Huseinova Kristina
Kyiv National University of Technologies and Design (Kyiv, Ukraine)
Language and scientific supervisor – Denysenko V., senior lecturer

GREEN SYNTHESIS OF METALS AND THEIR OXIDE NANOPARTICLES: APPLICATIONS FOR ENVIRONMENTAL REMEDIATION

Purpose and objectives. This study aims to explore the fundamental processes and mechanisms of a green synthesis approach, specifically focusing on metal nanoparticles and metal oxides such as gold (Au), silver (Ag), copper oxide (CuO), and zinc oxide (ZnO) which are synthesized using natural extracts. The objective of this study is to evaluate the potential use of the synthesized compounds in addressing environmental pollution, including their capacity to eliminate dye contaminants, detect heavy metal ions, and showcase their antimicrobial and catalytic properties.

Object and subject of research. The object of research is green synthesis as a reliable, sustainable, and environmentally friendly protocol for the synthesis of a wide range of materials and nanomaterials, including metal and metal oxide nanomaterials. The subject of the study is metal or metal oxide nanoparticles used for environmental remediation.

Results of the research. The first decade of the 21st century was marked by the rapid development of nanotechnology, which produced new types of materials consisting of nanoparticles. According to the generally accepted terminology, nanoparticles (NPs) are defined as particles with dimensions between 1 and 100 nanometers (10^{-9}nm). Nanomaterials (NM) are materials with at least one external dimension at the nanoscale or with an internal or surface structure at the nanoscale. Nanomaterials affect virtually all areas of human activity, penetrate the structures of living and non-living environments, and have important social, technological, and medical implications [1]. Among metallic nanomaterials, nanoparticles of gold, iron, titanium, zinc, copper, and silver are the most important [2].

Metal nanoparticles and their nanoclusters are among the earliest objects of nanotechnology that were produced using traditional physical and chemical methods [1]. The synthesis of nanoparticles by employing physical and chemical methods involves the use of reactive and toxic reducing agents that pose environmental hazards and incur high costs. Large-scale synthesis faces several issues, including low stability and monodispersity [3]. To counteract these limitations, there is growing interest in a new generation of green synthesis methods within current research and development in materials science and technology. Essentially, the green synthesis of materials and nanomaterials, created via regulated, controlled, cleaned-up, and remediated processes, will promote their environmental sustainability. Some basic principles of "green synthesis" can thus be explained by several components like prevention or minimization of waste, reduction of derivatives and pollution, and the use of safer (or non-toxic) solvents and auxiliaries as well as renewable feedstock [4, 5].

The green synthesis of metal nanoparticles has been applied to several biological materials, including bacteria, fungi, algae, and plant extracts. Of the available green methods, the use of plant extracts is a relatively straightforward process for large-scale production of nanoparticles compared to synthesis mediated by bacteria or fungi. Various parts of plants, roots, stem, leaf, seed, and fruit, are widely used for the synthesis of metal or metal oxide nanoparticles due to the presence of potent phytochemicals in various plant extracts, especially in leaves, such as ketones, aldehydes, flavones, amides, terpenoids, carboxylic acids, phenols, and ascorbic acid. These components are capable of reducing metal salts into metal nanoparticles. The metal nanoparticles synthesized by the plant extract are stable and monodisperse, easily controlled by various influencing factors such as pH, temperature, retention time, and mixing ratio [4, 5]. Green metal nanoparticles are synthesized from various plants, such as neem leaves (Azadirachta indica), tulsi leaves (Ocimum tenuiflorum), curry leaves

(Murraya koenigii), guava leaves (Psidium guajava) and mango leaves (Mangifera indica) [2].

By "greening" the nanoparticle synthesis process, the use of biological systems and their components helps to reduce the environmental impact, increase economic efficiency, and open up additional opportunities for creating nanoparticles with a given composition and properties. Many studies have been conducted on environmental remediation in terms of antimicrobial activity, catalytic activity, removal of polluting dyes, and sensing of heavy metal ions [3].

Various studies have been conducted to enhance antimicrobial activities in response to the increasing resistance of microorganisms to traditional antiseptics and antibiotics. In vitro, studies have indicated that metal nanoparticles are effective in inhibiting various types of microbes. The antimicrobial effectiveness of metal nanoparticles depends on two critical parameters: the material used during the synthesis of nanoparticles and their particle size. Nanoparticles are effective in combating drug resistance, as they can impede multidrug resistance and biofilm formation through various mechanisms. As a result, microbes would need to possess multiple gene mutations within a single cell to overcome the mechanisms of nanoparticles. However, it is improbable for biological genes to undergo multiple simultaneous mutations within the same cell [3, 5].

Herbicides, insecticides, and synthetic dyes are frequent organic pollutants in wastewater that can significantly damage ecosystems. The most effective and straightforward approach to reducing them is by introducing NaBH4 as a reducing agent alongside metal catalysts like Au NPs, Ag NPs, CuO NPs, and Pd NPs. Metal NPs possess the high catalytic potential owing to their remarkable surface adsorption capacity and high surface area-to-volume ratio [4, 5].

Cationic and anionic dyes cause undesirable water turbidity, which reduces the penetration of sunlight, leading to resistance to photochemical synthesis and biological attacks on aquatic and marine life. Therefore, the management of wastewater containing dyes is one of the most challenging tasks in the field of environmental chemistry. Similar to metal oxide nanoparticles, metal nanoparticles also exhibit enhanced photocatalytic degradation of various dye pollutants due to the large number of surface reactive sites on their surface, which leads to an increase in the removal rate of contaminants at low concentrations. Consequently, less nanocatalyst is required to treat contaminated water compared to bulk material [4, 5].

Heavy metals, such as Ni, Cu, Fe, Cr, Zn, Co, Cd, Pb, Cr, Hg, and Mn, are notorious for their ability to pollute air, soil, and water. Metal nanoparticles are preferred for the detection of heavy metal ions in contaminated water systems due to their tunable size and distance-dependent optical properties. The benefits of using metal NPs as colorimetric sensors for heavy metal ions in environmental samples or systems include simplicity, cost-effectiveness, and high sensitivity [3, 4, 5].

Conclusions. The green synthesis of metals and metal oxide nanoparticles has been a highly appealing research field for the last ten years. Many natural extracts, including plants, bacteria, fungi, yeast, and plant extracts, have been successfully exploited as resources to synthesize and produce materials. Plant extracts have been empirically demonstrated to be exceptionally effective as stabilizing and reducing agents in the synthesis of controlled materials, such as those possessing controlled shapes, sizes, structures, and other specific features. Thus, future research and development in the production of advanced green materials and nanoparticles must extend laboratory work to an industrial scale while taking into account traditional and current concerns, particularly environmental and healthcare impacts. The production of eco-friendly materials and nanoparticles using biocomponents is poised to gain widespread use in environmental remediation and other crucial sectors like the pharmaceutical, food, and cosmetic industries [2, 4, 5].

REFERENCES

1. L. Xuan (2023) Nanoparticles-induced potential toxicity on human

health: applications, toxicity mechanisms, and evaluation models. Vol. 4, no. 4. Retrieved from: https://doi.org/10.1002/mco2.327 (date of access: 17.03.2024).

2. S. Vijayaram (2023) Applications of green synthesized metal nanoparticles – a review. *Biological trace element research*. Retrieved from: https://doi.org/10.1007/s12011-023-03645-9 (date of access: 17.03.2024).

3. Patra J. K., Baek K.-H. 92014) Green nanobiotechnology: factors affecting synthesis and characterization techniques. *Journal of nanomaterials*. P. 1–12. Retrieved from: https://doi.org/10.1155/2014/417305 (date of access: 17.03.2024).

4. H. Kumar (2020) Flower-Based green synthesis of metallic nanoparticles: applications beyond fragrance / *Nanomaterials*. Vol. 10, no. 4. P. 766. Retrieved from:https://doi.org/10.3390/nano10040766 (date of access: 17.03.2024).

5. J. Singh (2018) 'Green' synthesis of metals and their oxide nanoparticles: applications for environmental remediation / *Journal of nanobiotechnology*. Vol. 16, no. 1. Retrieved from: https://doi.org/10.1186/s12951-018-0408-4 (date of access: 17.03.2024).