extrapolating the linear region to the x-axis, the band gap energy can be estimated. For g-C3N4, the band gap is typically around 2.7 eV, while for Bi2O3, it ranges between 2.8 to 3.1 eV. The composite’s band gap might lie within this range, influenced by the interaction between the two materials.

### Light Absorption Efficiency

The UV-Vis DRS spectrum indicates that the g-C3N4/Bi2O3 nanocomposite exhibits strong absorption in the visible light range (400-800 nm). This property is essential for photocatalytic applications, where efficient light absorption is critical for generating electron-hole pairs. The enhanced absorption in the visible region suggests that the composite can utilize a broader spectrum of sunlight, increasing its efficiency in photocatalytic processes such as water splitting and pollutant degradation.

### Potential for Photocatalytic Applications

The strong visible light absorption of the g-C3N4/Bi2O3 nanocomposite makes it a promising candidate for photocatalytic applications. The composite can harness solar energy to drive chemical reactions, such as the degradation of organic pollutants or the production of hydrogen through water splitting. The presence of Bi2O3 can enhance the photocatalytic activity of g-C3N4 by facilitating charge separation and reducing recombination rates of photogenerated electron-hole pairs.

### Band Structure and Electronic Properties

The absorption characteristics and band gap information obtained from UV-Vis DRS provide insights into the electronic structure of the composite. Understanding the band alignment between g-C3N4 and Bi2O3 is crucial for designing efficient photocatalysts. The staggered band alignment can create a type-II heterojunction, where the conduction band of Bi2O3 lies below that of g-C3N4, and the valence band of g-C3N4 lies above that of Bi2O3. This alignment facilitates the separation of photogenerated electrons and holes, enhancing the composite’s photocatalytic performance.

### Quantitative Absorption Analysis

UV-Vis DRS can also be used for quantitative analysis of the composite’s light absorption properties (Saadh et al., 2024). By integrating the area under the absorption curve, the total light absorption capability can be quantified. This quantitative information is valuable for comparing different batches of the nanocomposite or optimizing the synthesis parameters to achieve maximum light absorption.

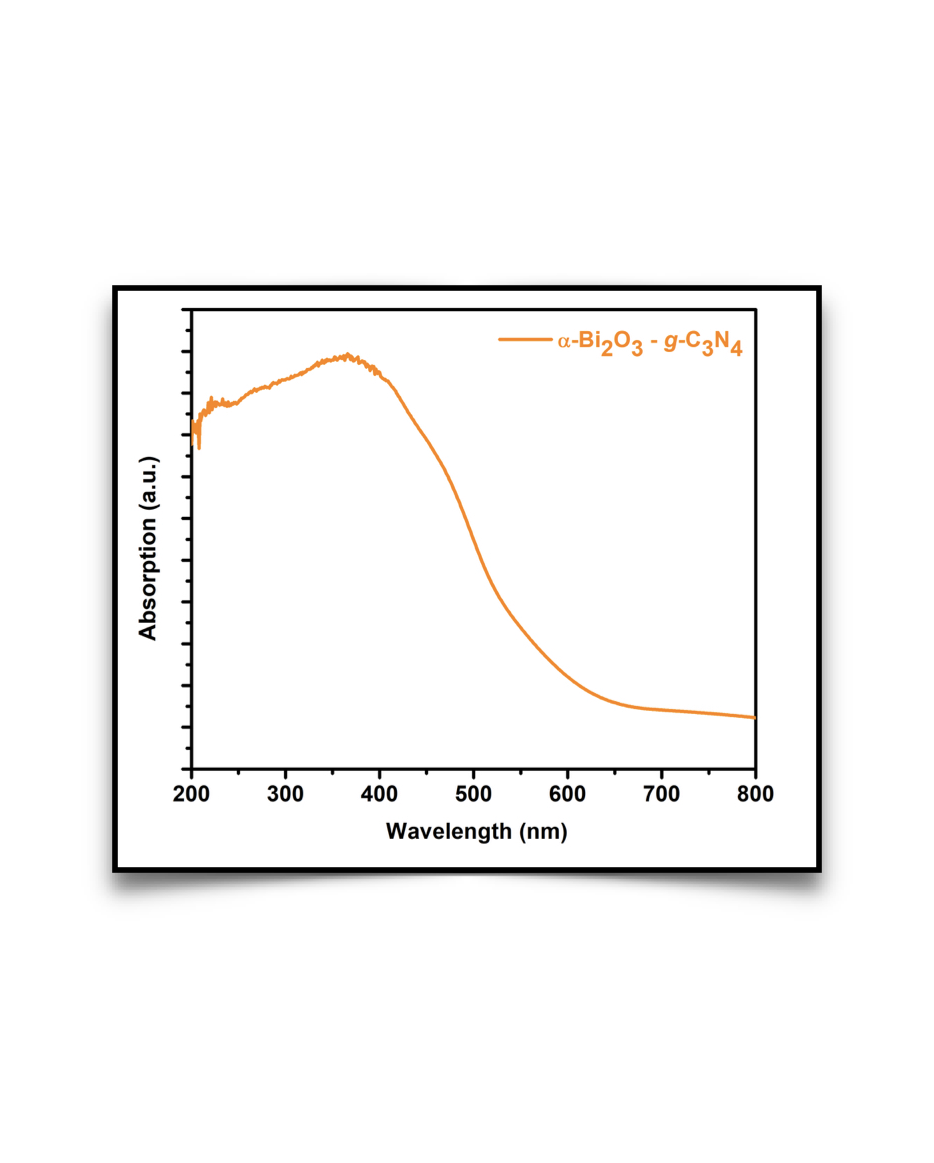


Figure 3: Wavelength vs. absorption

## Antimicrobial potential

The image presents the antifungal activity of a bismuth oxide-modified g-C3N4 nanocomposite against Aspergillus and Candida albicans. The antifungal effectiveness is measured by the inhibition zone diameters at different concentrations of the nanocomposite (50 µL, 75 µL, and 100 µL). For Aspergillus, the inhibition zones are 11 mm, 12 mm, and 14 mm for 50 µL, 75 µL, and 100 µL respectively, compared to a 10 mm zone for the negative control. For Candida albicans, the inhibition zones are 12 mm, 14 mm, and 17 mm for 50 µL, 75 µL, and 100 µL respectively, with a 10 mm zone for the negative control. These results demonstrate that the nanocomposite has a concentration-dependent antifungal effect, with higher concentrations leading to larger inhibition zones, indicating greater antifungal activity against both fungal species.

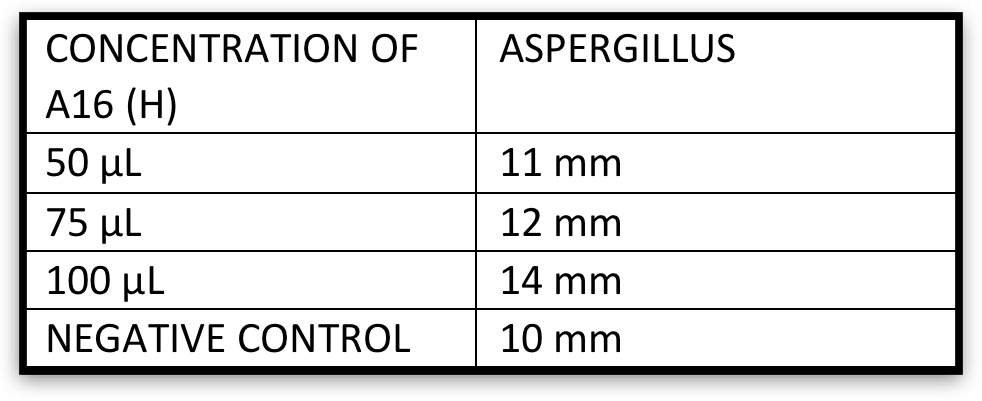


Figure 4: Antimicrobial potential

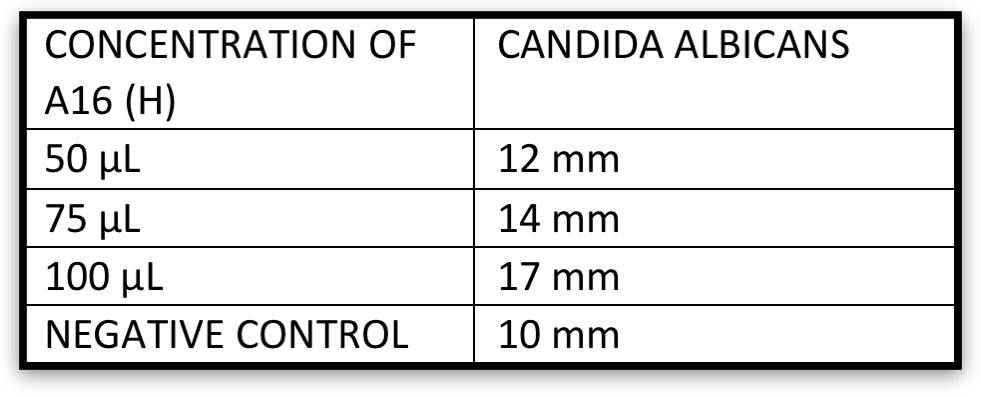
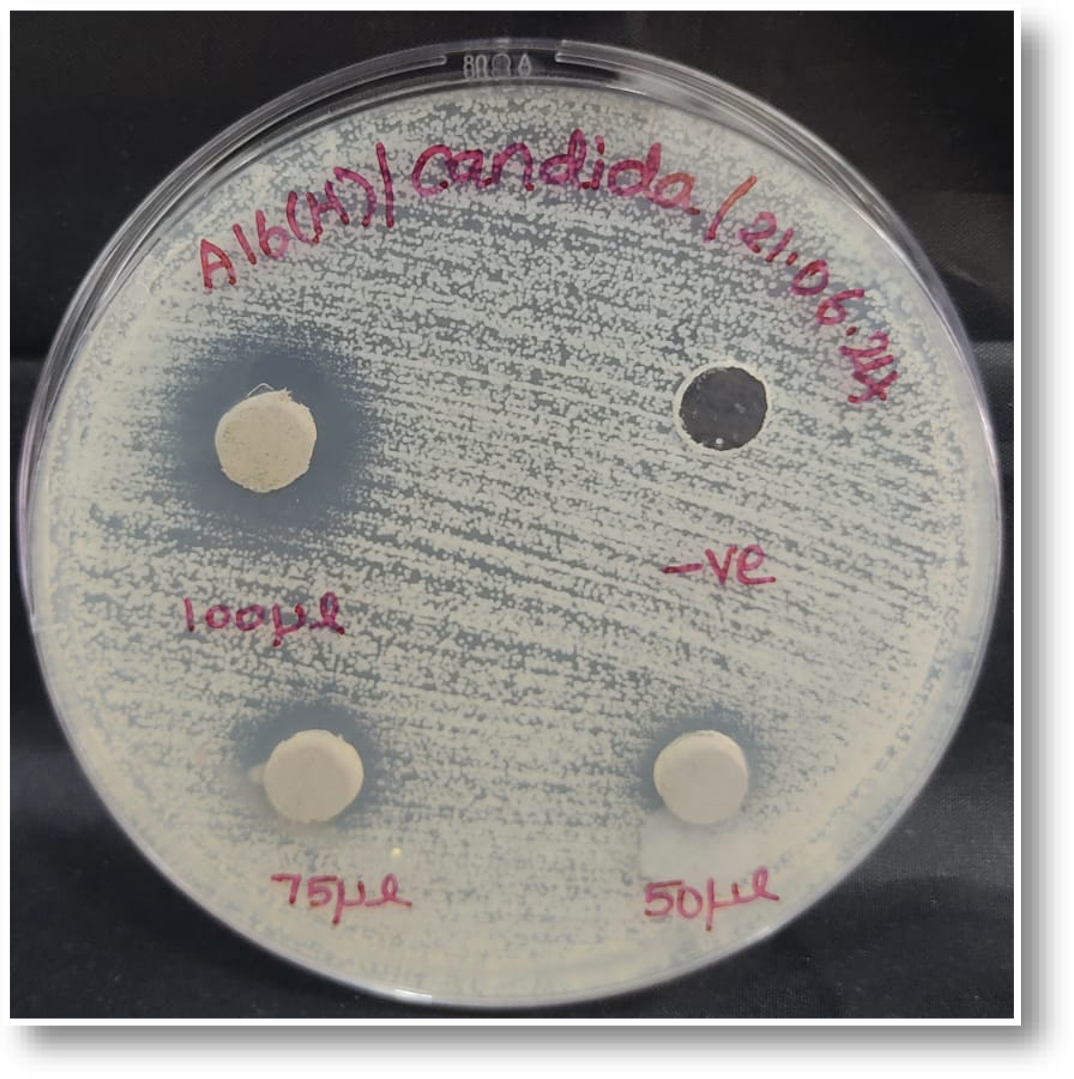


Figure 5: Antimicrobial potential

## Transmission Electron Microscopy (TEM)

The TEM image provides a detailed view of the morphology of the g-C3N4/Bi2O3 nanocomposite. The image reveals a layered structure characteristic of graphitic carbon nitride (g-C3N4) with interspersed bismuth oxide (Bi2O3) particles. The image’s scale bar, indicating a magnification level, highlights the nano-scale dimensions of the composite materials. In the image, dark regions correspond to the heavier Bi2O3 nanoparticles, while lighter regions represent the g-C3N4 matrix. This distribution is critical for applications requiring a high degree of interaction between the two components, such as photocatalysis and antibacterial activity. The uniform distribution of Bi2O3 particles within the g-C3N4 matrix is essential for maximizing the composite’s surface area and enhancing its catalytic efficiency.

## High-Resolution Transmission Electron Microscopy (HR-TEM)

HR-TEM images provide a closer look at the lattice fringes, confirming the crystallinity of the nanocomposite. The presence of well-defined lattice planes indicates high crystallinity, which is essential for enhancing the material’s electronic and optical properties. The observed lattice spacings can be indexed to specific crystallographic planes of the constituent materials, providing further confirmation of the composite’s phase composition. The high degree of order within the nanocomposite suggests effective synthesis methods, leading to materials with predictable and reproducible properties. These detailed images are crucial for understanding the interfacial interactions between g-C3N4 and Bi2O3, which can significantly influence the composite’s overall performance in various applications.

## Selected Area Electron Diffraction (SAED)

The SAED pattern provides information about the crystalline structure of the nanocomposite. The presence of distinct diffraction spots arranged in a ring pattern indicates a polycrystalline nature with multiple crystalline phases. These rings correspond to the diffraction from various crystallographic planes of g-C3N4 and Bi2O3. The sharpness and arrangement of these spots suggest high crystallinity and good phase purity. This information is crucial for applications where the electronic structure and band alignment are affected by the crystalline order, such as in photocatalytic and electronic devices. The SAED pattern corroborates the findings from the HR-TEM images, further validating the high-quality synthesis of the nanocomposite.

# DISSCUSION

The XRD patterns of the Bi₂O₃-modified g-C₃N₄ nanocomposite exhibited distinct peaks corresponding to both Bi₂O₃ and g-C₃N₄, confirming the presence of both materials in the composite. The diffraction peaks at 13.1° and 27.3° for g-C₃N₄ indicate its graphite-like structure, corresponding to the (100) and (002) planes, respectively. These peaks are characteristic of g-C₃N₄ and signify its well-ordered structure.[(Deepika et al., 2022; Dharman, 2021)](https://paperpile.com/c/ytOql9/ekQq+XINP) The sharp peaks observed for Bi₂O₃ in the XRD patterns verified its incorporation into the g-C₃N₄ matrix. These peak locations matched the Joint Committee on Powder Diffraction Standards (JCPDS) data for Bi₂O₃, confirming the crystalline nature of Bi₂O₃ within the nanocomposite.TEM images revealed a uniform distribution of Bi₂O₃ nanoparticles on the g-C₃N₄ nanosheets, which significantly increases the surface area available for antifungal interactions. High-Resolution TEM (HRTEM) images showed clear lattice fringes of Bi₂O₃ with interplanar spacings that corroborate the XRD results, confirming the high crystallinity of Bi₂O₃ nanoparticles. The close contact between Bi₂O₃ and g-C₃N₄ observed in the TEM images suggests strong interfacial interactions, which are crucial for efficient charge transfer and enhanced antifungal activity.The UV-DRS spectra demonstrated that the Bi₂O₃/g-C₃N₄ nanocomposite exhibited enhanced visible light absorption compared to pure g-C₃N₄. This increased absorption is indicative of the nanocomposite’s improved capability to harness visible light for photocatalytic applications. [(Harsha & Subramanian, 2022)](https://paperpile.com/c/ytOql9/IJzY)The observed redshift in the absorption edge of the nanocomposite suggests that the presence of Bi₂O₃ lowers the bandgap energy, thereby expanding the light absorption range and enhancing the efficiency of solar energy utilization for antifungal purposes.The FTIR spectra of the Bi₂O₃/g-C₃N₄ nanocomposite showed distinct absorption bands for both g-C₃N₄ and Bi₂O₃. The bands at 810 cm⁻¹ and 1230-1650 cm⁻¹ correspond to the stretching vibrations of C-N and C=N bonds in g-C₃N₄, indicating that its structure remains intact after modification. The presence of new absorption bands attributable to Bi-O bonds in the nanocomposite spectrum confirms the successful incorporation of Bi₂O₃. The absence of these bands in pure g-C₃N₄ further verifies the effective modification of g-C₃N₄ with Bi₂O₃.

# CONCLUSION

In conclusion, the structural, optical, and functional features of the Bi2O3 modified g-C3N4 nanocomposite, confirmed by XRD,TEM, HRTEM, UV-DRS, and FTIR investigations, demonstrate its potential for improved antifungal applications. Improved lightabsorption, excellent charge separation, and strong interfacial contacts between Bi2O3 and g-C3N4 all contribute to its betterantifungal properties. This work highlights the potential of Bi2O3 / g-C3N4 nanocomposite in the development of improvedantifungal materials for use in healthcare and the environment.Upon light irradiation, the nanocomposite generates electron-hole pairs. The electrons are transferred from the conductionband of g-C3N4 to that of Bi2O3, while holes remain in the valence band of g-C3N4.This efficient charge separation leads to theformation of ROS, including superoxide radicals (•O2-) and hydroxyl radicals (•OH), which induce oxidative stress and damage to fungal cells. The ROS attack cellular components such as membranes, proteins, and DNA, ultimately leading to fungal cell death.

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