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SYNTHESIS AND CHARACTERIZATION OF ZINC OXIDE NANOPARTICLES IN A SOL-GEL ENVIRONMENT AND ITS ANTIMICROBIAL ACTIVITY

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ABSTRACT:
Zinc oxide and related materials have recently received a lot of attention. Zinc oxides have catalytic and electrical properties that can be applied to chemical synthesis, petroleum refining, recording medium, and sensors. They are also used in optical devices, and they are potential photoelectrochemical energy producers with large surface areas and great photo efficiency. We picked sol-gel because some of the previous techniques used high temperatures and harmful chemicals. The sol-gel method is the most sophisticated and environmentally friendly since it does not require high pressure or temperature, is low in cost, can monitor the crystalline size and structure of the nanomaterial by adjusting the medium pH, and can generate a big sample at once. Thus, in this paper, we offer a sol-gel approach for producing zinc oxide nanoparticles using citric acid as a surfactant. ZnO nanoparticles are floating in broth to assess their antibacterial, antifungal, and antimalarial properties.
KEYWORDS: zinc oxide nanoparticle; sol-gel method; antibacterial; antifungal: antimalarial.

INTRODUCTION

In recent years, a significant amount of time and energy has been put into researching zinc oxide and other materials in a similar manner. Zinc oxides have the potential to be utilized in the production of chemicals [i], the refinement of petroleum [ii], the production of recording media[iii], and sensors[iv]. Zinc oxides have distinctive catalytic and electrical capabilities. In addition to this, they find applications in optical device applications[v], and they are a promising material for photoelectrochemical energy production with a high surface area and greater photo efficiency[vi]. In addition, they are employed in applications for optical device applications[vii-viii]. For the preparation of metal oxide nanoparticles, there are a few different ways to choose from. Examples include solid-state synthesis, hydrothermal method, electrochemical method, sol-gel technique, co-precipitation method, microwave-assisted synthesis method, and thermal decomposition method. We chose the sol-gel procedure over other methods that required high temperatures and potentially dangerous chemicals. The sol-gel approach is the most recent and environmentally benign of these methods. It does not require high pressure or temperature, is inexpensive, allows you to simply modify the pH of the medium to see how the nanomaterial's crystals form, and can produce a large number of samples at once. Considering this, we have shown in this chapter a straightforward sol-gel process for the synthesis of zinc oxide nanoparticles in the presence of citric acid, which serves as an effective surfactant. Using broth floatation procedures, prepared ZnO nanoparticles are put through tests to determine whether they have antibacterial, antifungal, or antimalarial action.

EXPERIMENTAL

Materials and synthesis methods

The synthesis of zinc oxide (ZnO) nanoparticles was carried out by the sol-gel method. Initially, 0.25 M zinc chloride was dissolved in 100 ml of distilled water. 0.1 N hydrochloric acid improves the solubility of zinc chloride in water. Both solutions were mixed with constant stirring. After mixing the solutions, 1 gm of the citric acid solution was added as a surfactant. The pH of the above solution was adjusted to 8-8.5 using 3 to 3.5 ml of NH_4OH solution. Precipitation was formed, which stirred with constant stirring for an hour at room temperature. The mixture was filtered using Whatman filter paper No. 42 and washed with deionized water 2-3 times. The obtained product was dried in an oven at 100˚C for 2 hours. Finally, the dried material was calcinated for 3 hours at 500˚C in the furnace. The White colored precipitate was obtained as a final product and stored for further study, as shown in the flow chart figure 1.

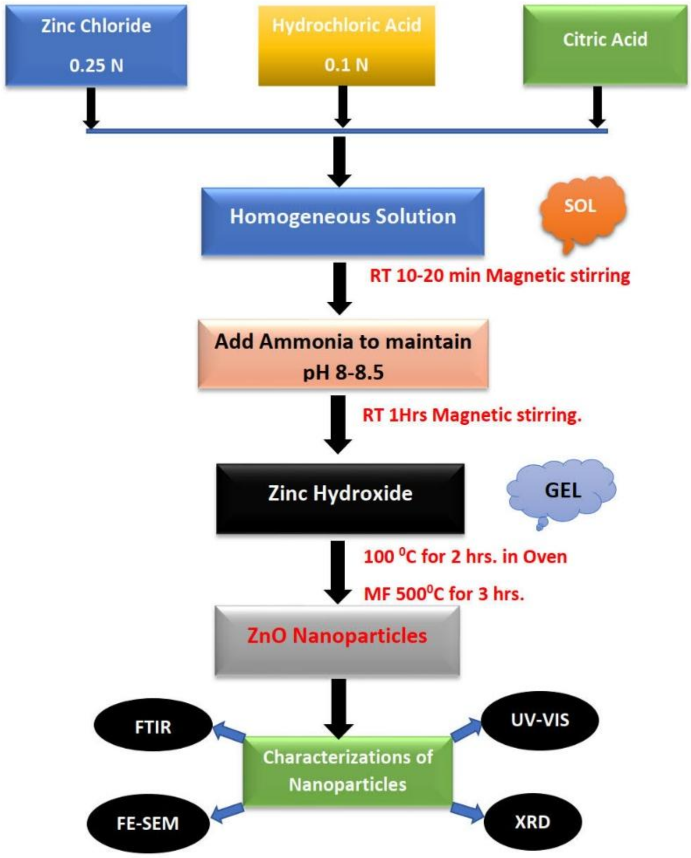


Figure 1. Flow Chart of ZnO Nanoparticles

UV-Visible Spectroscopy

Figure 2 depicts the UV-visible diffused reflectance spectra of nanostructured zinc oxide NPs with equal amounts of each. It absorbs a lot of light at 350 to 400 nm. This reveals that equimolar concentrations of zinc oxide nanoparticles reduce reflectance. These findings suggest that synthesised zinc oxide nanoparticles can shift the absorption spectrum from infrared to visible light. This means that transition metal oxides can alter light.

The shift in reflectance is primarily caused by the influence of zinc oxide nanoparticles on ZnO semiconductor band gaps. Zinc oxide NPs are significantly more photoactive and catalytic due to the increased rate of charge transfer between Zn^{2+} electrons in the valence band.

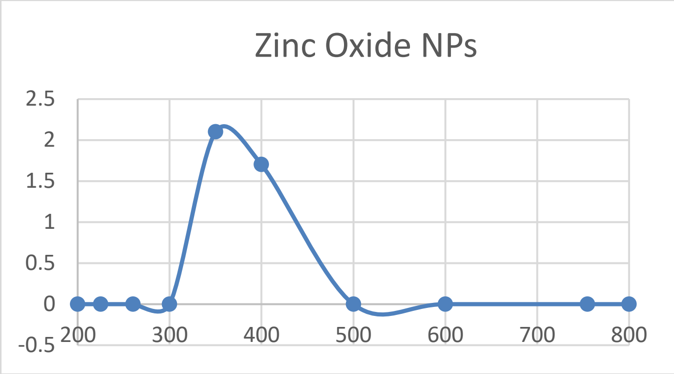


Figure 2. UV-Vis Spectrum of ZnO NPs

FT-IR Spectroscopy

The FT-IR spectrum of synthetic of ZnO nano particles with citric acid shows absorption bands due to O–H stretching at 3,530 cm^{-1}, asymmetric and symmetric C=O stretching of Zinc chloride at 1,630 and 1,510 cm^{-1}, O–H bending of hydroxyl group at 546.66 cm^{-1}, and Zn–O stretching of ZnO at 507.70 cm^{-1} show in figure 3.

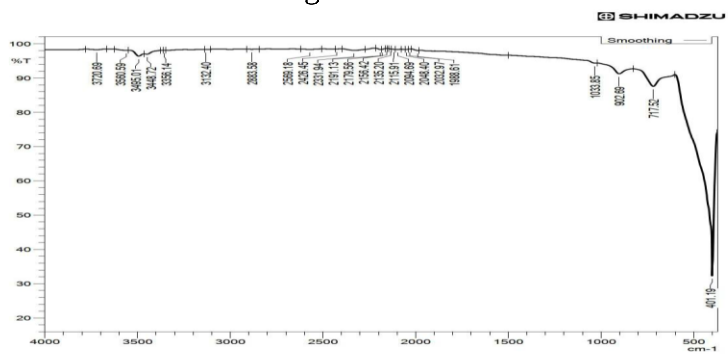


Figure 3. FT-IR Spectroscopy of ZnO NPs

XRD data Analysis

The XRD patterns of the synthesized products by sol-gel methods are shown in Figure 4. All diffraction peaks can be indexed as hexagonal wurtzite structure (JCPDS card No. 80-0075). The XRD pattern of ZnO nanoparticles indicates the prominent diffraction peaks at 2Θ values of 31.90˚, 34.50˚, 36.25˚, 48.90˚, 56.95˚, 66.80˚ and 68.10˚ which are shown to the typical hexagonal type of ZnO. The sharp diffraction peaks indicated the good crystallinity of the prepared crystals.

When citric acid was added as surfactant, it may cover the ZnO particles to prevent further growth. Therefore, the increased of citric acid concentration limits the growth of ZnO nano particles and diminished the diameter and length of ZnO crystals.

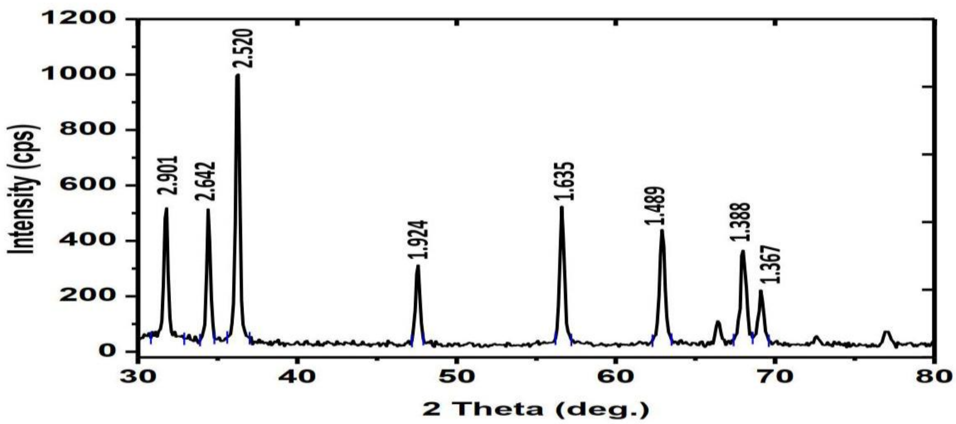


Figure 4. XRD Spectrum of ZnO NPs

FE-SEM

To examine the effects of cationic/anionic surfactants on ZnO morphology, we have done comparison in samples the addition of citric acid remarkably affected the morphology of particles, shows uniform arrangement of ZnO particle has been detected in figure 5.

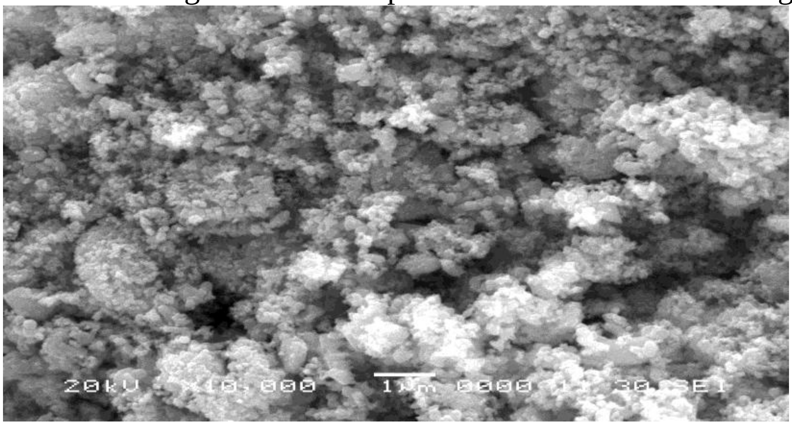
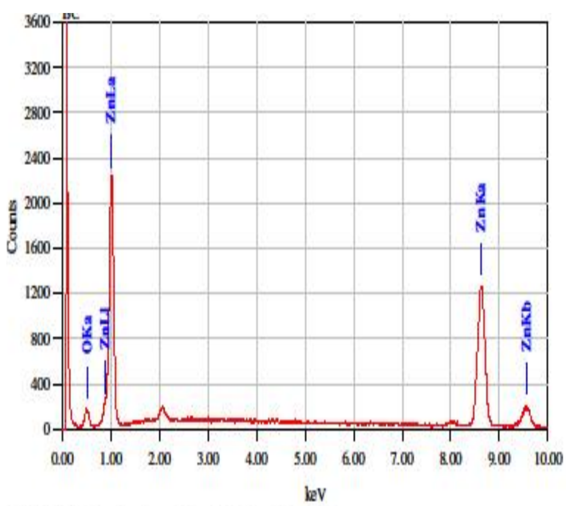


Figure 5. FE-SEM of ZnO NPs

The Energy Dispersive Spectroscopy (EDS)

The EDS was performed with the apparatus JOEL (Jed-2300).The formation of the ZnO nano structures was due to the presence of a citric acid as surfactant. The energy dispersive spectroscopy (EDS) shown in figure 6 showed the presence of Zn.

EDS-Data



Element	Line Type	Wt.%	Atomic %
O	K-Series	4.35	15.67
Zn	K-Series	95.65	84.33
Total		100	100

Figure 6. EDS spectrum & EDS-Data of ZnO nanoparticles

RESULT AND DISCUSSION:

Antibacterial activity

Antibacterial activity was tested on the synthesised zinc oxide nanoparticles compounds. The broth dilution technique was used to demonstrate antibacterial activity against. *E. coli* (MTCC 443), P. *aeruginosa* (MTCC 1688), *S. aureus* (MTCC 96), and *S. pyogenus* (MTCC 442) bacterial strains using *gentamycin, ampicillin, chloramphenicol, ciprofloxacin*, and *norfloxacin* as the standard drugs [x-xi]. zinc oxide nanoparticles showed a good antibacterial activity against *E. coli* and *S. aureus*, while the standard *chloramphenicol* (50 µg/mL) had weaker antibacterial activity against P. *aeruginosa* and *S. pyogenus* as compared to the standard chloramphenicol shown in (Table 1) **.** Zinc oxide nanoparticles showing weak antibacterial activity against *E. coli*, P. *aeruginosa, S. aureus,* and *S. pyogenus* the standard *gentamycin, ampicillin, ciprofloxacin* and *norfloxacin* show in (Table 1).

Table 1. Antibacterial activity data of ZnO NPs

ANTIBACTERIAL ACTIVITY TABLE					
MINIMUM INHIBITION CONCENTRATION (MICROGRAM /ML)					
SR.	CODE	*E.COLI*	*P.AERUGINOSA*	*S.AUREUS*	*S.PYOGENUS*
NO	NO	MTCC 443	MTCC 1688	MTCC 96	MTCC 442
1	**ZnO Nanoparticles**	**100**	**100**	**125**	**125**
2	*GENTAMYCIN	0.05	1	0.25	0.5
3	*AMPICILLIN	30	-	40	25
4	*CHLORAMPHENICOL	50	50	50	50
5	*CIPROFLOXACIN	25	25	50	50
6	*NORFLOXACIN	10	10	10	10
*STANDARD DRUG					

Antifungal Activity

Antifungal activity of zinc oxide nanoparticles was studied against *C. albicans* (MTCC 227), *A. niger* (MTCC) 282, and *A. clavatus* (MTCC 1323) fungal strains[xii-xiii]. The antifungal activity testing demonstrated that the formulations containing zinc oxide nanoparticles were less effective than standard *Nystatin* and *Greseofulvin*. When compared to both standards, the compounds showed lower efficiency against the fungal strains *C. albicans*, *A. niger*, and *A. clavatus* (Table 2).

Table 2. Antifungal activity data of ZnO Nanoparticles

ANTIFUNGAL ACTIVITY TABLE				
MINIMUM INHIBITION CONCENTRATION (MICROGRAM /ML)				
SR.	CODE	*C.ALBICANS*	*A.NIGER*	*A.CLAVATUS*
NO	NO	MTCC 227	MTCC 282	MTCC 1323

1	**ZnO Nanoparticles**	**1000**	**500**	**500**
2	*NYSTATIN	100	100	100
3	*GRESEOFULVIN	500	100	100
*STANDARD DRUG				

Antimalarial Activity

Zinc oxide nanoparticles synthesised compounds showed antimalarial activity against *Plasmodium falciparum*[xiv-xv]. The compound zinc oxide nanoparticles showed less antimalarial activity. The results of antimalarial activity revealed that zinc oxide nanoparticles compounds were moderately active but less potent than standard chloroquine, as shown in (Table 3).

Table 3. Antimalarial activity data of ZnO Nanoparticles

ANTIMALARIAL ACTIVITY (Plasmodium Falciparum)		
MINIMUM INHIBITION CONCENTRATION (MICROGRAM /ML)		
SR.	CODE	MEAN IC50 VALUESa
NO	NO	MTCC 227
1	**ZnO Nanoparticles**	**1.07** µg /ml
2	*CHLOROQUINE IC50	0.020 µg /ml
*STANDARD DRUG a:mean values in representative assay.		

CONCLUSION

In summary, we provide the synthesis and antimicrobial activity of zinc oxide nanoparticles. Zinc oxide nanoparticles have high antibacterial action against E. coli and S. aureus, the gold standard for chloramphenicol. Compounds containing zinc oxide nanoparticles were less effective against Candida albicans, A. niger, and A. clavatus. The compounds had moderate antimalarial activity, but not as much as ordinary chloroquine. The research has so uncovered antibacterial and antimalarial molecules, indicating their potential future importance in pharmaceutical chemistry. The sol-gel approach with zinc chloride as a reactant and citric acid as a surfactant was used to effectively compare ZnO nanoparticles. Because the sol-gel approach was used in the presence of an aqueous medium, we dubbed it the environmental begin sol-gel method.

CONFLICT OF INTERESTS

The authors confirm no conflicts of interest.

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