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GREEN SYNTHESIS OF INDIUM ZINC OXIDE FOR PHOTO CATALYSIS AND ANTIBACTERIAL APPLICATIONS

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Abstract: The current work illustrates the synthesis of Indium zinc oxide nano composites (IZO) through the green synthesis method. The prepared nanocomposites were investigated by TG/DTA and results specified that the peak temperature was 220^0C. The X-ray diffraction (XRD) showed that the prepared nano composites are polycrystalline in nature having a wurtzite structure and the average crystallite size showed as 15nm. A preferential growth at (002) and (101) orientation was noticed by XRD analysis. The small grain size with spherical nature was viewed from SEM analysis. Prepared nano composites show better antibacterial activity against Bacillus, Staphylococcus aureus, and Pseudomonas by the green synthesis method. The prepared nano composite photo catalysis also observed under visible light.

Keywords: Indium zinc oxide nano composites, green synthesis, antibacterial activity.

I INTRODUCTION

The number of industries that benefit humanity has significantly increased during the past few years. Unfortunately, as technology has advanced, environmental contamination has increased, negatively impacting the ecology. Hazardous organic dyes are the most commonly utilized pollutants across a range of sectors, including textiles, paints, paper, cosmetics, and medicines [1-4]. Unfortunately, as technology has advanced, environmental contamination has also increased. Cyclic methylene blue (MB), which is present in these organic dyes, Due to its reputation for resilience in both heat and sunlight, recycling these dyes is incredibly challenging. Among the aforementioned techniques, photocatalytic degradation is the most straightforward and economical. The majority of photocatalytic reactors use UV as the light source, which is extremely inconvenient for large-scale operations due to its high energy consumption, toxicity, short lifetime, and cost. In this respect, visible light active semiconducting oxide nanoparticles have been exploited extensively for photocatalytic applications due to their absorption capabilities, greater surface area, and distinctive optical characteristics when compared to bulk materials [5].

Healthcare-associated infection (HCAI) contracted by patients while receiving care is the most frequent adverse condition. Approximately 4.5 million people in Europe contracted an infection while obtaining medical care, according to The European Centre for Disease Prevention and Control (ECDC) .The effects of HCAI include increased antibiotic tolerance in microorganisms, prolonged hospital admissions, long-term disability, a large additional cost load on healthcare services, and a rise in mortality. HCAIs are responsible for 16 million more days spent in hospitals and 37 000 fatalities in Europe. Annual financial losses are expected to be over 6.5 billion dollars in the USA and 7 billion euros in Europe (2004). Bacteria like Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, and Enterococci are

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responsible for many hospital-acquired illnesses. The most prevalent bacterium species among these are S. aureus and E. coli [6-8].

Nano medicine has gained popularity recently as an active component in antibacterial treatments. Superior antibacterial activity has been discovered in metal oxide nanoparticles. Metal oxide nanoparticles' (NPs) antibacterial effectiveness is influenced by a number of factors, including the type of microorganisms present, pH of the solution, particle size, surface area, crystallinity, capping/stabilizing agent, morphology, concentration, and dosage. The bacteria's nanosize holes are easily penetrated by smaller nanoparticles (NPs) with the right shape [9-10]. The doping of semiconductor nanomaterial has prominent attention From the past decades because of intense electrical conductivity. Various transparent conductive oxides (TCOs) have importance in nanotechnology, presently the foremost TCOs are ZnO, SnO_2, TiO_2, and indium tin oxide. In specific dopants such as yttrium (Yb), indium (In) is doped it acts as good transparent conductive oxides [11]. Over recent years ZnO is a most ensuring semiconductor material with a varied range of antibacterial, photocatalytic applications [12]. ZnO has a wide energy direct bandgap of 3.37ev with n-type is semi-conducting material having hexagonal wurtzite crystal structure [13]. ZnO Nps can be improved by doping suitable metals such as In, Mn, Cd, and Al. combination of oxide nanoparticles with metals can be developed for the effectual removal of many bacterial strains [14]. As ZnO's biomedical application is utilized as antibacterial and anticancer its properties are enhanced by doping Indium [15,16].

The intense properties of ZnO-based nanocomposites show better results in bio-related applications, [17]. various techniques were adopted for doped ZnO nanocomposites like sol-gel method, electrochemical method, spray pyrolysis technique, chemical spray pyrolysis, atomic layer deposition, pulsed laser ablation in liquid technique, Laser sintering [18-25]. Among them, the green synthesis method is used for the synthesis of ZnO -based nanocomposites specifically using plant extracts, which are cost-effective, simple, cheap, and non-toxic [26,27].

Zinc oxide is suitable material for food prevention from being influenced by food pathogens such as Staphylococcus aureus and Escherichia coli in food packaging. used to treat skin problems such as baby powder, anti-dandruff shampoos, antiseptic ointments [28]. Microorganisms like Gram-positive (Staphylococcus aureus, Bacillus subtilis, and Escherichia coli are Gram-negative (Pseudomonas aeruginosa, Salmonella typhi, and Escherichia coli) bacteria were used to examine indium doped zinc nano composites [29]. This work reports the structural, optical properties, and antibacterial applications.

2.Material and Methods:

2.1 Experimental procedure

Indium oxide and Zinc oxide powder of 99% pure procured from Sigma Aldrich Bacillus, Staphylococcus aureus, and Pseudomonas were organized from Bio-Tech lab PVT Ltd. In-ZnO Ncs were prepared by green route method. The reagents used were Indium (III) acetylacetonate (99.99% pure) 0.5 gm, are Zinc Acetylacetonate Hydrate powder 1.5gm, and Neem gum from the local market. The precursors were made fine powdered by agate motor and pestle and further calcined in muffle finance at 3200^{o}C for 1hr. The calcined powder turned to brownish yellow color which confirms the formation of Indium zinc oxide Nano composites (InZnO Ncs).

3. Results and Discussions

3.1. Thermal studies :

The TG curve shows significant weight loss from 150^{0} C to 200^{0} C and to some extent 200 C to 300 C and further no more weight loss observed .The DTA curve shows the decomposition behavior between 200^{o}C to 250 C and a main exothermic peak was observed at 220^{0} C.

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Endo-thermic Peak(Evaporation of OH)	Endothermic Peak (Decom of CO and OH)	Exothermic Peak (Amorphous Phase changed)
150^oC	200^oC	220^oC

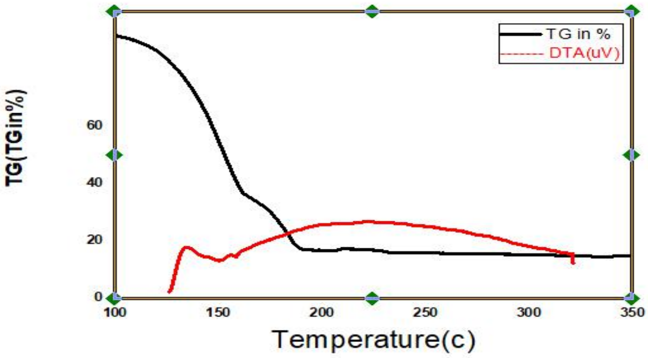

Fig1: TGDTA analysis of Indium Zinc oxide Ncs with Neem Gum

3.2. Structural Studies

The XRD pattern of Indium doped ZnO with neem gum confirms the formation polycrystalline hexagonal phase with wurzite structure from fig 2.The wurtzite structure agree with JCPDS: 36-1541 [30].At 2θ = 32º the diffraction peak specifies preferential orientation growth along (002) plane. The enhanced peaks at 2θ = 32º, 34.2º, 36.4º, 56.2º corresponding to (100), (002), (101) and (110) plane were observed.

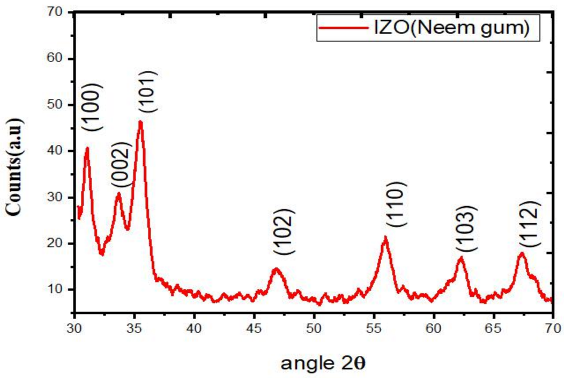

Fig2: XRD pattern of Indium Zinc oxide Ncs with Neem Gum

The pattern exhibit sharp intense peak (101) plane around 33.6° can be inferred as overlap plane of (222) In_2O_3 cubic plane and ZnO (002) plane [31].using Debye–Scherrer formula the crystallite size D is 15nm and full width half maximum (FWHM) 0.52000.

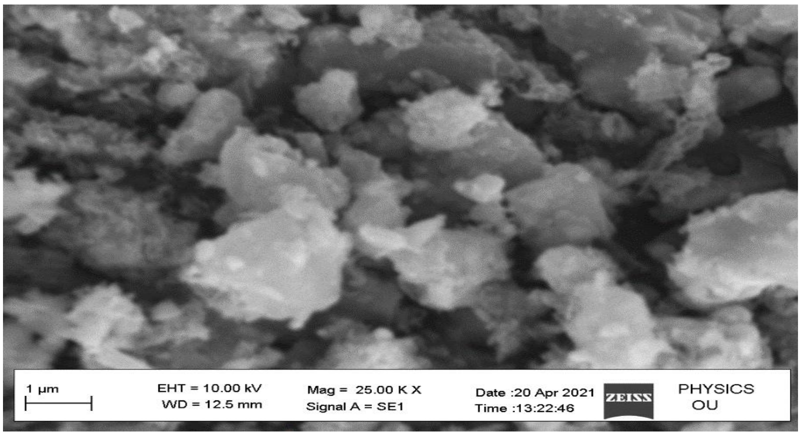

Fig 3. SEM images of Indium Zinc oxide Ncs with Neem Gum.

SEM images of the assynthesized Indium zinc oxide Nano composites powders, It can be seen that the as-synthesized Indium zinc oxide Nano composites powders consist of submicro crystals with the size of mostly 15–200 nm.. A sponge-like structure with nano spherical granular shape is visible in the SEM micrograph (Fig.3).Thus, a functional material with an adaptive ordered nanostructure has been created.

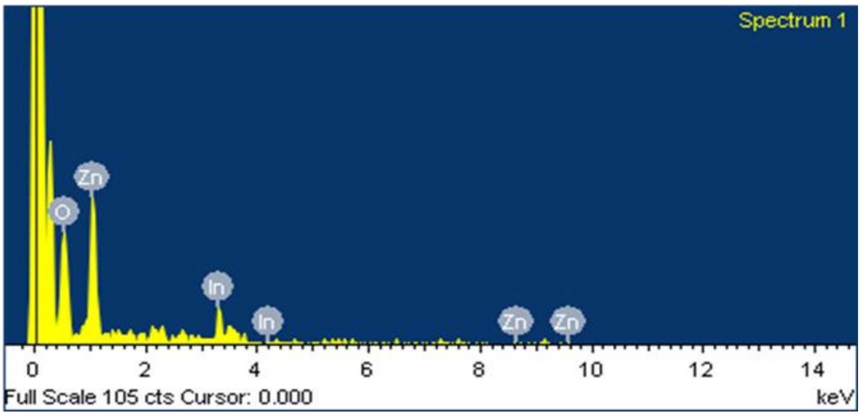

Fig 4. EDS images of Indium Zinc oxide Ncs with Neem Gum.

Fig 4. The percentages of the elements for the of Indium Zinc oxide sample are shown in the labeling. Clearly, In, Zn and O are the main constituents of the sample and no trace of impurities could be found of EDX of of Indium Zinc oxide.

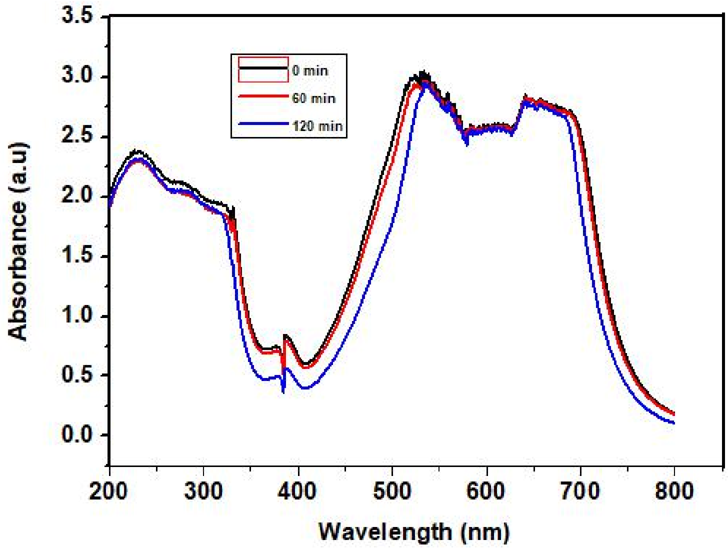

Fig 5. Absorption spectral decrement of MB dye aqueous solution degraded from Indium Zinc oxide Ncs with Neem Gum.

The photocatalytic activity of IZ-NPs was investigated for MB dye under UV–Vis irradiation. Fig 5. shows the change in the optical absorption spectra of MB dye solution for In-doped ZnO Ncs recorded at different intervals of time. From the Fig. 5 it is clear that the absorption decreases as the exposing time is increased from 0 to 120 min.

The production of electron-hole pair irradiation starts the photocatalysis process.When visible light (hv $\geq E_g$), which is equal to or greater than the band gap energy of ZnO, is absorbed, an electron from the valence band (VB) is stimulated to the conduction band (CB).Due to this, holes occur in the valence band, and electrons are stimulated into the conduction band [32]. Additionally, doping indium causes trap levels to arise between ZnO's valence and conduction bands. The band edge absorption threshold is effectively redshifted by these trap levels. In addition to the process of separating electron-hole pairs, electron- and hole-driven photoredox reactions generate the extremely active hydroxyl (OH) radical which is primarily accountable for the deterioration of organic dyes [33]. This is because the oxygen vacancy defects (VO+)

and In-doped Ncs on ZnO's surface act as a sink to enhance the separation of electron-hole pairs produced by photosynthesis.

Furthermore, the photoelectron can be readily captured by electronic acceptors like adsorbed oxygen to create a superoxide radical anion, whereas the photoinduced holes can be readily captured by electronic donors like organic pollutants to further the oxidation of organic pollutants.The separation effects of photoinduced electrons are strong during the brief instance of electrons and holes oxidation-deoxidization using electron donators or acceptors, and the photo-generated electrons and holes can be used efficiently [34]. The extremely potent, non-selective oxidants hydroxyl radical and photogenerated holes cause the indium at the catalyst's surface to deteriorate. This confirms that In-ZnO Ncs show a good photocatalytic activity.

Antibacterial activity:

Fig 6 shows antibacterial activity of Indium Zinc oxide Ncs with neem gum against bacteria Pseudomonas, Bacillus and Staphylococcus aureus. The mean inhibition zone is 4mm, 12mm and 9mm is noticed. The utmost inhibition zone is observed for Bacillus.

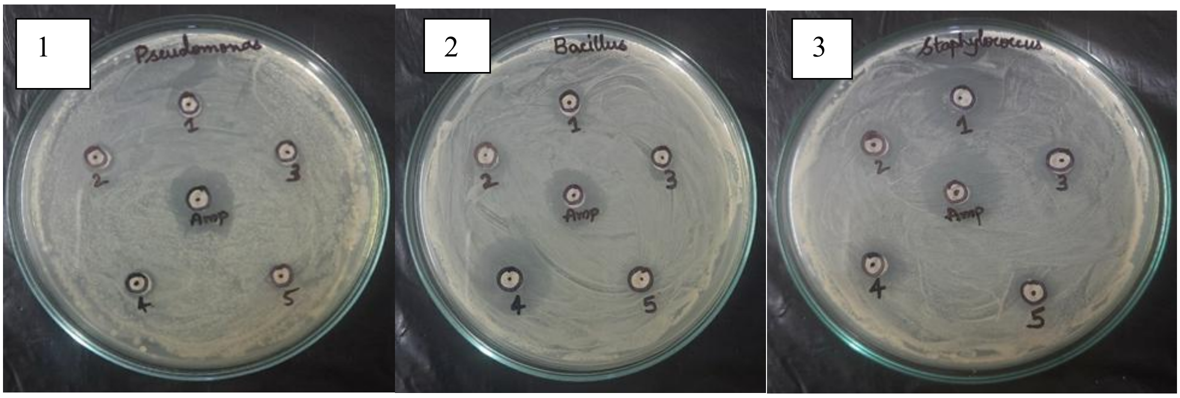

Fig 6: Antibacterial activity of Indium Zinc oxide Ncs with Neem Gum against bacteria 1) Pseudomonas 2) Bacillus 3) Staphylococcus

Conclusions:

Numerous pollutants are released into the environment both directly and indirectly as a result of global urbanization. As the world advances in its technological development, studies on environmental remediation are now strongly encouraged to counteract the negative impacts and to construct a sustainable environment. Since their physical and chemical characteristics have drawn so much attention for so long, metal oxides are currently regarded as the leaders in environmental remediation, particularly in the photocatalytic destruction of organic contaminants. The produced materials demonstrated strong photocatalytic activity under visible irradiations, which is crucial for optical devices and applications linked to organic pollutants. Indium-doped ZnO nanocompoites are more photoactive. The created nanocomposites are capable of easily inhibiting bacterial growth and show good antibacterial action Pseudomonas, Bacillus, Staphylococcus. These results imply that In doped ZnO nanoparticles have a potential application as a bacteriostatic agent and may have future applications in the development of derivative agents to control the spread and infection of a variety of bacterial strains. Doped ZnO-Ncs will be used in the near future to deliver anti-microbial or medicinal compounds.

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