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Topic of Research: Development of Sustainable Nanomaterials Their Effects on Polythene Degradation and Microbial Activity

Findings

Primary findings of my research are *green synthesis of nanomaterials and their application in environmental cleaning and microbial activity.*

Chapter 1 starts with the general introduction of the topic, definitions, types of nanomaterials and presented a detailed review of the literature with respect to metal, metal oxide, and the composite of nanomaterials more specifically Ag, ZnO, CuO, ZnO/Ag nanocomposites. The review of literature starts with the discussion of synthesis of Ag by using green methods reported by researchers. Its application in antibacterial activity reported by others is also summarized. Moreover, the synthesis of ZnO by using green methods adopted by several researchers was included in the review of literature also. Ag nanoparticles formed bionanocomposite dealt with one of the objectives of the thesis regarding Polythene degradation and adsorption of heavy metal with ZnO are also discussed in the review of literature.

Chapter 2 deals with the principles and techniques for characterization used in this thesis. The chapter discussed the synthesis methods adopted in coming chapters and the characterization techniques used with their principles and methodology.

Chapter 3deals with the green synthesis of silver nanoparticles aqueous solution of dry leaves of *Syngonium podophyllum* (nephthytis, arrowhead) is mixed with the silver nitrate ($AgNO_3$) precursor for the synthesis of silver nanoparticles (AgNPs), which serves as a reducing, capping, and stabilising agent.The change in colour from golden yellowish to dark brownish signified the synthesis of silver nanoparticles.The UV-Visible Spectroscopy, X-Ray Diffraction, FT-IR, and XRD all confirmed the reduction of the silver nanoparticles.SEM and TEM had been used to study the morphology of silver nanoparticles.The extracted solution produces high absorbance peak at 421nm.According to high-resolution transmission electron microscopy (HR-TEM), the biosynthesized nanoparticles are spherical in shape, of particle sizes ranging from 2-47nm.The morphologies of the synthesized AgNPs were analyzed using a field emission scanning electron microscope. The elemental synthesis of silver at 3 Kev was confirmed by EDX examination of silver nanoparticles. The compounds existing in the Syngonium podophyllum extracts were analysed using inductively fourier transform infrared spectroscopy (FT-IR) to recognize the nature of the capping agents in these leaf extracts. Antibacterial activity of silver nanoparticles has been demonstrated in this study.The well diffusion method was used to analyse antibacterial activity, and the 96 well plate method was used to test minimum

inhibitory concentration (MIC) against bacterial pathogens. (*Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis, and Staphylococcus aureus*).

Chapter 4 defined a facile, inexpensive, and benign method to fabricate silver nanoparticles (AgNPs) using*Tradescantia pallida (T. Pallida)* var. *purpurea* leaves extract. A UV-visible spectroscopic analysis in the 420-550nm wavelength range confirmed the formation of AgNPs. FTIR, XRD, TEM, SEM, and EDX methods were used to examine the stabilization of silver ions by phytochemicals, the crystal structure and size of AgNPs, and the morphology of AgNPs. Additionally, the Silver NP showed significant bactericidal activity against *Pseudomonas aeruginosa (P. aeruginosa), Bacillus subtilis (B. subtilis), Escherichia coli (E. coli), and Staphylococcus aureus (S. aureus)* bacteria and minimal inhibitory concentrations (MICs) compared to the plant extracts. The maximum activity (zone of inhibition) was found at 15 ± 0.15 mm and 14 ± 0.16 mm against *P. aeruginosa* and *E. coli*, respectively at a concentration of 60 µg/mL of AgNPs. The MIC values were 50 µg/mL for *P. aeruginosa*, 25 µg/mL for *S. aureus* and *E. coli*, and 100 µg/mL for *B. subtilis,* confirming their significant antibacterial action. AgNPs inhibited the DDPH free radical scavenging activity with an IC_{50} = 91.87 µg/mL. As a result of their biological efficacy, these AgNPs are considered to play a crucial role in determining *T pallida's* therapeutic potential.

Chapter 5 deals with the study to fabricate a novel, feasible, and cost-effective Zinc Oxide nanoparticles (ZnONPs) adsorbent from *Syngonium podophyllum* for the remediation of hexavalent chromium (Cr^{6+}).Various spectroscopic techniques were employed to identify the structural, morphological characteristics and adsorption interaction of the structure, including X-ray diffraction (XRD), scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), and transmission electron microscopy (TEM).Flavonoids, terpenoids, alkaloids, alcohols, phenols, carboxylic acids, ZnONPs are stabilized and capped by these agents and were detectedvia Fourier infra-red spectroscopy (FTIR) studies.Dynamic light scattering (DLS) analysis was performed on fabricated nanoparticles to determine their particle size.ZnONPs adsorption applicable in Cr^{6+} sequestration from aqueous solution using batch mode were performed to investigate adsorption time, pH value, adsorbent concentration, and initial adsorbate concentration. At 313 K, Cr^{6+} exhibited a maximum adsorption capacity of 267.068 mg/g. The Freundlich isotherm model suits best based on R^2 = 0.976–0.984; SEE = 0.095–0.631 values, demonstrating the possibility of multilayer confiscation of Cr^{6+} energetically onto heterogeneous surface. Upon scrutinizing investigational data, it was found that sequestration occurred through chemisorption. Thermodynamics studies showed that removal of Cr^{6+} was thermodynamically spontaneous and feasible. The $\Delta G°$ values between -20 and 0 kJ/mol indicate that the adsorption method is predominantly physisorption. ZnONPs showed strong antibacterial activity against *S. aureus* bacteria compared to antibiotics, therefore ZnONPs can be used as an alternative to present antibiotics. The ZnONPs also demonstrated impressive antioxidant activity, with an IC_{50} of 127.01 µgm/L. ZnONPs synthesized from biosynthetic processes are excellent nano sorbents, antioxidants and biocompatible.

Chapter 6 discussed the fabrication of ZnO/Ag nanocomposite by co-precipitation method This chapter also deals with the antibacterial activity of the nanocomposites. FTIR analysis confirms the presence of a functional group responsible for the

stabilization and reduction of fabricated NCs. TEM and SEM analysis showed the internal morphology of the ZnO/Ag NCs as nearly spherical and the average crystallite size of NCs 16.64nm. The NCs are polycrystalline, as demonstrated by the selected area electron diffraction (SAED) pattern. The NCs show good antimicrobial action against Prokaryotic and Eukaryotic organisms. The Minimum inhibitory concentration (MIC) of the NCs are 12.50 and 50µg/mL for E.coli and S. aureus respectively. The finding reveals, ZnO/Ag is found to be an efficient combat agent against prokaryotic and eukaryotic organisms and may be employed as an antimicrobial in the future.

Chapter 7 discussed about the biodegradation of polythene bag via microbial degradation. This research focuses on the separation, characterization, and degradative capacity of soil-based plastic-degrading microorganisms. Bacteria and fungi isolated from discarded soil samples were used to successfully break down polythene. Biochemical tests and gram staining methods are used to identify bacteria. *Bacillus sp., Arthobacter sp., and Pseudomonas sp.* were found to affect the degradation of polythene bags of LDPE in mineral salt media (MSM) in-vitro culture under laboratory conditions for 30 days using a weight determination process. The weight-loss method was used to measure polythene degradation. This study reveals that the *genus bacillus* is more effective in decomposing plastic bags.

In Chapter 8, the first-ever synthesis of ternary bionanocomposites from an aqueous extract of Syngonium podophyllum was discussed. Various analytical techniques were used to characterize these nanocomposites, which were then employed as a remediation agent for the degradation of polyethylene. Given that microbial degradation can be a time-consuming process, there is a pressing need for a rapid remediation method for polyethylene.The study utilized various analytical techniques to characterize the synthesized bionanocomposites. These techniques include X-ray diffraction, Fourier transform infrared spectroscopy, scanning electron microscopy, and energy-dispersive X-ray spectroscopy. The results of these analyses showed that the synthesized bionanocomposites had a uniform particle size distribution and a high degree of crystallinity, which make them potentially useful for various applications.

One of the significant applications discussed in the study is the use of these bionanocomposites as a remediation agent for polyethylene degradation. Polyethylene is a widely used polymer, but its disposal can be challenging as it takes a long time to degrade. Microbial degradation is a common method for remediation, but it is a slow process. The study suggests that these bionanocomposites can be used as a quicker alternative for polyethylene remediation.

Overall In this thesis, metal oxides are explored for their role in environmental remediation and antimicrobial activity. Nanomaterials can be synthesized Via green synthesis methods that are effective in addressing environmental and antimicrobial concerns. Due to industrialization and globalization, there is a greater need for energy-efficient and sustainable materials to combat water pollution. This work focuses on the green synthesis of nanomaterials for the removal of pollutants from water, degradation of polythene, adsorption, antimicrobial activity, and antioxidant activity. Various characterization techniques such as XRD, FTIR, SEM, TEM, UV-vis, TGA, DLS, and Zeta potential were used to study the nanomaterials. Optimization of parameters like dose, concentration, pH, and time was done for the adsorption process in wastewater treatment. Additionally, the synthesized

nanomaterials were tested for their antibacterial activity against common pathogens such *as E. coli, P. Aeruginosa, S. aureus, and B. subtilis,* as well as their antioxidant and anti-yeast activities.