TRENDS IN MEDICINAL AND ENVIRONMENTAL SCIENCE: AN INTRODUCTION

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ECOFRIENDLY SYNTHESIS OF ZINC OXIDE NANOPARTICLES USING *MORINGA OLEIFERA* LEAVES EXTRACT AND ITS CHARACTERIZATION

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Abstract

Nanoparticles (NPs) have emerged as a transformative technology with diverse applications across various industries such as environmental science, healthcare, renewable energy, and agriculture. The UN's Sustainable Development Goals (SDGs) can be achieved by harnessing the unique attributes of nanoparticles, including their elevated surface-area-to-volume ratio and enhanced reactivity, to address crucial sustainability challenges. However, traditional methods for synthesizing nanoparticles often involve energy-intensive processes and hazardous chemicals, prompting concerns about resource utilization and environmental impact. In turn, there has been a growing interest in the sustainable alternative of green synthesis, particularly through plant-mediated production, which utilizes naturally occurring plant biomolecules as stabilizers and reducing agents. Furthermore, this process offers a sustainable, cost-effective method for producing biocompatible nanoparticles while minimizing environmental impact. This chapter explores how green-synthesized nanoparticles, such as gold (AuNPs) and silver (AgNPs), can advance sustainable development projects. The discussion focuses on the role of bioactive substances, such as polyphenols, flavonoids, and terpenoids, in reducing metal ions and

stabilizing nanoparticles during the production of plant-based NPs. The quality and safety of these nanoparticles depend on a range of characterization techniques, including UV-Vis spectroscopy, TEM, XRD, FTIR, and DLS. These methods offer insight into the size, shape, crystalline structure, and surface chemistry of the particles. Nanoparticles produced through green synthesis show great potential for various sustainable applications. They can purify water from pollutants, enhance the efficiency of solar cells, improve crop resilience using nano-fertilizers, and offer antibacterial properties for medical purposes. Nevertheless, several barriers impede their widespread adoption. Variability in plant biochemistry undermines the reproducibility of synthesis, making it challenging to scale up production for industrial purposes. Moreover, there is uncertainty about the potential long-term impacts of NPs on the environment and human health, underscoring the need for comprehensive ecotoxicological studies and regulatory guidelines.

Keywords: Green synthesis, ZnO NPs, characterizations.

5.1. Introduction

The term "nanomaterial" refers to materials with at least one dimension measuring between 1 and 100 nanometers (nm). Although nanomaterials have a similar composition to macro-scale or bulk materials, they exhibit unique physicochemical characteristics[1]. When materials are reduced to nanoscale dimensions, their properties can change dramatically from those observed at the macroscale. For instance, at the nanoscale, copper, which appears opaque, becomes transparent, whereas bulk platinum is inert but can act as a catalyst. Stable elements like aluminum suddenly become combustible, and solid gold changes to a liquid state at room temperature, while insulators such as silicon begin to conduct electricity at the nanoscale[2]. These distinctive properties of nanomaterials result from two main factors: increased relative surface area and quantum confinement effects. For instance, when a particle is smaller in size, more atoms are located at its surface than