



Synthesis and biological function of Nickel and Copper nanoparticles

Jyoti Chaudhary^a, Giriraj Tailor^{a,*}, B.L. Yadav^b, Oshon Michael^c

^a Department of Polymer Science, M.L.S. University, Udaipur, Rajasthan, India

^b Department of Botany Mewar University, Gangrar, Chittorgarh, Rajasthan, India

^c Department of Chemistry, Mewar University, Chittorgarh, Rajasthan, India



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ABSTRACT

Nickel and Copper nanoparticles were synthesized by simple chemical method and studied for antimicrobial activities. The size of synthesized Nickel and Copper nanoparticles was found to be 24.00 nm and 13.13 nm respectively. The XRD analysis reveals the crystal system of Nickel and Copper nanoparticles. Copper nanoparticles were found orthorhombic whereas the nickel nanoparticles were monoclinic. The antimicrobial activities of Nickel and Copper nanoparticles dispersed in DMSO was investigated. Comparative sensitivity test of these synthesized nanoparticles was carried out against three pathogenic micro-organisms (Gram negative bacteria), viz. *Escherichia coli*, *Klebsiella pneumoniae* and *Pneumonia Typhus*, using agar diffusion cup plate method. Copper and Nickel nanoparticles have shown appreciable sensitivity at 100 µg/ml against all test micro-organisms. Comparatively, Copper nanoparticles were found to exhibit higher zone of inhibition (ZOI) than Nickel nanoparticles.

1. Introduction

Metallic nanoparticles (NPs) are known for potential application in catalysis, electronics, optoelectronics, information stock, biosensors, and surface enhanced Raman spectroscopy (SERS), their synthesis and properties have been studied in depth by several workers [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]. These particles have a wide functional diversity and can exist as common structural elements or composites compared to bulk materials. The physico-chemical properties of metallic nanoparticles are mostly rated by the parameters like size, shape, and composition [11, 12, 28]. Metallic nanoparticles of exclusive sizes and morphologies can be readily synthesized using chemical and physical methods [29, 30]. Most of the methods use toxic chemicals as reducing agents, organic solvents and non-biodegradable stabilizing agents which are potentially dangerous to the environment and biological systems. Moreover, most of these methods are complicated and involve non-standard conditions making them quite expensive. Thus the biosynthesis of nanoparticles is being proved as a cost effective environmental friendly alternative to chemical and physical methods [31, 32, 33, 34, 35, 36]. Consequently, micro-organisms and plant extracts have been used in synthesis of nanomaterials [24, 25]. The use of plant extracts for synthesis of nanoparticles is profitable over microorganisms due to elaborate process of maintaining cell cultures. The synthesis of metal nanoparticles using

plant extracts has provided a rapid, cost-effective biosynthetic protocol for bulk synthesis of stable metallic nanoparticles. In the present work an attempt has been made to develop green synthesis of metal nanoparticles through a single-step, room-temperature from metal ions using environmentally benign reagents [13, 14].

The noble metals such as gold and silver have been used in synthesis of nanoparticles. Now a day, copper (Cu) and nickel (Ni) are being used instead of noble metals in synthesis of metallic nanoparticles as they are more economical than gold and silver. Recent investigations have been extended to the study of other metals, such as Cu and Ni, that could have antibacterial activity. However, little attention has been paid to the study of bimetallic Cu–Ni NPs, although some studies have already shown some features of alloy NPs that distinguish them from the pure ones [15]. Cu NPs [16, 17, 18, 19] and copper oxide NPs [20, 21] have reported to have antimicrobial activity. Similar findings have been reported for Ni NPs. Many studies have shown that Cu and Ni NPs have bactericidal activities [26, 27]. Nevertheless, they have not been synthesized in aqueous solution without using stabilizers as polymers, ligands, salts, etc. That can hinder their properties. Finally, it is important to note that until now, the anti microbial properties of Cu–Ni bimetallic NPs have not been studied. Therefore, the purposes of this study were the synthesis and characterization of Cu, Ni to investigate their antimicrobial activity.

* Corresponding author.

E-mail address: giriraj.tailor66@gmail.com (G. Tailor).

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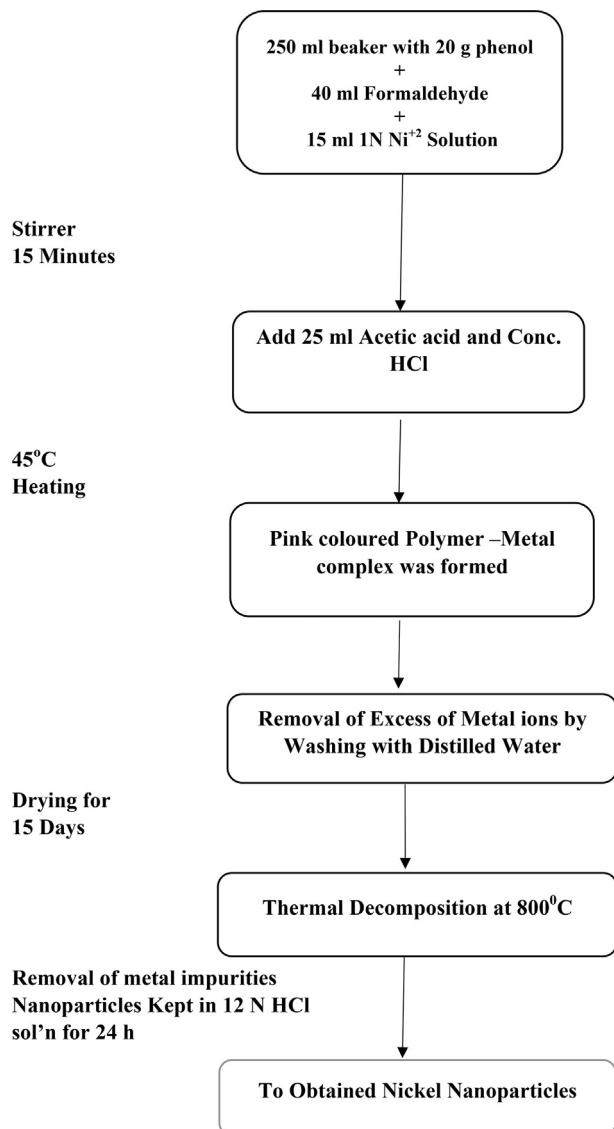
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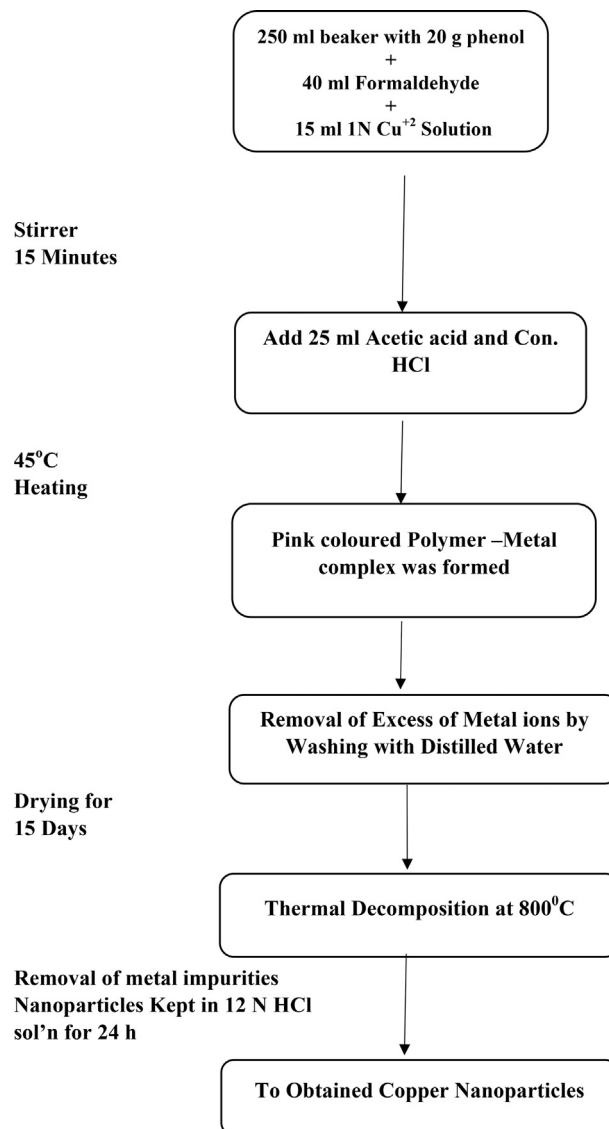
2. Materials and methods

During the present study AR grade chemicals such as Phenol, formaldehyde and acetic acid (Central Drug House Pvt. Limited) and hydrochloric acid (Fisher Scientific) were used. Metal ion solutions have been prepared by dissolving suitable amount of metal salt in distilled water. Copper and Nickel nanoparticles have been prepared by simple chemical precipitation method and characterisation was done by SEM, thermal gravimetric analysis and infrared spectroscopy. The synthesis of metallic nanoparticles is a twostep process. The first step includes the synthesis of polymer metal complex and second step the synthesis of metallic nanoparticles. The detailed method of synthesis of metallic nanoparticles has already been given in our earlier publication [22]. However, the process of synthesis of Nickel and Copper nanoparticles has been presented below in the form of flow chart:

2.1. Synthesis of nickel nanoparticles



2.2. Synthesis of copper nanoparticles



2.3. Antimicrobial activity

Comparative sensitivity test of Copper and Nickel nanoparticles was carried out against three pathogenic micro-organisms, namely, *E. coli*, *K. pneumoniae* and *P. typhus*, using agar diffusion cup plate method. Luria agar media was prepared and used for this purpose. Both nanoparticles were screened for antimicrobial activity at 100 µg/ml concentration. Ciprofloxacin was used as control. 0.001g each of Copper and Nickel nanoparticles were accurately weighed and dissolved in 10ml of DMSO. 100 µl of each stock solution was diluted with 900 µl of DMSO, to get a concentration of 100 µg/ml. Luria agar medium was prepared appropriately and dispensed (half filled) into six sterile petri dishes, and allowed for about 1 hour to gel uniformly. After gelling, the petri-dishes were inoculated with 50µl of each test micro-organism and uniformly spread with a spreader and labelled accordingly. Well diffusion method was followed for sensitivity test against the pathogenic bacteria. Wells of 7 mm in diameter were made with the help of a sterile cork borer in each petri dish. 100 µg/ml concentration of each of copper/nickel nanoparticle solution was dispensed (half filled) into the wells. The petri plates were incubated at 37°C for 24 hours. The zone of inhibition was measured in millimetre (mm).

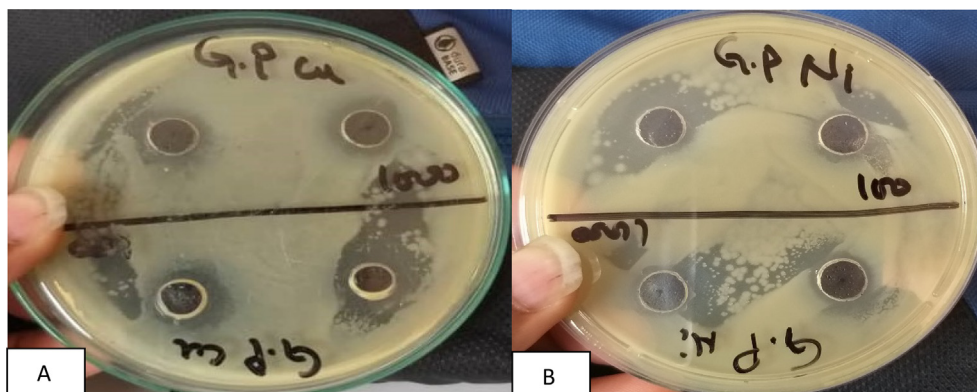
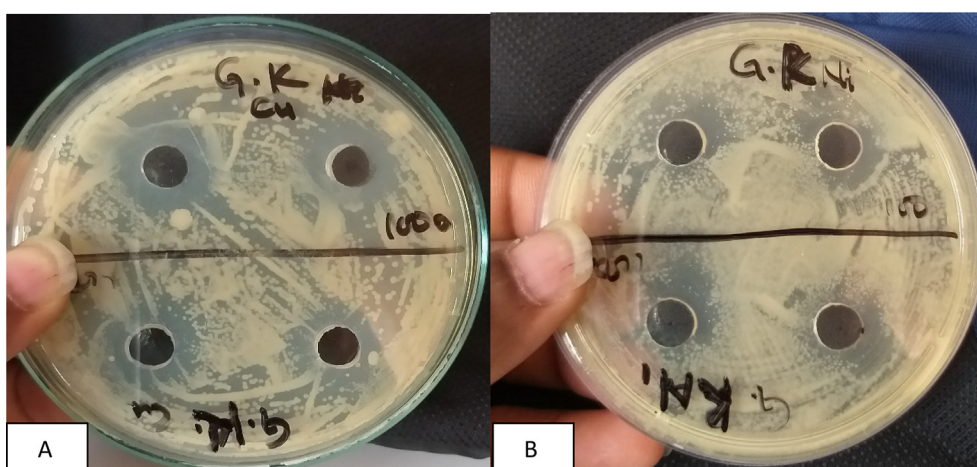
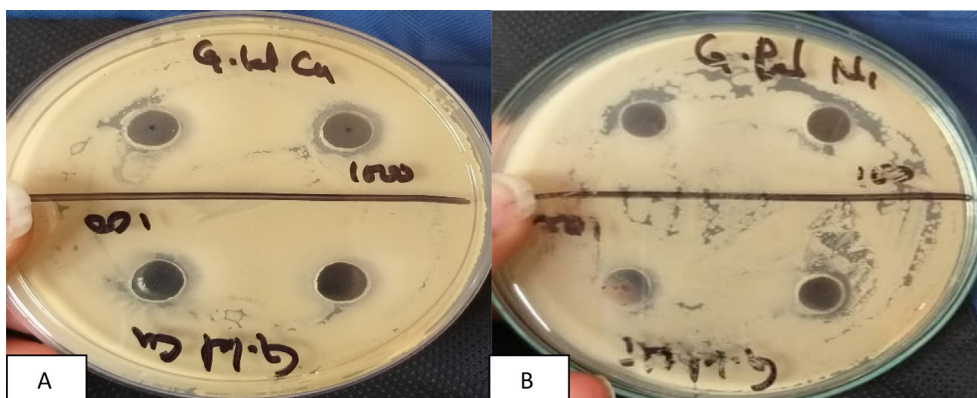
Table 1

Zone of Inhibition (mm) at 100 µg/ml of Copper and Nickel nanoparticles.

Nanoparticles	<i>E. coli</i>	<i>K. pneumoniae</i>	<i>P. typhus</i>
Copper	5.0	9.0	6.0
Nickel	4.0	7.0	4.0

3. Results and discussion**3.1. X-RD characterization**

X – RD diffraction pattern provides information's on size and shape of the unit cell from peak positions and information on electron density within the unit cell. Orthorhombic copper nanoparticles have been determined using XRD technique. Applying Debye – Scherrer equation to the XRD pattern of the copper nanoparticles, it has been found that the average size of nanoparticles is 13.13 nm, bravais lattice is primitive, space group is pcn (56) and $2\theta = 42.045$ [22].

**Fig. 1.** A-B Zone of inhibition of Copper and Nickel nanoparticles respectively against *P. typhus*.**Fig. 2.** A-B Zone of inhibition of Copper and Nickel nanoparticles respectively against *K. pneumoniae*.**Fig. 3.** A-B Zone of inhibition of Copper and nickel Nanoparticles respectively against *E. coli*.

XRD pattern showed that the size of nickel nanoparticles was 24.0 nm and has maximum intensity diffraction peak at $2\theta = 12.50290$ which indicate the presence of crystalline structure and the crystal system is monoclinic [23].

3.2. Antimicrobial activity

Observations on the zone of inhibition of Nickel and Copper nanoparticles against the three pathogenic bacteria have been presented in Table 1 and Figs. 1, 2, and 3.

The data presented in table – 1 reveal that both copper and nickel nanoparticles exhibit highest ZOI against *Klebsiella pneumoniae* (Fig. 2) However, the ZOI of nickel nanoparticles is comparatively lower (7.0 mm) than copper nano-composite (9.0 mm). Zone of inhibition of copper nanoparticles against *E. coli* and *Pneumonia Typhus* are comparatively higher than those shown by nickel nanoparticles (Figs. 1 and 3). Nickel nanoparticles are more effective against *K. Pneumoniae* than the other two bacteria. Thus, copper nanoparticles are more effective against *K. pneumoniae*, *P. typhus* and *E. coli* than nickel nanoparticles. The sensitivity of the microorganisms to the copper nanoparticles may be arranged starting with *K. Pneumonia* (9.0 mm) followed by *P. typhus* (6.0 mm) and *E. coli* (5.0 mm) in descending order. The higher ZOI in case of *E. coli* by the copper nanoparticles synthesized by electrolysis method was reported earlier [24] and an efficient antimicrobial activity of nickel nanoparticles against pathogenic bacteria has also been reported earlier (Chaudhary et al 2015). Values of Control.

Heavy metals are toxic and reactive with of proteins and produce the significant increase in permeability affecting transport system through plasma membrane as a result of which bacterial cell becomes unable to regulate the transport across the plasma membrane resulting into the death of bacteria [23].

The present paper reports a simple, fast, effective polymer based technique to synthesize copper and nickel nanoparticles using thermosetting polymer and copper and nickel metal salt as a precursor. Nanoparticles synthesized by the simple chemical precipitation method. XRD analysis proves the nanostructure of the copper and nickel nanoparticles through its crystal analysis and spacing pattern. The antibacterial activity of copper and nickel nanoparticles was compared for various microorganisms using the agar diffusion cup plate method. The diameter of inhibition zone (DIZ) reflects magnitude of susceptibility of the micro-organism. Both copper and nickel nanoparticles showed appreciable sensitivity at 100 µg/ml against all test micro-organisms. Comparatively, copper nanoparticles showed higher zone of inhibition (ZOI) than nickel nanoparticles.

Declarations

Author contribution statement

Jyoti Chaudhary: Contributed reagents, materials, analysis tools or data.

Giriraj Tailor: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Oshon Michal: Performed the experiments.

B.L. Yadav: Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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