Anti-microbial mechanism of ZnO nanoparticles in the presence of cationic surfactant against pathogenic bacteria for pharmaceutical applications

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ABSTRACT

Metal oxide nanoparticles with quite prodigious enactment in the field of research. ZnO is considered to be an exact candidate for an antimicrobial agent. ZnO in the form of fine nanoparticles possess enhanced antibacterial action than when it is in the bulk form. It is obvious that ZnO, which have the average crystallite size in the range between 15nm to 20nm exhibits enhanced antimicrobial activity against pathogenic bacteria, so the present investigation is carried out to explains the role of cationic surfactant in the antimicrobial execution of ZnO nanoparticles enzymatic about precipitation method annealed at the temperature of 600°C. The outcomes are cogitated by XRD spectra, SEM, and Fourier Transform Infra-Red spectra. The crucial antimicrobial activity of the complex ZnO NP’s antagonistic pathogenic bacteria were studied quantity-wise. ZnO nanoparticles have the capability to interfere with NorA protein, which is developed for conferring resistance in bacteria and has pumping activity that mediates the effluxing bacterias from a cell. Thus, antimicrobial effect Zinc oxide is widely used in nursing a variety of skin conditions, including dermatitis, itching due to eczema, diaper rash and acne.

INTRODUCTION

Zinc oxide has an energy gap of 3.37 eV, which corresponds to emission in the ultraviolet range, which broadens when the dimension of the nanoparticles concise beneath the verge of nanometers (Jin et al., 2009). Because of these characteristics, this can be used in the field of science Zinc oxide nanoparticles are most often practised in the multifold firmament of human activity such as cosmetics and pharmaceuticals because they are less expensive with interesting properties such as antibacterial and antifungal properties (Li et al., 2009). This is an important feature of zinc oxide nanoparticles which is considered an effective antibiotic against infectious microorganism. Zinc oxide nanoparticles exhibit different bacterial mechanism, which can be helpful to identify the defects.

In the present work, Cationic surfactant-assisted Zinc oxide nanoparticles have been synthesised, and their antimicrobial mechanism was manifested against pathogenic bacteria. ZnO –NPs disrupt bacterial cell membrane integrity and downregulate the genetic oxidative tenseness in bacteria (Gu et al., 2014).

MATERIALS AND METHODS

Material synthesis
Analytical grade of Zinc acetate dihydrate and
cetyltrimethylammonium bromide (CTAB) was added in 500ml of deionised water. All the chemicals were used as such without further purification. NaOH Pellets was gradually introduced to the solution of zinc acetate dihydrate and cetyltrimethylammonium bromide. White precipitated powder is obtained after 2 hours of stirring. The product was subjected to remove water-soluble impurities to obtain zinc oxide nanoparticles dried for 1 hour at 600°C.

**Characterization studies**
The crystallite size, lattice parameters, lattice strain, and crystal phase was found by X-ray Diffractometer. The influence of temperature and the morphological changes of the ZnO nanoparticles was examined scanning electron microscopy (SEM). The chemical bonds in the molecules are identified from FITR analysis.

**RESULTS AND DISCUSSION**

**XRD analysis**
XRD Pattern of ZnO nanoparticles are shown in Figure 1 implies their good crystallization with higher and narrower diffraction peaks. Both the crystallinity and phases of ZnO NP’s were characterized. Using the Debye–Scherer formula, the crystallite size ‘D’ is calculated using Equation (1) for three intense peak (0 0 2), (1 0 1), (1 0 2),

\[
D = \frac{0.9 \lambda}{B \cos \theta}
\]  

No other crystalline phases were detected except the hexagonal wurtzite phase, which was verified with the JCPDS 36-1451 of ZnO ([Otsuka et al., 2003](#)). The size of the prepared crystals is found to be 17 nm and the good crystallinity of the diffraction peaks was indicated as well.

**SEM Analysis**
Figure 2 portrays the direct visualization of the zinc oxide nanoparticles with a cationic surfactant. To Evaluate its surface morphology, the sample was subjected to SEM analysis.

CTAB ionizes completely in the water as it is an ionic compound and, when added with ZnO, have the tendency to reduce the surface tension of the solution, and which in turn decreases the energy that is in need to cast a new notch which states that, ZnO NP’s could be formed in a lower supersaturation state. ([Hassan et al., 2014](#)). The origin of the different morphology can be explained by The chemical interaction that takes between the surface of ZnO and the ions explains the allegiance of the various anatomizations.
**Figure 4: Antimicrobial activity against pathogenic bacteria by disc diffusion method**

**Table 1: Inhibition zones against different bacterial strains**

| Sample                      | Zone of inhibition (mm) by adding 100 ml NaOH extract |
|-----------------------------|-------------------------------------------------------|
|                             | 25 m/ml | 50 mm/ml | 75 m/ml | 100 mm/ml | Dominion |
| Bacillus subtilis           | 16      | 18       | 20      | 22        | 20       |
| Staphylococcus aureus       | 16      | 19       | 22      | 26        | 22       |
| E.coli                      | 12      | 15       | 18      | 20        | 20       |
| Klebsiella pneumonia        | 14      | 17       | 20      | 25        | 22       |

The ionization produced by the addition of CTAB leads to the passivation of its positively charged ions towards the ionized oxygen O⁻ over the surface of Zinc oxide by the process of electrostatic interaction, which in sequence subdued the augmentation of Zinc oxide crystal.

**FTIR analysis**

Figure 3 showcase the FTIR spectrum of cetyltrimethylammonium bromide (CTAB) assisted ZnO NP’s.

From the Figure 3, the characteristic peak at 3,373 cm⁻¹ is due to stretching of hydroxyl group, two peaks at about 1,723 and 1,553 cm⁻¹ were assigned to symmetric and asymmetric C=O Stretching. The peak at about 1060 is because the CH deformation implies the –CH₂ and CH₃ bending. The value below 1060 the metal oxides showpiece the absorption band in the fingerprint region because of the interatomic vibrations. The stretching of Zn-O is traced at around 450 cm⁻¹ in the infrared region (Sirelkhatim et al., 2015). This FTIR observation denotes CTAB molecules get absorbed on synthesized ZnO. The dissimilarity in the wave number and frequency depends on the variance in the particle size.

**Antimicrobial Mechanism of ZnO Nanoparticles**

Cationic surfactant-assisted Zinc oxide nanoparticles tested for their bactericidal activities, which is synthesized at 600°C. Interestingly, the ZnO nanoparticles reveals a significant antimicrobial mechanism in resistance to pathogenic bacteria. Figure 4 shows the antimicrobial action of CTAB assisted ZnO nanoparticles detrimental to pathogens. The zone of inhibition (mm) of different pathogens was ordered in Table 1, which were maintained in nutrient broth.

The analysis of the biological activity of cationic surfactant-assisted ZnO nanoparticles was tested for different organisms in sterilized Petri dishes adopting agar diffusion technique for the sample annealed at 600°C (Sondi and Salopek-Sondi, 2004). The nutrient agar ambience was processed by incapacitating at about 121°C. It is then sterilized, aseptically engulfed in petri plates and permitted to densify. Each petri plates were swabbed with the bacterial broth using sterilized twigs. Then the wells were aseptically added with the organic solvent extracts of leaves.

The cell culture dish is detected to spot its zone of inhibition incubated at 37°C for 24 hrs. The MIC of ZnO with CTAB is thus calculated.

Table 1 indicates the zinc oxide nanoparticles assisted with cationic surfactant have moderate activity with the concentration of 75 and 100 mg/mL, and the following values were observed with respect to the control (22 and 26 mm) against Staphylococcus aureus, against Bacillus subtilis (20 and 22 mm), against E.coli (18,20), against Klebsiella pneumonia (20,25) when concentrations were used (Veerapandian and Yun, 2011; Zandonella, 2003).

**CONCLUSION**

From the present study, synthesized cationic surfactant-assisted Zinc oxide nanoparticles have a high minimum inhibitory concentration (MIC),...
which makes it quite effective to be used as antibacterial antiseptic cream and lotions for skin diseases. On the other hand, the disc agar diffusion method reveals that ZnO nanoparticles possess substantial antimicrobial agents iminal to pathogenic bacteria. The antibacterial mechanism of ZnO with the intermediary crystallite dimension of 17 nm resistant to human aerobes reported a higher effect of ZnO nanoparticles. The present study emerges that among other pathogenic bacteria, ZnO nanoparticles shows great competence against Staphylococcus aureus. It is also clear that escalation of CTAB interprets a vital task in the antimicrobial mechanism of ZnO nanoparticles.

ACKNOWLEDGEMENT

The author is highly grateful to SEM Facility, Consultancy on the characterization of Nanomaterials (CCN), Centre for Nanoscience and Nanotechnology, Department of Chemistry, The Gandigram Rural Institute – DU, Tamilnadu, India, Nanofluids Lab, Centre for Nanotechnology and Advanced Biomaterials, SASTRA Deemed University, Tamilnadu, India and also to Eumic analytical Lab and Research Institute, Tiruchirappalli.

Funding Support

The authors declare that they have no funding support for this study.

Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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