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Nanostructured ZnO&CoO Doped Transition Metal Oxide Nanoparticles as Antibacterial Agents

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***Abstract*—A systematic investigation of ZnO& Co-doped ZnO nanoparticles on the structural, and antimicrobial properties wereevaluated using hydrothermal synthesis, which is considered as one of the most efficient, environmentally friendly approaches. The synthesized nanoparticles were thoroughly characterized using UV-Vis spectroscopy, SEM with EDS and XRD analysis. The antibacterial property test was carried out using the disk diffusion method against E.Coli bacteria, the activity was compared against standard drug gentamicin also, and the antibacterial activity was evaluated for various concentrations. The results showed the nanoparticles synthesized were effective as a potent antibacterial agent thereby inhibiting cell growth.**

***Index Terms*— Nanoparticles, ZnO, CoO nanoparticles, Antibacterial activity.**

I. INTRODUCTION

Nanomaterial research is the most promising and attractive field in this contemporary era [1,2]. The fabrication of metal oxide nanoparticles recently grew intensively for various chemists, biochemists and material science researchers due to their gaining applications in different fields. Among various transition metals, Zn and Co metal oxide nanoparticles show an incredibly wide range of applications. CoO and ZnO nanoparticles are enriched with antimicrobial and magnetic properties. Also, the doping studies increase the antimicrobial properties against a very broad spectrum of microorganisms. [3,4]. It is noteworthy that the inorganic metal oxide nanoparticles are non-toxic, and show high microbial properties even at very low concentrations that are unfavourable for pathogenic bacteria. This increased resistance with metal oxide nanoparticles shows new solutions to eliminate bacteria to be more infectious nowadays. Moreover, in the last few decades, the use of metal oxide nanoparticles has provided new hopes for overcoming bacterial resistance. [5,6]. Co is a relatively less abundant metal which has a more beneficial action on a human because of its presence in the form of vitamin B12. Vitamin B12 is one of the very essential components, that treat anaemia in pregnant women [7]. Further CoO&ZnO nanoparticles have enormous applications in the fields of catalysis, superconductors, textile, pharma, electronics and many more. Among various ZnO doped metal oxide nanoparticles, Co has been a centre of interest many studies have reported the preparation of Co-doped ZnO nanoparticles with a wide variety of physical and chemical routes. Many methods for synthesis of ZnO and CoO composites have been reported in the literature including sol-gel, chemical vapour deposition, electrochemical, precipitation and thermal vaporization. All these methods have disadvantages due to their high cost of equipment and also time-consuming. [8-16]. Considering all the drawbacks hydrothermal method is identified also less research has been carried out for synthesizing ZnO with CoO doped nanoparticles. Hydrothermal synthesis is the synthesis of

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substances using a sealed heated solution above ambient temperature and pressure. The concept of Hydrothermal originated from earth science in the nineteenth century and implies a rule of high temperatures and water pressures. [17]. Hydrothermal synthesis offers many advantages with moderately fewer operating conditions of less than 3000C, with a single-step environmentally friendly procedure. A Hydrothermal method is inexpensive in terms of its instrumentation. [18]. Considering all the above facts, the present study is focused on synthesizing ZnO metal oxide nanoparticles doped with CoO nanoparticles, and evaluating various morphological properties using U-Vis Spectroscopy, DLS Particle size, SEM with EDS. The study also evaluates the antimicrobial effect of synthesized nanoparticles to analyse their inhibition activity for different pathogens

II. EXPERIMENTAL DETERMINATION

a) Hydrothermal synthesis of ZnO/CoO nanoparticles:

The synthesis of ZnO/CoO np's was carried out via a hydrothermal method. Zinc acetate dihydrate (25 ml of 0.5 M, AR Grade ≥97%, SRL) and Cobalt Nitrate (5 ml of 0.5 M, AR Grade ≥98%, SRL) were each dissolved in distilled water under constant stirring. The solutions were mixed thoroughly and 10 ml of 0.5 M Sodium hydroxide was added dropwise with continuous stirring with an additional 50 mL of distilled water, vigorous stirring was continued for another 1 hr. Later the reaction mixture was transferred to a Teflon-lined autoclave heated in a hot air oven at 140 oC for 12 hr and allowed to cool at room temperature. The obtained mixture was filtered and the resultant green solid obtained was washed with double distilled water till the pH of the filtrate was neutralised. In order to remove moisture and other impurities, the wet powder was calcinated at 400 oC in the muffle furnace for 6 hrs.

III. RESULTS AND DISCUSSIONS

a) UV-Visible Spectroscopy

UV-Visible spectrum range at room temperature from 200-800nm shows the ZnO/CoO nanoparticles has been illustrated in Fig. 1. The band gap energy is estimated to be 3.17eV for ZnO/CoO nanoparticles. Λmax was observed at 380nm and 450nm. The presence of a prominent excitation band around 380nm confirms the presence of ZnO nanoparticles, as reported by other researchers [19,20]. Similarly, the excitation around 450nm validates the presence of dopant CoO nanoparticles as reported by researchers [21,22]. The doping has predominantly increased the energy levels due to two factors, of Burstein-Moss shift and due to interactions among the carriers. These factors are responsible to show the optical broaden band gap observed in the UV spectra.

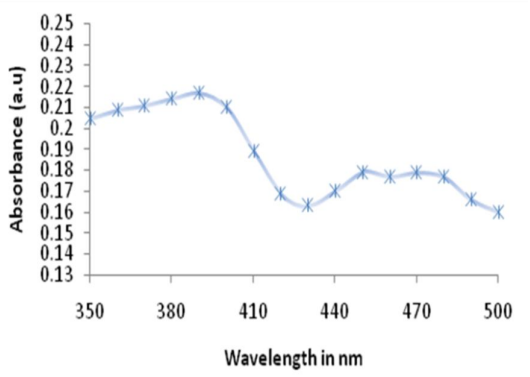

Figure 1: UV-Visible Spectroscopy of ZnO/CoO nanoparticles

b) XRD:-

ZnO/CoO nanocomposites were characterized by powder X-ray diffraction (PXRD) as shown in Fig. 2. The main diffraction peaks of the ZnO/CoO np's exhibit (a = 14.52 Å, b = 3.9018 Å and c = 10.277 Å), $\alpha = \beta = 90^o$, $\gamma \neq 90^o$ and V = 553.2 Å (JCPDS # 36-1451). The data obtained indicate that ZnO/CoO nanocomposites belong

to the Monoclinic crystal system with a crystal size of 21.23 nm. The cell parameters for ZnO NPs calculated was found to be, a =b and $b \neq c$ (a = 7.495 Å, b = 7.495 Å and c = 21.42 Å), $\alpha = \beta = \gamma = 90o$ and V = 1203 Å. This represents that ZnO NPs fit in the Tetragonal crystal system. The major diffraction peaks observed for ZnO/CoO nanocomposites were 9.057 (001), 18.12 (002), 24.63 (111) and 36.80 (004). As these diffraction peaks were absent in ZnO, it confirms that the formed product was ZnO/CoO np's.

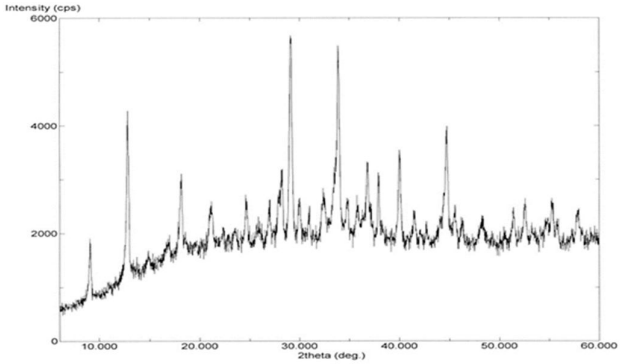

Figure 2: XRD Patterns of ZnO / CoO nanoparticles

C) SEM &EDS

The surface morphology of ZnO/CoO nanoparticles was analysed by using Scanning electron microscopy, the result was compared with ZnO and CoO doped ZnO nanoparticles indicating the presence of dopant CoO with ZnO nanoparticles. The surface morphology was drastically modified after adding dopant. Also, there was clear evidence for less agglomeration between the nanoparticles. The images of the samples are given in Fig. 3a & 3b.

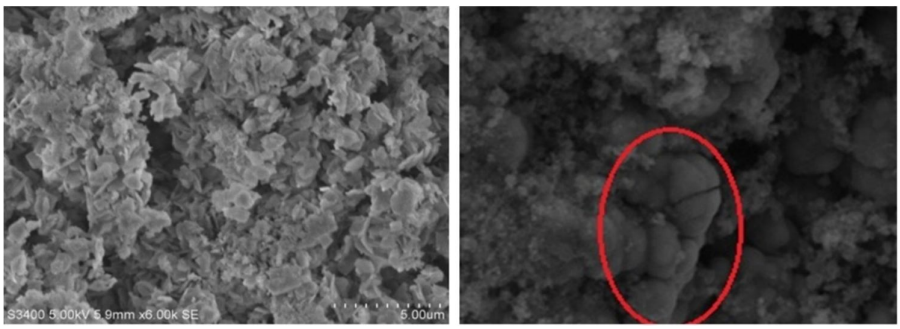

Figure 3: SEM micrographs of 3a. ZnO& 3b. Co-doped ZnO nanoparticles

*Energy-dispersive X-ray spectroscopy (EDS):*The relative proportions of quantitative elemental composition were analysed using SEM-EDS. The corresponding output data obtained suggest the presence of ZnO nanoparticles and Co dopant was added successfully to ZnO nanoparticles. The relative elemental compostion are shown in Fig. 4a & 4b.

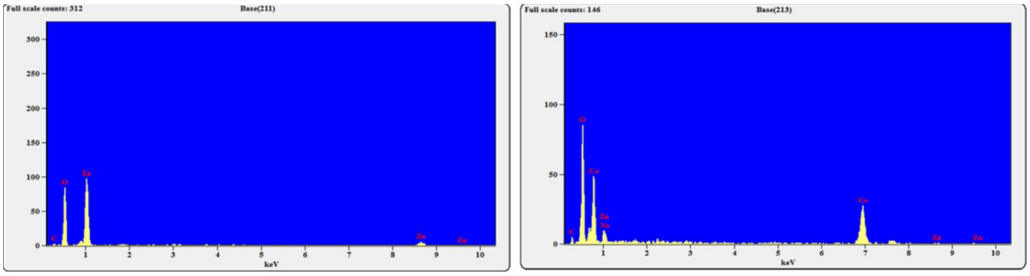

Figure 4: EDS image of 4a. ZnO& 4b. Co-doped ZnO nanoparticles

IV. Antibacterial Activity

The synthesized ZnO and CoO doped ZnO nanoparticles were evaluated for inhibition of antibacterial activity evaluated by the disk diffusion method. Antibacterial activity was performed using nutrient agar and medium, The antimicrobial activity assay was evaluated against gram-negative bacteria (E.Coli). Microbial cultures were subcultured on nutrient agar and uniformly swabbed on individual plates. Nanoparticles of different concentrations (6, 4 & 2 mg/ml) were impregnated on 6mm filter paper discs, dried and placed on the culture plate and incubated at 370C for 24h. the antibacterial activity was studied using the diameter of the zone of inhibition with deionized water as the negative control and gentamicin as the positive control.

a)Antibacterial activity of ZnO Nanoparticles

In disc diffusion assay, the suppression of E. coli bacterial growth was determined in the cultured nutrient media Petri plates loaded with 0.006, 0.004, and 0.002g/mL ZnONPs after 24 h at 37°C (Fig. 5 and Table 1). Zone of inhibition was not observed in control plates loaded with deionized water and gentamicin showed higher growth inhibition. It is evident from Fig. 5 shows that the size of the inhibition zone increases linearly with an increase in ZnONPs concentration (0.006 to 0.002mg/mL).

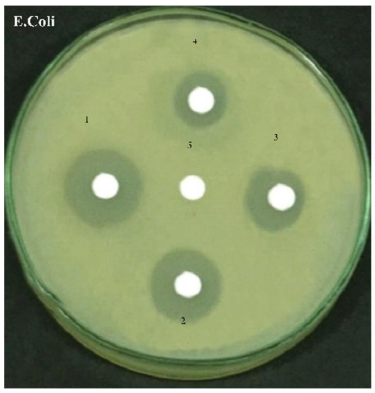

Figure 5: Zone of inhibition of ZnO nanoparticles against E.Coli bacteria

TABLE 1: ANTIBACTERIAL ACTIVITY OF ZNO NANOPARTICLES AGAINST E.COLI BACTERIA

Sl.No	Loaded in E.Coli cultured plate	Concentration in mg/ml	Zone of inhibition in mm
1	Positive control Gentamicin	0.03	23.3
2	ZnONPs	0.006	21.5
3	ZnONPs	0.004	20.1
4	ZnONPs	0.002	18.5
5	Negative control D.I water	00	00

b) Antibacterial activity of Co-doped ZnO Nanoparticles

In disc diffusion assay, the suppression of E. coli bacterial growth was determined in the cultured nutrient media Petri plates loaded with 0.006, 0.004, and 0.002g/mL Co-doped ZnONPs after 24 h at 37°C (Fig. 6 and Table 2). Zone of inhibition was not observed in control plates loaded with deionized water and gentamicin showed higher growth inhibition. The diameter of the inhibition zone was 25.1 mm for standard drugs, 23.3 mm, 20.2 mm, and 19.5 mm. It is evident from Fig. 6 shows that the size of the inhibition zone increases linearly with an increase in Co-doped ZnONPs concentration (0.006 to 0.002g/mL).

V. Conclusion

ZnO and Co-doped nanoparticles were successfully synthesized by the hydrothermal method which is a simple and cost-effective process for nanoparticle synthesis. The synthesized nanoparticles were thoroughly characterized using UV-Vis, and SEM with EDS and XRD techniques. The crystalline ZnO and Co-doped ZnO nanoparticles were in spherical morphology and within the nano range. The NP's synthesized were used for the antimicrobial assay which was found to be more efficient in inhibiting the bacterial action against E.Coli

Bacterial species. It was found that all the nanoparticle concentrations were showing inhibition activity linearly with an increase in concentration. It is noted worthy that the Co dopant action increased the activity in all concentrations when compared with ZnO nanoparticles. Furthermore, in both ZnO and Co-doped ZnO nanoparticles 0.006mg/ml concentration showed the highest inhibitory action against E.Coli bacteria.

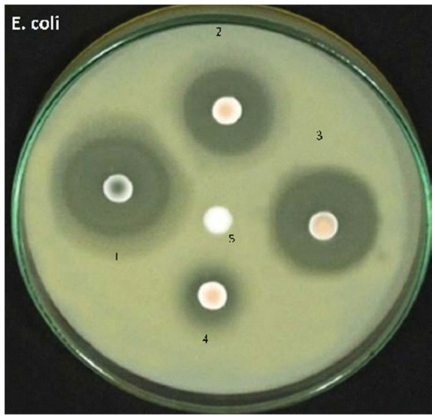

Figure 5: Zone of inhibition of ZnO nanoparticles against E.Coli bacteria

TABLE II: ANTIBACTERIAL ACTIVITY OF CO DOPED ZNO NANOPARTICLES AGAINST E.COLI BACTERIA

Sl.No	Loaded in E.Coli cultured plate	Concentration in mg/ml	Zone of inhibition in mm
1	Positive control Gentamicin	0.03	25.1
2	Co doped ZnONPs	0.006	23.3
3	Co doped ZnONPs	0.004	20.2
4	Co doped ZnONPs	0.002	19.5
5	Negative control D.I water	00	00

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